Sustainable Development in Drylands – Meeting the Challenge of Global Climate Change

Proceedings of the Ninth International Conference on Development of Drylands, 710- November 2008, Alexandria, Egypt

IDDC
INTERNATIONAL DRYLAND DEVELOPMENT COMMISSION

International Dryland Development Commission

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Editors

Adel El-Beltagy and Mohan C. Saxena

Conference
Organized under the auspices of
The International Dryland Development Commission (IDDC) and the Bibliotheca Alexandrina
Sponsored by
Agricultural Research Center (ARC) of the Ministry of Agriculture and Land Reclamation, Egypt
International Center for Agricultural Research in the Dry Areas (ICARDA)
Arid Land Research Center (ALRC) of Tottori University, Japan
Chinese Academy of Sciences (CAS), China
Desert Research Institute (DRI), Nevada, USA
Food and Agriculture Organization of the United Nations (FAO)
Japanese Agency for International Cooperation (JICA)
Japan International Research Center for Agricultural Sciences (JIRCAS)
United Nations University (UNU)

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Sustainable Development in Drylands – Meeting the Challenge of Global Climate Change

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Bibliotheca Alexandrina, Alexandria, Egypt

The International Dryland Development Commission (IDDC) is an autonomous nongovernmental nonprofit organization established in 1987 by the individuals and institutions interested in and concerned about the sustainable development of dry areas. It is promoting all aspects of dryland studies by fostering cooperation, collaboration and networking between various international, regional and national organizations. One of the important modus operandi of the networking of IDDC has been to hold a major scientific conference every three to four years to provide opportunity to participants from around the world to exchange research results and experiences in dryland development and combating desertification. In pursuance of this objective the IDDC has organized in the past eight international conferences.

The Ninth International Conference on Dryland Development (ICDD) with the theme "*Sustainable Development in the Dry Lands - Meeting the Challenge of Global Climate Change"* was organized under the auspices of the IDDC and the Bibliotheca Alexandrina, and was sponsored by the Agricultural Research Center (ARC) of the Ministry of Agriculture and Land Reclamation, Egypt; the International Center for Agricultural Research in the Dry Areas (ICARDA), Arid Land Research Center (ALRC) of Tottori University, Japan; Chinese Academy of Sciences (CAS), China; Desert Research Institute (DRI), Nevada, USA; Food and Agriculture Organization of the United Nations (FAO); Japanese Agency for International Cooperation (JICA); Japan International Research Center for Agricultural Sciences (JIRCAS); United Nations University (UNU) and other national and international organizations. Beside the support of the sponsors, the Conference was also co-financed by AAAID, IFAD, OFID, and GFAR.

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Foreword

The Ninth International Conference on Development of Drylands (ICDD), with the theme "Sustainable Development in the Dry Lands - Meeting the Challenge of Global Climate Change", was attended by more than 450 participants from 42 countries and 19 international and regional organizations. The scientific program of the Conference covered the following topics:
Climate change in arid lands and its impact on natural resources of land and water and biodiversity in the dry areas

- Desertification processes and tools for assessment and their application
- Enhancing resilience of agriculture in dry areas through management of water and land resources and agronomic practices
- Biodiversity conservation and utilization
- Range management and forage and livestock production
- Stress physiology: drought, heat, cold and salinity
- Improvement of stress resistance in dry area crops, shrubs and tree species through conventional breeding and application of biotechnology
- Reducing greenhouse gas emission through harnessing renewable energy in the dry areas
- Blending indigenous/traditional knowledge and heritage with modern science in the sustainable development of oases
- Enhancing livelihood of desert communities, socioeconomic studies and crosscutting issues.

There were five plenary sessions, six concurrent oral- presentation sessions and three poster sessions on the above ten topics. The plenary presentations included three keynote speeches, one each by the Vice President of the International Fund for Agricultural Development (IFAD) Dr. Kanayo Nwanze, the President of OPEC Fund for International Development (OFID) Dr. Suleiman Al-Herbish, and the Secretary General of the World Meteorological Organization (WMO) Mr. Michel Jarraud, and twenty-one other presentations from leading experts in their field highlighting the impact of global climate change on the natural resources and communities in the dry areas, methodologies to assess these changes and for scenario building, indicators for assessing changes and integrated measures to enhance adaptive and mitigation capabilities of the communities in the dry areas to cope with the climate change and to achieve sustainable development. In the oral presentations made in the concurrent sessions information was presented on the outcome of scientific efforts in different fields to enhance the resilience of the dry areas to cope with climate change, drought and degradation of natural resources of land, water and biodiversity.

The deliberations clearly established that climate change was certainly impacting the dry areas, majority of which would become warmer and drier, with grave consequences for flora and fauna, cropping systems, crop and livestock productivity, food security and livelihoods of the people in these areas. Although the evidence was unequivocal about the change, precise information at the regional and local levels, which would be essential to develop effective coping strategies, was still insufficient and efforts were needed to develop this information. There was a need for enhancing the awareness of the impact of climate change at all levels of the society, attract investment in research to develop coping strategies, forge regional and international linkages for mobilizing cutting-edge science integrated with traditional knowledge for developing adaptive and mitigation measures, and bring about institutional reforms and empower the communities to benefit from the outcome of these efforts as they face the climate change.

This volume contains most of the scientific contributions made by the participants in the plenary and the concurrent sessions under different themes. We hope all those interested in the sustainable development of dry areas and enhancing the resilience of dry area communities to cope with the adverse effects of climate change will find the information contained in this volume useful. The proceedings will hopefully also contribute significantly to the objectives of the International Dryland Development Commission of enhancing information exchange and promote scientific research for sustainable development of dry areas which is becoming all the more urgent and necessary in the wake of climate change.

Adel El-Beltagy and Mohan C. Saxena

Inaugural Session Addresses

Opening Remarks

Dr Adel El-Beltagy
Chair International Dryland Development Commission

Your Excellency the Minister of Agriculture and Land Reclamation, Government of Egypt, Mr. Amin Abaza,
Representative of H.E. Mr. Hani Hilal, Egyptian Minister of Higher Education and Scientific Research,

Eminent Guests,
Colleagues from around the world interested in dryland development,
Ladies and Gentlemen!

It is my pleasure to welcome you all to the Ninth International Conference on Dryland Development. Let me share with you a couple of issues and facts about the International Dryland Development Commission, which was established in 1987 after an engaging dialogue for more than 10 years between the concerned scientists. During this period, these scientists pledged that the Commission will promote all aspects of Dryland Science by fostering cooperation and networking between international, regional and national organizations. It was also agreed that we will hold a major scientific conference every three or four years to provide opportunity to the dryland scientists and development experts from across the globe to exchange research results and development experience in dryland and thus have an impact on the livelihood of about 2 million people who inhabit the dry areas.

So far, we have organized nine international conferences. These have been held in countries that have large stretches of dry areas: Beijing-China, Mexico, Lubbock-Texas, Cairo-Egypt, and Tehran-Iran. Today we are here in Alexandria on the wonderful platform that was created to see that the minds of the world share with each other the vision for the future, which is the essence of the Library here. We are therefore pleased to be here today and the topic of the Conference dealing with the challenges of global climate change to the sustainable development of the dry areas relates to an issue with which we all are concerned.

Let me move the proceedings forward by inviting the colleagues from the podium to make their welcome remarks.

Welcome Remarks

Welcome Remarks by Dr Ayman Abou Hadid, President, Agriculture Research Center, Egypt

Your Excellency Mr. Amin Abaza, Minister of Agriculture & Land Reclamation, Egypt,
H.E. Dr Ismail Serageldin, Director, Library of Alexandria,

Excellencies,
Distinguished Guests,
Dear Colleagues,
Ladies and Gentlemen!

It is great pleasure to welcome you all to such a gathering of eminent scientists in Egypt. On behalf of the Agriculture Research Center (ARC), Egypt, a cosponsor of this Conference, I will like to welcome you to the Ninth International Conference on Dryland Development to address the issue of meeting the challenges of global climate change. The ARC is the main agricultural research organization in Egypt that includes 24 research institutes and central research laboratories as well as 48 agricultural research stations in all the different agro-ecological regions in the country. The ARC has a strong think tank of over 6600 scientists of different specializations and technical backgrounds. The ARC also has a special institute dealing with climate issues and climate change that was established in 1996. The ARC makes it a point to include the climate change issues in the last two Five Year Plans in all relevant institutions dealing with plant and animal production, agricultural economics as well as genetic engineering. It gives me great pleasure to extend to all of you my invitation to visit any of the ARC institutes of interest to you in Cairo after this meeting.

I wish you all a fruitful meeting and a pleasant stay. Thank you very much.

Welcome Remarks by Dr Stephen Wells, Director of the Desert Research Institute (DRI), Nevada, USA

Ladies and Gentlemen!

I will like to express my gratitude to Prof. Adel El-Beltagy, Dr Ayman Abou Hadid, Prof. Mohan Saxena and the Egyptian Colleagues for the hospitality and the organizational efforts put by them in bringing the Ninth International Conference on Dryland Development (ICDD) together. The DRI first co-sponsored the ICDD held in Beijing in 2006 due to the gracious efforts and support of Prof. Wang Tao, who is present in the audience. We greatly appreciate his efforts in that meeting. At that time we had only four faculty members from DRI. At this meeting we have ten faculty members of DRI participating reflecting the importance of this initiative.

I will like to use this opportunity to briefly mention the magnitude of the current challenge that we face as scientist, engineers, planners and leaders. I will then like to balance the challenge we have with the opportunity, I think, a very unique opportunity. The world faces the greatest challenge to sustainability and functioning of our systems in support of humanity and sustainability of humanity. There is a rapidly changing landscape of the world, environmental as well as to economy, political setting and science and technology. And these changes are altering both directly and indirectly the earth's hydrological cycle, affecting distribution, availability, and storage of usable water as well as increasing human susceptibility to environmental changes, such as the loss of agricultural productivity and drought. A rapidly changing environment, combined with increasing population and its demands on water resources related to agriculture, municipal use, energy, maintenance of biodiversity, puts humanity, especially in the drylands, to harm's way. The global demand for water is expected to grow up by 40% by 2025. But there is an opportunity that we can use to leverage this challenge. Never before in the history of humanity has there been such an acute awareness of these environmental problems, from the local to the global scale. So the burden rests upon us, the scientific and engineering community, not to miss this global opportunity and calls for an immediate integrated collaborative science- and engineering-based and risk-informed approach. This approach should take up several challenges and goals to be met. And, probably the most important of one of those would be to create a global water culture, one that promotes water as a global resource, not bound by countries or by regions but by the world as a whole, and we leverage our collective research results and educational outreach initiatives to enhance the global understanding and stewardship of the hydrological cycle. And finally, a good communication process requires listening. We can not and must not pretend to understand what is important to dryland development in global context as scientists alone. It is our listening to the stakeholders' need and the knowledge provided by our global colleagues as we have in this meeting that should guide us as we prepare to study the dryland issues.

Thank you for the opportunity to share my thoughts.

Welcome Remarks by Prof. Dr Iwao Kobori, Senior Advisor, United Nations University (UNU), Tokyo, Japan

Excellencies,
Guests,
Colleagues,
Ladies and Gentlemen!

I am extremely pleased to be here and represent the United Nations University on behalf of Prof. Konrad Osterwalder, the Rector of UNU. Prof. Osterwalder unfortunately could not be present here because of some other unavoidable business in Tokyo. He sends his best regards to all of us. At this unique occasion I will like to introduce our activities in connection with the International Dryland Development Commission and Egypt. The UNU, as you would know, is a small member of the family of the United Nations Organization, headquartered in Tokyo, with more than 14 research centers including the important research and training center, International Network on Water, Environment & Health (UNU-INWEH), in Canada. Its mandate covers all issues related to UN and it operates mainly in a networking mode with international institutes and individual scientists. In connection with the dryland studies the UNU has developed in recent years close collaboration with other organizations such as UNESCO, FAO, ICARDA and other institutions. Very happily, the latest agreement of collaboration signed by the UNU is the agreement with Bibliotheca Alexandrina (BA). The ceremony was held in Tokyo on 5th October 2008 in the presence of Dr Ismail Serageldin. This will open ways for collaboration between BA and UNU in different fields of mutual interest. For example, in Alexandria we will have several symposia at the BA. The UNU also has good collaboration with the University of Alexandria in the field of dryland studies. UNU has also been working very closely with the CGIAR, UNESCO, FAO and others. Last year, which was the International Year of Desert and Desertification, UNU organized a large Conference involving all the major international institutions interested in policy issues related to combating desertification. Under the same spirit, we will like to continue efforts to promote collaboration with all of you working in drylands all over the world. With the arrival of Prof. Osterwalder as the new Rector, there is going to be a little change in the orientation of future research at the UNU. It will lay special emphasis on sustainability and peace, which is going to be the most important motto for work all over the world. Personally speaking, I have been here in Alexandria several times in the past in connection with our collaboration on dryland research with scientists here. With respect to the new target of our efforts, sustainability and peace, the UNU will like to further collaborate with like minded institutions in addition to our collaboration on dryland studies.

In the end I will like to express my appreciation for the hard work done by Prof. Adel el-Beltagy, President of the IDDC, Dr Mohan Saxena, and their collaborators and colleagues in the local organizing committee in arranging this Conference. I will like to express our many thanks to Dr Serageldin, who has put at our disposal such an excellent venue for holding this Conference.

Thank you very much.

Welcome Remarks by Prof. Dr Atsushi Tsunekawa, Director, Arid Land Research Center (ALRC), Tottori University, Japan

Ladies and Gentlemen,

On behalf of the Arid land Research Center (ALRC) of the Tottori University, Japan, I will like to express my sincere gratitude to Prof. Dr Adel El-Beltagy and Dr Mohan Saxena and the organizers of this Conference. I will like to appreciate their great efforts in preparing such a big Conference. I think this Conference is very significant platform for the dryland scientists to meet. In particular, the Conference is quite unique because the scientists from a variety of backgrounds meet together and also because scientists working on fundamental studies and those carrying out applied research meet together. That is the reason that I called up on two important Japanese organizations, Japanese International Cooperation Agency (JICA) and the Japanese International Research Center for Agricultural Science (JIRCAS), to co-sponsor this Conference and they readily agreed.

Personally speaking, I was attending the meeting of the Science and Technology Committee of the United Nations Convention to Combat Desertification (UNCCD), held in Istanbul, Turkey until yesterday, as a member of the Japanese delegation. As you are aware, the dryland science is expected to play an important role in the UNCCD and I hope, from this Conference, new challenges and new paradigms of dryland science will emerge that will contribute to the dryland development. That is my expectation.

Thank you for your attention.

Welcome Remarks by Dr Mahmoud Solh, Director General, International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria

Your Excellency Mr. Amin Abaza, Minister of Agriculture & Land Reclamation, Egypt,
Dr Ismail Serageldin, Director, Library of Alexandria,
Prof. Dr. Adel El-Beltagy, President of ICDD and Chair of GFAR,
Excellencies,
Distinguished Audience,
Ladies and Gentlemen!

On behalf of the International Center for Agricultural Research in the Dry Areas, I will like to welcome you to this International Conference on Dryland Development. The impressive gathering of distinguished experts and specialists here today is a reflection of the importance of dryland development in this critical time of the global crisis and serious threat of climate change implications to global food security, and in particular, in the dry areas. The presence of H.E. Mr. Amin Abaza, the Minister of Agriculture and Land Reclamation today is a clear reflection of the importance that the host country Egypt is putting on the development of drylands. ICARDA, as one of the major organizers of the Conference, will like to thank Prof. Dr Adel El-Beltagy and Dr Mohan Saxena for their leadership in organizing this important event and for their services to promote science and technology in dry areas, much of the time working at or with ICARDA. We would also like to thank the Agriculture Research Center and the Alexandria Library for hoisting this important event and the presence of Dr Ismail Serageldin, who is a distinguished visionary and intellectual leader in this part of the world, is a reflection of the intellectual importance of the Conference. I will like to express special appreciation to our national, regional and international colleagues who are contributing to the rich program of our Conference today. I would also like to express appreciation to the donors and the co-sponsors for making this important event feasible.

Now, let me briefly talk about the challenges of dry areas. We talk about water scarcity, desertification, and land degradation, and the climate change is going to accelerate the negative implications of these challenges. So, this Conference is coming very much at a time when we really have quite a few challenges in this part of the world, which suffers from environmental poverty. What will make the difference? Certainly, science and technology and the political will as well as policies that are important and essential for the sustainable development of agriculture in these areas.

Let me now give a glimpse of what we at ICARDA are doing to meet the challenges facing the dry areas. We have been working at the climate variability ever since ICARDA was established in 1977. We had not been thinking of climate change because it was at that time a topic of academic debate. But now it is a reality. We therefore need to ensure that this problem is tackled by various stakeholders. It is a problem that is certainly beyond any single institution or country to cope with.

Therefore, I feel, our combined experience here, in a brainstorming atmosphere, would permit us to delebrate on the challenges squarely and by the end of the Conference we will be able to come up with deliberations that will put on track future steps that we take both in science and development in order to cope with the climate change.

Let me conclude by thanking again all of you for being with us here in this important event and we look forward to the important deliberations of this Conference.

Thank you for your attention.

Welcome Remarks by Dr Suleiman Al-Harbish, President, OPEC Fund for International Development (OFID), Vienna, Austria

Excellencies,
Ladies and Gentlemen!

I am honored and delighted to be here on behalf of the OPEC Fund for International Development (OFID). This is an institution which was created thirty years ago by same members of OPEC organization. Our organization works parallel to the OPEC organization. OFID was created in 1976 as an out come of the deliberations of OPEC in Algiers in 1975. The main mission of OFID is to extend social and economic assistance to the developing countries in different parts of the world, regardless of race, religion, or region. Our involvement in this important and prestigious Conference stems from our interest in sustaining development in developing countries.

Sustainable development has become an international agenda item number one in recent years. It has three pillars, economic development, protection of environment and social progress. Combining economic development with protection of environment is very important and this is what we are doing in the developing countries, especially very poor countries. Nearly 50% of the involvement of our activities is in Africa, and 90% of this input is in Sub Saharan Africa. We think of this sustainable development to be converted to the Millennium Development Goals, one of which is the eradication of poverty. Poverty in our institution is defined in a very broad context which includes poverty of health, education and energy. The eradication of the energy poverty was the main issue which was handled by the Third Summit of OPEC held in Saudi Arabia. We were called for to start programs for eradication of energy poverty. We are doing some work with the World Bank.

This issue of energy poverty is closely related the subject of this conference. I was in Burkina Faso two years back and saw poverty not measured by per capita income but by per capita consumption of water and energy. The per capita consumption of clean water in Burkina Faso is 20 liters per day for their whole domestic use in contrast to 200 liters, and of the per capita consumption of energy only 20% is from commercial sources, the rest coming from the primitive sources. This is the broad issue which we are involved and that is why I am honored to be here, honored to be associated with this organization, the International Dryland Development Commission run by this group of intellectual people.

Thank you for your attention.

Statement by H.E. Mr. Hani Helel, Minister of Higher Education and Scientific Research presented on his behalf by Prof. Magd Sherbeeny, Vice Minister of Higher Education and Scientific Research of Egypt

Your Excellency Mr. Amin Abaza, Minister of Agriculture & Land Reclamation, Egypt,
Dr Ismail Serageldin, Director, Library of Alexandria,
Prof. Adel el-Beltagy, Chairman of ICDD,
Ladies and Gentlemen!

Good morning! It is a great pleasure to be here with you on the occasion of the Ninth International Conference on Dryland Development in the magnificent premises of the Bibliotheca Alexandrina. On behalf Mr Heni Hilal, the Minister of Higher Education and Scientific Research, I will like to welcome you here in Alexandria in such an important meeting. Now a days climate change has become an important part of international agenda. The sustainable development of the dry areas forces lots of challenges on us to collate our efforts and it is very essential for us to face these challenges. We believe that climate change has no boundaries and Egypt is no different than any other country. In Egypt, water, food and agriculture are on the top of our national priority. Egypt needs to grow economically like any other country and climate change forces some challenges for this. Egypt and most of the other Arab countries lie in desert zone. To meet these challenges there is a need to collate our efforts and commit resources. We believe that the most effective tool to meet these challenges is science and technology. Last year, Egypt launched its first scientific satellite, which is being utilized for such purposes. It is mainly focusing on environmental and climate change, mainly to design better tools to mount and evaluate sustainable development. In Egypt we have great number of research institutes in agriculture and one of them is the Agriculture Research Center, which is one of the best in the country in terms of research. There are also researchers in different universities. We have lots of tools and we utilize biotechnology to develop tools to help us meet these challenges.

Today, with such a distinguished gathering of international scientists I have no doubt in my mind that this meeting will come out with very fruitful results and very good planning for the future. Finally, I wish you a very good meeting in the Bibliotheca Alexandrina in the state of art facilities here. I will also like to invite you to enjoy this magnificent city of Alexandria.

Thank you very much.

Statement by H.E. Mr. Amin Abaza, Minister of Agriculture & Land Reclamation

Excellencies,
Distinguished Guests,
Ladies and Gentlemen!

It gives me great pleasure to welcome you all to this Ninth International Conference on Dryland Development. Holding the Conference at Bibliotheca Alexandrina is a clear sign of the linking our heritage with modern sciences for the welfare of humanity. Being the heart of the arid region, Egypt is working hard to rationalize its water utilization in different sectors and specially in agriculture. The ministry of agriculture is working with other ministries to form policies and build institutional capacities to confront climate change and to adapt to the possible scenarios that may occur in the future. We are aware of the impact of climate change in our region especially on our country. Knowing the degree of vulnerability of our ecosystem we are determined to save no efforts to adapt to the impacts and to improve our resilience.

We hope that we can work together, hand in hand, to use local and global knowledge to enhance mitigation and adaptation process for the sake of improving livelihood of two million people living in the dry areas.

I wish you a pleasant stay in Egypt.

Thank you

Inaugural Address

Inaugural Address

Surviving the Climate Change*

Dr Ismail Serageldin

Director, Library of Alexandria, Alexandria, Egypt; *e-mail: is@bibalex.org*
*Transcripted from an oral presentation

Excellencies,
Ladies and Gentlemen:

It is a rare privilege for me to welcome you all here and I hope that some of you will take time while you are here to visit the Library of Alexandria, which is much more than a library and receives about a million visitors every year.

Today I have the honor of addressing you on the theme of surviving climate change. I will start with what I consider as the biggest challenge and I call it the 3 Fs + 2 Cs. The 3 Fs are Food, Feed and Fuel and the 2 Cs are Climate Change. And then I will briefly review the likely impact of climate change and the role of policy and science. It is important at these times of industry and carbon emission to remind us of the wise statement of a good friend of many of us here, Dr M.S. Swaminathan, who said, “We are all on this earth as the guests of green plants and those who tend them.” And that is so true and important to remember.

So, what is the biggest challenge? I called it as 3Fs because we start with the fact that although we have a lot of food, the hunger continues unabated. More than that, it is the most massive failure the world has had when we set ourselves a target eight years ago to half the number of hungry people, from 850 million to 425 million by 2015. Instead, the number of hungry people has increased to 950 million and is approaching the one billion mark. It is unconceivable that in this time we must still see the ghastly images of starving children on the face of the earth. The challenge is that we will have to deal with the fact that we already have 950 million hungry people, we will have 2.5 billion more people on the planet, and because of rising income we will have greater demand for animal protein in the diet, which will translate into increased demand for feed. All of that will have to be dealt with by agriculture, which is, at the same time, being expected to help solve the problem of climate change through biofuels. But biofuels result in displacing food and feed production. This is a major technical challenge which is being exacerbated by global climate change. In my thinking, it is wrong to burn the food of the poor to drive the car of the rich. Is there no other way of dealing with it? Although started by major industrial countries, the major impact of climate change will be on the poorer countries. The dryland countries and those in the tropics and arid and semiarid tropics will suffer the most. Hence, my dismal equation, 3Fs+2Cs.

Let us take the 3 Fs, the ‘Food, Feed and Fuel’ challenge. On the ‘Food’ side, we have the challenge of food security. We have to meet the demand of rising population by making food available everywhere at affordable prices, without destroying our patrimony of natural resources. So, we have to produce more with less land and other resources, and that would require addressing the policies that govern the international trade in food stuffs so we could cope with the enormous volatility of prices and be able to focus on the small-holder farmer in developing countries, and, of course, in line with the theme of this Conference, in the dry areas specifically.

If we look at the figures developed by International Food Policy Research Institute (IFPRI) some years back on the increase in demand for cereals, it is clear that the share of the developed countries will be rather small and almost 85% of the demand will come from developing countries. However, if we look in terms of meat products, the story is more telling. There is going to be a massive increase in demand in China, but in India it may be very limited due to cultural and other reasons. To meet the increased demand for meat products, the demand for feed would rise. So the question is: Can science bring about sustainable, precision, and ecologically balanced agriculture to cope with these problems in different eco-zones including dry areas? My belief, based on my long association with the CGIAR System and scientists like yourselves, is that the answer is certainly 'Yes'. The developments in biotechnology and bioengineering have opened a whole set of new opportunities for producing crop plants that are not only high yielding but also tolerant of diseases and pests and the aboitic stresses of drought, cold and heat, and are better users of available soil nutrients and water. There is an important program ongoing to improve the nutrient content of the food that is produced, and most famous amongst these efforts are the development of 'golden rice' and quality protein maize. There are even edible vaccines available to provide longer and more productive lives to the people. But the shortfall is already there: nearly one billion hungry people today, not to mention 2.5 billion coming along, and other demands. The other demands translate into feed. Producing more feed is a major challenge to cope with the increase in demand for meat by 30%, for milk by a quarter and eggs by a third. FAO has estimated that all these requirements massively increased the feed demand almost by a billion tons in the last 40 years. And the production of livestock is being done in a fashion that poses problems both in terms of the scale, for the income of small farmers and for the potential of animal diseases, as we know from the avian flu and SARS. There is not enough rangeland to raise cattle, which will have to rely on feed, and feed is again going to put pressure on food production, whether it is for milk or meat. One often hears of the conversion ratio of grain to beef of 7:1, but that is not true because we have to take into account the carcass yield of 60%. So, it is closer to 10:1. And all of that goes back again to the question whether the farmer can produce more to meet the increased demand.

On top of the above mentioned two challenges there is the fuel, and the fuel has become a new fashion in the industrialized countries as a way of dealing with the perceived responsibility for the massive increases in the emissions of the greenhouse gases. Many of them are talking about biofuels as a magic answer, and in fact are heavily subsidizing biofuel production. There are political campaigns to promote various kinds of biofuels and there are subsidies and tariff protection.

The key thing is that we have already witnessed that from 3 to 20% of the acreage available for corn production in the USA has gone to corn for ethanol. And if we were to reach the current target of 35 million gallons of fuel by 2017, at the current yield level, that would require the entire US corn harvest. So, it is a big challenge and even the popular magazines such as 'National Geographic' have started questioning how green are the biofuels, because so much energy and petrofuel are used in producing the biofuels that the equation comes out to be almost a wash. In this particular case, the corn ethanol is 30% improvement, at the best. On the other hand, cellulosic grasses present an enormous promise in the USA, because there is a large area in the Great Plains and the ratio is 20:1 and it could go to as high as 36:1 depending on the nature of cellulosic grasses and how they are harvested. Possibilities are also there for biofuels from algae and biodiesel from the marine sources, and today the biodiesel production is coming to 2.5:1 in terms of output to input. The production of ethanol from cane, as is being done in Brazil, using bagasse as the fuel for the fermentors, is providing a ratio of 8:1 between the output and input in terms of energy balance. Thus, we do not want to exclude all biofuels, but it is important to say that we should not displace food production to produce biofuels. Soybeans present the same situation. Certainly the first generation of biofuels is not helping either ecologically or in terms of meeting the targets of the needs of the poor.

Against this background come the 2Cs, the Climate Change. The climate change is really the most serious issue facing humanity. There is no longer any doubt about the figures available regarding the climate change. The global mean surface temperature is rising and it is related to the CO_2 emissions. Right now, the CO_2 concentration is around 400 ppm and if we stabilize and not produce any thing any more, we will reach this level by 2100. We have thus gone beyond the 350ppm, which many scientists consider to be the threshold that we should watch for. Do we have evidence that this in not cyclical? Yes, there were cycles. If we go back 400,000 years, there is evidence of cycles for temperature, CO_2 levels in the atmosphere and the dust, and the correspondence between the levels of CO_2 and the temperatures is more than a coincidence. In fact, it is enormously convincing that it is one of the primary greenhouse gases if not the only one.The climate system now, in spite of all its complexities, is getting better understood. It is clear from the time trends for CO_2 concentrations in the atmosphere, with different emission paths to stabilizations including the business as usual, that keeping the CO_2 level around 450ppm, not to say of 350ppm, will require an immediate effort to curb greenhouse gas emissions right now. This is quite a challenge. Some are suggesting that there is an emissions market that would work in carbon trading, and some are saying that we must help the developing countries. However, it is despicable to see that whenever we need to raise money for war or for the current financial and credit crisis we find not billions but trillions of dollars, whereas for ODA for developing countries, the pledges do not exceed 150 million dollars, as was evident from the famous Montreal figures. The IPCC (Intergovernmental Panel on Climate Change), which involves more than 2000 scientists from over 100 countries, has produced reports in 1990, 1995, 2001 and 2007. The last report, for the body of work of which they won the Nobel Prize along with Mr El Gore last year, has obvious findings: it is very likely (meaning more than 90% probability) that human activity is causing global warming, and that the probable temperature rise would be between 1.8 and 4 ^{o}C and, therefore, action is needed now because the likely impact of climate change would be very stunning, as indicated by high profile and low profile best estimates made by them in contrast to the situation at the beginning of the century. There is a whole range of impacts. On the food side, there will be a decline in crop yields in many areas, particularly in the developing world but more so in the arid and semi-arid regions. Even in areas that receive rain, there is a lot of variability that will be exacerbated by climate change. The length of growing season, in most parts would decrease, by 20 to 50 days, to as short as 113 days per year. With the growing season becoming shorter, variability in rainfall increasing, and the rainfall on the long run showing a declining trend, the agriculture in these parts is going more and more to resemble the agriculture of the arid and semiarid tropics. Therefore, the research that has been done here will have an impact that goes beyond the dryland areas and will be beneficial to the areas that today we do not consider as the parts of dry areas. But, beyond that we expect some possible rise in yield in some high latitude regions, but falling yields in the rest of the regions. Here again there is an exacerbation of the differences between the rich and the poor and if the rich continue to behave in terms of misplaced policies and subsidies, the poor will continue to suffer. The availability of grain in the home-produced areas in developing countries will diminish against the rising population and the rich countries will be diverting the grain away from international trade. That is not all.

On the water side, we have disasters ahead of us. (In 1995, I stated that the wars of this century have been on oil and the wars of the next century would be on water. I still stand on that; we are still at the beginning of the new century.) The mountain glaciers will disappear, a trend that is so conspicuous from a comparison of figures for 1928 with those for 2004. There will be a significant decrease in the availability of water in many areas including the Mediterranean region and Africa, and even in China. We have already lost 50% of the wetlands around the planet, with which we have lost not only the habitat for the migratory birds but also the 'lungs' of the hydrological cycle we depend on. Underground water is being mined at unsustainable rates and we see this in the declining water tables every where. In Syria, for example, it has been falling by about a meter every year in last thirty years. This is stunning when we see that nearly 10% of the world's grain production depends on irrigation with underground water. Water is being pumped out, usually with subsidized energy rates, at a pace that does not auger well for continued production. The real human cost of declining water table can be seen in the Sahel where people keep on digging the wells deeper and deeper to get water, in ever decreasing amounts, until they get only a few drops of muddy water at the bottom. In the absence of the water, there is desertification, and with it marginalization, hunger, dispossession, and vulnerability. We will have all this in our dry areas if we do not restructure our work.

On top of that we are witnessing a rise in sea level, which threatens not just the major cities but also agriculture. Thinning of the arctic ice, the cause of sea level rise, has been occurring and 40% of its volume has already been lost. Polar bears are dying by drowning because the distances between the icebergs are increasing as a result of ice thinning. Atmospheric models are presenting the scenarios with ever greater accuracy, and there is a whole range of them concerning the rise in sea level. There is no indication of any one of them staying steady, and all variants are increasing. For example, consider the impact of rising sea level on the Nile Delta. What we are concerned here is not really the disappearance of Alexandria by rise of sea level by 50 cm because we are at a higher elevation than that, but the fact that is of concern is that 30-50 cm of rise in sea water would put an enormous additional weight on the salt water enhancing its intrusion into the land. This intrusion of saline water is extremely risky as it will salinate the existing agricultural land and strategies would have to be developed to keep this intrusion away, as is being done by Egypt by growing paddy rice on the lands facing the sea that would permit equivalent pressure of fresh water to counteract the pressure from sea water. But, more generally, ecosystems will be damaged everywhere. Coral reefs, which are wonderful temperature gauges for sea water and are magical gardens to look at, are disappearing to a dead landscape. An increasing number of species, from tiny microbes to crop plants and varieties, are facing extinction. About many of these species we do not even know. The loss of large genetic variability of these species can put the humanity at great risk in the future, as they could be of great benefit to humanity in the future.

Extreme weather events have been suggested by various climate change models and there are ample data to support this. The first industry to support the views on climate change has been the Insurance Industry. They have discovered that they have to pay a lot more now than before. The number of disasters where 10 or more people are killed, some 100 people affected, and the state of emergency declared is increasing dramatically and the payments made by the insurance agencies have increased faster than growth in premiums, population and GDP. This is attributed to climate change as predicted by the models. For example, a comparison between the numbers of hurricane tracks from 1985 to 1994 and from 1995 to 2004 over Florida, Cuba, and the Caribbean would reveal that there has been an increase in these events causing massive destruction and loss of life and property. Increased floods, drought, forest fires and desertification will all work together and will hit not just the developed countries, which are after all capable of handling them, but many of the poorest countries, as was the case in Mozambique recently. We know that drought in many parts of Africa has today become a reality. Forest fires are increasing, as also the soil erosion and dust bowl phenomenon. Desertification moves massively; for example, Sahara's boundaries can move 110km or more in one year, changing the area by 700,000 km^2, which is more than 20 times the size of the Netherlands. That is the kind of variation that exists in potentially available land.

All of this is drastic enough, but the most drastic of all is our fear of the abrupt, major and irreversible changes. There is the change in the environmental quality from pristine to degraded, and this we have seen over time occurring in almost every ecosystem and climate should be no different. There is a carrying capacity for the system. It gets strained and stretched and, all of a sudden, when we go beyond the assimilative capacity, the system breaks down. The problem is that we do not know when that actual stress point will come. It is predicted that it would come before the end of the century, but one should take note of the warning sign that every time the IPCC made a report (1990, 1995, 2001 and 2007), the previous forecast was reaffirmed and it came faster and worst than predicted. So, we have this enormous range of forecasts of impacts, all of which could cost the developing countries at least 10 % of their GDP, and the developed countries 2 to 3 % of their GDP, while mitigation and adaptive measures will cost less than 1% today.

The question is: Why the decisions can not be made? We need to change our policies. Wiser policies are needed and biofuels are certainly not the whole answer. An agreement on global actions for clean energy, and understanding where the emissions come from, is needed. Agriculture and land use are also a large source of these emissions while power, industries and others are also there. We therefore need to rethink about energy emissions in terms of renewables. We had wind power for a while, but today we have much more efficient wind power, we had small solar power plants and now have huge solar plants like the photovoltaic roofs in Germany, and we are rethinking about the power of the atom as well. We need to revisit all the options, and also think in terms of non-energy emissions, checking forest losses, which are today significant, whether for roads or timber logging or by forest fires or for expanding agriculture.

Global agriculture requires reformed policies and the markets. Globally, there is need for a fair trade. The developed world is putting a billion dollars a day in subsidies to its farmers; that is about six times the total amount of ODA for all purposes, not just agriculture. A typical cow in the European Union receives 2 Euros a day. Is that fair? Can we consider this as a world policy? Is the competition between the first world and the third world under these conditions fair?

Locally, the third world has a lot to do. We have to remove the urban bias in roads, infrastructure, education, and health and we have to address the short-term vulnerability of farmers, for which reason they live precariously and the down side of which is devastating and climate change is increasing vulnerability. We need to address that through education, community action, and behavioral change that deals with consumption, destruction of our environment, wasteland pollution occurring every where. The marginalization and poverty and the starvation and hunger in the world, with which I started my presentation, have to be dealt with. A changing role for women and a dialogue and cooperation to see no more wars are needed, as so much money is being spent on them in different countries. We need to address priorities, including 'more crop per drop', drought resistance, and salinity resistance so that the hungry and poor will have more food.

We need to look at options for immediate improvements, and not reinvent technology. Mitigation and remedial actions are needed, as well as harnessing new technology such as nanotechnology, remote sensing, and biotechnology. And science in that sense can provide for a second 'green revolution' with greater diversity, less use of chemicals, more interaction with nature, more integrated approach to soil, water and nutrient management, recognizing the gender dimension, focusing on small-holder farmers, addressing alternatives to existing issues, recognizing the post-harvest losses in farming and increasing the value of food production; always pro-poor, pro-women and pro-environment, but, above all, harness the tools of new biology focused on agriculture, to dissemination of existing findings but also new research, and use the new sciences, which I call BINT, 'Bio-Info-Nano-Technologies', and which are converging. How converging these technologies are can be illustrated by a simple example of new synthetic biology, Synthetic Genomics, used by Craig Venter to tailor-make a bacterium from scratch, for which he has filed a patent for this synthetic life-form that he wants to engineer. So, who knows where we are going to go with new biological tools.

Ladies and Gentlemen, the challenges are great and enormous. But time is running out. We all have to work together in order to serve the next generation and to be better stewards of the earth.

Keynote Addresses

Keynote address 1. Dr Kanayo F. Nwanze, *Vice President, IFAD, Rome, Italy*

Coping with climate change in rural communities: the untold story

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Abstract

The evidence from the Intergovernmental Panel on Climate Change (IPCC) is now overwhelmingly convincing that climate change is real, that it will become worse, and that the poorest and most vulnerable people, particularly those in the agricultural sector, will be affected first and most. Poor rural people today are hardly integrated with emerging structures and mechanisms for dealing with climate change. They have little access to resources and scientific knowledge. Their vulnerability to climate change is being aggravated by the stresses associated with subsistence production, including isolated location, small farm size, informal land tenure, low levels of technology and narrow employment options, in addition to unpredictable and uneven exposure to world markets. Yet, the rural poor are forced to cope with the frequent droughts, heavy flooding, intense cyclones and other extreme weather events they experience and have to find ways to adapt. Poor rural people do not only suffer from the effects of climate change, but they are also part of the solution. To show how poor rural people cope with climate change this paper discusses the impact of climate change on them and the means by which they can address climate change through adaptation and mitigation. These approaches must be suited to local conditions, involve the rural communities, be integrated with longer term development plans and should be low cost. This is substantiated with examples from IFAD and other organizations. Finally, it discusses what and how national and international parties through financing and other mechanisms can do more to help rural populations with the challenging consequences of climate change.

If we care about our legacy for succeeding generations, this is the time for decisive global action
Climate change is not science fiction, it is real and present

- UN Secretary General Ban Ki-Moon

1. Introduction

The evidence from the Intergovernmental Panel on Climate Change (IPCC) is now overwhelmingly convincing that climate change is real, that it will become worse, and that the poorest and most vulnerable people, particularly those in the agricultural sector, will be affected first and most.

Poor rural people today are hardly integrated with emerging structures and mechanisms for dealing with climate change. They have little access to resources and scientific knowledge.

[1] Authors would like to also acknowledge the contribution made by Ayu Tamara Lampe (IFAD).

Their vulnerability to climate change is being aggravated by the stresses associated with subsistence production, including isolated location, small farm size, informal land tenure, low levels of technology and narrow employment options, in addition to unpredictable and uneven exposure to world markets. Yet, the rural poor are forced to cope with the frequent droughts, heavy flooding, intense cyclones and other extreme weather events they experience and have to find ways to adapt.

Poor rural people do not only suffer from the effects of climate change, but they are also part of the solution. To show how poor rural people cope with climate change this paper discusses the impact of climate change on them and the means by which they can address climate change through adaptation and mitigation. These approaches must be suited to local conditions, involve the rural communities, be integrated with longer term development plans and should be low cost. This is substantiated with examples from IFAD and other organizations. Finally, it discusses what and how national and international parties through financing and other mechanisms can do more to help rural populations with the challenging consequences of climate change.

2. Climate change context

Climate change is now an unequivocal fact and its effects are accelerating.[2] Evidence from the Intergovernmental Panel on climate Change (IPCC 2007a, b)[3] shows that higher temperatures combined with changes in rainfall patterns lead to more frequent droughts and floods, to more seasonal peaks in river flow and stronger tropical storms. Such changes will affect water supplies; threaten the viability of coastal areas vulnerable to flooding; lead to a loss of biodiversity; increase wildfires; and reduce fish stocks due to ocean acidification.

Greenhouse gas emissions constitute one of the main causes of climate warming and change. These emissions, due to human activities, have increased at the rate of 1.6 per cent per year over the past 30 years with agriculture, including forestry, contributing to more than 30 percent. By far the most important source of emissions is the energy sector, with fossil fuel use for energy supply and consumption and road transport making up over 60 per cent of emissions. Most of these emissions come from industrialized and a limited number of large middle income countries.

Agriculture and deforestation are also important – particularly in developing countries, and together these make up over a quarter of all emissions[4]. More than half of this comes from deforestation largely caused by agricultural encroachment; other significant sources are the livestock sector and rice production, which result in methane emissions, and excessive use of fertilizers, which produces nitrous oxide. While North America and Europe have produced around 70 per cent of all CO_2 emissions since 1850, most future emissions growth will come from today's developing countries, because of their more rapid population and GDP growth, and their increasing share of energy intensive industries.

[2] The global average temperature rose 0.74°C over the last century and could increase 3°C during this century, primarily due to increases in greenhouse gas concentrations.
[3] IPCC 2007(a, b). Agriculture is particularly vulnerable to climate change. It is estimated by Cline et al. (2007a) that, under a business as usual scenario, agricultural productivity in general could decline between 10 to 25 per cent by 2080. For some countries, the decline in yield in rainfed agriculture could be as much as 50 per cent. Models indicate some initial productivity gains in countries of northern latitudes, but in the longer-term and persistent changes, all countries will stand to lose from climate change. See Fisher et al. (2002). See also Easterling et al. (2007) for effects on the poor in the agricultural sector.
[4] Since forests act as a carbon sink, deforestation results in increased levels of CO_2 in the atmosphere

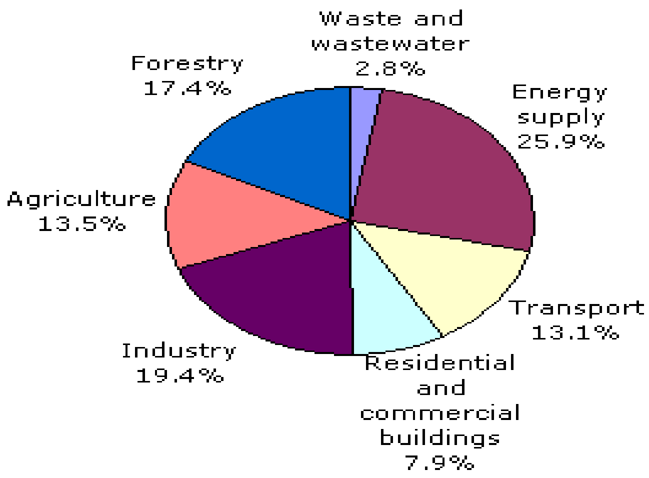

Figure 1. Sources of greenhouse gases 2004. Source: FAO, 2008

2.1. Climate change impacts on developing countries

While greenhouse gas emissions are primarily produced by industrial countries, developing countries suffer the most from its impacts. Indeed, the countries most at risk from drought, floods, storms, rising sea levels and changes in agricultural production are virtually all developing countries, and the vast majority is of the least developed countries. Sub-Saharan African countries dominate the list of the most drought-affected and consequently also suffer the largest negative impacts on agricultural production, South and South-East Asia are disproportionately flood-affected, and the Pacific and Indian Oceans are the areas most exposed to hurricanes. During the 1990s, 200 million people were affected by climate change-related disasters in developing countries versus 1 million people in developed countries.

Table 1. Countries most at risk from climate change-relate threats

Drought	Flood	Storm	1m a.s.l.	5 m a.s.l.	Agric.
Malawi	Bangladesh	Philippines	All low lying island states		Sudan
Ethiopia	China	Bangladesh	Vietnam	Netherlands	Senegal
Zimbabwe	India	Madagascar	Egypt	Japan	Zimbabwe
India	Cambodia	Vietnam	Tunisia	Bangladesh	Mali
Mozambique	Mozambique	Moldova	Indonesia	Philippines	Zambia
Niger	Laos	Mongolia	Mauritania	Egypt	Morocco
Mauritania	Pakistan	Haiti	China	Brazil	Niger
Eritrea	Sri Lanka	Samoa	Mexico	Venezuela	India
Sudan	Thailand	Tonga	Myanmar	Senegal	Malawi
Chad	Vietnam	China	Bangladesh	Fiji	Algeria
Kenya	Benin	Honduras	Senegal	Vietnam	Ethiopia
Iran	Rwanda	Fiji	Libya	Denmark	Pakistan

Note: m a.s.l.: meters above sea level Source: IDA (2007).

Developing countries are particularly vulnerable to climate change not only because of the specific climatic conditions they face, but also because of their lack of economic development. The majority of developing countries is predominantly rural, and they have a greater dependence on agriculture and natural resources. Limited infrastructure leaves these countries more exposed to the effects of climate change; low incomes and poverty mean that their populations have a lower capacity to adapt to the effects of climate change; and weak capacity constrains the ability of their governments to provide policies and investments in support of adaptation. The inadequacy of complementary services such as health and education only multiplies the impacts.

Agricultural production

Agricultural production, which remains a key element of the livelihoods of most rural people, will be particularly affected, and the ability of many poor rural people – and particularly smallholder farmers and artisanal fishers – to produce adequate food for their consumption needs will be further constrained. Most projections suggest that agricultural production will decline in most of the developing world, as a result of declining water availability, increased temperatures, uncertain – and in many cases reduced – growing season length, reduced area suitable for arable production, and new patterns of pests and diseases. Throughout Asia, a shrinking winter season is resulting in decreases in production of winter crops, particularly potatoes. In parts of Bangladesh, temperature and rainfall changes have already affected crop production and the area of arable land has decreased. In Ethiopia, farmers have noticed definite changes in local climate, referring to the increasingly erratic, yet reduced rainfall. Farmers have noticed that the sorghum-growing season has shortened over the years, and in years when rainfall starts later and ends early, yields are almost halved (IIED 2006a). Farmers and artisanal fishers will also find that their traditional knowledge about local agro-climatic conditions loses its value and relevance under changing weather patterns. Africa is expected to fare worst (Fig. 2) as a result of both declining yields and reduced arable area, and many poor rural people currently living in the margins of arable lands will find themselves unable to farm.

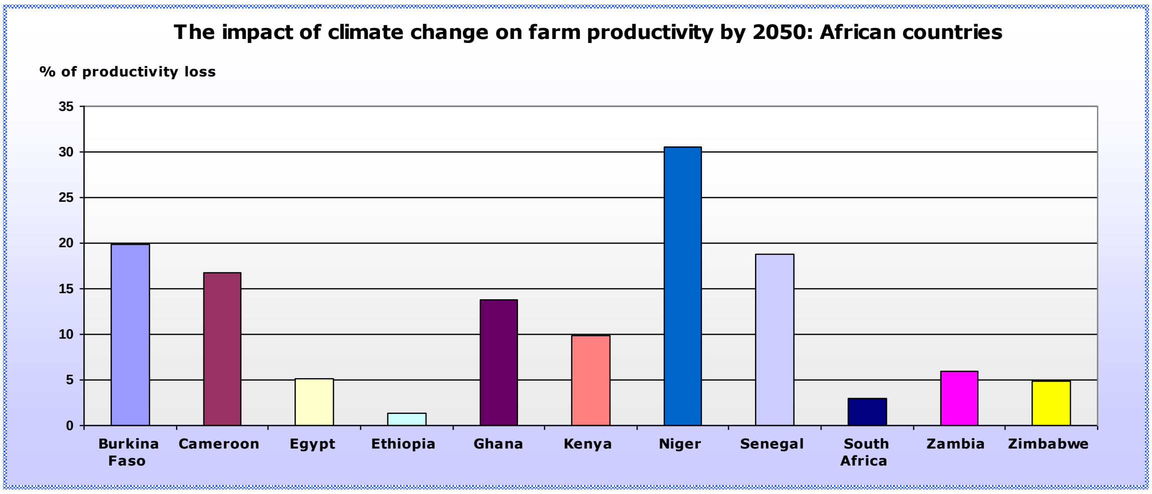

Figure 2. The impact of climate change by 2050 on farm productivity in some African countries.
Source: Based on Maddison et al. (2007)

Food shortages

Climate change poses a serious risk to poverty reduction and development, with adverse impacts expected on the environment, human health, food security, economic activity, natural resources and infrastructure (African Development Bank et al. 2003; IISD 2007). The

IPCC's Fourth Assessment Report warned that global warming would cause widespread food shortages in the developing world (IPCC 2007; Harvey 2007) and a recent analysis by Cline (2007) suggests that global agricultural production will decline between 10 and 25 per cent by 2080, with an 8 percent increase in developed countries offset by a 9 per cent decrease in developing countries. This will lead to increased levels of hunger, with the poorest countries worst affected.

Conflict

The depletion of natural resources often leads to conflict over access to and rights on water and land. In Kenya during times of drought, pastoralists have traditionally converged at Sambarwawa riverbed to dig shallow wells of water. Yet the increased frequency and severity of droughts have led to a drop in water levels. The traditional strategy for coping with droughts is under enormous strain as shallow wells are drying up. As a result, different ethnic groups are fighting one another over the remaining viable boreholes leading to frequent injuries as well as deaths.

Natural disasters

The sharpest impact of a changing climate will be the rise in incidence and severity of climate-related disasters such as increased flooding, particularly in Asia, as well as fiercer storms and prolonged droughts. In Kenya, the Turkana have experienced this increased frequency of droughts, and have called the latest drought *Atiaktiak ngáwiyei*, 'the one that divided homes' as families have been forced to split up, migrating for survival. The severity of the droughts, have left the Turkana to resort to practices that are often damaging in the long run to their livelihoods and environment, such as resorting to increased charcoal production that encourages deforestation, fighting over water and pastures, the selling of livestock, and keeping children out of school to seek work (IIED 2006a).

While the Kenyan experience shows that smallholder farmers are struggling to derive coping measures, it also shows the lack of sustainable mechanisms available to these farmers to deal with a life threatening situation. Climate change poses a set of new challenges to farmers, governments and the international community in building the resilience of people who rely on climate dependent resources for their livelihoods. People's adaptive capacity depends on how they can draw from resources to maximize their livelihood outcomes.

3. Coping with climate change

Tackling the adverse impacts of climate change requires a considerable effort both in terms of adaptation and mitigation. Mitigation – reducing emissions of greenhouse gases or sequestering emissions - is critical to stemming climate change. Adaptation aims to reduce the vulnerability and improve the adaptive capacity or resilience of people who rely on climate-dependent resources for their livelihoods. Adaptation is critical to enabling the rural poor cope with the adverse impacts of climate change now and in the future.

Coping strategies of rural communities

Rural areas in developing countries are the home to some 450 million smallholder farmers whose livelihoods depend on agriculture and are therefore more prone to the adverse impacts of climate change. Yet, they are barely integrated into the emerging structures and mechanisms addressing climate change. They have little access to resources and scientific knowledge. Their vulnerability to climate change is being aggravated by the stresses associated with subsistence production, including isolated location, small farm size, informal land tenure, low levels of technology and limited employment options, in addition to unpredictable exposure to world markets. Climate change represents an additional threat to the already-precarious livelihoods and coping strategies of poor rural households, and it reinforces their existing vulnerabilities.

Yet, smallholder farmers are continuously adapting to climate variability as they change crops or varieties, choose different harvest and sowing dates, alter land management, and employ water efficiency techniques (FAO 2007). They can provide traditional knowledge about adaptation practices and can be taught to implement innovative, low-cost adaptation options. These autonomous adaptations, on-going implementation of existing knowledge and technology in response to experienced changes in climate, are highly relevant to smallholder farmers.

What follows are stories illustrating evidence of the impact of climate change on poor rural communities. Equally important, these stories also present solutions that are already taking place. Poor rural people do not have the option or luxury of sitting back and waiting for external assistance or for their situations to change as their livelihoods and survival remain in jeopardy. The international community can learn from these simple measures they are taking, to see what is working and what may not be sustainable. As an international community, we can help poor rural people be part of the solution; we can complement their efforts and support them in their struggle to adapt and mitigate the impacts of climate change.

The first story of farmer Liakat shows how climate change has shaped his fortunes. Mohamed Liakat, a 52-year-old farmer from the village of Gidari in Bangladesh, started his farm in the mid-1970s with 19.8 acres of land, eight cows, a variety of crops and a pond with fish, but now he is completely landless. First, let us look at the factors that led to this misfortune.

- Liakat has witnessed many changes over the last few decades such as fewer crop varieties, more floods and erosion and many other farmers becoming landless.
- He observed that temperatures are steadily increasing in summer and decreasing in winter.
- He has experienced heavy rains and frequent floods
- Liakat has experienced many climate change-related disasters. The first was the 1978 flood in August/September. A second flood came back with a vengeance in 1984 from June to September. There were also heavy hailstorms that damaged most of his crops in February 1985. In 1988, fierce floods hit Liakat’s village again from June to September. These washed away all of his crops, livestock and other assets. The flood was followed by severe river erosion.

A study by Practical Action Bangladesh has confirmed these observed changes.

Meteorological data prove that temperatures have been increasing over the last 30 years. Winters are becoming warmer than they were 30 years ago, which affects winter crops, particularly potatoes; the number of days without rainfall is increasing although total annual rainfall varies little which indicates the occurrence of heavy rain over short time periods and also more droughts.

The consequence of these series of events confirming the impact of climate change is that flooding and erosion have led to the loss of land, crops and other assets. Liakat no longer had land for his farming, nor did he have a proper dwelling for himself and his family.

Liakat became very worried about his income and livelihood. The question is, “How does he adapt to changing climatic conditions that have had such diverse and adverse impacts on his life and livelihood?” Here are some of the measures Liakat took to overcome his misfortune:

- Out of necessity, he has shifted his homestead five times due to erosion and floods.
- He sought assistance and opportunities for a diversification of his livelihood.
- He received training and technological support and explored various activities to increase his income.
- After training he established a nursery in his backyard to grow vegetables; rears ducklings and grows vegetables on floating beds during the monsoon.
- He has sold 3,000 tree seedlings earning himself Taka 12,000 [USD 176]. He has reinvested some of this money to grow more saplings in his nursery.
- He now meets his family’s needs and is confident that soon he will be able to buy some agricultural land and livestock, which will make him a rich farmer in a few years like his father before him.

This illustrates that for poor rural communities, there is no option but to immediately respond to whatever crisis climate change has wrought. Simple measures such as switching means of livelihood and using simple solutions such as floating gardens are key activities undertaken by those affected by climate change and can improve resilience to the impact. With assistance from the international community, there are opportunities to enhance and scale up measures already being undertaken. Such stories must be told, to support building farmers’ resilience to climate change.

The story of Liakat is that of millions of farmers around the world seeking ways to improve their livelihood, while at the same time coping with the challenge brought by climate change and other crises.

Climate change and women

Poor women are more likely to become direct victims of climate change disasters[5]. Many of the poorest households in much of the developing world are headed by women, many of them living in marginal lands, along dangerous riverbanks, or on steep slopes, where they are most vulnerable to the effects of extreme weather. As a cyclone and resulting flooding hit Bangladesh in 1991, women’s death rate was five times higher than for men. Climate change also affects the day-to-day livelihoods of rural women. Because most agricultural work in many developing countries is done by women, any increased work load is likely to fall on them; and reduced agricultural production means that they have to work that much harder to secure the food requirements of the family. At the same time, erratic rainfall, drought and deforestation mean that women and girls also need to spend more time collecting water and fuel wood. Climate change thus risks magnifying existing inequalities, and reinforcing the disparity between women and men and their capacity to cope.

[5] For example, in North Aceh district of Indonesia, 80 per cent of tsunami deaths were women (UNIFEM 2005)

In Tajikistan, women have observed that the beginning and end of winter has become less predictable; snow pack is also increasing which makes roads inaccessible for up to 5 months in the year. Agricultural productivity is in decline due to shortened growing seasons and food availability during the winter months is limited with insufficient nutritional value. Women are also traveling longer distance to collect fuel in the face of colder winters. To adapt to these new climatic conditions, women increased their community action, they constructed cold frames (small greenhouses) and are now planting seedlings earlier in the year. Cold frames extend the growing season by two months. Planting kitchen gardens, women are teaching each other food preservation for the winter months which allows for a greater variety of food and improved nutritional value of winter diets.

Traditional knowledge

In Sri Lanka, traditional knowledge has enabled Ranjith to adapt to the increasing salt water found in the coastal rice fields. Rising sea levels cause salt water intrusion into coastal lagoons and estuary systems. The increasing soil salinity is further exacerbated by higher temperatures and declining rainfall which leads to decreasing ground water levels. Agricultural productivity and yield are in decline due to soil salinity. Getting less than half of their expected yields, farmers' livelihoods are in jeopardy. Some farmers have been forced to abandon their barren fields. With the assistance of a local NGO, Ranjith and other farmers tested different traditional rice varieties for their salinity tolerance. Ranjith chose to start cultivating his field with a traditional variety and abandoned the hybrid that had been previously promoted. He increased his use of organic fertilizer and decreased the use of chemical pest control which mitigated the soil salinity problem. While the traditional variety does not produce as high a yield as hybrids, he is still able to make good profits since there is great consumer demand for traditional rice varieties.

Rural communities as part of the solution

Farmers observe first hand the effects of climate change that impacts upon their lives. This places them in the best position to identify the problems and solutions. In Ethiopia, peasant farmers and pastoralists are aware of increasing climate variability and have long developed strategies to respond. A diversified resource base, changing crop varieties and species, changing timing of activities, techniques and location are some adaptation measures used by Ethiopian farmers. These farmers have sought to conserve water resources so as to avoid unnecessary crisis during dry seasons. They have also learned that spreading risks across locations and time is proving to be essential. Observation of the natural environment, such as looking at the appearance of plants, flowering density of trees, immature dropping of fruits, wind direction and appearance of certain animals or insects is long been used to predict near future weather conditions (Kalbessa 2007).

Whilst some practices are unsustainable, engaging in these practices is often a result of lack of information, opportunities and access to resources to engage in first choice options. We must consider that poor rural people are often able to identify the problem and solution, though they may require assistance to apply these solutions. The case of farmer Joshua in Kenya is an illustration of unsustainable practices.

Joshua is one of 2 remaining farmers in a community which once consisted of 300 farmers. He grows eggplants, peppers and other crops for local and export markets. Twenty years ago, his land and the area around him were fertile and verdant due to irrigation from a canal that flowed for 7 km. Today, due to the drop in rainfall levels, the water only travels for 0.5 km. Joshua estimates that the community now gets 40% less rain than they used to. As a result, farmers have abandoned their farms. Without a livelihood, these farmers have become destitute and impoverished. Joshua has identified water management and assistance with irrigation systems as the solution. In particular, the canal needs to be repaired to reduce leakages. Yet, he lacks the resources and technical knowledge to implement his solution. Therefore, he requires support from his government and the international community to effectively adapt to the consequences of climate change in his area.

This story shows us that farmers have a strong interest in being a part of the solution. They have been able to identify their problem and the solution to the problem. In this case, farmers recognize that irrigation and improved water management could be an important part of the solution to their problem. As such, external assistance is sought to complement existing efforts. The international community can learn from these simple measures that rural communities are taking to see what is working and what may not be sustainable.

4. Support from the international community

Long-term climate change poses a new set of challenges to farmers dependent on natural resources, and so at the national and international level, governments and development agencies play a fundamental role in building the capacity of farmers to cope with and adapt to a changing environment (Soussain et al. 2003).

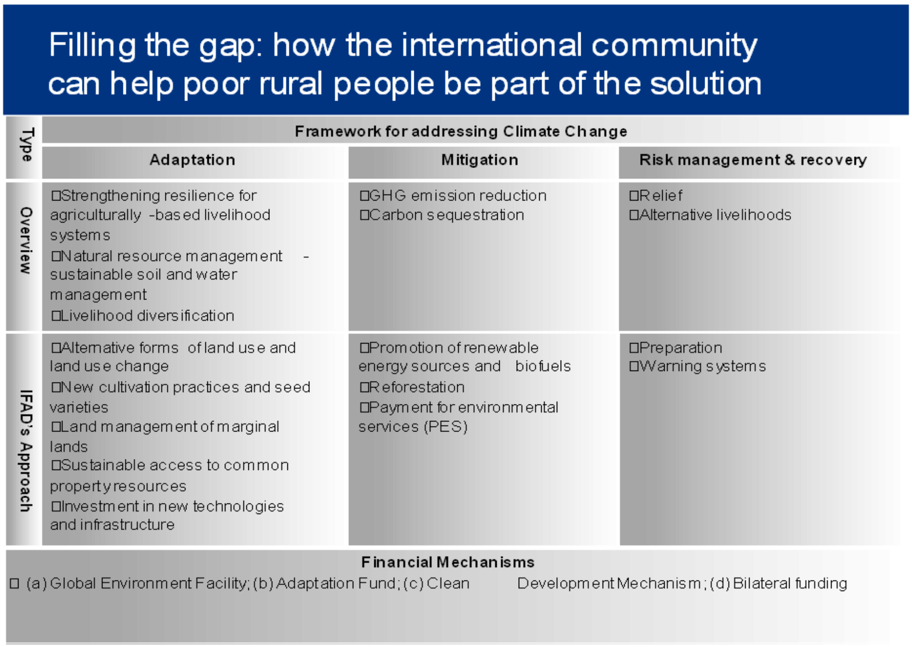

Figure 3. Role of international community in making rural poor as the part of the solution for the problems emanating from climate change.

4.1. Adaptation approaches

Poor rural peoples' adaptation capacity is often negatively affected by lack of access to financial resources and technology. However, there are many low cost technologies which give excellent results in terms of adaptation by poor rural people. Projects which involve low investment requirements are often small-scale, low-technology projects. In addition to providing low cost adaptation options, they offer the advantage of local control, direct benefit to the poor rural people, and are more easily manageable by poor rural people themselves[6]. While there can be various options for adaptation, both large and small scale, poor rural people are better served with adaptations which are:

a) Geared to the specific needs of poor rural people and suited to local conditions;
b) Involve the community;
c) Integrated with longer term development plans; and
d) Low cost.

These are often small scale and less expensive options that may be scaled up.

Location specific adaptation

Given the existence of country-specific factors of vulnerability, and given the diverse impact of climate change across regions and countries, there cannot be a unique adaptation approach. On the contrary, adaptation has to respond to the local conditions and diversities. Solutions have to be specific in focus and yet flexible enough to be tailored to specific needs.

Community-based approach

Adoption of a community-oriented approach is key to better understanding such diversities and to provide adequate solutions for adaptation. For example, community-based adaptation (CBA) has so far produced impressive results. CBA begins by identifying communities that are most vulnerable to climate change, and involves identification of risks and constraints through a process of participation of all the actors of the community. Knowledge from indigenous people and local coping strategies can be taken as a starting point for further adaptation planning.

CBA has produced great results in Bangladesh, where a CARE-led project is helping poor rural people living in coastal zones to cope with sea-level rise, loss of biodiversity, increasing salinity, more extreme rainfall variability, and more intense cyclones. Through local partners, CARE developed the community's capacity to engage with climate adaptation, and promoted livelihood diversity as a practical response. Two positive results have been observed in this flood prone area: 270 households started growing vegetables on floating gardens in waterlogged areas, and 1,700 households began rearing ducks.

Improved agricultural techniques

There are preventive measures that can be taken to avoid the negative impacts which include the promotion of sustainable natural resource management. There is the use of improved agricultural techniques to address the present and future changes that they are and will experience such as the planting of faster maturing maize in Malawi by some small-scale farmers dependent on rain-fed agriculture to cope with more frequent droughts.

Conservation agriculture

Conservation Agriculture (CA) is another low-cost adaptation practice that promotes sustainable natural resource management and is easily implementable by rural poor. CA

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[6] "The types of interventions that are appropriate rarely involve large-scale irrigation schemes. The focus is on schemes that are easy to operate and maintain locally and that target female and male smallholders", *IFAD and FAO (2008). Water and the Rural Poor, Interventions for Improving livelihoods in sub-Saharan Africa, Rome 2008*

maintains and improves crop yields and resilience against drought while protecting and stimulating the biological functioning of the soil. It is based on three simple principles: direct planting of crop seeds (zero tillage), permanent soil cover, and crop rotation. Zero-tillage practices save about 30% of the water needed and between 30% and 40% of labor required. Considering that, in sub-Saharan Africa, 64% of cultivated land is tilled by hand, CA can save time and labor for other income-generating activities in this area. While conservation agriculture promotes sustainable natural resource management, preventive and responsiveness measures should go beyond simple natural resource management and foster resilience to the impacts of climate change. In Zambia for example, conservation agriculture has helped vulnerable households survive drought and livestock epidemics, and more than 200 000 farmers are now using this technique. In the 2000–2001 drought, farmers who used conservation agriculture managed to harvest one crop, others farming with conventional methods faced total crop failure. In Ghana, more than 350 000 farmers now use conservation agriculture. Through IFAD-provided grants, CA is now also being promoted in Western and Central Africa by the African Conservation Tillage network (ACT) and the World Agro-forestry Centre; and in southern Africa, by the International Maize and Wheat Improvement Centre. Whilst contributing to improved nutrition and incomes from sales, tree planting has also proven to help stabilize the fragile ecosystems, reducing landslides and enhancing soil fertility.

Coastal zone protection

Even coastal zone protection may be implemented through very simple practices. A good example is represented by mangrove preservation, which shelters coastal zones from extreme weather events. Mangrove preservation is currently supported by the IFAD-financed Post-Tsunami Rehabilitation and Coastal Communities Resource Management project in Sri-Lanka. This project is aims to develop and replicate three key coastal ecosystems – mangroves, coastal lagoons, and sand dunes – at specific sites all along the East Coast, to protect poor rural people from floods and storms.

Water management

To cope with droughts, water storage can be implemented easily by building stone walls and terraces to stop water run-off, as demonstrated by an IFAD-supported project in Jordan. This project helped poor farmers build more than 1,000 cisterns to collect winter rainfall; these cisterns used gravity to drive water through the farm irrigation systems, providing water during the drier seasons. As a result, land in the project area has become more fertile, and farmers have been able to plant olive and pistachio trees, grapes and barley. The incomes of more than 40,000 people have risen by 12 per cent and family nutrition has improved. The second phase, which began in 2005, promotes water harvesting techniques, such as wadi bank (stone barrier) protection, instead of relying on groundwater for irrigation. It has helped establish associations of water users and supports research on using treated domestic wastewater to irrigate trees. Initiatives such as this have helped Jordan diversify its agriculture and increase the replenishment of groundwater.

Income diversification – Bangladesh

To cope with frequent floods, women farmers in Bangladesh are growing vegetables on hyacinth rafts in flood-prone areas. In the Sunamganj District of Bangladesh, fishing communities do not have a regular income for more than four months a year during the monsoon. Many of the families live on one meal a day. IFAD supported project is mobilizing poor people and training members of community in: group building; leadership development; savings and credit management; fisheries resource management; alternative income-generating activities such as backyard agriculture, food processing, and livestock, poultry and duck rearing. A group of 75 fishers gained access to 27 ha of *beels* (wetlands). They were introduced to community-based sustainable fisheries management to ensure lasting resources; and they participated in activities such as planting swamp trees and establishing a fish sanctuary. The group made a profit of USD 3500 from these activities.

Through the savings and credit schemes supported by the project, two women's groups comprised of 52 members saved USD 2310. These women received credit from the project, which they used to invest in small trades such as starting up grocery and tailoring shops, buying boats and nets, and livestock rearing and agricultural activities. The investments provided project participants with a substantial additional income. The group savings and credit schemes have also freed the members of these groups from the clutches of moneylenders.

However, adaptation to climate change illustrated by the examples given above is only one approach. Poor rural people can also contribute to mitigation measures

4.2. Mitigation measures

Mitigation has revolved around the reduction of greenhouse gases (GHG) and the enhancement of carbon sinks to absorb them[7] (Boyd 2002). Although responsibility for carbon emissions resides primarily in developed countries, fossil fuel use and industrial processes, rural poverty, and subsistence agriculture account for a portion of emissions of carbon dioxide that stem from deforestation and land use change.[8] In addition, rural poor women and men generally lack access to energy-efficient services that do not degrade the ecosystem or contribute to environmental change. Rural households typically rely on biomass for cooking and heating. Thus, rural poor people can contribute to the reduction of GHG emissions through carbon-neutral agricultural practices, or by sequestrating carbon through forest management (WB, FAO, IFAD 2009).

As natural resource 'users', farmers are consumers and at the same time potential providers of a wide range of environmental services that contribute to carbon sequestration and limit carbon emissions, such as planting and maintaining forests, managing rangelands and rice lands, and watershed protection that limits deforestation, soil erosion and flooding risks.

However, the rural population is under-compensated for the services they can provide to secure ecosystem conservation and restoration. In that context, the payment for environmental services (PES) and other rewards systems, tailored to local specificities, can provide an accounting approach for pricing these incentives, and through proper design can be a powerful pro-poor mechanism for mitigation.

Payment for environmental services

One encouraging IFAD program underway is Rewarding Upland Poor for Environmental Services (RUPES) which works on pro-poor implementation of PES in Indonesia, Philippines and Nepal. The activities under RUPES have had a significant impact on secure access to land, payments for water, maintenance of biodiversity and carbon sequestration. Nonetheless,

[7] The causes of global warming can be reduced either by reducing the emissions of greenhouse gases or by subtracting carbon dioxide from the atmosphere (http://www.fao.org/clim).

[8] http://www.fao.org/clim/mitigation_en.htm.

due to high transaction costs and the difficulty to access the relevant markets, on carbon sequestration, RUPES has yet to reach the stage of providing real benefits to the upland communities concerned. Rural populations are ready to sell their services, but the connection with carbon credit buyers is not yet effective. It is expected that the market will develop shortly.

Carbon sequestration

The potential of indigenous practices in terms of contribution to mitigation has been recognized since the Third Assessment Report in 2001, where IPCC stated that "*instead of an exclusive reliance on financial and technological assistance, […] there is a need to invest in indigenous capacity to undertake mitigation without compromising the development agenda*" (IPCC 2007). Despite indigenous populations practicing sustainable, carbon-neutral, or even carbon-negative, lifestyles, thus contributing to global GHG mitigation, indigenous people are still not integrated into financial mechanisms rewarding the provision of environmental services. Few schemes have been undertaken to reduce transaction costs associated with contracting for poor or indigenous communities. One of them, the *Scolel Té project* in Mexico, provides a good example of what could be done to integrate indigenous people into PES mechanisms.

The Scolel Té project in Mexico is a carbon sequestration scheme based on agroforestry practices, and tries to integrate indigenous communities into small-scale carbon trading. The project benefits 400 individuals from 30 indigenous communities representing four different ethnic groups. The particularity of the project is its ability to initiate carbon trading at a very small scale and to function with minimal resources. The Scolel Té project has resulted in community empowerment. In addition, a survey found that participants highly valued the information and training they received on forest management (Tipper 2002).

Another example is a project implemented by the Fundación Sol de Vida in the Santa Cruz and Nicoya counties of the Guanacaste region of Costa Rica. The focus is to promote the use of solar power for cooking and to build women's capacity for other activities through constructing and using solar cookers. Over 130 households have switched from wood, electricity, or gas to solar cooking, thereby reducing greenhouse gas emissions. The project has reduced the health risks associated with wood burning and reduced women's workload, because they no longer collect fuel wood. Women build the stoves themselves then teach others to do the same. Sol de Vida has exported this model to Guatemala, Honduras, and Nicaragua. (WB, FAO, IFAD 2009).

4.3. Risks and recovery

In terms of natural disasters and climate change, the international debate has evolved in recent years, with many experts asserting that efforts to curb global warming or reduce greenhouse emissions are not enough to protect the most vulnerable populations in the near term. Measures to adapt to climate change and reduce the risks of crises must be put in place. Typically such efforts are highly localized, and to be effective must be tailored not only to the local environment but also to poor rural communities.

In Indonesia the Post-Crisis Program for Participatory Integrated Development in Rainfed Areas was designed to build poor rural people's institutions in the form of self-help groups that work closely with other community-based organizations managing local resources. Group members can develop their skills, undertake a range of initiatives through collective action and become self-reliant. This program aims to reach 450 000 people living in some of the poorest villages in Indonesia.

Beyond enhancing the population's resilience after disasters, some of IFAD's support has been extended to help rural people better prepare for future risks. In Sudan and Ethiopia, environmental warning systems were established to allow rural populations to adjust their livelihoods to expected drought effects. In China, farmers are exposed to cyclical poverty as a result of regular crop failures, induced by erratic weather patterns. IFAD has therefore co-funded an initiative to develop and implement an index-based weather insurance system. Particularly for economies based on rain-fed agriculture, weather continues to be one of the most persistent production risks. In this regard, index-based weather insurance, particularly for the agricultural sector, is an opportunity for managing weather risk. The system is based on local weather indices (common variables include temperature, rainfall), usually highly correlated to local yields. For the agricultural producer, identifying weather risk involves identifying a measurable weather index that is strongly correlated to the farmers' losses on a particular crop in a defined time period. Compensations are triggered by pre-specified patterns of the index, rather than yields. As the insurance is based on reliable and independently verifiable indices, the risk can be efficiently transferred to the market at a premium (UNDESA 2007).

This private-public funded activity will insure rural poor people's incomes against weather hazards, breaking the pattern of the frequent risk of 'short term shock – long term impact.' IFAD has been supporting improved warning and preparedness systems, focusing on meteorological risks in arid zones with increased frequency of droughts.

5. Mobilizing resources

Both adaptation and mitigation will need additional resources.[9] Unfortunately, financial support for smallholder farmers for implementing adaptation and mitigation options has been too little and too slow in reaching them. According to UNFCCC, 50-170 billion US$, will be globally needed for adaptation in 2030, and 200-210 billion US$ for mitigation. In developing countries, US$ 90-100 billion will be needed for mitigation, and 30-70 billion for adaptation. As for the rural poor, US$ 55-65 billion per year are needed to mitigate in the agriculture, land use, land use change and forestry sectors, and 28-67 billion US$ to implement adaptation. Current estimates of costs are tentative,[10] and depend on the climate change scenario, and on how ambitious the adaptation regimes are expected to be.

Funds for adaptation

The Global Environment Facility (GEF)[11] is the primary institutional structure through which most of the funds set up under the UNFCCC and the Kyoto Protocol are channeled. There are four financial resources for adaptation currently managed by the GEF: the Least

[9] In addition to the current level of Official Development Assistance, which in 2006 stood at about US$104 billion.

[10] On the basis of 13 NAPA budgets, Oxfam estimates that for all developing countries an additional US$7.7 billion (projection on population basis), US$33.1 billion (projection on GDP basis) and US$14.4 billion (projection on land area use basis) are needed. See Oxfam briefing paper 104 (2007). An UNFCCC-sponsored study on financial flows estimates the cost of adaptation in the AFF sector in 2030 at about US$14 billion, but warns about the tentative nature of its estimates.

[11] The Global Environment Facility (GEF) is the primary financial mechanism of the UNFCCC. It provides the structure for the transfer of financial resources from developed to developing countries.

Developed Countries Fund (LDCF), the Special Climate Change Fund (SCCF), the Strategic Priority on Adaptation (SPA) under the GEF Trust Fund and the Adaptation Fund (GEF 2007b). Through the SPA, the LDCF and the SCCF, the GEF has provided (as of 2007) US$289 million for adaptation.

The Adaptation Fund, established at the Thirteenth Conference of Parties (COP13) in Bali,[12] supports "concrete adaptation activities." The Adaptation Fund is expected to become the largest and most reliably funded of the existing funds. The World Bank estimates that the amount of money available may amount to a total of US$100 to $500 million by 2012 (World Bank 2006).

Funds for mitigation

In mitigation, options for financing are much broader and are still emerging. The growing market for carbon for projects and activities such as the Clean Development Mechanism (CDM) and voluntary markets demonstrates that the sequestration of carbon could offer opportunities for smallholder agriculturalists to gain from the mitigation potential of the agriculture sector. In this case too, the participation of developing countries, and particularly the poorest communities within them, in the global carbon market, has been extremely challenging, because the modalities and procedures of the CDM in particular are complex and present many barriers to action.

Part of the problem lies in the detailed set of standards for CDM verification, which results in high transaction costs for CDM certification, and this excludes small-scale projects. Generally speaking, smallholders are not competitive sellers in carbon markets because of high transaction costs, and the small size of their projects. Efforts to overcome these barriers are important in engaging smallholder farmers in mitigation efforts and in making sure they benefit from the opportunities presented.

National adaptation programs of action

At the national level, National Adaptation Programs of Action (NAPAs) provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their urgent and immediate needs with regard to adaptation to climate change. The rationale for NAPAs rests on the limited ability of LDCs to adapt to the adverse effects of climate change. In order to address the urgent adaptation needs of LDCs, a new approach was needed that would focus on enhancing adaptive capacity to climate variability, which itself would help address the adverse effects of climate change. The NAPA takes into account existing coping strategies at the grassroots level, and builds upon that to identify priority activities, rather than focusing on scenario-based modeling to assess future vulnerability and long-term policy at state level**.** In the NAPA process, prominence is given to community-level input as an important source of information, recognizing that grassroots communities are the main stakeholders.

The LDC Fund was set up to support a work program to assist LDCs carry out the preparation and implementation of their NAPAs. However, full implementation of NAPAs can be limited by lack of resources. GEF does provide the opportunity to access funds for priority projects identified in the NAPA, but cannot finance a fully comprehensive national program for adaptation. Furthermore, implementation of NAPAs will really require institutional commitment and buy-in, and should be integrated with development objectives and priorities.

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[12] The management structure of the Adaptation Fund was finalized at COP13 to the UNFCCC in Bali in December 2007, and the fund is expected to become operational in June 2008. The fund will be located at the Global Environment Facility (GEF) and will be administered by a 12-member committee.

Access to most of the existing funds by smallholder farmers so far has been rather limited.[13] Among various barriers to accessing the funds, the complexity of project design and implementation and the need to comply with overwhelming administrative and financial management requirements have been identified as most critical (Solomon 2007). Most of these constraints can be removed through simplifying and standardizing project design and implementation procedures, simplifying administrative and financial requirements, and building awareness and capacity to comply with the requirements to access those funds.

6. Conclusions

Climate change and global warming are adding a new dimension to the challenge of eradicating poverty and hunger. Climate change has the potential to reverse much of the recent progress in reducing poverty, particularly in Africa. In confronting climate change, agriculture – especially smallholder agriculture – can play a major role. But whether poor farmers store or release carbon will depend on the opportunities they have and the incentives they are offered. We can help them to become part of the solution – helping to feed the world and store the carbon. To achieve this, we need to sharply increase investment in crop, range and forest lands, to manage them sustainably to increase production, as well as to contribute to mitigation and adaptation.

There is consensus on the importance of climate change and the need for the international community to address it in a collective effort as testified by the statement from the recent G8 Summit in Hokkaido, Japan where the discussion provided initial direction for global efforts that must be accelerated. The commitment made by the G8 to reduce emissions by at least 50% by 2050 is yet another testimony to this effect taking into account a differentiated approach between developed and developing countries.

Scientific issues have received a lot of attention at the international level. However, the issues related to the poor rural populations and their respective economies, including regional and local markets, have not received as much attention. There is a need to assist these populations in building resilience and to reassess their ability to address issues such as those related to their respective local economic conditions, including how they are influenced and how they affect prices and other market related parameters.

The willingness by the G8 to provide financial resources toward adaptation and mitigation in developing countries is a welcome development, although this should be done without compromising on-going efforts on development financing.

The very survival of hundreds of millions of poor rural people depends on the ability of the international community to provide support in an effective and sustainable way. A concerted, coordinated and collective effort is needed to increase investment in agriculture, if we are to be able to tackle the triple scourge of poverty, climate change and high food prices.

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[13] Some of the funds are relatively new and therefore it is too early to judge their accessibility. However, most of the funds that have been set up for some time are judged to have very limited accessibility by poor smallholder farmers.

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Keynote address 2. Dr Suleiman Al-Herbish, *Director-General, OFID, Vienna, Austria*

OFID - OPEC Fund for International Development, supporting sustainable development in dry areas*

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Abstract

While the institutions represented in this conference are different in many respects, we have much in common. Each organisation is dedicated to research, and service to society, including assisting with the application of knowledge to benefit humankind. Meeting the challenges of dry-lands, including desertification and land degradation requires large and long-term investments that are difficult to mobilize from central and local government budgets alone. OFID is committed to uprooting poverty and to working co-operatively with all spheres of public and private sectors to raise investor awareness and to ensure the maximum impact of local economic development initiatives and poverty alleviation strategies. The strengthening of ties between OFID and the International Dryland Development Commission (IDDC) comes at a moment of unprecedented challenges and opportunities for development in the dryland areas

The world population needs clean water, clean energy and an abundant nutritious food supply. World food production and water use by crops will need to double by 2050 to meet the growing food demand. Meeting the challenge of drylands, including desertification and land degradation, requires large and long term investments that are difficult to mobilize from the central and local government budgets alone. Meeting these challenges are in the heart of OFID's mandate. The heads of the states and governments of the member countries of OPEC, who are the shareholders of my institution, confirmed in Caracas and Riad declarations that commitment. Here I will like to quote from their Declaration in the meeting in Riad, Saudi Arabia, in November 2007, "The Heads of States acknowledge that forests play a crucial role in maintaining ecological balance and act as sink for greenhouse gases and share the international community concern that all policies and majors developed to address climate change concerns are both balanced and comprehensive, taking into account their effect on developing countries. In this regard they are committed to the promotion of management, conservation and sustainable development of all types of forests. They urge the developed countries to facilitate access to modern technology by developing countries that are reliable, economically viable and environmentally sound." Fulfilling the aspiration of the developing and developed world in combating desertification and land degradation requires large amount of investment. OFID is committed to participate in any global effort towards this objective. OFID was established in 1976 as a multilateral development financing institution by the member countries of OPEC, as a token of south-south collaboration and solidarity. A central aspect of OFID's broad vision of development is our dedication to support the attainment of the Millennium Development Goals, which the world was called up on to target to move humanity forward. OFID has cumulatively made available funding of 9.9 billion dollars in the form of grants, conditional private sector and public sector loans, and state financing facility, benefiting 121 developing countries worldwide regardless of region, race or religion. Of these countries, 50 are in Africa, 40 in Asia, 27 in Latin America and the Caribbean and four in Europe. In line with its mandate, OFID takes a basic need approach in the allotment of its financing, in an effort to maximize the impact of its assistance on the poorest countries in the region. Consequently, almost 30% of OFID's financing went to the cumulative public sector conditional loans and 24% to energy and transportation. Agriculture and water received 28% of OFID'd grant support to help combat desertification in arid and semiarid countries in cooperation with the specialized international agencies. Additionally, grants and program-related loans were made available for education, environment and emergency food aid.

To help promote greater partnership and cooperation, OFID believes in strategic partnership for development as evidenced by the strong ties we have forged over the years with various like-minded institutions. OFID's founding fathers were instrumental in establishing the International Fund for International Development (IFAD) in Rome and similarly we are involved in establishing the Common Fund for Commodities (CFC) and supporting it by membership and contribution in LDC. Further more OFID closely cooperates with FAO in fighting hunger, and the Global Mechanism of the United Nations Convention to Combat Desertification (UNCCD), as well as the CGIAR centers, in particular ICARDA.

OFID recognizes the value of combating desertification that damages land productivity and causes reduction in the food producing capacity, thus undermining basic food security. It should be recognized that desertification resulting from natural causes or wrongful governmental policies should be genuinely and adequately addressed.

It is alarming that the world food supply is now facing duel threat of global climate change and the boom of the biofuel industry. With this in mind, OFID, in cooperation with an international institution, is currently funding a study that would assess the negative impact that the developing countries will face by the worldwide production and use of biofuels, in terms of sustainable agriculture and food security as well as on the soil environment. The study will also investigate the value of biofuels in the energy mix to be used. According to one study in the University of Minnesota, even if the entire crop of corn in the USA was used for producing ethanol, it will only meet 12% of the gasoline consumption in that country. But the price will be that the entire world will be deprived of this production for food and the impact on corn price in the world market will be drastic. What is needed is the vision, strong commitment and determ-ination, sound leadership and lasting partnership for development and enhancing financing for advancing science and technology, education, economics and management into sustainable local institutions and feasible projects. What is really needed is to create a political climate for cooperation and shed off negative stereotyping and negative political will.

OFID is trying to strengthen its relationship with the International Commission on Dryland Development. The time has come to remove the historical neglect of agriculture in the dry areas and food security and we are willing to do what ever it takes to cooperate in this process.

Keynote address 3. Mr. Michel Jarraud, *Secretary-General, World Meteorological Organization, Geneva, Switzerland*

Climate change and drylands impacts on natural resources and the role of WMO

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Abstract

The most important issue facing the people who live in the dryland regions of the world is to ensure long-term agricultural productivity while conserving land, water, and biodiversity. In this context, sustainable agricultural development is very crucial. Lack of access to water supplies, overpopulation, migration, and conflicts overwhelm soil resources and reduce the ability of communities in providing food. Sustainable development of countries affected by drought and desertification can only come about through concerted efforts based on a sound understanding of the different factors that contribute to land degradation around the world. The Fourth Assessment Report (AR4) of the World Meteorological Organization (WMO) co-sponsored Intergovernmental Panel on Climate Change (IPCC) shows that there have already been some observed climate changes in the dryland regions and there are many potential impacts due to future climate change. However, much is still unknown about the current year-to-year climate variability and its impact on drylands. Therefore, in order to sustainably manage current dryland resources with respect to impacts of climate variability and to adequately address likely future climate change impacts, decision-makers at all levels need to be aware of all aspects of the climate system.

The WMO, through a global network of National Meteorological and Hydrological Services (NMHSs) of its Members and other partners, plays an important role in weather and climate observation, monitoring, scientific understanding of climate processes, and the development of clear, precise and user-targeted information and climate predictions. It furthermore provides sector-specific climate services, including advice, tools and expertise, to meet the needs and requirements of climate-related adaptation strategies as well as decision-making. However, the climate system is so complex that the global network of scientific observations and research need to be strengthened.

1. Introduction

Drylands are climates defined by moisture water deficits where there is more evaporation than precipitation received during the year. There are many definitions of drylands but it is generally accepted that there are four types: dry sub-humid, semiarid, arid, and hyper arid or desert (MEA 2005, Trewartha 1968, Rudolf 1981). According to the Convention on Biological Diversity (CBD 2008) the arid and semi-arid regions include grasslands, savannahs, and Mediterranean landscapes which cover approximately 47% of the

Earth's terrestrial area, with the largest areas found in Australia, China, Russia, the United States, and Kazakhstan.

The most important issues facing the people who live in the dryland regions of the world is to ensure long-term agricultural productivity while conserving land, water, and biodiversity. In this context, sustainable agricultural development is very crucial. Lack of access to water supplies, overpopulation, migration, and conflicts overwhelm soil resources and reduce the ability of communities in providing food. The issue of soil resources, land degradation, global food security and environmental quality becomes significant when one considers that only about 11% of the global land surface can be considered as prime land, and this must feed the 6.3 billion people today and the 8.2 billion expected in the year 2020 (Reich et al. 2001). Combined with these factors, droughts can lead to land degradation and eventual desertification if the problem is not addressed. All these factors are difficult enough to manage and even without the concern of climate change added to the equation.

Sustainable development of countries affected by drought and desertification can only come about through concerted efforts based on a sound understanding of the different factors that contribute to land degradation around the world. Climatic variations are recognized as one of the major factors contributing to land degradation and it is important that greater attention be paid to understand the role of different climatic factors in land degradation (Sivakumar and Stefanski 2007). Only when climate resources are paired with potential management or development practices can the land degradation potential be assessed and appropriate mitigation technologies developed. The use of climate information must be applied in developing sustainable practices as climatic variation is one of the major factors contributing to or even acting as a trigger to land degradation. There is a clear need to consider carefully how climate induces and influences land degradation.

2. Observed climate change and impacts

According to the Fourth Assessment Report (AR4) of the WMO co-sponsored Intergovernmental Panel on Climate Change (IPCC) released last year, the warming of the climate system is unequivocal (Solomon et al. 2007). Eleven of the twelve years in the period between 1995 to 2006 rank among the 12 warmest years in the instrumental record of global surface temperature. The global surface temperature difference from 1906 and 2005 is 0.74°C. The linear warming trend over the last 50 years is nearly twice that for the last 100 years. At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather, including droughts, heavy precipitation and heat waves. More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics.

The AR4 report also stated there is a very high confidence that physical and biological systems on all continents and in most oceans are already being affected by recent climate changes (Rosenzweig et al. 2007). Significantly, an assessment of observed changes at a global scale indicated that, it is likely that over the last three decades, anthropogenic warming has had a discernible influence on many physical and biological systems. During the past 50 years, many animal and plant populations have been under pressure due to land-use changes and increased intensity of agriculture, causing many species to be in decline. The AR4 notes that the vast majority of studies of terrestrial biological systems reveal notable impacts of global warming over the last 30-50 years such as: earlier spring and summer phenology and longer growing seasons in mid- and higher latitudes, production range expansions at higher elevations and latitudes, some evidence for population declines at lower elevations or latitudinal limits to species ranges, and vulnerability of species with restricted ranges, leading to local extinctions (Fischlin 2007).

The AR4 report also states that while there were many studies related to trends in river flows during the 20th century at various spatial scales, no global trend has been reported (Rosenzweig et al. 2007). However, at the global scale, the report cited evidence of a broad pattern of change in annual runoff, with some regions experiencing an increase at higher latitudes and a decrease in parts of West Africa, southern Europe and southern Latin America. Changes in river discharge and the frequency of droughts and heavy rains in some regions indicate that hydrological conditions have become more intense. The report noted that significant trends in floods and evapotranspiration have not been detected globally. There have been indications of intensified droughts in drier regions.

The AR4 WG II Chapter on Freshwater resources noted that people and natural ecosystems in many river basins currently suffer from a lack of water (Kundzewicz et al. 2007). In global-scale assessments, river basins with water stress are located in Africa, the Mediterranean region, the Near East, South Asia, Northern China, Australia, the USA, Mexico, north-eastern Brazil, and the western coast of South America, with estimates of the population living in these regions ranging from 1.4 billion to 2.1 billion. The chapter stated that human water use is dominated by irrigation, which accounts for almost 70% of global water use. Additionally, in most countries of the world except in a few industrialized nations, water use has increased over the last decades due to demographic and economic growth, changes in lifestyle, and expanded water supply systems. The report noted that water use, in particular irrigation water use, generally increases with temperature and decreases with precipitation. However, there is no evidence for a climate-related trend in water use in the past because water use is mainly driven by non-climatic factors and to the poor quality of water-use data.

Rainfall amounts and intensities are important factors controlling climate change impacts on water erosion on land and the report stated that there is no evidence for a climate-related trend in erosion and sediment transport in the past, since data on this aspect are poor and climate is not the only driver of erosion and sediment transport (Kundzewicz et al. 2007).

3. Future climate change and impacts

The IPCC report further notes an increasing trend in the extreme events observed during the last 50 years, particularly heavy precipitation events, hot days, hot nights and heat waves (Solomon et al 2007). Climate change projections indicate it to be very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent in some parts of the world. The combination of these events can have an enormous impact on agricultural production, and quality, as well as on farmers' incomes. Looking ahead, the report expects the warming in the 21st century to be greatest over land and at the higher northern latitudes (Parry et al. 2007). For the next two decades a warming of about 0.2°C per decade is projected for a range of emission scenarios. Increases in the amount of precipitation are considered very likely in high latitudes, while decreases are likely in most subtropical land regions. Annual average river run off and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and to decrease by 10-

30% over some dry regions at mid-latitudes and in the dry tropics. In particular, soils exposed to degradation as a result of poor land management could increasingly become infertile.

The IPCC report has described significant impacts on land, water resources, and dryland biodiversity (Parry et al. 2007; Kundzewicz et al. 2007; Fischlin et al. 2007; Boko et al. 2007). Climate change may also exacerbate desertification by altering spatial and temporal patterns of temperature, rainfall, solar radiation and winds. Some of these impacts can be described as follows:

- In general, increased precipitation intensity and variability is projected to augment the risks of flooding and drought in many areas;
- For local mean temperature increases of up to 1-3°C, crop productivity is projected to increase slightly at mid- to high latitudes, and decrease beyond these values;
- At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C);
- In the drier areas of Latin America, climate change is expected to lead to salinisation and desertification of agricultural land;
- In Southern Europe, higher temperatures and more frequent drought are expected to reduce water availability, hydropower potential, and, in general, to affect crop productivity while increasing fire frequency and fire extent;
- With the virtually certain likelihood of warmer and more frequent hot days and nights, insect outbreaks impacting agriculture, forestry and ecosystems are projected to increase;
- Changes in a variety of ecosystems are being detected at a faster rate than was previously anticipated, particularly in southern Africa ecosystems;
- It is estimated that, by the 2080s, the proportion of arid and semi-arid lands in Africa is likely to increase by 5-8%;
- In some water-scarce areas, people and ecosystems are increasingly vulnerable to decreasing and more variable precipitation on account of climate change;
- There is high confidence that, if greenhouse gas emissions and other changes continue during the next 100 years at or above current rates, the ability of many ecosystems to adapt naturally is likely to be exceeded by an unprecedented combination of climate change-associated disturbances such as flooding, drought, wildfire and insects as well as other global change issues, especially land-use change, pollution and over-exploitation of resources;
- With global mean temperatures exceeding 2 to 3°C above pre-industrial levels, approximately 20 to 30% of all species currently assessed are likely to be at increasingly high risk of extinction;
- The most vulnerable ecosystems include coral reefs, sea-ice biome, high-latitude ecosystems such as boreal forests, mountain and Mediterranean-climate ecosystems;
- Many semi-arid and arid areas, such as the Mediterranean basin, western part of USA, southern Africa, and north-eastern Brazil, will suffer a decrease in water resources due to climate change;

- In some water-stressed regions, efforts to offset declining surface water availability due to increasing precipitation variability would be further hampered by population growth-enhanced water demand;

- Current water management practices are very likely to prove insufficient in reducing the negative impacts of climate change on water supply reliability, flood risk, health, energy, and aquatic ecosystems, although improved incorporation of current climate variability into water resources management could indeed contribute positively to future climate change adaptation;

- Some climate change scenarios predict that, with warming of 1.5 to 2°C by 2050, about one-third of the Sahel would become even more arid, which would be accompanied by a general Equator-ward shift of vegetation, while other scenarios show less pronounced changes;

- Increasing threats of desertification in Mediterranean-type ecosystems have been projected from the expansion of adjacent semi-arid and arid systems under relatively minor warming and drying scenarios, which would likely induce substantial species shifts migration rates that might exceed the capability of many endemic species;

- Several global studies have suggested that, at least until 2050, land-use change would be the dominant driver of terrestrial biodiversity loss in human-dominated regions and, conversely, that climate change is likely to dominate wherever human interventions are more limited, such as in the tundra, boreal, cool conifer forests, deserts and savanna biomes.

Soil erosion studies reviewed by the AR4 have suggested that, due to the erosive power of rainfall, increased rainfall will contribute to greater rates of erosion unless protection measures are adopted (Kundzewicz et al. 2007). Soil erosion rates are expected to change due to the erosive power of rainfall. Other causes of erosion include:

- Changes in plant canopy caused by shifts in plant biomass production in association with the perturbed moisture regime;

- Changes in ground litter cover caused by temperature-driven variations in plant residue decomposition rates driven by temperature, in moisture-dependent soil microbial activity and in plant biomass production rates, particularly on account of moisture-dependent microbial activity;

- Changes in soil moisture due to shifting precipitation regimes and runoff ratios;

- Changes in soil erodibility due to a decrease in soil organic matter concentrations leading to a soil structure more susceptible to erosion;

- Changes in soil erodibility due to increased runoff, on account of larger soil surface sealing and crusting;

- Shifts in winter precipitation from non-erosive snow to the more erosive rainfall, due to increasing winter temperatures;

- Melting permafrost- induced soil erosion;

- Changes in land use made in response to the newer climatic regimes.

With regards to the implications of climate change on soil conservation efforts, a significant conclusion from recent scientific efforts has been the fact that conservation measures should increasingly target extreme events, due in particular to the fact that intense rainfall events can contribute a disproportionate amount of erosion relative to the total rainfall contribution, which will be exacerbated in the future by the increasing frequency of such events.

4. Role of the World Meteorological Organization (WMO)

The International Meteorological Organization (IMO), established in 1873, was since responsible for international cooperation in meteorology. IMO became WMO in 1950, which is today the specialized agency of the United Nations System with a mandate in weather, climate and water and it has a key role in the area of sustainable development. The National Meteorological and Hydrological Services (NMHSs) of WMO's 188 Members have an essential role in adaptation to and mitigation of climate variability and change impacts. The most critical impacts are those potentially affecting human life and socioeconomic development, as well as those that disrupt food, water, transportation, and the various forms of biodiversity (marine, forest, agricultural, etc.). WMO has a vast reservoir of expertise, knowledge, data and tools among its Members, programs and technical commissions, as well as through its partnerships. It can thus bring into play strong scientific and technical capabilities along with local, regional and global knowledge, providing authoritative and targeted analyses for the various user communities.

It is widely recognized today that human activities are now modifying climate at an increasingly alarming rate, but such was not the case in 1976, when WMO issued the first authoritative statement on the accumulation of carbon dioxide in the atmosphere and the potential impacts on the Earth's climate. In 1979 WMO organized the First World Climate Conference, as a result of which in 1988 WMO and the United Nations Environment Program (UNEP) jointly established the IPCC, which they have continued to co-sponsor in successful partnership to this day. The IPCC was recently distinguished in 2007 with the prestigious Nobel Peace Prize. In addition, the First World Climate Conference led to WMO's establishing of the World Climate Research Program (WCRP) with the International Council for Science (ICSU) and, subsequently, also with UNESCO's Intergovernmental Oceanographic Commission (IOC). This was followed in 1990 by the Second World Climate Conference, which called for the establishment of a climate convention and ultimately resulted in the development of the United Nations Framework Convention on Climate Change (UNFCCC) "*to achieve stabilization of greenhouse gas concentrations in the atmosphere at a low enough level to prevent dangerous anthropogenic interference with the climate system*". The second conference also led to the establishment of the Global Climate Observing System (GCOS) by WMO, UNEP, IOC-UNESCO and ICSU, to facilitate the availability of systematic observations as needed for authoritative climate change studies.

Having warned the global community about the dangers posed by anthropogenic release of greenhouse gases into the atmosphere, WMO is now supporting the needs of climate prediction for societal benefits. To set the stage for a new era in forecasting as well as to generate the awareness of users and commitment by governments, WMO is organizing with partners the Third World Climate Conference (WCC-3), which will be held in Geneva from 31 August to 4 September 2009. The main theme of the WCC-3 will be "*climate prediction and information for decision-making*".

The development and application of these seasonal climate forecasts by a large number of NMHSs has increased over time, while specific institutional frameworks have been established to address relevant climate change issues at the local and regional levels. In this context, the Regional Climate Outlook Forums (RCOFs) constitute an important vehicle in developing countries for providing advanced information on the future climate for the next season and beyond, and for developing a consensus product from amongst the multiple available individual predictions. RCOFs stimulate the development of climate capacity in the NMHSs and facilitate end-user liaison to generate decisions and activities that mitigate the adverse impacts of climate variability and change, helping communities to develop the appropriate adaptation strategies.

Many institutions involved in the RCOFs had a close relation with WMO in their formation. In response to several droughts in Africa, WMO, with the support of UNDP and other partners, helped to establish the Regional Centre for Agricultural Meteorology and Hydrology (AGRHYMET) in Niamey, Niger, two Drought Monitoring Centres (DMCs) in Nairobi (Kenya) and Harare (Zimbabwe, recently moved to Gaborone, Botswana). In 1993, WMO and the Economic Commission for Africa sponsored the establishment of the African Centre of Meteorological Applications for Development (ACMAD) in Niamey, Niger. In 1998, the International Research Center for the El Niño Phenomenon (CIIFEN) was established in Guayaquil, Ecuador with the assistance of WMO and other partners (IRI, Permanent Commission for the South Pacific, and others). All of these regional institutions either host WMO-supported RCOFs and/or contribute their expertise and knowledge.

In addition to RCOFs and seasonal climate prediction, WMO plays a role in developing and highlighting the need for a comprehensive and integrated approach to more effectively monitor drought and provide early warnings. In 2006, WMO and the United Nations Convention to Combat Desertification (UNCCD) established a Drought Management Centre for South-eastern Europe in Slovenia. The main aim of the Centre is to observe, collect, and provide to the users the necessary data that are used in drought forecasting, supporting early warning systems in the participating countries on the occurrence of drought events, assessing the severity of these events, mitigating damages and preparing a drought sensitivity map for the region. This process is also being explored by the several Central Asian countries to establish a similar Drought Management Centre for Central Asia, in coordination with WMO and the UNCCD. There are other regional examples, such as the Australian National Agricultural Monitoring System and the US and North American Drought Monitor (WMO 2006).

With the IPCC Fourth Assessment Report, there has been a focus on climate change, future impacts, and potential adaptation strategies. However, the main determinant for many important sectors of the world (agriculture, economic activity, energy, health) is still seasonal climate variability. Climate variability can be defined as the deviation from long-tern climate averages over a certain period of time such as a month, season, or year. Examples of climate variability would include a stronger-than-normal monsoon, a more intense drought period (e.g. the Southwestern US Drought), intense rainfall causing flooding or a stronger-than-normal tropical storm or extra-tropical storm season. Seasonal climate regimes can be as important as climate change and these climate variations exist whether the climate is changing or not and have an impact on the sustainable development of drylands.

The issues of climate variability and climate change need to be integrated into resource use and development decisions. There is a need to optimally manage the different sectors with respect to today's natural climate variability and this requires a careful evaluation of the policies, practices and technologies currently in vogue. Decreasing the vulnerability of the different sectors such as biodiversity, forestry, agriculture, and energy to natural climate variability through a more informed choice of policies, practices and technologies will, in many cases, reduce the long-term vulnerability of these systems to climate change. Therefore, in order to sustainably manage current dryland resources with respect to impacts of climate variability (droughts, limited water resources) and to adequately address likely future climate change impacts, the latest knowledge and capacities in climate need to be translated into operational products enabling countries to enhance their capacities in climate-related risk management. The use of weather and climate information can assist the decision-makers of these various sectors and so it is very important that climate change adaptation is integrated into sustainable development plans at the national level (WMO 2007).

WMO contributes to understanding the interactions between climate and land degradation through dedicated observations of the climate system; improvements in the application of agrometeorological methods and the proper assessment and management of water resources; advances in climate science and prediction; and by promoting capacity building in the application of meteorological and hydrological data and information in drought preparedness and management WMO also provides support to the NMHSs in organizing Roving Seminars for farmers on weather and climate, to increase the interaction between NMHSs and the agricultural community. The overall goal is to make farmers more self-reliant by helping them become better informed with weather and climate issues that influence their agricultural production. The one-day seminars, which focus on basic weather and climate information, are provided by NMHSs experts emphasize on applications of weather and climate in agricultural decision-making, and on pest and disease control, which are provided by agricultural extension agents. However, as pointed out in the IPCC AR4 report, while there is significant evidence of observed changes in natural systems in every continent, the majority of studies come from mid- and high latitudes in the Northern Hemisphere and there is sparse documentation of observed changes in tropical regions and the Southern Hemisphere (Rosenzweig et al. 2007). In most developing countries, climate is seen as a lesser priority compared to other current needs and relatively few resources can be allocated to climate activities at national levels. WMO, in partnership with international and regional organizations, can guide and improve the capabilities of national institution frameworks for implementation of adaptation activities. They can also be provided with appropriate tools to develop climate models at smaller scales to suit national needs. Research activities and systematic observations can be promoted to overcome constraints on data needs and to build capacity related to vulnerability and adaptation components of national communications.

5. Conclusions

There has been a tremendous amount of work in assessing the impact of climate variability and change on the various sectors of the world (agriculture, economic activity, energy, and health). The issue of climate change is particularly important to the people living in the dryland regions of the world since they live in climates with water as a major limiting factor. Sustainable development is difficult in these regions even without the threat of climate change. Future climate change projections of more frequent heat waves, drought and heavy precipitation events will cause additional stress on already fragile water, soil and biodiversity resources. Resources must be focused on trying to reduce these stresses. In most developing countries, climate is often seen as a lesser priority compared to other current needs and relatively few resources can be allocated to climate activities at national levels. WMO, in partnership with other international and regional organizations, can guide and improve the capabilities of national institution frameworks for the implementation of adaptation activities. They can also be provided with appropriate tools to develop climate models at smaller scales, to suit national needs. Research activities and systematic observations can be promoted to overcome constraints on data needs and to build capacity related to vulnerability and adaptation component. The climate system is so complex and the scientific and computational requirements for providing societal-beneficial regional climate forecasts are so considerable that the nations of the world need to cooperate more closely with each other and share resources in order to tackle this major challenge.

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Plenary Presentations

1. Strategic governmental perspectives on climate change/current and future water and land use and human welfare

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Abstract

Dry areas by definition are very fragile and highly vulnerable to environmental changes. Climate change impact on dry areas means higher temperatures, changing rainfall patterns and rising sea levels. These changes will have strong impact on economic, social and political dimensions of development in dry areas. Generally speaking, expected impact of climate change might be similar across different regions of the world. Four types of impacts could lead to social destabilization and violence. These are: (a) changing availability of freshwater resources, (b) declining food production, (c) worsening storm and flood disasters, and (d) environmentally induced migration. The climate change will intensify poverty in dry areas, which will require a strategy for alleviation. This strategy will call for the short-, medium- and long-term measures.

Introduction

Climate change has attracted great attention in the Arab world and would be a theme for discussion in future Arab summit because of its negative impacts on the natural resources and livelihoods of the people in the dry areas in the Arab region. Climate change is reflected in higher temperatures, changing rainfall, increased disastrous weather events, and rising sea levels. All these impacts of climate change will lead to instability in the existing systems, increase human suffering, and will be an important cause of increasing poverty.

Dry lands are marginal and very fragile. Poverty is, therefore, more common in the dry lands, particularly in the rural areas. Hence, the poor communities in the dry areas will be most severely affected by the impact of climate change. The governments of the affected countries have, therefore, an onerous task to reduce the vulnerability of the poor to climate change.

Impact of climate change

The impact of climate change could be outlined and examined around four main areas: These are: (a) changing availability of freshwater resources, (b) declining food production, (c) worsening storm and flood disasters, and (d) environmentally induced migration.

Availability of freshwater resources

Freshwater is required for human use. At present there are 1.1 million of people having no access to safe drinking water. The human demand for water is increasing due to population growth and changing living habits. Climate change will make it more difficult to supply enough freshwater for all use. In addition, there will be shortage of water to generate hydro-electric power. This situation makes it very difficult for the government to meet such expanding demand.

Food production and food security

In many developing countries, a temperature rise of even 2^{o} C above baseline (39^{o} C) will be enough to increase food insecurity. Land suitable for agriculture would be lost as a result of desertification, soil salinization and water scarcity. This will increase the number of rural poor. At present more than 850 million people worldwide are currently malnourished. Food supplies will be also affected by lower land productivity.

Storm and flood disasters

Storms and floods already account for nearly 60% off all the damage caused by natural catastrophes. Their frequency is going to rise, as the rainfall would tend to come in storms, although the total rainfall will decline. Furthermore, because of temperature rise, the sea levels will rise bringing risk for many cities and industrial regions in coastal areas. Because of the intrusion of sea water, there will be salinization of farm lands in the coastal areas forcing the farmers to abandon those lands.

Environmentally induced migration

Loss of land and property because of natural disasters and loss of livelihood because of the degradation and desertification of land will force the affected people to migrate. This environmentally induced migration will mostly occur within the national borders at first but will eventually spread internationally, mainly in the form of south-south migration. This will cause sociopolitical upheaval and will present challenges for the governments to maintain peace and security.

Strategic governmental perspectives

Because of climate change and its consequences, the risk of destabilization and violence will increase considerably in many parts of the world. What is more, there will be various interactions between the four major impacts outlined above, making it difficult to predict the course of development. The governmental institutions are typically weak in these countries, where economic performance is poor while population is growing fast.

A strategy to counteract the negative impact of climate change should be phased ever time and must be in an integrated fashion.

The international community should assist the developing countries affected by climate change in coping with the adverse impacts. Developed countries have to limit the greenhouse gas emissions and also to implement the recommendations of the Doha round of trade negotiations by cutting on subsidies in order to facilitate market access for exports. Also emergency relief assistance will be needed in the face of extreme weather events. The international donor community should, therefore, coordinate and fund efforts to rise to the challenges of environmentally-induced migration.

The government strategy should include:

1. Building up of relief food stocks;
2. Subsidizing services such as transportation, health care, safe water, and education; and
3. Supporting in the period of adjustment to the new conditions.

Science and technological interventions should be an important part of the strategy to be adopted by the governments to enable the people to cope with climate change impacts. Some of these are:

1. Development of early warning systems;
2. Production of salt and drought tolerant plant varieties using conventional breeding as well as biotechnology;
3. Development of techniques for more efficient water management, water harvesting, and water saving;

4. Production of high yielding small ruminants (goat and sheep) and improving the management of rangelands and pastures;
5. Expansion and improvement of agricultural marketing and promotion of pilot processing plants to create non-farm activities;
6. Expansion of micro-lending opportunities and availability of small scale credit; and
7. Continuous monitoring of the new environment in order to design effective programs for poverty alleviation and effectively disseminating the information.

Building and strengthening rural institutions such as micro-credit facility, cooperatives, extension services, and rural leadership should be given high priority to enable the affected communities to help themselves in the implementation of the adaptive and ameliorative measures to cope with climate change. Training and the use of mass media are important elements for increasing awareness of people of the new environmental change and the possible measures that would enhance their resilience to cope with the climate change.

2. Food security, climate change and bio-fuels; focus on the Middle East*

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* Transcription from oral presentation

Abstract

High prices in 2007-08 have attracted attention to the food security crisis. The number of undernourished in the world has jumped from about 850 million in 2005 to some 925 million in 2007. The food crisis is not a temporary phenomenon. The number of undernourished in the world was unacceptably high even before food prices started rising. Looking forward, global demand for agricultural products is expected to continue increasing for two main reasons. First, the rise in world population together with accelerating urbanization and improved incomes will exert upwards pressure on food demand. Second, biofuel production has nearly tripled over the last five years and is expected to continue increasing rapidly, demanding more feedstock. Meeting the increasing demand for food and for biofuels will be a serious challenge for the agriculture sector, which will be further exacerbated by the impact of climate change. There will thus be a need for a quantum leap in agricultural investment and a policy framework that encourages agricultural production. Climate models predict that water resources in the Middle East will become even scarcer than they are today. To deal with this important long-term challenge, the Middle East and North Africa region should consider adopting policies to encourage efficient agricultural production and optimize the use of scarce water resources.

Introduction

High prices in 2007-08 have attracted attention to the food security crisis. The number of undernourished in the world has

jumped from about 850 million in 2005 to some 925 million (14% of humanity) in 2007, and is likely to have increased further to nearly one billion in 2008. The progress towards achieving the millennium development goal (MDG) of reducing the proportion of hungry people by half was occurring till 2005, but as the prices of grain started rising after 2005, there was a reversal in the trend, the percentage of hungry people started going up. Clearly, there is no indication that this MDG will be achievable, although there had been some improvement in Asia and Latin America, much less improvement in Middle East and North Africa and no improvement in sub-Saharan Africa (Fig. 1).

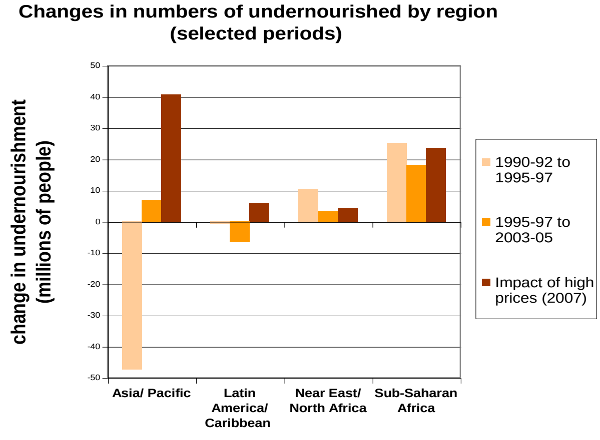

Figure 1. Changes in the number of undernourished people in different regions during two selected period and the number impacted by high prices in 2007.

The surveys conducted in several regions showed that the poor people, were most affected by the price rise and the rural poor were as much affected as their urban counterpart because most of the rural poor are net buyers of food. Landless farmers were particularly hard hit, as also the women.

The food crisis is not a temporary phenomenon. The number of undernourished in the world was unacceptably high even before food prices started rising. However, there has been a coincidence of rise in food prices, increase in hungry people, and the production of biofuels.

Food prices, food security and biofuel production

Production of biofuels has nearly tripled over the last five years and is expected to continue increasing rapidly, spurred by subsidies (estimated at $11 billon in 2007) and other support policies in developed countries. And, if the expansion planned by the major producing countries were to continue, the production will triple again by 2017. This trend is not driven by economic considerations but by policy factors.

Several studies have been made over the last six months to quantify the impact of biofuel production on the food prices in the last two years. The results have been highly variable, giving a range in the increase from 75% to 3%, depending on the approach used (Table 1).

According to FAO, the most reliable estimates for the increase in food prices over last two years attributable to the production of biofuels are between 20% and 40%. Therefore, biofuels are a significant contributor to the increase in food insecurity in the world.

It is generally expected that when food prices increase, there should be an increase in food production because of price incentive to farmers. Comparison of growth in food production, from 2007 to 2008, between the developed and the developing countries showed that it was about 9.7% in the developed countries and only by 0.9% in the developing countries. If the three countries, Brazil, China and India were excluded from the estimate for the developing countries, the growth was negative (-1.5%). Perhaps, the increase in input prices in contrast to the output prices in the developing countries were a major cause, although there might be several other factors such as infrastructure, technology, water availability etc. contributed to a lack of production response to increase in food prices

It is ironical that there are a billion hungry people in the developing countries, while the production is stagnating there.

Table 1. Estimate of the impact of biofuels on the rise in food prices in the recent years

Source	Estimate	Commodity	Time period
World Bank (April 2008)	75 %	global food index	January 2002 – February 2008
IFPRI (May 2008)	39 % 21-22 %	corn rice & wheat	2000 – 2007 2000 – 2007
OECD-FAO (May 2008)	42 % 34 % 24 %	coarse grains vegetable oils wheat	2008 – 2017 2008 – 2017 2008 – 2017
Collins (June 2008)	25-60 % 19-26 %	corn US retail food	2006 – 2008 2006 – 2008
Glauber (June 2008)	23-31 % 10 % 4-5 %	commodities global food index US retail food	April 2007 – April 2008 April 2007 – April 2008 January – April 2008
CEA (May 2008)	35 % 3 %	corn global food index	March 2007 – March 2008 March 2007 – March 2008

Impact of climate change

Climate change makes the things even worst. The global climate models project that the production of cereals as well as livestock in the south is likely to decrease, while in the north it might show some increase. Thus, the production divide between the north and the south will further increase. The dryland countries of Middle East and North Africa are going to have most drastic impact. The climate change is going to exacerbate the problems that the dryland countries are already facing.

Way forward

Looking forward, global demand for agricultural products is expected to continue increasing f because of demographic reasons and the possible competition offered by biofuel production to food production.

In order to meet the increasing demand for food and for biofuels, the 2007 World Development Report estimates that global grain production needs to double by 2030. Meeting this challenge, while dealing with the impact of climate change and protecting the environment, will require a quantum leap in agricultural investment and a policy framework that encourages agricultural production.

Nearly all studies on climate change predict that water resources in the Middle East will become even scarcer than they are today. To deal with this important long-term challenge, the region of Middle East should consider adopting a three-pronged strategy:

1. Increase public investment in agriculture particularly to improve infrastructure and support research and extension.
2. Adopt policies to encourage efficient agricultural production and optimize the use of scarce water resources.
3. Enhance economic integration and regional trade and encourage cross border investment in neighboring countries that have abundant land and water resources.

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3. Climate change and the World Bank Report on agriculture for development*

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Abstract

The World Bank's World Development Report 2008 on agriculture spells out the far-reaching consequences climate change can have on rural areas. These consequences will affect the rural poor disproportionately because they are more dependent on agriculture and have limited opportunities and resources to adapt.The main pathway out of poverty when using agriculture for development is to improve the productivity, profitability, and sustainability of smallholder farming. This will also enhance the resilience of rural poor and increase their ability to adapt to climate change. Long-term investments in soil and water management are needed especially with respect to subsistence farming in remote and risky environments. Global public goods, including climate information and forecasting, research, conservation and development of crops must be adapted to new weather patterns, and techniques to reduce land degradation. The public sector can, for example, facilitate adaptation through research on and dissemination of flood-, heat-, and drought-resistant crops. New irrigation schemes in dryland farming areas are also likely to be particularly effective, especially when combined with complementary reforms and better market access for high-value products. Beyond the issue of climate change adaptation, agriculture, as a major source of greenhouse gas emissions, has much untapped potential to reduce emissions through reduced deforestation and changes in land use and agricultural practices.

Introduction

The World Bank publishes its development report, World Development Report (WDR), every year dealing with different sectors impacting development in different parts of the world. It is seldom that it is devoted only to one sector. The World Development Report 2008 (World Bank 2007) makes an exception that it is devoted only to agriculture, only second time in the last 25 years, emphasizing the importance of this sector in the livelihoods of the poor and in taking them out of the poverty trap. This paper will attempt to weave the findings and analysis in that report for the region of Near East and North Africa and overlay that landscape on climate change challenge and come out with a few solutions to move forward. The arrival of the World Development Report 2008 – *Agriculture for Development* is very timely in the wake of the global food-price crisis, biofuel challenge, and the challenge of climate change and hopefully its findings and analysis will be helpful in thinking through these issues.

Analytical framework used in the report

Just a few comments on how the analysis was done in this report. The authors of the report looked at different countries and economies and grouped them according to the poverty challenge on one hand and on the place of agriculture in the macro-economy of those countries on the other, to identify their organizing principles and typology for developing research-for-development agenda for sustainable growth and pathways out of poverty. They identified that "agriculture operates in three distinct worlds" as indicated below:

(a) Agriculture-based countries where the face of poverty is very much rural and economy is very much based on agriculture; e.g. sub-Saharan Africa.

(b) Urbanized countries where there is high degree of urbanization and the poverty in also more in the urban than rural areas and the share of economy driven by agriculture is lesser; e.g. countries in Latin America and some parts of Asia.

(c) The transforming countries where this is still lot of rural poverty and vulnerability prevailing, while economy is already being driven by other sectors and the urbanization is ongoing, and the income divide between urban and rural parts is increasing; e.g. most of countries in South and East Asia, and the Middle East and North Africa (MENA).

Findings and analysis for the Middle East and North Africa region

Some 92% of the population of the region is in the transforming countries, where agriculture is no longer a major source of income growth. There is rapidly rising rural-urban income disparity and continuing extreme rural poverty, a source of socio-political tension in the region and the governments are very conscious of this. There are pockets of lagging regions, e.g. the Upper Egypt, North East Syria, and Moroccan hinterlands. On the positive side, they are in the proximity of a very lucrative large market in the European Union. But that is rather difficult to enter into, although there is great potential. Agriculture in the countries where there is political conflict is a fall back livelihood for the people and a safety net for them in this region.

There is overloading of the land and water resources in the region. The MENA region is experiencing the fragmentation of land, e.g. more than 95% of land holdings in Egypt are < 2 ha, whereas is Latin America, Europe and Central Asia there is so much exodus from agriculture that the size of land holding is increasing. There is, therefore, a definite constraint on agriculture production in the region.

If one looks at the population or community in the rural areas, there is a 'micro-holder' majority operating on a very small asset base and with very limited access to services, often excluded from political agenda or influencing it, with very limited education (e.g. in Tunisia 90% of farmers received only primary education), thus remaining outside of the mean stream of the society. The population in aging and in many countries the male farmers are either <24 years or >55 years of age. The people in the middle age group would look for gainful employment outside agriculture. Thus, the graying of agriculture is occurring. In many cases, there is also the faminization of agriculture and the women are leading the household and agriculture production. They often face more extreme vulnerability because of limited access to assets, production services and health care. Clearly, there is a target group that has to be kept in mind in agriculture research and development (ARD) agenda.

Water availability is a very serious resource constraint in the region. There is already population in the region experiencing absolute water scarcity. Farming is the major user of this resource. If one were to go towards more diversified high value agriculture the value generated per unit of water use would increase. There was one of the analytical outcomes of the work that would help guide the policy in the region. Proper water management is also an issue. Improper management is leading to water logging and salinization of the area, causing damage to the precious resource of land.

Moving to the 'lagging' areas, more than half of the rural population here lives in less favorable areas, based on agro-ecological potential and market access. In terms of agro-ecological consideration the MENA region is very seriously constrained because most of the rural poor live in the arid and semiarid areas. In terms of market, although they are better off than some other countries, there are quite a few communities that are more than 5 hours away from market for disposing their products or for getting inputs for agriculture. This isolation is therefore a major constraint to production, and is an issue. Many of the communities in the lagging areas in these countries are similar in these aspects to the agriculture-based countries and will therefore be benefited by the solutions that would be applicable to the agriculture-based countries, and agriculture and agriculture-based households will be the drivers of their economy and pathways out of poverty.

On high value agriculture, there is quite a bit of potential to invest more in high-value crops to diversify agriculture to access the Gulf region and the European Union markets. It was a bit of a surprise to find in the report that in the production of faba beans (*Vicia faba*) that are exported from Syria only 5000 farmers were engaged out of the 15 million that are there. Similar is the issue with the orange production in Tunisia. So, very small population of farmers exports the high value commodities. The challenge of linking the small holders to these high-value chains is an important issue to think about in order to improve their income and at the same time conserve their resources.

In summary, for dealing with the rural poverty itself in the MENA region, there is a need to support the role of agriculture as a source of jobs and safety-nets and also a need to look into how to target the most vulnerable population in these areas. IFAD has good experience in finding targets and developing instruments to deal with the most vulnerable, as mentioned by Kanayo et al. (this volume).The quality-oriented supply-chains for high value market, integrating those chains, building capacity and innovation in all of these, bringing market intelligence to look for opportunities and working towards functioning of those chains, enabled by public rural infrastructure (roads, markets, IT backbones, etc.), the public sector investment to enable the high- value chain to operate, are key elements in the pathway out of poverty. Training programs are needed for the youth; when they leave agriculture sector and go to the urban areas, they would have skills to sell or they could go to value addition associated with agriculture production. These are the main messages from the World Development Report 2008 regarding the MENA region.

Meeting the climate change challenge

Now, we can overlay the above mentioned landscape over the climate change challenge with respect to the MENA region. It is clear from the reports of the IPCC (2007a, b) that the MENA region is very prominent amongst the hotspots that will be most affected by the climate change. There are three major challenges in the region, and particularly here in Egypt: (a) The potential rise of sea level submerging the land in the coastal areas, and the intrusion of sea water in the agricultural fields damaging their productivity; (b) the change in the flow-volume of the Nile river, with very large watershed of the White Nile and the Blue Nile, and its effect on ground water resource; and (c) the frequency and onset of drought.

All these will have an impact on agriculture in Egypt and in the region. It is to be remembered that the human health agenda is very much linked to the agriculture production agenda. Water and sanitary constraints, associated with water shortage caused by frequent persistent drought events, would lead to a whole new dynamics of epidemics of infectious diseases and availability of fresh water. Immaterial how much good food might there be, the lack of good health would not permit its good absorption and that will be an issue for nutrition. In terms of research challenges, therefore, one of the gaps is probably this health and agriculture poverty nexus, which the research community will have to pay attention to.

In summary we find that in MENA region, especially Egypt, the whole issue of research in understanding this dynamics from biophysical point of view, from agriculture production point of view, and socioeconomic point of view will be very important. The World Bank, in collaboration with FAO, has just completed the first phase of a study in Morocco, taking the IPCC scenarios and downscaling them to the agro-ecological zones in that country, trying to look into high resolution scenes in terms of what measures to engage in to improve the situation at the more micro- climate levels. This is something that will have to be repeated at other places in the region. The capacity for that type of monitoring and forecasting and the regional collaboration for that would be essential.

Water-saving polices and technologies will be needed. There is quite a bit of scope there to improve the water use efficiency.

The public sector research and the CGIAR's strategic upstream research to find solutions for drought tolerance and also working together with the private sector to make their innovations available for use in the developing countries will be very important.

Local institutions have an important role to play in enhancing the capacity and resilience of poor communities to cope with the impact of climate change. Recognizing this, the colleagues in concerned groups in the World Bank are working to explore the local institutions center their capacity to respond to the challenges that they already face in agriculture production and rural development. But the work also involves predicting as to how much capacity is there in a particle local institution to serve the communities when there is more need for adaptation to climate change.

Based on this work, we have come up with five different strategies for the communities and the household to respond:

- Mobility - to move away from agriculture to another livelihood, if there is an opportunity for that;
- Storage - to spread risk over time
- Diversify the production;
- Communal pooling; and Market exchange- seeking markets from where one could drive income and manage risks better.

The aim is to look at risk, catalogue and to support solutions that are proactive measures in these institutions to cope with the adaptation challenge, not just react when hazards strike or conditions worsen. The institutions will have to have capacity, partnership, and coordination all the way from the local to central and international level. One of the interests is to see how the World Bank's experience in the territorial development or area-based development could be linked to adaptation of those local institutions.

The bank is financing several Egyptian government projects designed with Egyptian colleagues:

- **The Upper Egypt Integrated Governorates Development Project:** It looks at these challenges of agriculture in the vulnerable populations - prime example of the WDR's focus on the production, processing, and marketing of non-traditional, high value crops and livestock products, targeting both agriculture and related nonfarm rural enterprises
- **The Avian Influenza Preparedness and Poultry Reconstruction Project:** Emphasis is placed on disease control and management capacity, surveillance and diagnostic capacity, and a review of the legal and regulatory framework of Egypt's veterinary services. The project exemplifies the WDR's call for "better coordination of the agriculture and health agendas to yield big dividends for productivity and welfare of the poor".
- **The Sohag Rural Development Project**: Another project in Upper Egypt, focusing on access to credit by the rural poor, unemployed youth, and women, and developing capacity among communities and local government institutions to prepare to decentralize service delivery.
- **The East Delta Agricultural Services Project:** It is supporting services to facilitate the settlement and increased agricultural production of some 26,000 low income families on 130,000 feddans of reclaimed lands in the East Delta.

Our work in Egypt is therefore taking steps to understand the situation and how to move forward. Lot more needs to be done by the Bank for mainstreaming and climate proofing of our interventions – from biophysical understanding (e.g. GIS based modeling) all the way to local institutions, working with our partners in Egypt.

Conclusions

The main take-away messages from the above are:

- Rural economic growth based on agricultural livelihood is one way to mitigate the income disparity that is already there; but this cannot be done by agriculture alone. It will also require faster non-agriculture rural livelihoods and economic growth. Realizing the poverty-reducing potential of agriculture, it requires institutional innovations, e.g. high value agriculture, the producers' organizations and their linkage to high value chains and job creation and skill enhancement.
- Environment and climate change agenda needs to be mainstreamed into our agriculture-for-development agenda and also in the agenda of the countries in this region and elsewhere.
- Successful implementation requires explicit recognition of the political economy and the forces that are there; a state that is focused on facilitation, regulation and public good provisions to enable the private players – farmers, entrepreneurs, etc. to do their part in this mix.

The World Bank, as a member in the development community, is very much committed to support research to cope with climate change challenges and also development efforts to climate proof the intervention, that we are developing and dialoguing with our partners.

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4. Agriculture knowledge management using information and communication technology

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Abstract

The climate change will enforce growers to adopt new cropping patterns, technologies, and possibly marketing. The ultimate objective of Agriculture Knowledge, Science and Technology (AKST) activities is to come up with research results that would further advance research in that areas, and engender technologies that AKST stakeholders can use to address the problems arising from climate change, increase agricultural production, and conserve the environment. The AKST activities, in developing countries, face challenges related to sharing, exchanging and disseminating knowledge and technologies generated which are most needed by growers, extension workers, researchers and decision makers. It is urgent to exploit all means to meet these challenges and the emergence of Information and Communication Technologies (ICT) in the last decade has opened new avenues in knowledge management that could play important roles in meeting these challenges. There are many existing information technologies that can be used for knowledge management: database management system, multimedia information systems, geographic information systems (GIS), decision support system including simulation and modeling, expert systems, and Internet and Web technology. This presents the experience of the Egyptian Ministry of Agriculture and Land Reclamation in using ICT as an appropriate technology for speeding up development in the agricultural sector since the establishment of the Central Laboratory for Agricultural Expert Systems (CLAES) in the Agricultural Research Center (ARC).

Introduction

The emergence of Information and Communication Technologies (ICT) in the last decade has opened new avenues in knowledge management that could play important roles in meeting the prevailing challenges relating to ICT and knowledge management. ICT allows capitalizing to a greater extent on the wealth of information and knowledge available for Agriculture Knowledge, Science and Technology (AKST). The ultimate objectives of AKST activities are to come up with results that can contribute to further advancement of that research and enable AKST stakeholders to get information that they can use to increase agricultural production while conserving the environment.

AKST activities, in developing countries, face challenges related to sharing, exchanging and disseminating the generated knowledge and technologies that are most needed by growers, extension workers, researchers and decision makers. The text that follows, describes these challenges, indicates how ICT could play a role in addressing them, and presents briefly the efforts made in using ICT for this purpose in the Central and West Asia and North Africa (CWANA) region.

Challenges in sharing, exchanging and disseminating knowledge and technologies

The first challenge is the poor mechanisms and infrastructure for sharing and exchanging agriculture knowledge generated from research at national and regional levels. Many research activities are repeated due to the lack of such mechanisms and infrastructure at the national level. Researchers can find research papers published in international journals and conferences more easily than finding research papers published nationally in local journals, conferences, theses and technical reports.

The second challenge is the inefficient mechanisms and infrastructure for transferring technologies produced as a result of research to growers either directly or through intermediaries (e.g. extension system). Knowledge and technologies fostering agricultural production and environment conservation are examples. Although many extension documents are produced by national agriculture research and extension systems to inform growers about the latest recommendations concerning different agricultural practices, these documents are not disseminated, updated or managed to respond to the needs of extension workers, advisers and farmers. This is also true for technical reports, books and research papers related to agriculture production.

The third challenge is keeping the indigenous knowledge as a heritage for new generations. The traditional knowledge is available through experienced growers and specialists in different commodities. They embody a wealth of knowledge that researchers need to examine thoroughly in devising sustainable solutions. However, they are rarely documented.

The forth challenge is the access of economic and social knowledge to different stakeholders at operational, management and decision-making levels, to enable them to make appropriate decisions regarding the potential value of certain technologies and their effect on resource-poor farmers.

Role of ICT in agriculture knowledge management

Knowledge sharing, exchange and dissemination are elements within the broader theme of Knowledge Management (KM). The central purpose of KM is to transform information and intellectual assets into enduring value (Metcalfe 2005). The basic idea is to strengthen, improve and propel an organization by using the wealth of information and knowledge that the organization and its members collectively possess (Milton 2003). It has been pointed out that a large part of knowledge is not explicit but tacit (Schreiber et al. 1999). This is true also for knowledge in agricultural science and technology where a lot of good practices are transferred without being well documented in books, papers or extension documents. To manage the knowledge properly, ICT is needed.

In effect, there are many information technologies that can be used for knowledge management. The technologies available and their role in agriculture knowledge management are given below.

Database management system: It is the core of information and knowledge management. This technology can be used in different applications as given below:

- Building a national agriculture research information system (NARIS) that includes research outcomes, projects, institutions and researchers in the country, and a regional research information system that works as a portal for all the NARIS. The example is the NARIS developed at the Agriculture Research Center in Egypt (ARC 2007).

- Developing an information system of indigenous agricultural practices to enable researchers to examine this knowledge and decide on its usefulness for sustainable development. Such a system will also keep this knowledge for future generations preventing its disappearance as a result of new advanced technologies.

- Developing an information system to record matured technologies, that on a trial basis have proven successful, and success stories that have contributed to economic growth. This will strengthen the interaction between inventors and innovators and will lead to an innovation-driven economic growth paradigm.

Multimedia information systems: These are needed to store and retrieve images confirming the occurrence of certain diseases and disorders in plants and animals, and videotapes and audiotapes describing how to control them. These can also illustrate how best different agricultural operations could be performed under different agro-ecological conditions and variable environments.

Geographic information systems (GIS): These are needed to store databases about natural resources with a graphical user interface that enables users to access these data easily using geographical maps.

Decision support system techniques: These are needed for many applications such as:

- Simulating and modeling methods can be used to build computer systems that can model and simulate the effect of different agricultural production policies on the economy and the environment to help in decision making.
- Expert systems technology to help users in improving their skills in crop and livestock management and tracking their effect on conserving natural resources (Rafea 1999). This technology may also be appropriate for keeping indigenous knowledge (Rafea 1995, 1998, 2000).

Modern ICT: Internet and Web technology are excellent source of global knowledge of technical information that is amicable to up- or out-scaling. There is a need to make these systems available regionally and globally. Accessing the Internet will bring a wealth of information to all agriculture stakeholders in rural areas and will help in overcoming the digital divide. As most farmers in CWANA have no hands-on experience or access to digital networks, leaders of national agricultural research and extension systems should be encouraged to consider the ICT option. Training farmers and extension workers, including women, in ICT will help them access a lot of useful information if each country tries to develop contents in the local language.

Use of ICT in CWANA region

In 1987, officials at the Egyptian Ministry of Agriculture and Land Reclamation (MALR) recognized the ‘Expert Systems’ were an appropriate technology for speeding up the development in the agricultural sector. To realize this technology, MALR initiated in 1989 the project on Expert Systems for Improved Crop Management (ESICM), in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Program (UNDP). The project began in mid-1989 and the Central Laboratory for Agricultural Expert Systems (CLAES) that implemented the project, eventually joined the Agricultural Research Center (ARC) in 1991. Through the development, implementation and evaluation of knowledge-based decision support systems, CLAES is helping farmers throughout Egypt to optimize the use of resources and maximize food production. A dozen different Expert Systems have been developed for horticulture and field crop management.

In 2000, the Technical Cooperation Program (TCP) of FAO funded the project on ‘Virtual Extension and Research

Communication Network' (VERCON) to develop a Web-based information system to strengthen the link between research and extension (CLAES 2002; FAO 2003). This network has been extended to include other stakeholders and services through a project funded by Italian Debt Swap Program and executed by FAO in collaboration with CLAES (CLAES 2008). Several expert systems have been made available on this network in addition to other modules. Two Expert Systems on the diagnosis of the sheep and goat (CLAES 2006a) and bovines (CLAES 2006b) are now available on the CLAES Web site.

In collaboration with ICARDA, CLAES has developed three regional Expert Systems for wheat (CLAES 2006c), faba bean (CLAES 2006d) and barley (ICARDA 2006).

CLAES has also developed the National Agricultural Research Management Information System (NARIMS) through a project funded by FAO/TCP. This system has five modules: Institutes Information System, Researchers Information Systems, Projects Information Systems, Publication Information System, and National Research Program Information System (CLAES 2007). The system is of great value to researchers, extension worker and policy makers.

Role of ICT in coping with challenges of climate change

Using the efficient tools to manage information in any domain is very important in general, but when there is a pressing need to share, exchange and disseminate knowledge, using efficient tools is of paramount importance. Climate change is likely to bring new challenges to agricultural production in the developing countries, particularly in the dry areas where the environment is fragile and sustainable agricultural production a daunting task. There will be change in growing period, water availability will become scarcer, new pest and disease problems will emerge and higher agricultural production on limited land area will have to be produced to keep with the demand of food, feed and fuel. As there will be need for new knowledge by growers and other stakeholders, the researchers will respond to this challenge and generate new information that will enable the farmers to cope with these changed conditions. New information technology ranging from simple data base to complex advanced information technology such as the Artificial Intelligence, as described above, would enable faster dissemination of information to the farmers in the dry areas and help them in adopting appropriate remedial and mitigation strategies including the use of new cropping patterns and production technologies, and exploring new markets to cope with climate change.

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5. Enhancing resilience in dry areas to cope with vagaries of climate change

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Abstract

There is a general agreement that the climate change is happening and it is going to have serious implications for the Earth's diverse flora and fauna (including the marine and inland fisheries). There is a need for developing more precise assessment of the impact of climate change on the ecosystem at the national and regional levels, where the major action for adaptation and mitigation would have to occur. It is anticipated that the impact of climate change would cut across all boundaries. Crops, cropping systems, rotations, and biota will undergo transformation, and, to maintain the balance in the system, there will be a need for new knowledge and policy and institutional changes. The marginalized people in the dry areas are likely to be most seriously hit by the shifts in moisture and temperature regimes as a result of the global climate change. In order to help them cope with the challenges there will be a need for a new paradigm in agricultural research and technology transfer that makes full use of modern science and technology as well as the traditional knowledge. This would necessitate more investment by national governments and international agencies for supporting the relevant integrated research and development efforts, with full participation of the target communities. Only such an approach can enable the vulnerable communities of the dryland areas to use the natural resources in a sustainable manner and thus help protect the environment for present and future generations.

Introduction

The planet Earth, on which we live in communities, is being increasingly 'ruptured' because of human activities. Its carrying capacity is under great stress because of demographic pressures. The pressure is specially affecting the people living in the dry areas because of the marginal and fragile nature of the resources they have access to. There are over 2000 million hectares of land that have been pushed to degradation, loss of agrobiodiversity, increased water scarcity, and increased natural resource destruction. While this has been happening all the time, there is something else that is also happening, as a result of accumulated effect of what we have been doing over centuries to this planet. The neglectful and exploitive use of the natural resources has set the train of global climate change in motion.

Climate change and its impact

The planet is literally on 'fire'. The increase in global temperature is evident (Fig. 1). The reports of the Intergovernmental Panel on Climate Change (IPCC) clearly indicate that the temperature has increased and it is

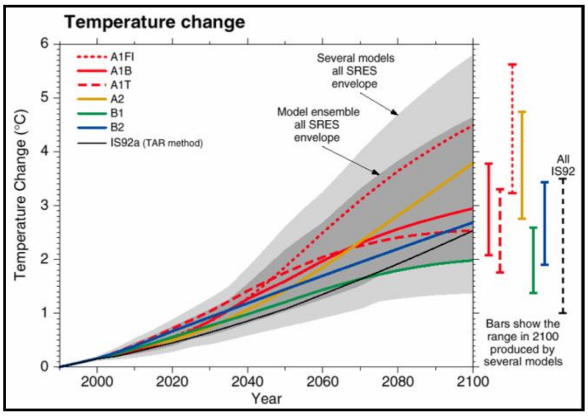

Figure 1. Projected increase in global temperature to 2100 under different cenarios of climate change.

going to continue increasing in the future and faster unless measures are taken (IPCC 2001). What was projected to happen by 2100 is going to happen earlier than expected. Glaciers are melting away and ice disappearing, giving a warning of what might come in the future.

There is going to be a change in the precipitation. The areas which are wet are likely to become wetter and the dry areas are going to become drier. The water scarcity is therefore going to increase in the dry areas (Fig. 2). The water poverty indicators show that the maximum decrease is going to occur in the West Asia and North Africa (WANA) region.

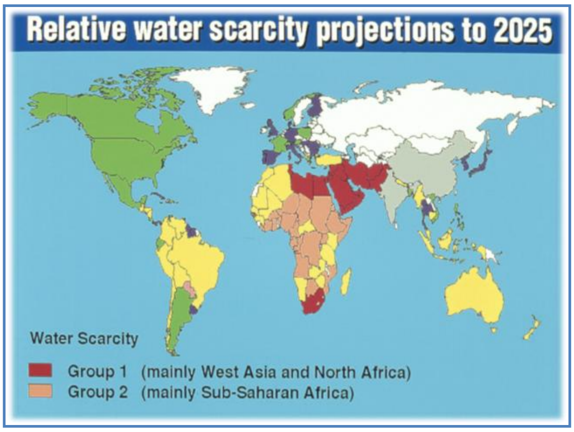

Figure 2. Water scarcity projection to 2025 in different regions of the world.

In addition to this, there is going to be a rise in sea water level (Fig. 3), which would have grave implications for countries whose lands are at elevations close to the sea level. For example, in Egypt nearly 1800 km^2 land area in the north coast and Nile delta will be under sea water if there was a rise of 50 cm in the sea level, affecting 3.8 million people. Many of the old deltas, where agriculture first started on the earth, are amongst those that are most threatened by sea water rise. Not only there will be loss of land and its productivity, but also the people living there will have to migrate out to safer lands, adding to social and economical problems there. Tension would increase between communities and even wars might erupt, as has been happening between the people who have historically depended on rangelands and those who have been practicing settled agriculture. As many of the countries where some of the migrants might arrive are likely to be the economically advanced countries, they might face social and political upheavals and political tension between the nations might grow.

Frequency of flooding and hurricanes will increase causing large damage to life and property with enormous costs to the nations.

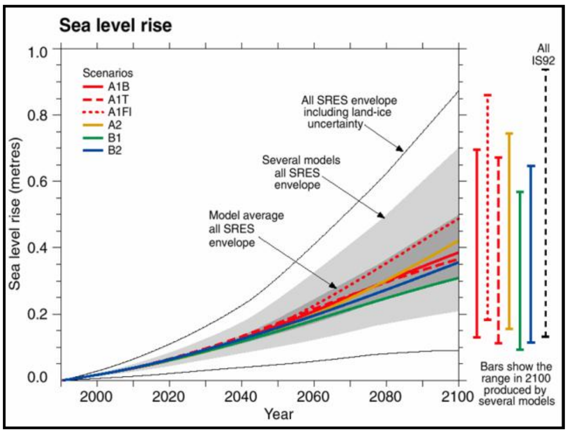

Figure 3. Sea level rise projections to 2100 under different scenarios of climate change.

The climate change will also affect aquaculture, which is the fastest growing food production sector in the world and is good source of revenue to the people, particularly the poor communities.

According to the World Fish Center, the rise in the temperature of inland water may reduce the wild fish stock by harming water quality, worsening dry season mortality, bringing predators and new pathogens, and changing the abundance of food available (WorldFish Center 2009). The marine fishery will also be affected because of the change in the coastal system. The rise in temperature and tidal waves, and changes in ocean currents and CO_2 concentration, because of climate change, will be the cause. There will, thus, be a need for developing a responsible aquaculture system based on the wider ecosystem approach of shared natural resources, in partnership with other sectors including the nature conservation. There will also be a need for ecosystem-based policies, plans and projects for aquaculture to cope with the climate change.

There is compelling evidence, as presented in the IPCC reports, that the climate change will affect seriously the sustainable development challenges that we face not only in environmental issues but in other areas as well. The climate change is not going to be selective to a country; but the fact remains that the developing countries are going to suffer the most, especially the poor countries. The climate change will undermine the ability of the developing countries to attain the millennium development goals and achieve sustainable development.

With all these negative impacts of climate change, brought about by excessive pressure of human activity on natural resources and environment, the question arises as to whether the situation is really as grim and would the world be able to survive. The pessimists hold the view that the future of the world is under great risk because of the constraints on natural resources and degradation of environment. The optimists, on the other hand, opine that human ingenuity would always find ways or develop substitutes to deal with the scarcity of natural resources. The later strongly believe in human resilience.

Enhancing the human resilience to cope with impacts of climate challenge

Let us examine the complexity that we face and glimpses of hope to tackle them.

The climate change is going to have drastic impact on dryland ecosystems and the people living there. All the climate models used by the IPCC suggest that the dry areas will become drier and more water stressed (IPCC 2001; 2007). With environment becoming drier and soil getting further degraded and eroded, desertification will become irreversible.

The desertification and climate change will greatly impact plant biodiversity. Traditionally, the genebanks in different institutions have collected, evaluated, and conserved germplasm of different plant species under short and long term storage conditions. With the initiative of the Scandinavian countries and the Global Gene Fund, the conservation efforts have moved further to store germplasm in the facilities created in the arctic permafrost. The idea is to have valuable and diverse genes of important species conserved for posterity and to provide resources for developing cultivars that might adapt to new eco-environments. Adaptation to the changed climate would necessitate that.

The dryland areas (Fig. 4) are home to over two billion people, accounting for 35% of world population. Some 55% of the dryland inhabitants live in rural areas. More than 90% of the dryland inhabitants are in the developing world. Approximately half of all the poor people in the world live in the dry

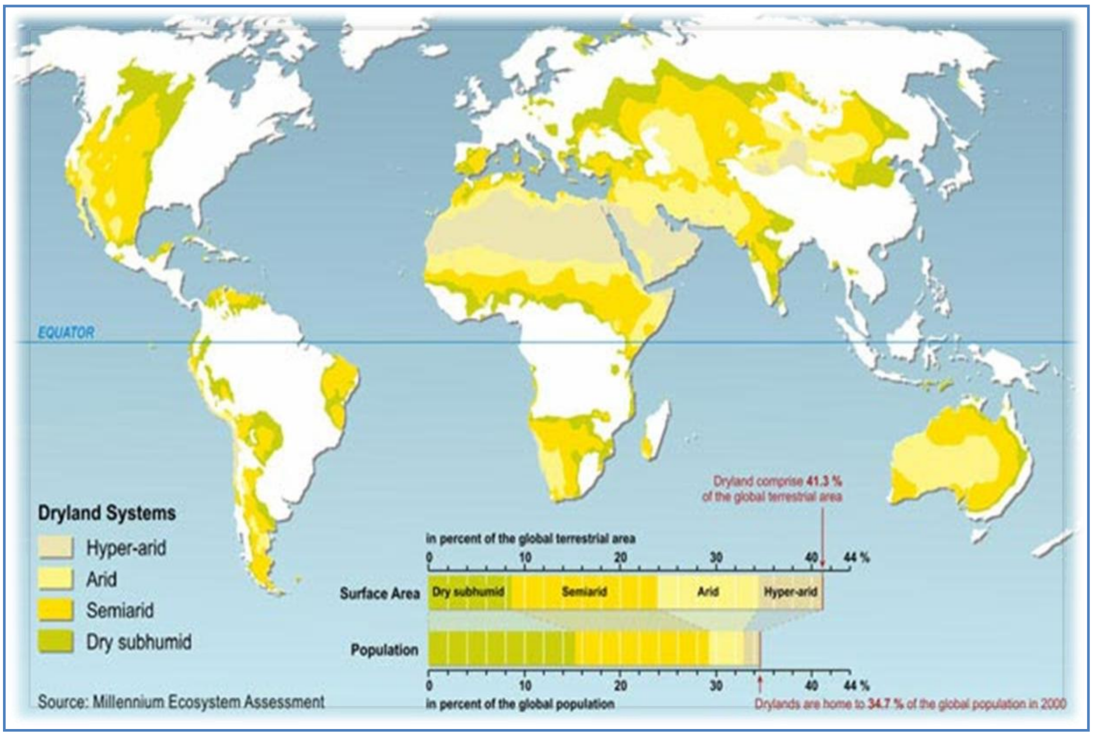

Figure 4: Dryland areas of the world (Source: Millenium Ecosystem Assessment).

areas. The drylands have the highest population growth rates. These statistics highlight the importance of dry areas in the global community. One may ask as to why the climate change is of specific significance to the dryland areas. There are several factors. Most dryland ecosystems are already affected by increasing resource demands and unsustainable management practices and human-induced climate change adds an important new stress. Most dryland systems are sensitive to both magnitude and rate of climate change. And the vulnerability of the people living in the dry areas is going to increase if their adaptive capacity is not improved.

The direct effects of the climate change will be through changes in temperature, rainfall, length of growing season and timing of extreme and critical threshold events relative to crop development. In the drylands of tropics and subtropics, where the crops are near their maximum temperature tolerance level, the yield will decline. In the region where there is likelihood of decreased rainfall, the agricultural productivity will be seriously impaired.

Drought is a recurring feature of drylands and climate change will further exacerbate the frequency and magnitude of drought in some places. In the arid and semi-arid regions people derive their water resources from single point systems such as boreholes or isolated reservoirs. If the primary supply fails these systems are vulnerable. The impact will depend on the baseline conditions of the water supply system, but also on population growth, changes in demand, technology available, and socio-economic and legislative conditions.

The dry areas are highly variable spatially. Global modeling of climate change can only provide information in general terms because their resolution is too course to capture regional and local climate processes. To develop strategies that can enhance the resilience of different

communities in the dry areas there is a need to go further down in the assessment exercise from the global to the continental, to the regional, to the national, and, finally, to the local levels, looking at mitigation and adaptation strategies. This is because the global assessment masks the regional difference, regional assessment masks the sub-regional differences, and national assessment masks the local differences in ecologies. Thus, navigation across scales is essential for making progress towards sustainable development, and the task of assessment at lower levels should not be delayed, if the resilience of the affected communities is to be promptly and cost effectively enhanced.
Enhancing the resilience of communities to cope with climate change would require a series of steps:

1. Run an awareness campaign for the need for resilience;
2. Study the strategies for enhancing resilience;
3. Develop goals and plans of action;
4. Implement; and
5. Measure progress and identify lessons learnt.

The work done in the CGIAR system (http://www.icarda.cgiar.org/) over a decade has enabled the development of the concept of the Integrated Natural Resources Management (INRM), which is essential for the improvement of the livelihoods of the people and communities. It is an approach to research that aims at improving livelihoods, agro-ecosystem resilience, agricultural productivity and environmental services. It, thus, aims to augment social, physical, human, natural and financial capital by helping solve complex practical problems affecting natural resources in agro-ecosystems. Its strategy involves: (a) empowering relevant stakeholders; (b) resolving conflicting interests of the stakeholders in the community; (c) fostering adaptive management capacity; (d) focusing on key causal elements to deal with complexity; (e) integrating levels of analysis; (f) merging disciplinary perspectives; (g) making use of wide range of technologies; (h) guiding research on component technologies; and (i) generating policy, technological and institutional alternatives. The INRM 'tool box' comprises 'diagnostic tools', 'tools for problem-solving and capitalizing on opportunities', and 'process tools'. A very important item of the diagnostic tools is the use of the 'integrated research sites,' which enable up-scaling in the similar environments through the application of GIS, and out-scaling to different environments with the application of GIS and bio-economic modeling. Therefore, the returns on investment made in the research process are greatly enhanced. Excellent examples of the application of the concepts of INRM in the dry areas can be found in ICARDA's research in its Mashreq and Maghreb (M&M) Project in eight countries in WANA, and the research at the Khanaser Integrated Research Site in the north-eastern dry zone in Syria (http://www.icarda.cgiar.org/INRMsite/index.htm).

As indicated before, the frequency and severity of drought events is predicted to increase in the dry areas as a result of the climate change. An important component of the strategy for enhancing the resilience of the people in the dry areas to cope with this challenge is development of early warning system for drought. The World Meteorological Organization (WMO) is working on this. Coupled models and high resolution regional models are being used to develop climate outlooks at multi-seasonal and inter-annual scales (see Jarraud in this volume). Reliable forecasts can help communities to resort to different coping strategies, including avoidance. There is a need to build the capacity of the people to take adaptive and, if necessary, ameliorative measures, so that they could benefit from the early warning system. Chinese scientists have made good progress in this regard and they have been able to prevent land degradation in some parts and recover degraded lands in other areas through appropriate policy, institutions and capacity building of the stakeholders to take appropriate measures.

Some policy responses to climate change challenge to agrarian societies in the dry areas

As mentioned before, the population growth rates in the drylands have been high and poverty is widespread. The policy response here will be for greater regional cooperation to scale up successful initiatives in the drylands to curb population growth and improve livelihoods.

The areas in Sahel, the Mediterranean, southern Africa and parts of southern Asia are becoming drier adding challenge to the livelihoods of the people. There is an urgent need for support to the governments of the developing countries in the dry regions to engage effectively with the climate change negotiation process and have access to resources for adaptive and amelioration measures.

The ecological indicators in the drylands, such as soil formation process, soil fertility status, and water resources availability and distribution, and environmental pollution, are already showing negative trends and they will be further challenged by climate change. There is, therefore, a need to focus on water resources and river basin management, at the regional, national and local levels, to reduce flooding risks and capture rainfall for agriculture and ecosystem use.

Climate change will increase the likelihood of disasters caused by storms, floods and drought, displacing large number of people who should find new homes. Response to this will require to main stream climate change in plans and strategies at national and local (district) levels and at the sectoral levels, such as water resources management, agriculture and livestock management, etc. As the differentiated effects of climate change impacts and inequitable distribution of the adaptive capacity to climate change are poorly understood, action research is required to counteract socioeconomic processes of differentiation. Successful community-based initiatives for enhancing resilience to variable climate by the poorest have to be scaled out.

As the poor climate observation data make climate forecasting by down-scaling from the global models very problematic, effective public information campaigns will have to be organized in different regions and districts to help people understand and respond to climate change.

The agrarian populations in the dryland regions are already affected by non-climatic stresses, which will strongly interact with the climate change effects. Hence, there will be a need to scale up community-based adaptation with poor and vulnerable communities, in urban and rural areas, to ensure rapid documentation and replication of these activities.

Pastoral groups that manage significant proportion of national livestock wealth are particularly vulnerable to climate change in the dry areas. Therefore, existing land tenure arrangements and services will come under increased pressure exacerbating tensions between communities and fueling conflicts. Policies will be needed to enable herd mobility while securing rights to key resources such as dry season pastures and water. Robust conflict management institutions will have to be in place. Effective drought mitigation systems, including early warning, insurance, and safety nets, will be needed to protect assets, and thus livelihood. The pastoral groups will have to be strongly engaged in the policy issues directly affecting their lives. Combination of large scale migration, impoverishment and people seeking new lands has potential to lead to significant conflicts and raises security issues. Therefore regional and national initiatives to improve governance will have to take into account climate change effects and to factor in ways to address these through formal and informal institutions.

Role of science and technology

It is clear from the above that the drylands face a massive challenge because of climate change. What could science and technology do to improve the capacity of the dryland inhabitants to cope with it? Science and technology can certainly make a huge difference, particularly with the recent availability of new tools and technologies. The new tools, amongst others, include GIS and remote sensing, simulation modeling, biotechnology/genetic engineering, advanced artificial intelligence, techniques to harvest renewable energy (solar, wind, second and third generation biofuels), new energy-saving techniques to desalinize sea water and transporting it, and nanotechnology.

Taking just one example, that of nanotechnology, one can see the potential offered by new technologies. Nanotechnology can have wide applications in agriculture, opening enormous new opportunities (www.sprayforlife.com), BASF, The Chemical Company**)**. These include fabrication of nano-sensors for protecting food and its quality in storage from pathogens, pests and elements, producing food additives to add value and enhancing food security, identification and control of insect pests and pathogens (whose incidence and diversity is going to increase because of climate change), purification of waters polluted by microbes, pesticides and fertilizer nutrients, new tools for molecular and cell biology, including more efficient techniques for gene delivery for genetic engineering, and molecular machines and devices. Control for such diseases as avian flu can be effectively achieved using nano-selenium and use of nono-feed for chicken could replace the use of antibiotics. Use of nanotechnology has also been experimented by Norwegian scientists to stabilize sand dunes. The nanotechnology is already picking up the pace in different parts of the world, including some developing countries. Nanoceuticals are already being marketed. For example Nano-Synergy Energy Booster- 'Spray for Life'- with calcium and vitamin B-complex, and 'Lyco-O-Mato' for high lycopene in tomatoes are available for general use. Thus, use of nanotechnology in agriculture has begun and will continue, to usher new revolution with significant effect on different areas of agriculture and food industry. This would certainly help scientists and engineers to design measures for enhancing resilience of the people to cope with the adverse effects of climate change.

The way forward

In the light of what has been presented above, the way forward for enhancing the resilience of dry area inhabitants to cope with the challenges of climate change has several essential elements. These include:

1. Better assessment of climate change scenarios, by doing assessment at the regional and national /local levels to navigate through and across scales.
2. Rapid transition to inter-sectoral thinking, institution building, planning and policy making for responsible and sustainable agriculture, including aquaculture and fishery.
3. Coping with uncertainty, recognizing that there will be shifting of baseline as further assessment of climate change is done.
4. Increased investment in research and information system is absolutely essential.

We need to work together –communities, policy makers and scientist. Therefore, we have to forge a strong global alliance for food security, peace and prosperity of the people living in the dry areas under the changing climate.

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6. Old problems - new challenges and new opportunities

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Abstract

Some in the international community speak of the end of the era of cheap food, plentiful low cost energy and easy credit. Others suggest that global oil supplies have peaked and that prices will continue to rise so affecting the whole global economy. Yet others add to their analysis the pervasive impacts of climate change on, and the over/miss-use of, limited water supplies in large tracts of this planet. Nowhere are these issues more relevant than in the 'drylands' of the developing world and particularly West Asia/Middle East. Many here are challenged by poverty, soaring food costs and very limited economic prospects. In the sustainable development of the drylands, many interwoven problems can be recognized. These include water poverty and misuse, huge climatic variability and uncertainty, land degradation and desertification, and climate change (with projected deceases in annual rainfall, and increases in mean annual temperature, in extreme events, and in sea level). There are limited areas of fertile, well-watered land and often inefficient and unsustainable food production and continuing population growth. These challenges must be faced within the fluid socio-political environment of globalization, of continuing urbanization, of migration pressure, of local, regional and international competition and conflict for natural resources, influence, wealth and ideological supremacy. The roles and expectations of women are changing as is the global focus of fiscal power (and responsibility) from the "West" to the sovereign funds and the emerging economies. Belatedly, there is also international realization of the gross neglect of the agricultural research and development sector. This paper explores some of these issues for the drylands and highlights the opportunities which could arise from the development of novel policy options, from exploring new technical interventions, by exploiting current best practice and research, and by identifying economic opportunities within the constraints of international pressure to limit carbon emissions and climate change.

Introduction

Within the international community many speak of the end of the era of cheap food and of plentiful, low-cost fossil energy and of easy credit. Others, more apocalyptically, suggest that we face a perfect storm, combining not only as the global credit and economic crisis and 'peak' global oil supplies (at the very least, the peak of readily-extractable, cheap oil) so that rising energy prices will continue to dampen the global economy, with the challenge of responding to climate change and the need to curb our dependence on fossil fuels.

In relation to the drylands we must add the pervasive impacts of climate change on areas already challenged by dryness and by the over- or miss-use of limited water supplies. Further physical trials hover on the horizon. It is not clear, whether or not the global community will move with the necessary vigour to build a low-carbon global economy so as to avoid the more calamitous impacts of climate change, for example, a sea level rise of 1 to 2 meters with disastrous consequences for areas such as the Nile delta. Many experts agree that keeping atmospheric green house gasses including CO_2 to below CO_2 equiv. 450ppm is vital to avoid dangerous positive feedbacks e.g. release of tundra methane, and irreversible changes, but it must be seriously doubted if this will be achieved (Anderson et al. 2005; Bows et al. 2006).

In facing these immense challenges, history suggests that it is the poor, dispossessed and marginalised who will suffer most from social and economic convulsions and from any 'natural' or 'man-made' physical disasters. Nowhere more so than in the fragile 'drylands' of the developing world, including West Asia and North Africa (WANA) --- the classical interface between the Mediterranean, European, and 'eastern' worlds.

While a favoured few in this region are the beneficiaries of enormous oil and gas wealth, the majority of the inhabitants of the drylands remain burdened by poverty, soaring food costs, limited economic and resource options, poor educational prospects, and social discrimination while yearning for improved living standards for themselves and their children. Together, these evils ferment further social unrest. Too often the ensuing civic and international conflicts further undermine any possibility of improving human welfare and living standards. It is also abundantly clear that the "Washington free-market development consensus" and strands of *laissez-faire* capitalism itself have been discredited on their own home ground of Wall Street and the City of London (as had, previously, the pretensions of centrally-planned economies). The 'Washington model' can no longer provide convincing diagnoses or answers, especially from the perspective of the rural, marginalised poor of the drylands whose social horizons and access to global markets and information is very limited. Importantly, the financial trauma in the 'North' implies that peoples round the world will have to look to their own resources, imaginations, skills and initiatives to seek to solve their problems, as the current financial crises will focus 'Western' minds, for some time to come, on their home-grown difficulties.

Challenges to sustainable development in dry areas

The sustainable development of the 'drylands' (home to some 25% of this planet's population) is characterised by interlinked physical problems. These include, as is all too well recognised, water poverty (but including competition, misuse and resource over-use); huge climatic variability and uncertainty; insidious land degradation, and desertification and very limited areas of 'good land'. On to which we must superimpose mean climate change (with projected deceases in annual rainfall and river flows, and increases in mean annual temperature and evapo-transpiration), and increases in extreme events (including extended periods of drought and storm events). Within the drylands, the limited areas of fertile, well-watered land are crucial but insufficient to provide adequate sustainable food production, resulting in many nations being dependent on imported staple foods and exposure to world market prices and to external political pressures (see ICARDA 2007).

Of equal, perhaps even greater, significance are the social, cultural and economic challenges. Fragile social structures are threatened, internally and externally, while investments in educational and social programmes and in research and development are too low and, of course, even these are all challenged by the pressures of continuing population growth (see UNDP & AFESD 2003).

It is within the fluid socio-political environment of globalisation (which tempts the rich to be both protectionist and exploitative) and of fast changing power and economic relations, of continuing urbanisation and migration pressure (to cities barely able to cope and/or to developed countries reluctant, even frightened, to accommodate new migrants) that the basic 'dryland' issues must be addressed. Crucially, the roles and expectations of women are changing -- half our population and talent should and can not any longer be relegated to subservient, peripheral roles.

The global focus of fiscal power and responsibility is shifting from the “Northern Axis” to the “sovereign funds” (several from the Gulf States) and to the emerging power-houses of China, India, Brazil and others. Belatedly there is also international recognition of the gross neglect of the agricultural research and development sector and the continuing need for food production to keep up with population growth (noting that ICARDA's annual budget of about $30 million would not purchase one star footballer in Europe for Manchester United or Real Madrid, adding that Manchester City, which is now Gulf-owned, is wishing to compete with the high rollers).

In the text that follows these issues are analyzed and the opportunities, which could arise in the dry lands areas from the development of novel policy options, from exploring new technical interventions, by exploiting current best practice and research and by identifying economic opportunities particularly within the context of international pressure to limit carbon emissions and mitigate climate change, are highlighted.

Water, food and people

I will not dwell on the problems as these have been discussed in some detail by others but will focus briefly on the related issues of water, food and people, by way of context to the proposals to be made in the later section.

Drylands are, of course, water short and that this shortage can be expressed in various ways (e.g. Falkenburg et al. 1990). Available and renewable water resources in the Middle East and North Africa approximate to 1,100 m^3 $person^{-1}$ y^{-1} (see Fig. 1), falling to 550 m^3 $person^{-1}$ y^{-1} by 2050, given population growth projections, but this latter figure does not take into account likely climate change scenarios; all of which predict lower rainfall, higher temperatures and evapo-transpiration for this region. Thus, it is likely to be a significant overestimate. Currently some 80 to 90 % of available water is used for agriculture and for food production (see Fig. 2) but, despite this, the region is a major and growing grain importer of around 50 million tonnes now, but doubling by 2030 to near 90 to 100 million tonnes (ICARDA 2007).

It is worth recalling the formal definitions of national water scarcity that lie behind the values in the Figure 1 (Falkenburg et al. 1990). Countries are classified as: (a) Water stressed (<4654 litres per person per day or 1700 m^3 $person^{-1}$ y^{-1}), (b) Water scarce (<2738 litres per person per day or 500 m^3 $person^{-1}$ y^{-1}) ; and (c) With absolute water scarcity (<1369 litres per person per day or 250 m^3 $person^{-1}$ y^{-1} . For comparison, the global water foot print is 1240 m^3 $person^{-1}$ y^{-1} of which some 16% arises from international trading.

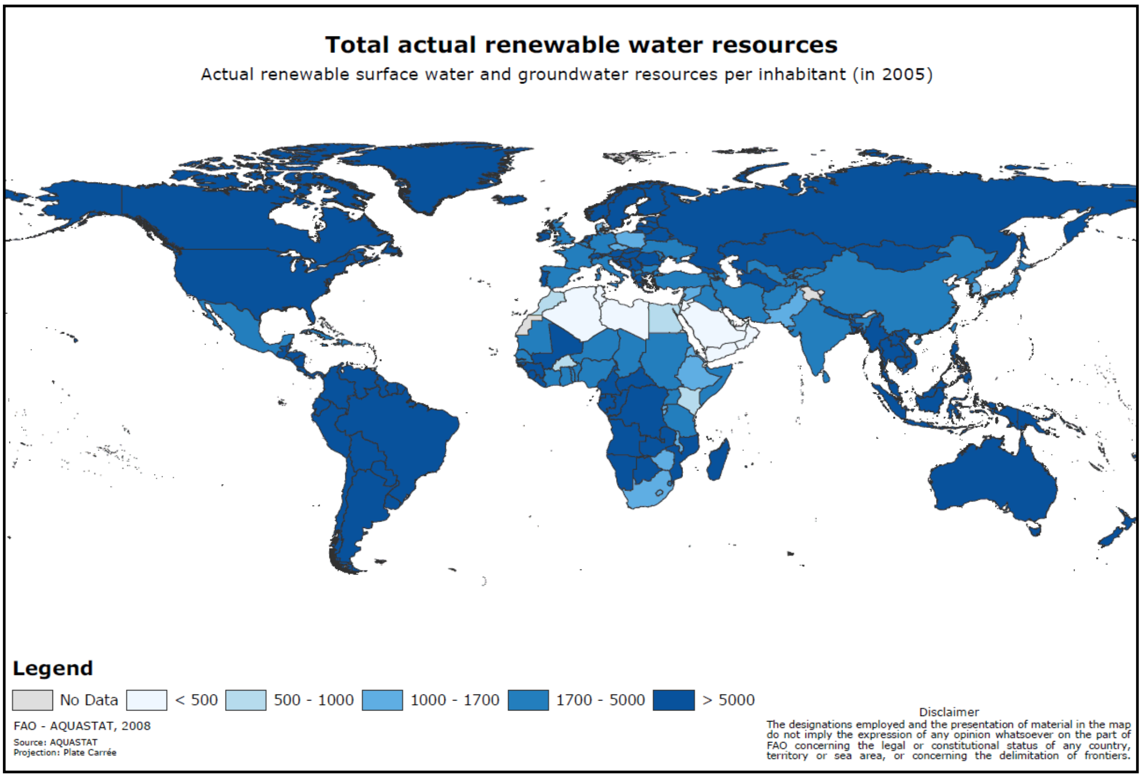

Figure 1. Total actual renewable water resources per inhabitant in 2005 in different countries in the world.

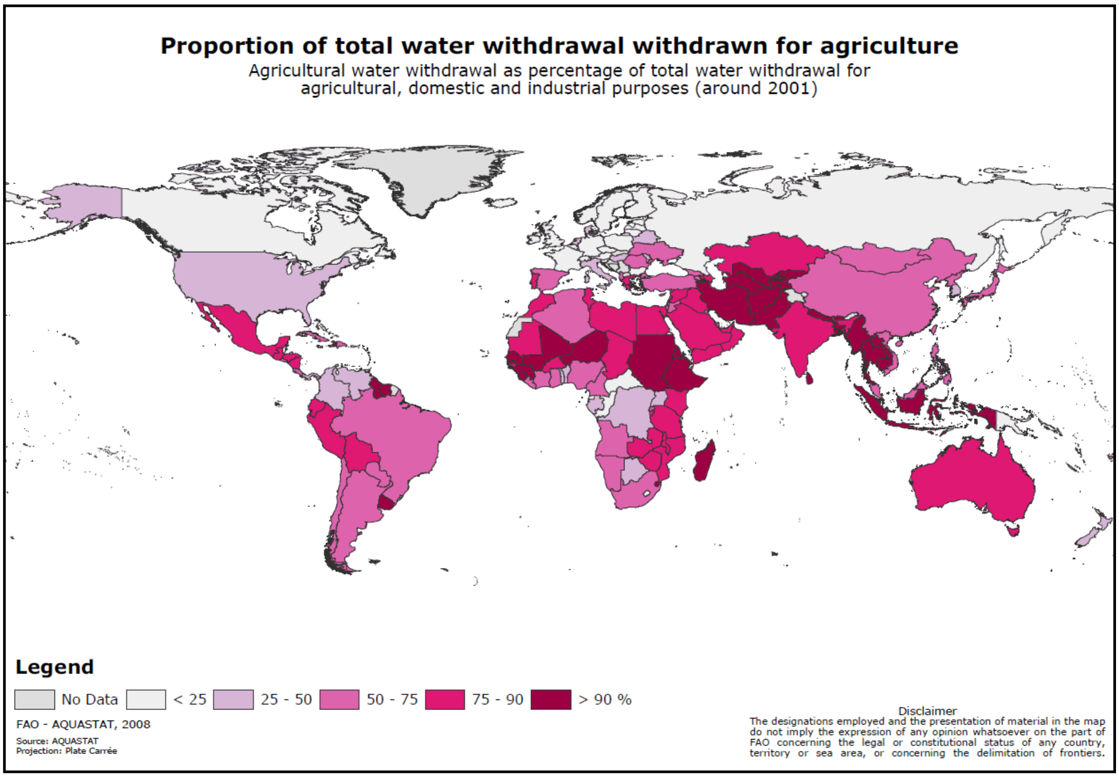

Figure 2. Agriculture water withdrawal as percentage of total water withdrawal (for agricultural, domestic and industrial purposes) around 2001.

Within the WANA region, Jordan is already on only 170 m^3 $person^{-1}$ y^{-1} i.e. absolute water scarcity and, on any reasonable projection, much of this region will be in dire straits in the near future. Nevertheless, it is essential to recognise and examine the basic assumptions of the Falkenburg index, i.e. the index is based on the amount of water that would be required, in a semi-arid country, to achieve food self- sufficiency.

Two questions obviously arise: is this a rational assumption? Is it rational and/or economically or socially desirable for water-challenged countries to seek to be self-sufficient in food? Recalling the food rationing in wartime and post-war Britain, this is not a trivial question to be posed lightly and that the absence of food self-sufficiency carries with it significant hazards, but it may be inevitable and *de facto* the least worst scenario.

The predominance of water use in agriculture (Fig. 2) reflects historic practice. Even as countries urbanise, rural communities are vital. Official policy tends to favour national food self-sufficiency as opposed to seeking to maximise food security through trade, reinforcing the importance of the ruralareas. Certainly a headlong rush from the countryside to already crowded cities is a daunting prospect.

Nevertheless obvious questions are: [a] Is the current situation sustainable? [b] Are there alternative scenarios? [c] What might be the optimum water and land use policy? [d] Should the policy be dominated by economic considerations or by a political need for food security? [e] How (if at all) should water be priced? [f] When water resources are limited, what crops should be grown? [g] If there will be a move from traditional agriculture, how can rural communities support themselves? [h] Can a country entrust its staple food supply to the international market place or, indeed, can it avoid doing so? [i] How much additional benefit can be derived from recycled water and improved water use efficiency in both rain-fed and irrigated system?

There is no prospect of answering these questions in a single short contribution. But, to place the overall issue in specific context, a reference to the work of Chewoweth (2008) would be helpful. He argues that, if we discard the traditional agricultural focus, a nation could offer a high quality of life with as little as 135 litres of water per person per day: i.e. about a tenth of the level of absolute water scarcity, as currently defined above. In the Netherlands individuals use 125 litres water a day. Even at this low consumption Chewoweth (2008) suggests that with relatively simple mechanisms for enhanced water use efficiency a decline to about 85 litres is possible. Clearly, to secure a national perspective, domestic water use must be supplemented by water for the service, business and the industrial sectors. Chewoweth (2008) points out that in the UK, excluding the very water intensive industries, e.g. some chemical manufacture, textiles, paper etc., these sectors only require the equivalent of 34 litres per person per day -- hence an overall requirement of about 125 to 130 litres.

This, therefore, represents a water efficient scenario without the allocation of water resources to either irrigation agriculture or to water-intensive industrial processes (extensive use for recreation, e.g. golf courses). This appears, roughly, to be the situation in places with little agriculture and high population densities such as Malta and Singapore even today, but is of course a stark contrast to many dry land countries in WANA where 80 to 90% of water is allocated to agriculture.

Interestingly, some individuals and households in the least developed countries or regions, such as the communal areas of Namaqualand in South Africa, have to survive on about 20 to 25 litres per person per day (May et al. 2006). No one would argue that this is satisfactory. Such figures need to be interpreted with care as they could be affected by the local climate and other factors, but it is revealing to place these figures in their physical context. However, it is worth noting that a 5 x 5m roof area in a rainfall of 350 mm, assuming a capture efficiency of 80%, could theoretically yield some 6500 litres of water per year or some18 litres per day per unit – a significant contribution to drinking and cooking needs. Obviously, the reality would depend on the capture systems (guttering/tank capacity etc.) and on the periodicity of the rainfall (Prof. Timm Hoffmann University of Cape Town, personal communication). But the significance to local capture to supplement other supplies needs serious and wide spread consideration.

While these international comparisons suggest that communities and individuals and economies can prosper on a little over 125 liters of water per day per person, the concept rests on the assumption that 'virtual' water is imported in the goods, especially the food, and that most of their requirements for food and water-intensive materials would come from other water-rich regions. It is, therefore, important to note the virtual water content (Table 1) of some common foods and goods (Hoeskstra and Chapagain 2006), while recognizing that such figures are first approximations that do not distinguish different production systems, e.g. intensive corn-fed beef from range grass-fed animals.

It was noted earlier that WANA currently imports large volumes of grain, projected to rise to some 100 million tonnes of grain annually by 2030. Since a tonne of grain approximates to 1000 m^3 of virtual water; this is equivalent to 10^{11} m^3 or 10^{14} litres of virtual water. Assuming a population in 2030 of *circa* 650 million (see FAO projection) this amounts to 154,000 litres per person per year -- only for grain. If all food imports are included, there is no doubt that regional virtual water imports will be significantly higher, especially considering water- intensive meat imports. As noted above, textiles, shoes and other items also incorporate a great deal of virtual water, a fact that needs to be taken into consideration. As far as I am aware, none of the figures for WANA or NENA demand factor in the impact of climate change on either the water resources or regional crop yields. These figures may be compared to a hypothetical basic “food-independent” requirement in 2030 of 125 litres per person per day, i.e. 45,625 litres per person per year, and the current Jordanian figure for water availability for all uses of 93,000 litres per person per year.

Table 1. Selected averaged global virtual water contents (Hoeskstra and Chapagain 2006)

Product	Virtual Water (litres)
milk 200 ml	200
bread 30g	40
potato 100g	25
cotton T-shirt	2000
glass of wine 125ml.	120
hamburger 150g	2400
egg 40g	135
tomato 70g	13
microchip	32
pair of leather shoes	8000

I would argue that it is highly probable that a combination of urban pressures, physical limitations on water supply for agriculture and future climate change will force a major rethink. A marked decline, over a span of one generation (10-20 years), in the water available to irrigation agriculture is surely inevitable (ICARDA figures suggest a decline of 220 m^3 or 220,000 litres per capita every 25 years in water for agriculture in the southern Mediterranean).

This will catalyse the adoption of technologies and the breeding of cultivars which increase yields and water use efficiency as is advocated by ICARDA and others. In all probability, there will also be a move to higher value crops to increase the economic return per unit water. Yield per unit water and economic return per unit water are becoming major concerns. Fortunately there is also compelling evidence that significant improvements can be achieved in rain-fed systems. Nonetheless, critical questions arise; firstly, if some of the more profitable types of irrigated or part-irrigated agriculture are destined to decline and /or to be concentrated in fewer hands in a generation due to physical, social and economic pressures, how will this affect the capacity of the rural poor to escape poverty through agriculture? Even now in numerous studies summarised by De Janvry and Sadoulet (2000) and including ICARDA's Khanasser Project (ICARDA 2007), agricultural production is only a modest contributor to rural livelihoods. In our MAPOSDA project in Namaqualand (Wyn Jones et al. 2003), it contributed at best about 10%, although in the Maloti mountains for Lesotho with much higher rainfall it approached 40%. There is little prospect of this increasing for the reasons given above and it may well decrease.

So we need to consider complementary or alternative pathways from rural poverty and to re-assess the policy framework. The near universal historic assumption, in both developed and developing countries, that agricultural research, related extension, development and support policies are virtually synonymous with rural development has to be questioned. Very careful consideration must also be given to the type of agriculture practised in semi-arid countries as well as general development priorities. It may well be that both food demand and prices will increase but is there evidence that the marginalised poor farmer in a semi-arid highly unreliable climate will be a major beneficiary? This analysis does not seek to undermine the urgent need to well focused research and development in the agricultural sector. Any improvement in the welfare of subsistence farmers is to be welcome and every effort must be made to achieve sustainable improvements in food production in both rain-fed and irrigated systems. Additionally, there are pressing concerns related to continuing sustainability and efficiency of current systems, e.g. soil conservation, N leaching into ground and surface waters. However, there appears little reason to expect agriculture per se to provide more than a minor escape route from rural poverty.

Comparative advantages of dryland areas

Since water is a very limited and potentially diminishing resource, we must ask what are the abundant resources and comparative economic advantages of the drylands? I suggest the following:

1. Abundant 'free', non-polluting, carbon-free renewable energy from the consistently high and reliable levels of solar radiation. This, through numerous technologies, can be converted into abundant renewable electricity and, potentially through controlled photolysis, to renewable hydrogen capable of replacing oil and gas resources as the underpinning to the global economy. This same radiation can be harnessed in large biological production potential, e.g. of algae (if linked to a modest supply of water and nutrients to biomass production), again a renewable carbon-neutral source of aviation fuel etc.
2. Huge financial resources.
3. Energetic skilled people. This resource is presently underdeveloped but, one should remember that many of the insights and inventions which underpinned the evolution of mathematics, medicine and science and technology in Europe were transmitted from WANA, the Indian subcontinent

and China. Those skills must be reinvigorated.

A concerted effort should be undertaken to exploit the above mentioned strengths and, at the same time, alleviate some of the well documented problems discussed herein and elsewhere.

Proposals for seeking sustainable development in the dry areas:

I wish to put forward four propositions to seek to assist dryland development in the WANA region:

1. A 'regional' initiative on solar energy capture and renewable energy generation, both basic research and demonstration and development project, is vital. The potential of various solar technologies is enormous and can be crystallized by the suggestion that an area of approximately 600 km x 600 km of solar energy capture (at a rather low efficiency) could supply the energy needs of one billion people (roughly whole Europe and North Africa) at the European consumption rate of 125 kWh per day (MacKay 2008). Let us consider the following scenario: In 7 years time the atmospheric CO_2 level reaches 400 ppm, coinciding with the disappearance of summer ice in the Arctic (Greenland icecap is melting at an unprecedented rate), a very hot European summer (party due to an El Nino event) kills thousands, serious hurricanes elsewhere and poor harvests in Australia (again!) -- a sure recipe for an international panic. It is realised that atmospheric CO_2 levels will continue to increase and, in consequence, the danger of positive feedbacks is even more acute. Unfortunately these are not the ravings of madman but an entirely plausible set of events. We can anticipate the reaction in the 'North' especially just as it is emerging from a long financial/economic crisis. The drylands of WANA could be part of the solution. It can seriously be envisaged that solar renewable electricity could be exported into the European grid to power that continent and run its cars as well as fuelling the economies of WANA. It follows - not food for oil but food and goods (and their attendant virtual water) for carbon-free, renewable energy and /or goods produced with that energy. Also more locally abundant solar power could support desalination and the purification of recycled water to ease water shortages in the region

2. If this region will inevitably need to divert more and more water resources from irrigation agriculture to urban and commercial use (and that rain-fed agriculture will become more uncertain as a result of climate change) then mechanisms must be found to help rural communities diversify their incomes. Two initiatives suggest themselves.

3. Firstly, mechanisms to convert the international public goods produced by ICARDA and the other international, regional and national agricultural research institutions into local commercial advantage. I realise full well that ICARDA is doing all it can in this area. But its resources are limited (one footballer equivalent per year) and it is constrained by its primary mandate – as an international research organisation producing IPGs. Already, and I would argue quite properly, it is stretching the definition of international public goods (IPGs). The transmission and conversion of IPGs to local advantage is principally the work of NARS but as far as I am aware, few have the skills in business development, in social issues, in marketing, in credit generation and distribution etc. that are required. New thinking is required, either with re-vamped NARS or something more radical, which could include a regional initiative.

4. Secondly, as noted above, even now agriculture per se is often relatively modest contributor to income generation and livelihood support in semi-arid and arid communities (e.g. see work in Khanasser project and others). While

ARD can contribute to the alleviation of rural poverty, non-agricultural enterprises are becoming ever more vital. The traditional link between rural development and agricultural development and productivity is still important but not enough in itself. This implies much greater emphasis on skilling and supporting men and women in a wide range of non-agricultural activities in households, communities, villages and small to medium-sized towns (in part to slow the rush to the cities).This has been part of EU thinking for many years and WANA would be well to learn from successes and failures of EU. New thinking, new organisations and new initiatives are required to meet these new challenges.

5. How is this new thinking to be generated to address the interrelated issues of national food self-sufficiency and/or food security, water availability and national water use profile, land-use and conservation and poverty alleviation? These issues cross the conventional institutional and disciplinary boundaries, which characterise and plague all civil services. A nation may also consider that a number of acute problems may arise from an exposure to international markets in a time of financial instability coupled to climatic shifts. Nonetheless, for many countries and sub-regions, the status quo is either not at all or a very poor option. There is a strong case for regional think-tank drawing on skills and experience of ICARDA, IWMI, IFPRI and the other international and regional experts to which government could seek advice on options, planning scenarios etc. Importantly, such an unit could make more radical, cross-disciplinary, proposals. But proposals which would be 'deniable' by government i.e. would arise for outside the national systems and be open for discussion prior to formal adoption and implementation by government.

6. Finally, in the whole area of renewable natural resources, which lie at the heart of the future of the drylands, there is the need for well educated, well motivated individuals in a wide range of sciences, technologies and social sciences. The establishment of a major endowed fund to provide scholarships and fellowship for young men and women to develop their potential will go a long way in achieving this objective. One could envisage, for example, gifted youngsters working on joint projects between ICARDA or ICRISAT or IWMI and local University and involving an European or USA institution. One cannot imagine a greater catalyst to creativity and the improver of research standard than such an arrangement. Of course there will be problems and rivalries, as always, but the regional rewards are also huge.

It was noted earlier that there are pockets of enormous wealth in the drylands. One does not know how long the oil wealth will be maintained (who knows how the relationships between peak oil, limiting $C0_2$ emissions and the global economy will play out!) nor how soon our world will panic and move dramatically to cut its dependence on fossil fuels and curb the global emission of $C0_2$ and other greenhouse gasses. Do we have 10, 20 or even 30 years? My best guess is that it will happen sooner than we expect. There is consequently a huge regional self interest in re-positioning the drylands, arguably one of the most vulnerable regions, for the new economy and environmental reality. European and international demands for carbon-free, renewable energy will be huge and the high solar radiation of the drylands can play a part in fulfilling that need (while recognising significant technical issues must be solved especially in relation to efficient long distance electricity transfer).

To return to my introduction, in many ways the challenge is huge but very simple; will the enormous financial resources of this region be used to provide mechanisms to address these issues or for footballers?

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7. Improved food security and livelihoods in dry areas in the context of climate change

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Abstract

Dry areas cover 41% of the earth's surface and are home to over 2 billion people – and the majority of the world's poor. Food insecurity and the current food crisis are the most immediate challenges facing national, regional and international communities in fragile ecosystems of dry areas. The situation is further aggravated by the extreme weather conditions as the result of climate change. Enhancing food security and improving livelihoods of the resource poor here require an integrated approach involving the three major pillars for sustainable agriculture development namely natural resource management, crop and livestock improvement, and policy and institutional capacity development. To have positive impact on food security and improving livelihoods, changes are needed in the development of supportive policies and institutions as well as in having effective technology transfer. ICARDA has been working on increasing agricultural productivity and production in the dry areas and providing improved livelihood options to resource-poor farmers in support of sustainable agricultural development. The Center has released, in collaboration with national programs, nearly 850 improved varieties of wheat, barley, lentil, faba bean and chickpea adapted to the dry areas. Integrated fungal and insect pest management techniques have cut production costs and have protected the environment. High value crops and protected agriculture are now available to farmers in Afghanistan and Yemen to diversify production systems, improve human nutrition and improve livelihoods. The Center has introduced improved crop management methods by more efficient water management (e.g. water harvesting, supplemental irrigation), and introduced conservation agriculture to increase rain water infiltration, raise yields and reduce production costs. Agricultural research in dry areas will enhance food security and ameliorate food price increases in addition to developing capacities of scientists and institutions to help farmers cope with climate change in developing country. It is a noble cause with global relevance that deserves the greatest support.

1. Introduction

Food insecurity is perhaps the key challenge facing communities as well as governments in the dry areas. The food crisis of 2008 was triggered by several reasons including conversion of food crops to biofuel, reduced availability of staples in global markets because of prolonged droughts in major grain exporting countries such as Australia and Canada, high demand for grains spurred by economic growth in China and India, and the change in eating habits in many developing countries. We know now that part of what we are experiencing can be attributed to climate change.

2. The challenge of dry areas

Dry areas cover 41% of the earth's surface, and are home to over 2 billion people – and the majority of the world's poor. Over 80% of the population in these regions lives on less than $2/day, most of which is spent on food. Climate change will aggravate the situation unless governments muster the political will to make the right investments and restructure their policies.

UNESCO's classification distinguishes five major categories of dry areas: non-tropical with winter rainfall; non-tropical with summer rainfall; non-tropical with transitional, often bimodal, rainfall; tropical dry areas; and hyper-arid areas (or 'true' deserts). ICARDA's geographic mandate focuses on the non-tropical dry areas of the developing world, encompassing North and Sub-Saharan Africa; Central, West and South Asia and China; and Latin America.

While there is a wide diversity of agro-ecologies in dry areas, wheat and barley represent the main components of rainfed cropping systems, although such crops as sorghum, especially in Sudan, and cotton in Egypt and Syria (under irrigation), are also important. Faba bean, chickpea and lentil are important food legumes, and a major source of protein in the daily diet of low-income people. Other crops, such as potatoes, summer crops, oilseeds and sugar beet are also important, especially where irrigation is available. Dryland fruit and vegetable crops are an integral part of the farming systems, and include olive, almond, fig, pistachio, apple, apricot, peach, hazelnut, grape, quince, date palm, cucumber, melon and others. Livestock, particularly sheep and goats; forages; and rangelands that provide feed, represent a major component of the farming system and are an important source of lively-hoods,articularly in low-rainfall areas and marginal lands.

Environmental poverty in dry areas: water scarcity and land degradation: Future projections of population growth indicate a further decrease in per capita water resources. In the Middle East and North Africa, for example, current per capita renewable water resources (1100 m^3/yr) are projected to drop to 550 m^3/yr by 2050. This will trigger a higher water withdrawal rate with both ecological and human livelihood implications.

The Middle East, North Africa and Sub-Saharan Africa are the world's most water-scarce regions and they are extracting water at a rate that is not sustainable. Most countries in the dry areas are facing increasing water scarcity. In some cases, such as Jordan, per capita availability of fresh water has already dropped to 170 m^3/year, well below the internationally recognized water scarcity standard of 500 m^3/year.

Water scarcity and quality are potentially serious threats to food security and health in dry areas. There is a direct relationship between access to water and access to food and feed security. The proportion of the population without access to reliable, uncontaminated water is as high as 78%. Irrigation accounts for 80-90% of all water used in dry areas. However, increasing competition for water among various sectors will likely reduce the share for agriculture to about 50% by 2050.

Climate change*:* The recent report of the Intergovernmental Panel on Climate Change suggests that the severest impacts will be felt in West Asia, North Africa, and Sub-Saharan Africa. The crop varieties grown today are not likely to survive in the changed climate of tomorrow. The areas of cultivatable land are projected to decrease, which will exacerbate the precariousness of food security situation.

Climate change models project that North Africa and West Asia will see a 6.5 and 3% decrease in rainfed cereal production, respectively. However, North Africa, West Asia and Central Asia are projected to see a 6.5, 4.5 and 10% increase in irrigated cereal production, respectively. Depending on the climate change model, North Africa and

West Asia are projected to see a 49% to 33% decrease in production from grasslands/scrubland and a 14-15% decrease in production from woodlands.

Climate change is already severely affecting the already scarce natural resources in the dry areas; crops and livestock are facing more extreme temperatures and drought has become more common. ICARDA, through its focus on dry areas, is developing technologies that are helping farmers to cope with climate variability and change through adaptation, mitigation and greater resilience of production systems. The Center and its partners are developing crop varieties and production technologies to cope with the threats of drought, heat stress and other climate change implications. There is also need for technologies to improve water productivity, halt land degradation and combat desertification, e.g. soil and water conservation and better rangeland management practices. The approach must include community-based co-management of scarce natural resources and allow land users to link with research institutions and policy makers. It is much more cost effective to prevent land degradation and desertification, than to reverse degradation once it has occurred. This is true irrespective of the causes of degradation (over-grazing, erosion, salinization etc).

***Population growth, urbanization and unemployment*:** In most dry-area countries, food demand is outstripping production, due in part to rapid increases in population (the growth is about 2.5 % annually). The proportion of arable land to total area is lower (4–11%) than in other climatic zones in other developing regions.

Urbanization is one of the critical global trends shaping the future, according to World Resources 1996-97. Measuring everything from urban expansion to energy consumption to declining fish stocks, the report uses projections based on scientific studies, scenarios, and quantitative models to document future environmental challenges, including those caused by massive and rapid urbanization. The report identifies some positive trends, but also finds that greater environmental challenges lie ahead unless the human race charts a new course. Taken one by one, these trends extending into the future appear manageable. But when you put them all together, they pose a potentially serious hurdle to the aspirations of all nations for a better quality of life and for the preservation of natural resources and environmental assets. The effects of urbanization on environmental degradation can be expected to hit the dry areas of the world very hard. Many countries in the Middle East and the Gulf are already more than 50% urbanized; about 95% of Kuwait's inhabitants live in Kuwait City.

Policymakers in the MENA region are faced with the challenge of reducing the high level of unemployment and creating sufficient jobs to absorb rapidly growing populations. Meeting this challenge is neither simple, nor should it be postponed. Unemployment is a waste of society's scarce resources. It has direct adverse effects, especially on those with no assets to compensate for joblessness. Further, a high concentration of unemployment among the educated youth can be politically destabilizing.

***Food insecurity - prices, trade and self sufficiency versus self reliance*:** Taking cereals as an example, WANA will continue to be the largest cereal importer in the world, although the projected trends for Sub-Saharan Africa, with a large dry-area component, are also alarming. Demand for animal feed also exceeds the region's current production levels. The feed shortages, coupled with water shortages and threats of diseases, are leading to low productivity and poor reproductive performance of livestock.

The dry areas of the world are primary importers of wheat. The combination of increasing demand for food and limited land resources has a potentially negative impact on the overall food security situation. The West Asia and North Africa (WANA) region has changed from a net food exporter in the first half of the last century to the largest food importer in the developing world.

In an increasingly globalized world it makes more economic sense for a nation to buy food instead of growing it. Whether or not the current situation subsides and market forces correct themselves, the crisis has alerted people to the global food issue and is forcing nations to consider their own food security.

Food prices in recent times have been rising very sharply for various reasons. These reasons include drought in major food producing countries including exporting countries like Australia and Canada, increased global demand, and the diversion of food grains into bio-fuel production. Unfortunately the price rise trend does not seem to be reversible at least in the very near future. While the reasons may be a debatable, we all agree that higher food prices will directly affect the poor.

It is projected that the dry areas of the world will be the biggest losers based on the costs of importing more food. Agricultural research is one of the few ways that will permit countries to become more self sufficient, as was achieved by Syria, Iran and Uzbekistan.

Desertification or land degradation is major global challenge to food security. The dry areas are particularly vulnerable to land degradation and desertification. The recent Millennium Ecosystems Assessment Report indicates that desertification threatens over 41% of the world's land area, mostly in the dry areas.

***Inadequate policies*:** Dry area countries have mostly marginal areas, very high population growth rates, and over 30% of the work force engaged in agriculture. They thus rely heavily on agriculture to address major economic development problems, and face food insecurity, high unemployment, rural to urban migration, and migration to better endowed areas. In most developing countries, agricultural policies are inadequate to resolve these problems. These countries have inadequate policies to provide (a) sufficient investment to keep with advances in science and technology; (b) sufficient monitoring and research impact assessment; (c) special attention to less well-endowed agro-ecologies; (d) incentives to research staff in certain countries, and (e) support for regional and international cooperation.

Food security and poverty trap

The above mentioned key challenges are interrelated and interactive, leading to a "Food Insecurity and Poverty Trap" in which a large proportion of the population is caught (Fig. 1). Hunger and poverty are widespread. About 360 million people or 16% of the total population in the non-tropical dry areas of developing countries lives on less than one US dollar a day. And almost 1 billion people – again, mainly in dry areas of developing countries – live in absolute poverty and hunger on less than two US dollars a day. Women and children are affected the most.

However, there are clear pathways out of the poverty trap and natural resource degradation, as presented in Figure 2. The dry areas have their own specific

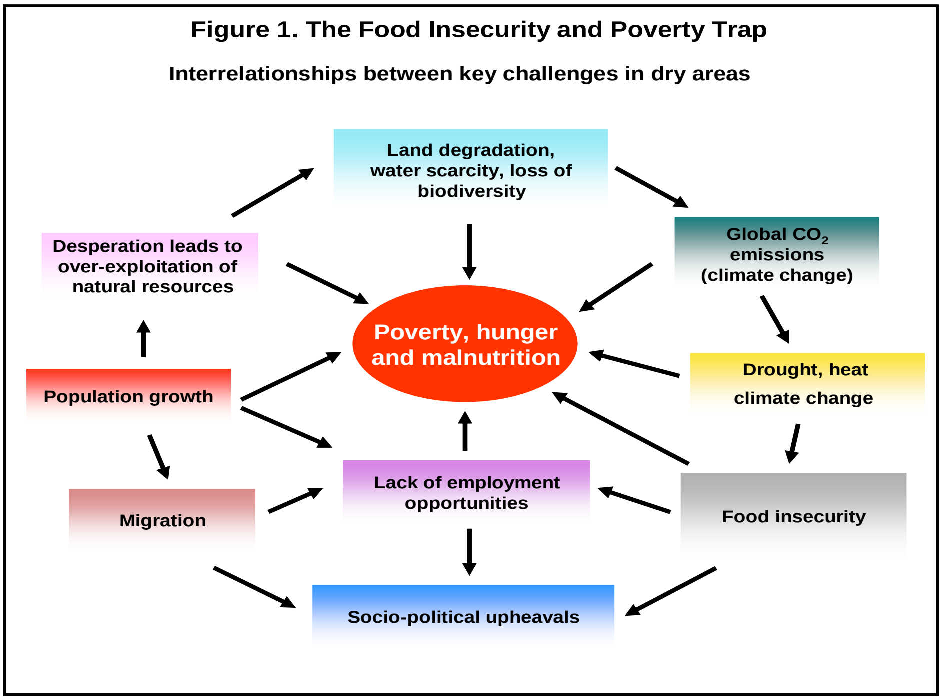

Figure 1. The food insecurity and poverty trap.

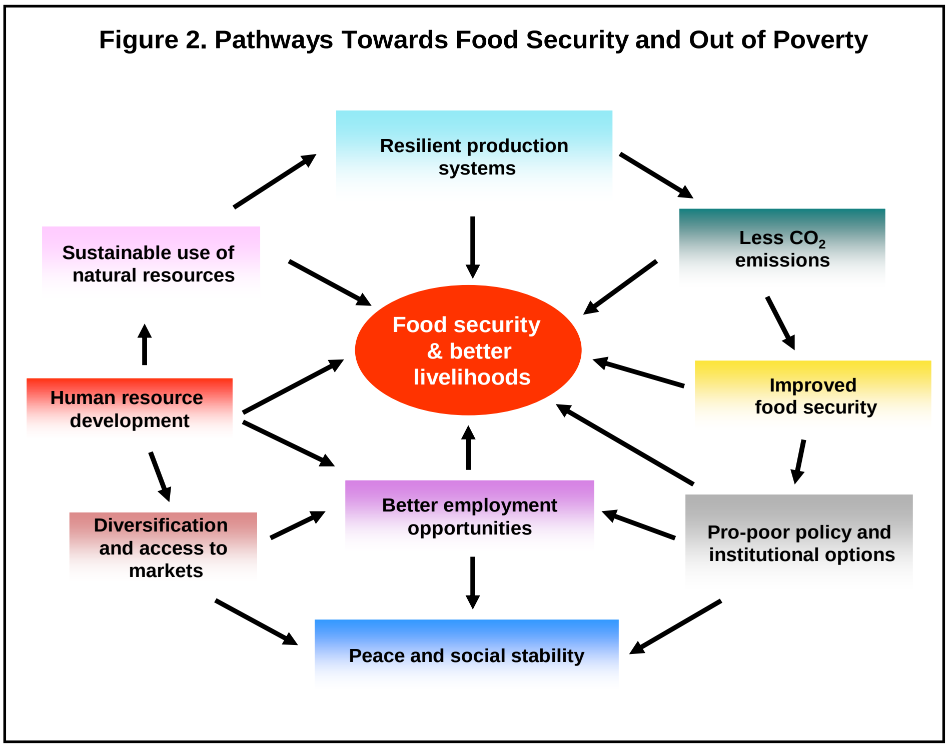

Figure 2. Pathways towards food security and out of poverty.

advantages, such as plentiful sunshine, a long growing season, and warm temperatures.With good investment in research and efficient management of natural resources, dry areas can be highly productive.

The following can make the difference:

- Enabling policy and political will;
- Advances in science and technology (S&T);
- Sustainable intensification of production systems;
- Integrated approaches and better NRM for economic growth;
- Sustainable intensification of production systems;
- Public awareness of the long term benefits of conservation technologies;
- Capacity development and institutional support;
- Partnerships.

Advances in S&T: Several advances in S&T are important to achieve food security. Among these, biotechnological tools will be very important in the future for solving the food crisis but it is important to remember that with increasing complexity of the technology the cost also rises. The dry area countries in the Near East are far behind other regions of the world in terms of developing crops with biotechnology tools. Geographic Information System (GIS) is an important tool that has helped advance our understanding of the world by allowing us to focus on the power of maps and geography. Through national poverty maps, for example, social scientists are better able to focus on areas where poverty exists, which are likely to be first affected by additional problems such as drought and food price increases.

Another tool is the Expert Systems, which are computer programs that simulate the judgment and behavior of human authorities or organizations that have expert knowledge and experience in a particular field. Agricultural Expert Systems are specifically developed for certain crops or commodities or practices to aid extension staff, farmers and scientists apply best available advice that has been collected from the best experts in each field. ICARDA has been co-operating with the Central Laboratory for Agricultural Expert Systems (CLAES) in Egypt in the development of expert systems (see Rafea in this volume). NEPER expert system was jointly developed by CLAES and ICARDA to provide expert advice on wheat and it performs better than many human experts. It suggests integrated schedule for irrigation and fertilizer application using a crop model, and provides advice on seed selection, tillage, seed depth and density, pesticides and other production factors. It diagnoses weeds and provides advice to control them. It covers the diagnosis and treatment of 38 disorders afflicting wheat.

Integration and the pillars for sustainable agricultural development: Improving food security and livelihoods of the resource poor in the dry areas requires an integrated approach based on the three pillars of sustainable agriculture: crop and livestock improvement, natural resource management, and development of policies and institutional capacity. Technology options for crop / livestock improvement and natural resource management are available. But for these technologies to make a positive impact, supportive policies and effective technology transfer are needed, which in turn require stronger institutions. Policy makers must provide incentives to farmers to invest in new technologies. Simultaneously, they must ensure long-term investment in research to maintain a flow of new technologies.

4. ICARDA's research programs

During the past three decades ICARDA's research portfolio has been changing based on emerging priorities and challenges. In ICARDA's new Strategic Plan for 2007-

2016 (ICARDA 2007), the research portfolio is designed to integrate research and training activities carried out at headquarters and in collaboration with national partners. These are complemented by participation in the CGIAR Challenge Programs, System-wide Programs, Eco-regional Programs and Global Initiatives. Essentially, ICARDA's new portfolio is based on a wide range of partnerships and a holistic approach to solving problems. This portfolio is built on four major programs:

- Biodiversity and Integrated Gene Management
- Integrated Water and Land Management
- Diversification and Sustainable Intensification of Production Systems
- Social, Economic and Policy Research

Research outputs from the new portfolio seek to directly contribute to the national programs' agendas, the Millennium Development Goals 1, 7 and 8; and indirectly to other five MDGs as well as to the CGIAR System priorities.

ICARDA's global eco-regional mandate covers the countries with massive dry areas. Of these, 35 are located in the Central Asia, West Asia and North Africa (CWANA) region, which represents more than 80% of the non-tropical dry areas. This is why ICARDA focuses on the CWANA as the platform for most of its research and training activities to address the problems of non-tropical dry areas globally. It reaches other dry areas in the world from this platform.

5. Major achievements

In the past 30 years, ICARDA has made a substantive contribution to agricultural development and improvement in livelihoods of the poor, especially in CWANA region, through its research. Some of these achievements are highlighted below.

5.1. Biodiversity

ICARDA's germplasm collection focuses on landraces and wild relatives of its mandate crops, drawn from diverse eco-geographic origins. Future collections will be based on gap analysis and targeting of valuable traits. The gene bank holdings currently stand at 133,000 accessions (Table 1). Over 40,000 samples are distributed each year to cooperators throughout the world to facilitate their crop improvement efforts.

Table 1. Make up of the germplasm collections in ICARDA's genebank, March 2008

Crop	Accessions
Barley	24,492
Wheat	33,105
Wild cereals	7,266
Forage legumes	28,364
Food legumes	32,342
Wild food legumes	850
Forage and range	5,653
Total	132,072

ICARDA operates within four centers of origin and diversity. Around 70% of the collection originates from CWANA. Some of the world's most important crops were domesticated in the region within which ICARDA operates – thus there is tremendous diversity in CWANA region both in cultivated landraces and wild species.

5.2. Crop improvement

More than 900 improved cereal and legume varieties have been released by national programs in partnership with ICARDA, and adopted by farmers worldwide (Table 2). One example is our wheat research jointly conducted with the Syrian national program. Over 80 improved wheat varieties have been released by the national program of Syria.

Table 2. Improved crop varieties released worldwide in collaboration with national programs using ICARDA germplasm, 1977 to 2008

	Developing countries	**Industrialized countries**	**Last 2 years, all countries**
Cereals			
Barley	175	31	6
Durum wheat	102	14	1
Bread wheat	224	6	9
Legumes			
Chickpea	108	31	9
Faba bean	51	6	1
Lentil	96	16	9
Forage legumes	30	2	2
Peas	9		
Total	**795**	**106**	**37**
	901 varieties released		

These cover about 90% of total wheat area. Production of wheat has increased almost four-fold since the 1970s, from about 1.2 million tones to 4.8 million tones; moving Syria from its importer status in the past to a net exporter of wheat. This increase in production generates gains of over 350 million US dollars per year, and it has also helped in saving about 3.5 million hectares of land for other crops. Such partnerships have led to similar trends elsewhere: Iran and Uzbekistan have achieved self sufficiency in wheat production. Similar developments have occurred in the production of legume crops such as faba bean, which is important in China, the Middle East, Ethiopia, Eritrea and parts of South America. New high-yielding varieties and better production practices have helped Egypt achieve self-sufficiency in faba bean, while in Sudan, Ethiopia and other countries the faba bean output has been greatly increased. One of the biggest achievements has been the development of faba bean cultivars resistant to the parasitic weed Orobanche.

Heat and drought tolerance: Several high-yielding wheat cultivars with tolerance to heat stress have been developed in Sudan. This has made wheat an attractive crop in the areas south of Khartoum where heat stress once prevented its cultivation. Heat tolerance is very important in the context of adaptation to climate change.

ICARDA has developed drought-tolerant lentil varieties, which have been widely adopted by farmers in Jordan, Libya and Syria because they give economic returns even in dry years. Genetic material from the Middle East and Argentina has been used by ICARDA to improve south Asian lines, and a number of new varieties have been released to farmers in Bangladesh, Nepal, India and Pakistan.

The Kabuli chickpea cultivar ‘Gokce’, developed by ICARDA and Turkish national scientists, withstood severe drought in Turkey in 2007 and produced an economic yield when most other crops failed. Gokce is used on about 85% of the chickpea production areas (over 550,000 ha) in Turkey. With a yield advantage of 300 kg/ha over other varieties, and a world price of over USD 1000/t, this represents an additional USD 165 million for Turkish farmers, in 2007 alone.

ICARDA is also working to identify the genes that confer drought tolerance, using DNA-micro-arrays, which permit analysis of genes during different growth stages. For the transcription analysis mRNA is extracted from cells that were grown under different environmental conditions, and labelled with two different fluorescent dyes. The labelled nucleic acids are then hybridised with the micro-arrays and the fluorescence intensity of the individual spots quantified through laser light. Up-and down-regulated genes are identified.

Resistance or tolerance to diseases and insect pests*:* Stem, leaf and yellow rusts are the most devastating wheat diseases.

Working with the national programs of Egypt, Ethiopia, Sudan and Yemen, we mapped the routes followed by these diseases to spread in the region. In the

1980s and 1990s we also identified genes for resistance and developed varieties resistant to leaf and stem rust.
Recently wheat production has been threatened by a new race of stem rust, first identified in Uganda in 1999, and named Ug99, which has the potential to devastate wheat crops globally and pose a real threat to food security. In 2005, small-scale farmers in Kenya lost as much as half of their wheat crop. Subsequently, the disease moved north, crossing several countries and the Red Sea, and has now been reported in Yemen. It could spread further through the Middle East, southern Europe, South Asia and the Americas, because the pathogen spores can be transported by wind, over long distances. To combat this threat, ICARDA and CIMMYT launched the Global Rust Initiative (GRI) in September 2005, in which FAO is now a full partner. The GRI is a consortium involving over 30 countries, for developing and deploying wheat varieties with stable resistance to Ug99 and other races of stem rust.

Major successes have been achieved in protecting wheat against the Sunn pest, using integrated pest management methods with a major biocontrol component. The use of natural enemies decreases the amount of pesticide in the environment and reduces costs of inputs needed to protect the crop.

Nutritional factors: Given that the grasspea (*Lathyrus* spp.) never had the same breeding effort devoted to it as field pea and other grain legumes, more progress is anticipated through breeding. In times of drought and even of water logging, grasspea is the only hope for the poor. However, it contains a neurotoxin (ODAP), which induces paralysis of the legs in humans when they consume this legume as a major part of the diet, a feature common when drought devastates other legumes. In collaboration with national partners, ICARDA has developed new, low-neurotoxin grasspea cultivars safe for human consumption. One such variety was released in Ethiopia last year.

5.3. Grain-for-seed concept to cope with excessive drought

In a good season with no seed shortage, about 75% of the seed required for planting comes from farmers themselves. In a bad season with severe seed shortage because of excessive drought (as a result of climate change), it is possible with advance planning and management to convert seed for grain to seed for planting. This can be used to maintain an adequate supply of certified seed with known varietal purity and performance.

5.4. Water resources

ICARDA's water research focuses on sustainable increase of water productivity both at the farm and basin levels. The Center has launched a new water management project, involving 10 WANA countries. The goal is to promote community participation, efficient use of resources and expertise, and the use of technologies that increase water productivity. The project coves three major agro-ecosystems: the marginal lands or "Badia", rainfed and irrigated systems. This research has helped understand the drivers to increase water productivity at different scales. These can be summarized as follows:

- At the basin level: competition among use sectors (environment, agriculture, domestic), conflicts between countries, and equity issues;
- At the national level: food security, availability of hard currency, and socio-political factors;
- At the farm level: maximizing economic return, and nutrition in subsistence farming;
- At the field level: maximizing biological output.

ICARDA has also been studying and promoting the use of alternative water resources. For example, marginal-quality water and treated wastewater have been found useful for growing cotton, forages and trees. In Uzbekistan, studies have shown that conjunctive or blended use of drainage water with regular irrigation can optimize yield while conserving fresh water. It has also been observed that Water Users' Associations are the best alternative for proper irrigation management at the river basin level.

5.5. Integrated livestock/rangeland/crop production systems

A range of technologies have been developed to integrate crop-livestock-rangeland production systems. These include:

- Barley production
- On-farm feed production
- Feed blocks produced from agro-industrial by products
- Cactus and fodder shrubs
- Flock management
- Natural pasture enhancement and rangeland management.

Water productivity is a key issue in crop-livestock systems. Technologies have been developed to enhance feed water productivity, through feed selection, use of residues, feed water management and multiple use of water. Research covers water harvesting as well as watershed management, and builds on traditional systems such as the *tabia* and *jessour* system of Tunisia. One way of mitigating variable rainfall in rainfed agricultural farming systems is to provide supplemental irrigation during periods of moisture stress. Data from ICARDA show that water use efficiency under supplemental irrigation is twice as high as in fully irrigated or rainfed regimes.

Similarly, research has focused on how best to modify traditional systems to reduce the pressure on rangelands. Options include:

- Barley / livestock systems
- Rangeland/livestock versus confined feeding.

5.6. Conservation agriculture

Conservation agriculture – which maintains the productivity of ecosystems – is an important innovation for the fragile ecosystems of dry areas. Zero tillage, minimum tillage, and raised-bed planting have shown considerable promise in ICARDA's collaborative projects in Kazakhstan. Zero-till direct sowing is in use around the world. It involves minimum soil disturbance, stubble retention and crop rotations (especially with legumes and oilseeds). The benefits include:

- savings in time, fuel, machinery wear
- better soil structure
- soil-water dynamics (OM, porosity)
- improved trafficability – timely sowing
- higher yield potential
- less erosion.

5.7. Diversification and sustainable intensification of production systems

Diversification of agricultural systems and value-added products can greatly contribute to reducing risk and generating income, thus helping particularly small farmers to move from subsistence to sustainable livelihood. For example, indigenous fruits, such as olives, date palm, almonds, figs and pomegranate, are an important source of vitamins, protein and calories, especially for children and women, and especially in famine periods. Fitting targeted fruit trees and vegetable crops in the cropping systems can greatly help in improving livelihoods. Another important example is protected agriculture, which provides multiple benefits: diversifying production and diets, generating income and improving water use efficiency. This has been tested and disseminated in several countries of the Arabian Peninsula, as well as in Afghanistan and Yemen. In Yemen, with the use of protected agriculture, it has been possible to both conserve the mountain terraces and increase farm income by diversifying into vegetable production in plastic houses.

5.8. Socio-economic and policy research

The work in ICARDA's Socio-Economic and Policy Research Program adopts an integrated approach, working closely with all research programs. It also focuses on analysis of poverty, livelihood strategies and gender. Impact assessments are one of the tools used to measure the quality of research interventions and these are combined with studies of markets, policies, institutional needs, etc. A key part of the ICARDA approach is to include natural resource economics, which often means natural resource valuations.

Successes from socio-economics and policy research include:

- New methodology for poverty mapping - combines financial and environmental indicators (as seen above);
- Building impact assessment culture (as we will see below);
- Frameworks and methodologies for assessing adoption and impact of technologies at various scales;
- New approach to analyze on-farm water use efficiency;
- Providing policy options to decision-makers in countries throughout dry areas to ensure sustainable use of natural resources.

Impact assessment: ICARDA has always sought to monitor and quantify the impact of its research at household and farm levels. In 2005 and 2006, ICARDA was ranked highest among all Centers for its commitment to an impact assessment culture. We were third highest in 2007 and highest overall for the three year average.

5.9. Capacity development

National agricultural research systems in developing countries are often limited by a shortage of trained, skilled staff. ICARDA therefore places great emphasis on capacity building. We offer a range of opportunities: support for Masters or PhD degrees, short-term specialized courses, internships, collaborative projects, participation in research conferences etc. Over 600 postgraduate students, interns and research fellows have done theses research at ICARDA. Advanced institutions have co-supervised MSc and PhD students. To date, over 16,200 researchers, students and development workers have benefited from various types of non-degree training programs, in 825 group courses and individual training opportunities. The curricula for training courses are tailored to NARS' requests. The emphasis is on hands-on training that can be put to immediate use. In addition to agricultural science, training programs also cover vital areas such as database management, website administration, and science publishing.

Other examples of capacity building include technical support for upgrading IT infrastructure, developing 'virtual libraries', and improving information access through the use of modern ICT tools.

5.10. Community approach

ICARDA has always used a participatory, community-driven approach. An example of the community approach is typified by the Mashreq/Magreb (M&M) Project on "Developing Sustainable Livelihoods of Agro-pastoral Communities of West Asia and North Africa". This successful project really comprises five separate projects/phases strung back-to-back since 1995 and funded by the International Fund for Agricultural Development (IFAD) and the Arab Fund for Economic and Social Development (AFESD). The M&M project blended science and technology with socioeconomic studies to create a new paradigm of allowing community participation in the way we conduct our research and in developing their action plans for development following a participatory approach. This approach has expanded into participatory plant breeding and many other areas of ICARDA's current work.

6. Conclusions and future trends

Our common goal is to ensure food security in dry areas despite the various challenges – including climate change, declining natural resources, population growth and other factors. It is widely accepted that intensification of production systems will have to be the primary means of increasing agricultural production. To achieve this objective, two areas are important:

1) Sustainable intensification through expansion of conservation technologies: good agricultural practices, sustainable water use and management, integrated production systems and diversification, integrated pest management, integrated plant nutrient system, no till / conservation agriculture, urban and peri-urban agriculture, organic agriculture.

2) Increasing productivity of marginal lands through the development of integrated livestock/ rangeland/crop production systems.

Policy makers in dryland developing countries must consider several key factors:

- Food and feed insecurity are vital issues. Many poor countries have economies based on agriculture, yet many of these countries are net food importers.
- Rural poverty is widespread; the majority of poor are in rural areas. Widening income inequality and rising food prices are matters of great concern.
- Natural resources are scarce, with significant degradation.
- Climate change is occurring and is having implications for agriculture – more drought and temperature extremes.
- The share of public spending allocated to agriculture is declining. This will have severe and long-term consequences.
- Public awareness of the long term benefits of conservation technologies are important and incentives should be provided to farming communities to demonstrate and realize these benefits for sustainable food security.

Reference

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8. New challenges for science and technology in dryland development - bridging dryland science and on-the-ground practice

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Abstract

What are the roles of science and technology in dryland development, and how can we enhance the practical functionality of science and technology to develop drylands? Dryland science and technology can be defined as "science and technology that contribute to maintaining and improving the sustainability of the nature-society system in drylands". The major roles of dryland science and technology should be to support rational decision-making based on scientifically accumulated knowledge and use newly developed technologies to solve problems in drylands. We suggest the following three important future tasks: (1) Establish global networks for dryland studies to share common perspectives in prioritized topics of dryland studies, identify research equipment and facilities in the world, and enhance outreach efforts for conveying research results to policymakers and the general public; (2) Enhance the linkages between dryland science and on-the-ground practice. In this context good relationships between academic society and international cooperation organizations (e.g., JICA, the Japan International Cooperation Agency) is necessary to make the best use of new knowledge and technology; (3) Develop human resources. For this purpose, it is important to make use of international academic networks such as the Global Network of Drylands Research Institutes and the 'Central and West Asia and North Africa Plus Partnership' (CWANA) Plus) to develop young scientists and others who can who can work effectively to combat desertification while enhancing their careers in dryland scince –related international organizations and foreign institutions.

1. Introduction

The Ninth International Dryland Development Conference provides unique platform for exchange of views on dryland issues because of its interdisciplinary nature, international participation and a long history of its parent organization - the International Dryland Development Commission. Thus, the Conference provides excellent opportunity to discuss the modality and way of furthering of the dryland science. The Arid Land Research Center of the Tottori University published in 2007 a book titled "Dryland Science in the 21st Century: Sustainability of Nature and Society". Basing on the coverage in that book, I would like to discuss here about the status of dryland science and modality of enhancing it by answer such questions as: How do we define dryland science? What is the role of science and technology in dryland development? How can we enhance the role of science and technology to make it useful for dryland development?

2. Relationship between science and society

I would like to start by pointing out an important change that has currently been occurring regarding the role of science in society. There is an increasing shift from 'science for the sake of science' to 'science in the service of the society'. This change

can be attributed to the growing concern about the future of humanity on Earth.
In July 1999, the World Conference on Science, organized by UNESCO and ICSU in Budapest, marked a turning point for the academia when the mission of science was reexamined by scientists themselves. The Conference adopted a ‘Declaration on Science and the Use of Scientific Knowledge’ and the ‘Science Agenda Framework’ as a new commitment of science for the twenty-first century. It was motivated by the growing concern about the environment in the future, and it emphasized that “The sciences should be at the service of humanity as a whole, and should contribute to providing everyone with a deeper understanding of nature and society, a better quality of life and a sustainable and healthy environment for present and future generations” (World Conference on Science 1999).

The participants of the Conference agreed that science in the twentieth century had been developed based on the concept of ‘science for knowledge’ and although its achievements provided various benefits to the society, they were accompanied by several negative effects as well, such as the environmental degradation and problems associated with it. The academic community recognized the urgent need for a change in the way science was deployed if the crisis had to be avoided. It was resolved that the science and technology in the twenty-first century would have to contribute to solving those negative issues, otherwise it would lose trust and support of the society. The Declaration proclaimed new concepts of ‘Science for Peace’, ‘Science for Development’, and ‘Science in Society and Science for Society’ adding to ‘Science for Knowledge, Knowledge for Progress.’ The concept ‘Science in Society and Science for Society’ merits particular attention.

In the subsequent ‘Conference of the World’s Scientific Academies’, held in 2000 in Tokyo, the scientific and technological community was requested to promote the use of existing knowledge more widely and effectively, to generate new knowledge and beneficial technologies, and to work with governments, international organizations and the private sector to promote a worldwide transition to sustainability (World’s Scientific Academies 2000). And this has led to the emergence of the ‘Sustainability Science.’

3. Sustainability science

In parallel with the increasing recognition of the importance of sustainable existence of human beings and nature through sustainable development, there started an associated movement on the part of scientists. A ‘Synthesis Workshop on Science and Technology for Sustainable Development’ was held at Mexico, just before the 2002 World Summit on Sustainable Development (WSSD) at Johannesburg. The Workshop, held on May 20-23, 2002, was organized by the ‘Initiative on Science and Technology for Sustainability’, the Third World Academy of Sciences (TWAS), and the International Council for Science (ICSU) to prepare documents for WSSD events.

In the WSSD itself, a side event on ‘Science and Technology for Sustainable Development’ was organized by TWAS, ICSU and other partners. The document tabled at the event (ICSU 2002) declared that, “Enhancing the S & T Community’s capacity to contribute to sustainable development will require significant changes to the current scientific and technological agendas. The S&T Community is committed to implement the necessary changes through the development of appropriate partnership. These changes include: more policy relevant science; broad-based, participatory approaches; long-term perspectives; new and traditional technologies and capacity building in science and technology.”

In this context, academies started to recognize the need for science to contribute to sustainability. Kates et al. (2001) stated, "A new field of sustainability science is emerging that seeks to understand the fundamental character of interactions between nature and society and to encourage those interactions along more sustainable trajectories. Such an integrated, place-based science will require new research strategies and institutional innovations to enable them especially in developing countries still separated by deepening divides from mainstream science. Sustainability science needs to be widely discussed in the scientific community, reconnected to the political agenda for sustainable development, and become a major focus for research."

The National Academy of Sciences of the United States of America published on July 8, 2003 its Proceedings under the title 'Science and Technology for Sustainable Development Special Feature' providing an overview of future targets and challenging subjects toward sustainable development, focusing on several case studies. In that issue, Clark and Dickson (2003) wrote, "In seeking to help meet this sustainability challenge, the multiple movements to harness science and technology for sustainability focus on the dynamic interactions between nature and society, with equal attention to how social change shapes the environment and how environmental change shapes society. These movements seek to address the essential complexity of those interactions, recognizing that understanding the individual components of nature-society systems provides insufficient understanding about the behavior of the systems themselves. They are problem-driven, with the goal of creating and applying knowledge in support of decision making for "sustainable development."

4. Dryland science and sustainability science

According to Millennium Ecosystem Assessment (2005), drylands cover about 41% of Earth's land surface and are inhabited by more than 2 billion people. People living in drylands face many challenges. They tend to have the lowest levels of human well-being, including the lowest per capita GDP and the highest infant mortality rates. In addition, drylands experience highly variable environmental conditions, particularly frequent drought events. Approximately 10–20% of the world's drylands are degraded. Thus, it is important to contribute to solve these dryland problems using the capacity of science and technology.

It is pertinent to ask: What roles can science and technology play in dryland development? How can we enhance the function of science and technology to facilitate dryland development? Here, I suggest that dryland science and technology should be defined as the science and technology that contribute to maintaining and improving the sustainability of the nature–society system in drylands (Tsunekawa 2007). The major role of dryland science and technology should be to support rational decision-making based on scientifically accumulated knowledge and to provide alternative solutions based on newly developed technologies that solve dryland problems.

Considering the development of sustainability science in the academic community, the dryland science has to adopt new paradigm. Firstly, it is necessary for the dryland scientists to enhance the linkage and cooperation with the society, because they are required to contribute to the welfare of the society and the mankind. At the same time, the dryland scientists have to make their best efforts to gain trust of the society. Secondly, the society would expect the dryland science to contribute towards sustainable development. Therefore, the dryland science should consider maintaining and improving sustainability of the nature-society system as its main objective, and organize its research agenda based on this recognition. At the same time, it is necessary to examine new issues such as: How can the research achievements obtained by the dryland scientists be disseminated to other stakeholders in the society including policy makers, enterprises, NGOs and citizens? How can the dryland scientists cooperate with the people working at the grass root level for sustainable development? Thirdly, the major role of dryland science and technology can be to support rational decision-making based on scientifically accumulated knowledge and to provide alternative solutions, based on newly developed technologies, to the problems that pose challenge to drylands. The dryland science has to include, on one hand, fundamental research to clarify the mechanisms and processes occurring in nature and society in the dryland areas, and on the other the applied research to contribute directly towards conservation and improvement of sustainability of the nature-society system in dryland.

Assuming the contemporary position of dryland science as described above, I would like to suggest the framework for new paradigm of dryland science as follows:

- Firstly, the recent review on sustainability science suggests that we understand dryland as the nature-society system, which consists of a society-based subsystem and a nature-based subsystem, and capture a comprehensive vision by giving greater importance to the dynamic interaction between them (Fig. 1).
- Secondly, the dryland science should have both basic and applied science agenda. Basic dryland science should aim at understanding the mechanism of human and nature interaction in the drylands to clarify the processes behind it. The applied dryland studies should aim at improving the sustainability of human and nature in the drylands.
- Thirdly, some concepts used in sustainability science like adaptation and mitigation, sensitivity and vulnerability, and collapse and resilience are useful to understand processes in dryland. Applied dryland studies are involved in undertaking the diagnosis of the sustainability in the target area, to present appropriate measures based on the result of diagnosis and to develop new measures and technologies to give solutions to the problems in the area. Taking medical science as metaphor, dryland science may be divided into two major components, 'diagnosis' and 'curative measures'. 'Diagnosis' will clarify the present status and problems of target area, and help in developing the appropriate 'curative measures' ('prescriptions').The diagnosis should cover ecosystem health, poverty and human health. For developing the 'curative measures like prescription or surgery', it is of particular importance in the dry areas to make use of the traditional knowledge. As most of the drylands are located in the developing countries, with low income base, it is often difficult to introduce expensive modern technologies. It has also been observed that modern technology proved effective in the short-term, but failed to provide benefit in the long run. Accordingly, the traditional knowledge, accumulated over a long period of time, is thought reliable especially in the dryland areas.

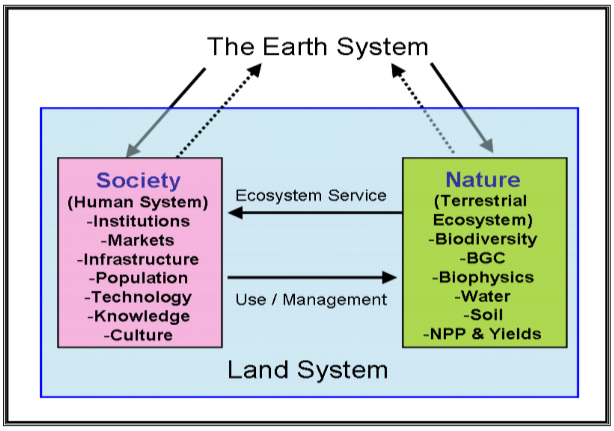

Figure 1. Interactive nature-society system in land system. (**Source: modified from Global Land Project, Science Plan 2004).**

5. Future tasks

For making dryland science effective in meeting the challenges of sustainability of human and nature, there is a need to take several important measures. Firstly, it is important to establish global networks for dryland studies to share common perspectives in prioritized topics of dryland studies, identify sites having the needed research equipment and facilities in the world, and enhance outreach for conveying research results to policy makers and the general public. Secondly, it is important to enhance the linkage between dryland science and on-the-ground practice. In this context, it is essential to have good linkage between academic society and the international cooperation organizations, such as Japan International Cooperation Agency (JICA) in the case of Japan, in order to ensure that the new knowledge and technology developed by research institutions is made use of for the benefit of the society by the cooperation agencies. Thirdly, there is a need for strong human resource development program to meet the research and development needs of the dryland areas. For this purpose, it is important to make use of international academic networks such as GNDRI (Global Network of Drylands Research Institutes) and 'CWANA Plus Network' to develop a new generation of individuals who can effectively work and enhance their career in international organizations and research institutions involved in dryland science and in combating desertification.

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9. African land degradation in a world of global atmospheric change

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Abstract

Changes in atmospheric chemistry appear to mask land degradation in sub-Saharan Africa (SSA). We analyzed the vegetation observed from space as well as climate data from 1982 – 2002. A significant improvement in biomass was seen on 30% of SSA and a decline on about 5%. Global changes in atmospheric chemistry are likely responsible for increases in vegetation productivity and this masks anthropogenic land degradation processes such as land conversion, over grazing and soil degradation. A re-analysis of the vegetation productivity dynamics, taking into account atmospheric fertilization, suggests that 7 times more than the area of actual productivity decline is affected by land degradation processes that are masked by atmospheric fertilization. With this rate of surreptitious loss of vital land attributes and with the current rate of population growth (3%), the SSA subcontinent may soon lack the land resources necessary for economic development.

1. Introduction

Land is central to development in sub-Saharan Africa (SSA) as the livelihoods of about 60% of the population are dependent on agriculture (Moyo 2000). With population pressures increasing and the low investments in land conservation, the future health of the land is in question (Vlek 2005). Degradation of this terrestrial ecosystem (Millennium Ecosystem Assessment 2005) sets in when the ecosystem services, notably the primary production services, are persistently reduced or lost (Safriel 2007; Katyal and Vlek 2000; Reynolds et al. 2002). Assessing land degradation based on this definition in its spatial and temporal extent continues to pose a challenge. Climate change or other natural events may lead to land degradation, but the phenomenon is mainly due to the interaction of the land with its users. Separating human-induced land degradation from that caused by natural processes adds complexity to the assessment but is important for developing mitigation strategies.

A better understanding of the extent and nature of human-induced land degradation remains imperative, but quantitative data on land degradation as defined above for SSA is scarce (Vlek et al. 2008). Early land degradation assessments have focused on the soil aspect of land degradation (Safriel 2007), e.g. the Global Assessment of Soil Degradation – GLASOD- project (Oldeman et al. 1990). These studies used an expert-based approach that offered a snapshot of the situation in the late 1980's but failed to capture the dynamics of the process. The study is now rather outdated. More recently a number of land degradation assessments using remote sensing technologies have been published. These studies tried to infer land degradation from the long-term relationship between vegetative productivity and weather dynamics. Most of these dealt with the dynamics of desertification processes in arid and semi-arid areas (Prince

2004; Herrmann et al. 2005; Wessels et al. 2004; Wessels et al. 2007), but most recently an analysis was done of all of SSA (Vlek et al. 2008).

2. Remote-sensing based land degradation assessment

A wide variety of remote sensing products are now available, some of them dating back more than 20 years, providing a long enough track record to capture the dynamic aspects of the land degradation process in terms of primary productivity. Combined with global data on climate, topography, soil, land use and human demographics, the remote sensing data allows for further analysis of the underlying causes and processes (Vlek et al. 2008). This study makes use of remote sensing databases that are sufficiently long-term and with frequent enough data sampling to provide longitudinal datasets to identify areas where land degradation is occurring and remedial measures are needed or where land is relatively stable or even improving.

Land degradation expresses itself as reduced biological activity (Millennium Ecosystem Assessment 2005; Safriel 2007; Reynolds and Smith 2002) reflected in above ground net primary production (NPP). The most common remote-sensing derived indicator associated with vegetation productivity is the Normalized Difference Vegetation Index (NDVI), best described as a relative measure of vegetation vigour and photosynthetic activity. NDVI is strongly correlated with NPP and is often used to estimate NPP at large spatial scales and as a tool for monitoring temporal changes in vegetation (Field et al. 1995; Prince and Goward 1995). We performed a spatial regression analysis between mean annual NPP and NDVI (1982 – 2000) across different biomes of SSA and found a strong linear relationship between the two parameters ($R^2 = 0.816$, $p < 0.001$). This study firstly utilized monthly composite NDVI data (1982-2003) to assess the spatial and temporal patterns of land productivity. The long-term persistent decline in NPP (as indicated by NDVI) reflects land degradation. Subsequently, in a step-wise approach we correlated the long-term decline in NPP to rainfall, land cover and land use and population density to identify areas of human-induced land degradation in SSA and assess their true extent.

To analyze long-term trends in green biomass changes over the SSA subcontinent, we processed a time-series NDVI product spanning from 1982 to 2003 from the Global Inventory Modeling and Mapping Studies (GIMMS), published by the Global Land Cover Facility (GLCF) (Tucker et al. 2005). The NPP trend for every pixel (8×8 km^2) was measured by a linear slope of NDVI over time. A pixel's NPP trend (improving or declining vegetation productivity) was considered meaningful if the NDVI slope coefficient was statistically significant ($p < 0.1$) and the NDVI net change was at least 10% of the initial status (1982) over the 22 years.

Above-ground NPP has been shown to increase with increasing annual precipitation (Huxman et al. 2004), and indeed the relationship between rainfall and NDVI is often used to differentiate between human-induced and climate-induced land degradation where any NDVI trends not explained by rainfall dynamics are ascribed to human actions (Herrmann et al. 2005). To distinguish human-induced biomass trends from climate-driven vegetation dynamics, we excluded those pixels that exhibited a strong biomass response to inter-annual rainfall variation. We extracted annual rainfall data for the period 1982-2002 from the Climatic Research Unit (CRU) dataset (Mitchell and Jones 2005). For every pixel, we calculated the Pearson's correlation coefficient between annual NDVI and rainfall over the period 1981 - 2002 and used the coefficient to determine areas of different NPP-rainfall relationships. The vegetation dynamics of a pixel was considered rainfall dependent if the correlation between NDVI and rainfall was statistically significant and its absolute value was more than 0.45. NPP changes for pixels in accordance with rainfall (positive correlation) were considered due to climate change or variation. Pixels with NPP not affected by rainfall (no or negative correlation) were interpreted as areas where green biomass (NDVI) changes had to be explained by other drivers, and was possibly human-induced.

The sensitivity of NPP to human interference or rainfall variation is substantially different across biomes (Huxman et al. 2004). To account for this effect, we stratified SSA into four precipitation zones: *Arid* (MAP < 500 mm.year^{-1}), *Semi-arid* (500 mm.year^{-1} ≤ MAP ≤ 800 mm.year^{-1}), *Sub-humid* (800 mm.year^{-1} ≤ MAP ≤ 1300 mm.year^{-1}) and *Humid* (MAP > 1300 mm.year^{-1}) using mean annual precipitation (MAP) for the period 1981 – 2002.
The NPP trend analysis shows that some of the most significant changes in NPP were found for areas of low primary productivity. These areas lie in the dryer parts of SSA where NPP are very small to begin with. Small changes in absolute NPP values constitute large changes in relative terms in these dry biomes. To take a closer look at these regions, we expressed overall change in NPP for the 22-year period as a percentage of what it was at the onset (1982). The areas that experienced a significant NPP change ($p < 0.1$), exceeding 10, 15, 20 or 25% of the baseline value in 1982 are summarized in Table 1. The areas of significant NPP decline are only a fraction of the area improving in NPP. Before offering an analysis of the decline in NPP, an interpretation of the widespread improvement is offered.

3. Improvements in NPP and atmospheric fertilization

The extent of declining, improving or stable NPP within each rainfall zone was calculated. The geographic distribution of the areas with long-term biomass improvement is shown in (Fig. 1) A large proportion of the improving areas are found in the arid zone such as the Sahel and Horn of Africa regions as well as parts of Botswana, designated in blue. These are areas that are responsive to improved inter-annual rainfall and are largely confined to zones with less than 500 mm annual precipitation. This phenomenon has recently

Table 1. Areas that experienced a significant change[(a)] in NDVI between 1982 and 2003 in excess of 10, 15, 20 and 25% of the NDVI value in 1982[(b)]. The total land surface of SSA is 21.4

Declining biomass	***Area (km^2)***	***% of SSA***	***Improving biomass***	***Area (km^2)***	***% of SSA***
dNDVI < - 10%	1,112,510	5.20	*dNDVI* > 10%	6,505,916	30.42
dNDVI < - 15%	542,334	2.54	*dNDVI* > 15%	4,382,136	20.49
dNDVI < - 20%	212,355	0.99	*dNDVI* > 20%	2,787,707	13.04
dNDVI < - 25%	80,005	0.37	*dNDVI* > 25%	1,781,628	8.33

a) The NDVI slope (*A*) is significant at $p < 0.1$
(b) The magnitude of the relative change in NDVI over 22 years (*dNDVI*) in which NDVI in 1982 is the baseline: $dNDVI = A \times 21 \times 100 / NDVI_{1982}$ where *A* is the linear slope of inter-annual NDVI for the period 1982-2003.

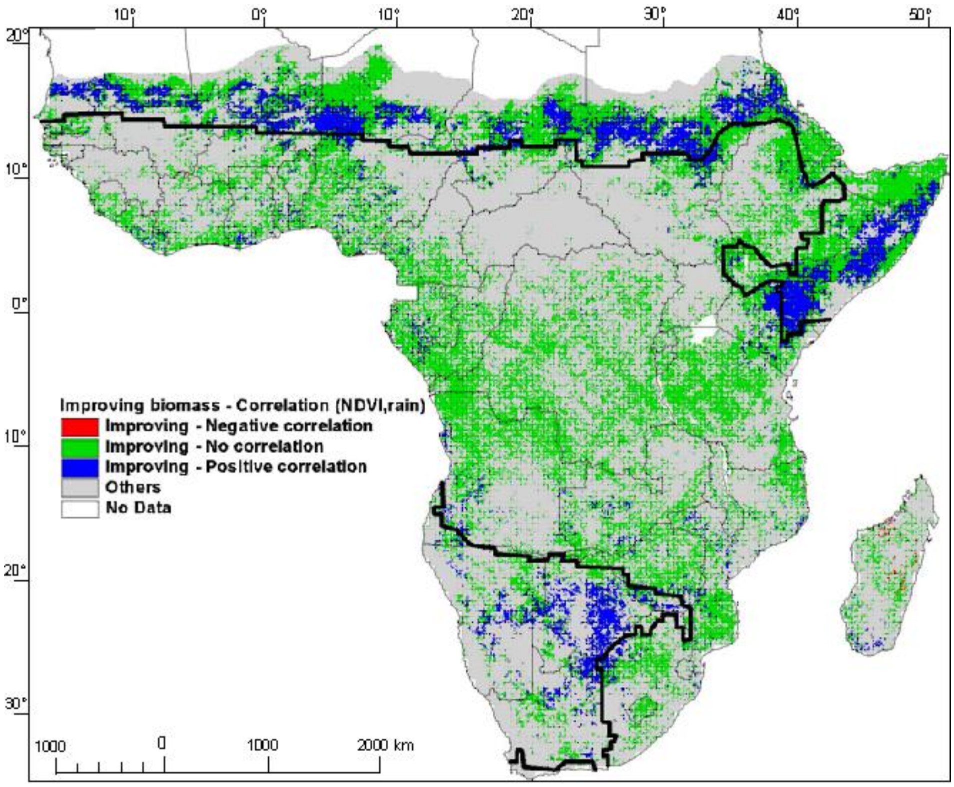

Figure 1. Geographic extent of areas with improving NPP and different vegetation-rainfall relationships for the period 1982 – 2002. The bold black lines are the 500 mm.year^{-1} isohyets averaged for the same period.

been reported in the literature as the "greening of the Sahel" (Olsson 1993; Prince et al. 1998; Tucker and Nicholson 1999; Eklundh and Olsson 2003; Olsson et al. 2005) and reflects the gradual recovery from the early eighties' drought.

The improvement in NDVI in the remaining areas (mostly green) in (Fig. 1) cannot be attributed to rainfall trends as no such correlation could be established for this region. The greening of these areas, representing 23.5% of the SSA land mass, may plausibly be related to the change in atmospheric composition, both in terms of CO_2 (Grace et al. 1995; Phillips et al. 2004, Lewis et al. 2004; Körner 2000; Long et al. 2004; Nowak et al. 2004; Norby et al. 2005; Ainsworth and Long 2005; Long et al. 2006; Boisvenue and Running 2006) and NO_x (Phillips et al. 2004; Lewis et al. 2004; 26 Laurance et al. 2004), (Boisvenue and Running 2006; Reay et al. 2008; LeBauer and Treseder 2008). An overall positive response of vegetation productivity to rising levels of atmospheric CO_2 due to a stimulation of photosynthesis has been established elsewhere (Grace et al. 1995; Nowak et al. 2004; Norby et al. 2005; Boisvenue and Running 2006). Elevated atmospheric CO_2 has also been shown to improve active-tissue quality in plants, yielding smaller C/N ratios (Körner 2000]. An additional explanation may be the increasing NO_x load of the atmosphere over SSA causing an increase in reactive nitrogen (N) deposition (Dentener 2006; Galloway *et al*. 2004; Reay et al. 2008; LeBauer and Treseder 2008). Recent experiments indicate that an increase in N deposition enhances carbon sequestration (LeBauer and Treseder 2008; Adam et al. 2005; Hagedorn et al. 2005). Ecosystem-level observations across Western Europe and North America demonstrated a high positive correlation (R^2 = 0.97) between average carbon sequestration and wet N deposition (Magnani et al. 2007). A recent study showed that most terrestrial ecosystems are N limited with an average response of NPP to supplied N of 29% and the strongest N control of NPP is found in tropical forests (LeBauer and Treseder 2008). Atmospheric fertilization at a rate of 0.63 ± 0.31 Mg ha^{-1} yr^{-1} over the past 4 decades was recently also reported for closed-canopy tropical forest sites in Africa (Lewis et al. 2009). Thus, the observed improvement in NPP in SSA is likely due to atmospheric fertilization.

4. Actual NPP decline

The actual area with sustained decline in NPP of at least 10% over the observation period of 22 years amounts to 1.11 million km^2 (Table 1). Of this area, 93% is not affected by inter-annual shifts in rainfall and is likely to reflect the human impact on vegetation. In addition, some 5% of the 1.11 million km^2 shows a negative correlation with rainfall and a declining NPP. These areas are of particular concern. The remaining 2% are areas with decreasing NPP but with a significant positive vegetation-rainfall correlation where any human-induced degradation processes may not be discernable. Similarly, in regions that are greening due to improved rainfall, some land attributes such as the soils may be degrading without this being reflected in NPP. As it stands, the step-wise analysis suggests that some 5% of the SSA land surface (1.09 million km^2) is experiencing a human-induced decline in NPP affecting at least 29 million people (Fig. 3a). A more detailed analysis of such findings in which the areas in decline are related to land quality, land use and human pressure on the land provides further insights that will help guide policy makers in mitigation and conservation matters (Vlek et al. 2008).

5. The benefits of atmospheric fertilization

We estimated the spatial extent of declining NPP for the hypothetical case that the atmospheric composition had remained stable. The actual change in vegetation productivity ($dNDVI_{act}/dt$ = slope coefficient-A) can be considered the net balance between the partial changes caused by human activities ($dNDVI_{human}/dt$) and those caused by natural processes ($dNDVI_{natural}/dt$) as shown below:

$$dNDVI_{act}/dt = dNDVI_{human}/dt + dNDVI_{natural}/dt$$

Positive values for $dNDVI_{natural}/dt$ can be due to environmental change such as improved rainfall or atmospheric fertilization and positive values for $dNDVI_{human}/dt$ can be related to aforestation, exclusion zones or soil remediation. Having excluded the areas with rainfall–related increases in NDVI, we sought to quantify the effect of atmospheric fertilization on the dynamics of vegetation productivity over time. To eliminate the compensatory effect of atmospheric fertilization we calculated the component of declining NPP trends that have been masked by this fertilization effect for each rainfall zone. To avoid confounding with human activity or shifts in weather, only 57983 pixels in pristine regions with no human disturbance and lacking significant NDVI-rainfall correlation were considered (Fig. 2). The rate of NPP improvement for these areas as expressed in the average NDVI-slope ($dNDVI_{act}/dt = A$) was ascribed to atmospheric fertilization.
The baseline slope values of biomass accrual in those pristine lands for each climate zone were subsequently used as a new baseline to re-calculate the trend of NDVI over the 22-years period. The baseline slope values of biomass accrual were 0.0012, 0.0025, 0.0028 and 0.0036 for the arid, semi-arid, sub-humid and humid zones, respectively. We then re-calculated the time-series of NDVI decline against these new baselines and delineated the areas that would have experienced significant and sustained loss in NPP had the atmospheric chemistry not changed. The spatial extent is shown in (Fig. 3b) and covers around 41%

of SSA instead of the 5% actually showing a human-induced decline in NPP. The actual extent of the degrading territory would diminish under both scenarios if the criteria for degradation were tightened; e.g. to require more than 10% decline over the 22-year period (Table 1). Either way, the chemical pollution of the atmosphere has obviously had a beneficial effect in sustaining NPP over wide areas of SSA that would otherwise have experienced a significant decline. The down-side of this phenomenon is that atmospheric fertilization is compensating for the degradation of land attributes that would otherwise have caused a decline in NPP such as soil degradation or deforestation that thus go undetected. The distribution of the degrading areas among the different types of land covers are summarized in Table 2 for each scenario. The areas where degradation processes are masked by atmospheric fertilization cover around 2 million km^2 in the mosaic woodland/shrubland, 1.4 million km^2 in the grasslands, 1.2 million km^2 for agricultural areas and 0.9 million km^2 for dense forest. The population affected by underlying land degradation processes increased from 29 million people to 276 million when atmospheric fertilization was taken into account. With the surreptitious loss of vital land attributes at this rate and with the current rate of population growth (3%), the SSA subcontinent may soon lack the land resources necessary for economic development.

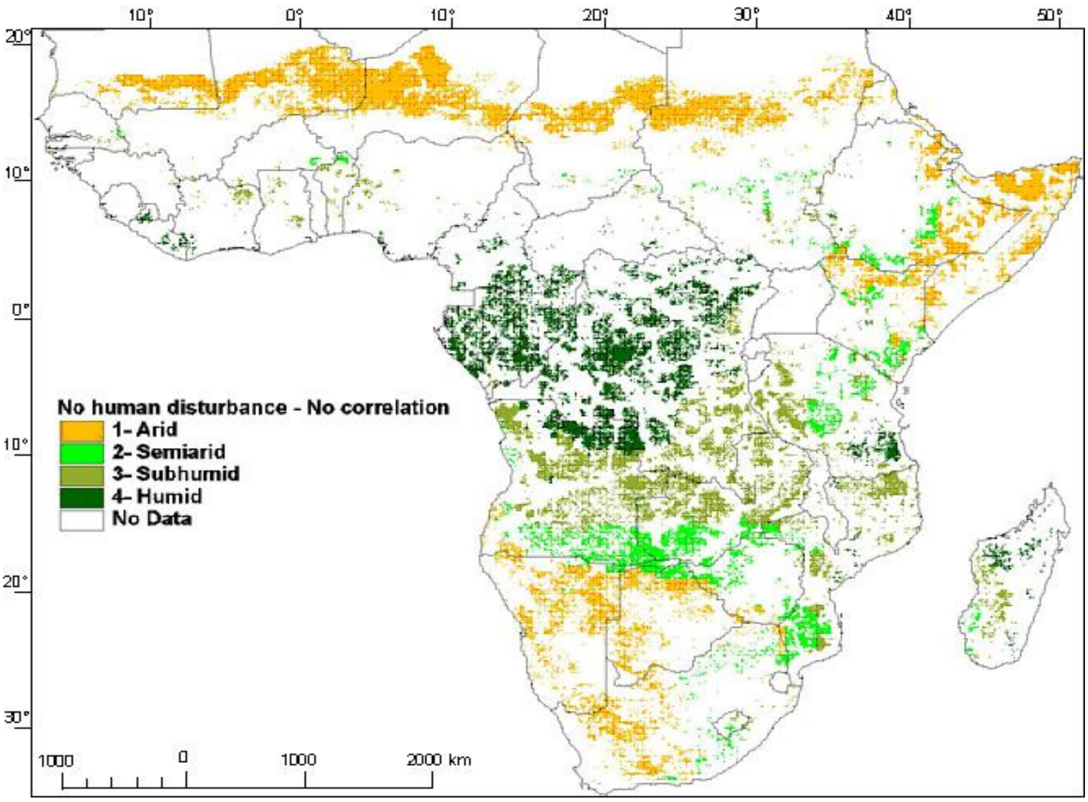

Figure 2. Areas across different precipitation zones free of human disturbance, and with no significant correlation between annual NDVI and rainfall during the period 1982-2002. Improvement in productivity in these pixels, if any, is likely due to atmospheric fertilization.

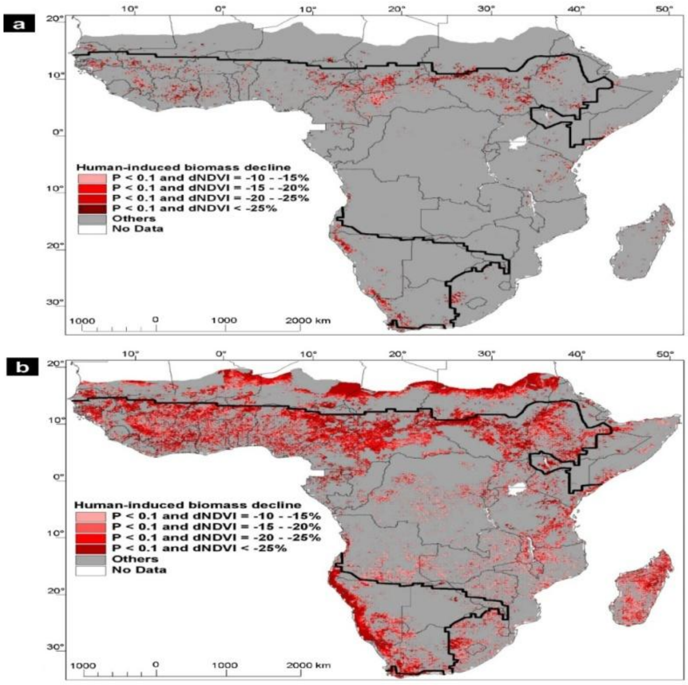

Figure 3. (a) Geographic extent of actual human-induced degradation in green biomass from 1982 to 2002. (b) Geographic extent of human-induced NPP decline in the same period after correction for atmospheric fertilization. The bold black lines are the 500 mm.year^{-1} isohyets averaged for the same period.

Table 2. Extent of land degradation in various rainfall zones of SSA estimated with and without accounting for atmospheric fertilization. Numbers within the parentheses are the area percentages compared to the SSA's land surface.

Land use/cover	Areas of human-induced degradation (km^2)		
	With atmospheric fertilization (WITH)	Without atmospheric fertilization (WITHOUT)	Degradation masked by atmospheric fertilization (i.e. WITHOUT - WITH)
Dense forest	71,172 (0.3)	1,006,333 (4.7)	935,161 (4.4)
Forest/savanna	54,462 (0.3)	430,470 (2.0)	376,008 (1.8)
Forest/crop	57,281 (0.3)	379,008 (1.8)	321,727 (1.5)
Woodland/shrubland	513,028 (2.4)	2,526,081 (11.8)	2,013,053 (9.4)
Grassland	154,239 (0.7)	1,534,982 (7.2)	1,380,743 (6.5)
Agriculture	173,502 (0.8)	1,373,761 (6.4)	1,200,260 (5.6)
Others	61,698 (0.3)	1,581,373 (7.4)	1,519,675 (7.1)
Total	***1,085,382 (5.1)***	***8,832,008 (41.3)***	***7,746,626 (36.2)***

6. Future prospects

This assessment can only be seen as a first approximation, and the maps and assessments made here need verification in the field. The analysis, in essence, is as good as the underlying databases. However, as better data becomes available the analytical framework proposed here allows for easy substitution of this information and rapid generation of a new assessment. As it stands, the following conclusions can be drawn:

(1) In the absence of any instruments for monitoring the rate of land degradation on the ground in SSA, satellite-based systems offer the best hope for tracking the state of this vital natural resource on this vast continent. A systematic research effort should be made to verify the validity of the findings reported here and to refine the analytical tool and interpretation of the results.

(2) The current mapping exercise can be used to identify application domains, areas with common climatic, vegetation, physiographic and soil and land use characteristics that appear to be threatened by human-induced land degradation. Sustainable land management options can then be targeted for these regions that will maximize social benefits from the use of the land.

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10. A few thoughts on dryland development and combating desertification

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Abstract

The paper presents a few considerations on sustainability and global change, before focusing more specifically on desertification and dryland development in the context of global change. It highlights global issues and challenges concerning the future of agriculture, through three entry points – multifunctionality of agriculture, dependence of agriculture on environment, and the role of agriculture in tackling hunger and poverty - keeping drylands and desertification as central focus.I

Introduction

There are three major points that concern the future of global agriculture. The first is the multifunctionality of agriculture. The second relates to the fact that agriculture is closely linked to the environment in its broadest sense. The third relates to the fact that removal of hunger and poverty is a global concern and collective responsibility and agriculture has a major role to play in achieving this.

There has been in the recent times a renewed emergence of agricultural priorities on the international agenda, associated with the recognized multifunctionality of agriculture for food and fiber production, for sustainable management of all services generated by ecosystems, for economic, social and cultural development, for income, nutrition, quality of life, etc. This emergence of renewed priority preceded the recent food crisis, and was substantially bolstered by it. The negative externalities of agriculture have also been recognized, especially by IAASTD, whether it is environmental degradation, or detrimental effects on human health or issues of poverty and social exclusion. The agricultural multifunctionality concept has been debated for long and has finally been recognized as relevant. The working definition proposed by OECD associates multifunctionality with the existence of multiple commodity and non-commodity outputs that are jointly produced by agriculture, some of the non-commodity outputs being externalities or public goods, mostly out of markets. This concept is obviously of interest for drylands and desertification.

The second important issue is that the future of agriculture is linked with external factors that make up its environment. This especially concerns global changes in general and climate change that seems to be accelerating; also the economic shocks (sharp rises/drops in agricultural product prices, financial crises, which are likely preludes to a global economic meltdown); population changes (population growth, demographic transition, urban/rural population ratio); social and cultural changes (especially changes in food habits); present and future energy crises; ecosystem transformation and losses; pollution, etc. These factors have many impacts in terms of public policies, two of which are mentioned here. The first is the need to gain further insight into global changes so as to be able to foresee them – hence the importance of public awareness on ecosystem evolution and the importance of prospective studies, which are being increasing conducted in the world. The second is the need to reduce the rate of these global changes and their impacts, and especially to adapt to them – this is a major role of agriculture overall, allthough agriculture cannot be the only driver.

The third point, which is more classical, is our collective obligation to feed the planet and eliminate poverty. This has continued to be crucial, but the food crisis has renewed our approach, boosting public awareness on the fact that poor urban and rural consumers have both been hit, and also that agriculture in rich and emerging countries has mainly profited from the rising prices while, contrary to what was generally claimed, agriculture in poor countries has got little or no benefit. There are still some major questions that require consideration: How will it be possible, and who will be able to feed by 2050, some 3 billion urban poor people living mainly in towns and cities of developing countries? It implies that global agricultural production will have to increase by 75% by that time and that prices will have to remain affordable for urban people! How could persistent poverty, in particular rural poverty, be alleviated? These questions are also crucial for areas threatened by desertification.

Of the many consequences arising out of the three points mentioned above, two seem to be prevalent and directly concern drylands: 1) We must, of course, adapt to global changes and sustainably manage our ecosystems and their services. This is a scientific problem, as well as a national and international public policy and governance issue. 2) We have to evolve towards what Thierry Gaudin, one of the leading French prospective analysts, calls a 'knowledge-based biosociety', by fostering knowledge transfer and innovation processes. This is also a scientific imperative.

Some considerations about climate change, sustainable development and global change

Over the last 10 years, the overall question of climate change and its impacts on agriculture and desertification has been a prime focus of often heated public and governmental discussions. Climate change is a facet of wider environmental and global changes. As stated by Louise Fresco, "Many of these global changes are a direct function of the economic development pathways that mankind has followed so far. And many of the fastest changes take place in developing countries, while at the same time some of the poorer of these countries will be the first to suffer. The relationship between climate, global environmental change and economic development is of great complexity". There is an urgent and crucial need to develop a better understanding of this complexity.

Concerning the scientific challenge, Louise Fresco also states that "There is nearly unanimous agreement that human activities cause effects that are of the same order of magnitude and even exceed the natural forces that regulate the Earth system. Climate is only one of the subsystems of the Earth system. As a consequence, climate should not be seen as a subject on its own, nor only in relation to the energy agenda or limited to reducing CO_2 levels. Our efforts to understand, mitigate and adapt to climate change must be an integral part of our move towards a sustainable society". "We can probably find common ground in the thought that sustainability does not exist in an absolute sense and that it is always a matter of tradeoffs between various alternatives with divergent long-term and short-term effects. Hence sustainability is both about being able to react to unexpected fluctuations and to deal adequately with negative effects, where they occur. Sustainable development aims to minimize human effects on the environment, to reduce our dependence on the scarcer natural resources and to close material and energy cycles in production processes."

In short, and although this is not mentioned explicitly in the Millennium Development Goals (MDGs), the relationship between sustainability and development should be a prime focus of our interest. This view of interactions between sustainability and global change is highly relevant when applied to the development of drylands and combating desertification.

Desertification and sustainable development in drylands in the global change setting

Land degradation currently has an impact on 2 billion people, a third of the Earth's surface, in around 100 countries worldwide. Deforestation and desertification are responsible for the degradation of ecosystems and human well-being, leading to loss of biodiversity, soil fertility and its water-retention capacity. These phenomena also increase soil erosion and reduce its carbon storage capacity, while deteriorating local inhabitants' living conditions and increasing poverty. This environment and development issue has a local and global scope. Humans are the cause of desertification but also its victim. Future scenarios indicate that degraded land will likely increase with population growth, food and energy needs and the higher drought risk due to global warming. If no remedial measures are taken, living conditions for a third of humankind will worsen to an unbearable extent: food insecurity, health risks, social destabilization, increased poverty, forced out-migrations, etc.

Combating desertification and global warming is far from being a purely technical issue and is now recognized as being heavily dependent on the policy enabling environment, which very strongly influences household wealth. Here lies the importance of scientific investment to enhance ecosystem management and gain greater insight into innovation processes, and the interactions between sustainability and development. These underlie the more realistic public policy measures that are discussed below.

1. **Dissemination policies and programs:** They should inform and train farmers on options to combat desertification and their impacts on costs and risks. They should promote classical land management options for drylands, such as new agroforestry systems, new ways of harvesting and managing water, or combining organic and inorganic sources of soil fertility, etc. They should also focus on collective land resource management practices, at watershed or ecosystem levels, including new ways of exchanging goods and services between stakeholders, like payment for environmental services. Technologies should also impact food security, climate change adaptation and mitigation, biodiversity preservation, and rural poverty alleviation. Practices based on intensive agro-ecology and on sustainable land management (SLM) principles, such as conservation agriculture, have to be generally used. Technology development and dissemination policies and programs should be multi-targeted, context-dependent, and always promoted in full cooperation with the land users.

2. Pricing and market policies: Policies that influence the level and variability of agricultural commodity prices also influence land management investments. Similarly, policies that influence the availability and cost of agricultural inputs also influence land management by altering the production costs and input availability and use. When markets are functioning well and households have clear and secure land tenure, policies that promote higher or more stable commodity prices and input prices promote investments in land management by increasing the expected returns and reducing the risks of such investments. With imperfect markets and trade or unclear and insecure tenure, which are very common in drylands, farmers have limited or no incentives to invest in land resource management.

This is particularly important today with the recent soaring food prices. Policymakers are often tempted to subsidize seeds and fertilizers in order to rapidly offset the increase in agriculture input prices. Such policies do not mean that the land will be better managed, or that desertification will be tackled more efficiently. They may artificially boost the land productivity and in turn hide the land degradation process and the need to manage the land ecologically. In other words, soaring prices may negatively impact land management, and finally reinforce the desertification process in the medium and long run. This is a major issue and a focus of diverging opinions with respect to public policies among regions and countries today.

3. Land tenure and land planning policies: They have marked impacts on land management. With land tenure insecurity, farmers have less incentives to invest in combating desertification. Policies that undermine tenure security, such as periodic land redistributions as used in some countries, tend to slow down such investments. In many cases, customary tenure systems, which are common in dry rangelands, provide good security for land access and use, whereas titling programs may undermine the advantages of traditional systems. To tackle land tenure and land use complexities, programs that integrate land administration policies with land planning and land management policies, as is the case in Ethiopia, involving different categories of public and private stakeholders as well as farmers' organizations, have to be developed in a participative manner.

4. Social and sectoral policies and program: Investments in infrastructure and education, promotion of non-farm income activities, and food-for-work programs, can have a substantial impact on land management decisions, given that many measures to combat desertification are labor intensive. Here again the multifunctional approach comes in play. This approach requires a careful review of various options with the land users and other stakeholders, scientists, the private sector, NGOs and farm organizations: (a) to replace damaging practices that local societies have been obliged to use during stress survival periods, and (b) to promote the adoption of new ways to protect and improve local livelihoods. Mobilization and gender policies that facilitate the empowerment of local people and communities, reinforcing their control and ensuring that they have safe and fair access to resources, are of prime importance. All land-related policies have to be formulated, implemented and monitored with the full participation and control of the users concerned.

5. National and international strategies and investments to combat desertification: Sectoral policies that influence desertification control cannot be applied separately, or only through rural development programs. Therefore, they must be embedded in national development plans and strategies, especially poverty alleviation strategies, as well as in budgetary and investment frameworks. They should be based on the elimination of institutional, legislative or infrastructure bottlenecks that hamper sustainable land management and should facilitate the management of development projects by stakeholders' decision-making processes.

Clearly, a set of consistent public policies must be implemented, along with high public investment in research,

information, infrastructures, water, education, health, markets, etc. It cannot be overstressed that the primary responsibility of the governments of countries crippled by desertification – despite the fact that they are usually poor – is to draw up, to negotiate with stakeholders, to partially fund and to implement global strategies.
Finally, official development assistance (ODA) should have contributed to financing these natural environment restoration investments. However, it has not been the case and over the last 20 years, this ODA, especially the share allocated to agriculture and natural environments, has decreased. There has been an upturn in this trend, but the situation is still very far from being acceptable. International efforts to get the global community involved in supporting dryland restoration and combating desertification have generated minor results with respect to the needs.

Conclusion

We have seen that public policies are crucial for dryland development and combating desertification in a setting of peace, economic freedom and political stability. Governments need to be tough and courageous to be able to cope with their lack of resources but also with the huge crises affecting our planet, economic and monetary crises, energy crises, climate change, etc. As scientists, we recognize our responsibility and are working hard towards fulfilling it. Governments, and the international community, are becoming increasingly aware of the urgency and importance of our current and future work towards sustainability and global change, especially in dryland areas.
Biology has, and will continue to have, a key role in dealing with desertification problems. This science enhances our understanding of functional adaptation mechanisms through different strategies, for instance using breeding techniques to promote adaptation to drought conditions, improving water use efficiency by modifying physiological mechanisms, developing favorable interactions via soil microorganisms (symbiosis), and finally tapping the potential of adaptation genes through comparative genomics and biotechnologies.
Innovation is also a primary focus of our research, as a complex process, but also as a crucial condition for biological progress to have impact.

We are all committed to fulfilling this task together and in synergy, we scientists of developed countries with our expertise inherited from our long-standing agricultural tradition, in partnership with international agricultural research and its centers, and in collaboration with the many national research teams in this region that are striving to develop their drylands and combat desertification.

Acknowledgement

This presentation draws on the text written especially for the 9th IDDC Conference by Marc Bied-Charreton, President of CSFD, the French Scientific Committee on Desertification, which has its headquarters in Agropolis International, at Montpellier, together with several UN documents, as well as two papers on agriculture of the future that the author presented to French authorities, and various prospective studies on agricultural development, particularly those carried out in France as part of the Agrimonde project. An article by Louise Fresco titled ‘From Kyoto to sustainability: new challenges for the 21st century’ published in 2007, some publications by ICARDA, and recent data from FAO were also of great use.

11. Alternative livelihoods to improve human well-being in marginal drylands

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Abstract

A new hope is at hand for successfully overcoming desertification and simultaneously improving the well-being of people and communities in drylands – particularly those living in ecologically and politically marginalized areas. Innovative livelihood strategies that are minimally dependent on land productivity – such as ecotourism, solar power utilization, handicraft production, brackish water aquaculture, etc. – have the potential to reduce the pressure on the fragile resource base in marginal drylands. At the same time, these strategies yield significantly higher income per unit investment than traditional land-based livelihoods. The Sustainable Management of Marginal Drylands (SUMAMAD) project has been a systematic effort to understand these 'alternative livelihood' strategies and apply them at nine demonstration sites located in China, Pakistan, Uzbekistan, Islamic Republic of Iran, Jordan, Syria, Egypt and Tunisia. The significance of policies in achieving integrated management was realized early in the project, and accordingly, clear policy messages were developed and acted upon at all sites. The site-specific work greatly benefited from the active exchange of knowledge between and excellent collaboration among the researchers in participating dryland countries. We conclude that application of alternative livelihoods must be central to approaches used for reversing the downward poverty-desertification spiral in marginal drylands. The international community must also support such efforts through focused policies and investment of resources.

1. Desertification in marginal drylands – the context

Desertification – persistent degradation of land and loss of productivity in drylands resulting from human and climatic factors – is now recognized as one of the most pressing global environmental challenges (Adeel et al. 2007). Overall desertification is attributed to the long-term failure to balance demand for and supply of ecosystem services in drylands (Adeel et al. 2005). The demands on dryland ecosystems for providing services – including *inter alia* food, forage, fuel, building materials, and water for humans and livestock, for irrigation, and for sanitation – have been increasing significantly. Many factors contribute to these demands: population growth, economic policies and globalization phenomena, land use patterns and practices, and climate-related processes like droughts and reduction in freshwater availability due to global warming.

Typically, desertification causes changes to biodiversity, decline in soil fertility, reduced water availability and destruction of vegetative cover. The impacts of a number of the secondary biophysical processes triggered by desertification are observed at a global level (Sivakumar and Stefanski 2007). The classic example is the intercontinental dust storms which lead to redistribution of nutrients and can significantly degrade air quality. Historical observations since the 1970's demonstrate a significant increase in dust concentrations from the Sahara and Sahel region moving into North Africa and Europe (Prospero and Lamb 2003); these trends will likely amplify as global warming leads to a drier North African and Sahara region. Similar trends in dust storm increase have also been noticed in China (Gaoming 2008). Destruction of vegetative cover has also been correlated to poor infiltration and retention of water from heavy precipitation events, leading to flooding in downstream areas. Severe flooding in the Yangtze River in China during the 1990's is often cited as an example of floods triggered by upstream vegetation removal combined with extreme rainfall events.

It is documented that many agricultural development policies exacerbate the desertification situation. Selective production and export subsidies in developed countries – particularly the European Union and the United States, which collectively spent over $300 billion (in 2002) on their agricultural sectors – lead to overproduction of many food crops in those countries. The overproduction of agricultural commodities skews international food markets by driving down prices and impairing the access for producers in developing countries to international food markets. A direct consequence is that the livelihoods of food producers in many poorer countries are often seriously undermined (Adeel et al. 2005).

Similarly, large-scale irrigation, while increasing agricultural yield in the medium term, has often led to many environmental problems, including waterlogging and salinization, water pollution, eutrophication, and unsustainable exploitation of groundwater aquifers. Additionally, such irrigation schemes also disconnect rivers from their floodplains and other inland water habitats, and lead to reduction in groundwater recharge.

Vulnerability of marginal dylands

Marginal drylands can be defined in two ways, both definitions often converging in the same geographical area. First, marginality of drylands is defined in terms of biophysical parameter, the most common is the Aridity Index. [The long-term mean of the ratio of an area's mean annual precipitation to its mean annual potential evapotranspiration is the Aridity Index (AI). AI value lower than 1 indicates an annual moisture deficit, and the World Atlas of Desertification (Middleton and Thomas 1997) defines drylands as areas with AI ≤ 0.65]. Studies have shown that ecosystems that exist at the margins of arid to semi-arid are most vulnerable to desertification; these typically correlate with margins of the deserts (defined as hyper-arid regions with AI values less than 0.05). Second, marginality can also be defined in political and social terms. This means that many of the arid regions are considered to be non-productive in terms of national development, and result in lower investment in infrastructure and government-supported services. This type of marginalization can lead severe impacts on wellbeing of people, high poverty rates and poor access to health and education services.

The ecosystems and people in marginal drylands are particularly vulnerable – in part because the population stress is often in excess of the sustainable capacity of the ecosystems. Faced with poverty and often lack of adequate social structures, the populations are vulnerable to abrupt changes in conditions – such as those brought by droughts. Addressing the environmental and social issues in these situations requires development of approaches that are sensitive to the social and settings and take into account the biophysical limitations of the natural systems. This paper explores implementation of approaches to improve the wellbeing of populations living in marginal drylands, reduce their vulnerability to climatic or economic shocks, and protect the productive capacity of these fragile ecosystems. We argue that introduction of alternative livelihoods achieves all three of these objectives.

2. Transforming policies and improving land management

Successful amelioration of desertification in marginal drylands requires both improved local management of natural resources and changes to policy approaches that promote sustainability of ecosystem services. When empowered adequately, local communities in marginal drylands can often become the key players in preventing desertification and providing effective natural resource. Essential empowerment means overcoming the traditional limitations like lack of institutional capacity, access to markets, and financial capital for implementation. Enabling policies that involve local participation and community institutions, improve access to transport and market infrastructures, inform local land managers, and allow land users to innovate are essential.

The overall objectives of transforming policies should include poverty alleviation, improvement in overall human wellbeing, effective restoration of ecosystem services and increase in agricultural productivity. We propose that the following six elements must be included in policy transformations at national and international levels:

a. Enable national development plans to explicitly include investments in marginal drylands. These policies should focus on development of essential infrastructure, provision of health and educational services, and enabling access to markets.

b. Maintain a focus on alternative livelihoods in order to reduce the stresses on natural ecosystems, while promoting secure, sustainable and better-paying livelihoods.

c. Engage and empower communities through development of social institutions and by providing technological and human capacity development opportunities.

d. Incorporate traditional knowledge and technologies into the overall development paradigms. Dwellers of marginal drylands have developed approaches to deal with their natural environment over the millennia that need to be adequately captured when planning for the future.

e. Enable South-South collaborations between countries and regions facing similar challenges in marginal drylands. Such horizontal exchange of information, ideas and approaches has been shown to yield positive results for marginal communities.

f. Mobilize international investments to focus more on the challenges of marginal drylands and combining these investments with efforts to reduce poverty and provision of basic amenities like access to safe drinking water and adequate sanitation facilities.

3. Focus on alternative livelihoods

Alternative livelihoods are defined as approaches that partially or fully replace traditional agricultural and pastoral practices, and do so with a minimal dependence on land primary productivity. Such approaches, to be successful, have to yield greater income per investment of local dryland resources, as well as providing diversification of local economies, as compared to the traditional livelihoods (Méndez 1993). The viability of these alternative livelihoods is dependent on capital investment and availability of trade-related infrastructure and services.

Therefore, development of enabling policy environment, as discussed in Section 2, is essential to their success.

Typical examples of alternative livelihoods demonstrated in marginal drylands are listed here.

First, afforestation and carbon sequestration in marginal drylands generates marketable fuel wood and biofuel, while playing a key role in sequestering carbon. In principle, the emerging carbon trading regimes can add value to dryland afforestation for carbon sequestration (Chichilnisky and Heal 1998).

Second, dryland aquaculture which allows the use of brackish groundwater often encountered in drylands (Kolkovsky et al. 2003). It can not only produce edible fish to overcome nutritional deficits but also provide value-added ornamental fish and micro-algae that bio-manufacture invaluable chemicals used in the health and food industry (Warren 2006). A significant challenge is to overcome the lack of aware-ness and know-how about the relevant technologies, and often the lack of infrastructure needed to storing, shipping, distributing and marketing the end-product.

Third, ecotourism in drylands can respond to the growing demand for non-congested, non-polluted, pastoral, and pristine land-scapes; such landscapes and vistas are often easily accessible in marginal drylands. The main drawback of this livelihood is its high water demand, which can be met by desalination and treatment of marginal water resources including urban waste-water.

Fourth, due to high solar radiation, low cloudiness, and cheaply available spaces drylands have a high potential to generate solar energy, and perhaps even export some of that energy to non-dryland markets.

Fifth, controlled-environment dryland agriculture based on the plastic-covered greenhouse that allows the penetration of the abundant light radiation of the drylands, yet provides a fully controlled, automated and enclosed environment (Jensen and Malter 1995). The caveat for this approach is the high investment in infrastructure, research and maintenance, as well as dependence on high-quality water supply.

Sixth, many urban-supported alternative livelihoods can allow for inclusion of approaches in dryland cities that meet the physical, social and economic demands of the dryland environmental conditions (Portnov and Safrie, 2004).

4. Case studies of introduction of alternative livelihoods

Alternative livelihoods were tested and promoted by a joint initiative of UNU (United Nations University), UNESCO (United Nations Educational, Scientific and Cultural Organization) and ICARDA (International Center for Agricultural Research in the Dry Areas) entitled the "Sustainable Management of Marginal Drylands" (or in short: SUMAMAD) project. The first phase of the project was implemented from 2003-2007, the inception of the second, 5-year phase was in 2009. The SUMAMAD project pursues the overall aim to improve livelihood conditions of dryland dwellers, while enhancing the sustainable management and conservation of marginal drylands in a number of study sites spanning from East Asia to Africa and Latin America. In addition to integrated approaches to land management, the SUMAMAD project places a major emphasis on diversification of livelihoods as a key contribution to ensuring human well-being and maintaining ecosystem services in marginal drylands. Participatory processes are at the centre of project implementation and, thus, local communities are closely involved in all stages of identifying, introducing and testing alternative income-generating activities at each SUMAMAD project site. Some alternative livelihoods are quite novel to dryland people, but they represent viable options for income generation, minimize pressures on land resources and are promising for replication elsewhere. The SUMAMAD case studies presented in this paper are selected from project activities in China, Pakistan and Egypt.

The Hunshandake Sandland is a SUMAMAD project site situated in Inner Mongolia, China, where cattle and sheep farming has led to severe degradation of natural grasslands over the past decades (see Fig. 1) (UNESCO 2008). The primary focus of activities at the Chinese study site is the natural restoration of degraded rangelands through removal of external stresses. To achieve this purpose, the SUMAMAD project in consultation with the local population introduced a number of alternative income-generating activities, including chicken farming, ecotourism and milk product processing, instead of livestock production.

Figure 1. The location of the study area and SUMAMAD site in Hunshundak Sandland, Inner Mongolia, China. (*Source:* Lee and Schaaf 2008).

Particularly poultry-raising in natural grassland sites proved to have a high economic and ecological efficiency as demonstrated by the researchers from the Chinese Academy of Sciences involved in the project. Approximately 15,000 chickens were raised in the 33 hectares of the village of Bayinhushu Gacha. The net economic return per hectare was nine times higher for chicken farming than previously generated through cattle-raising (Lee and Schaaf 2008). At the same time, poultry-raising has no negative effect on the grassland ecosystem and helps control pests.

The primary beneficiaries of the alternative livelihood are the local people. The researchers estimated that each family involved earned at least 60,000 Yuan (ca. US$7,900) in comparison to 15,000 Yuan (ca. US$1,975) raising cattle (Lee and Schaaf 2008). Thus, many local villagers have switched to the novel livelihood, gradually replacing the less sustainable sheep and cattle farming. The removal of cattle farming has helped recover the degraded grasslands without pro-active vegetation restoration activities. This allows local villagers to produce hay as an additional source of income. Each family was expected to earn an additional 12,000 Yuan (72 families in the village), while previously they had to spend 10,000 Yuan per annum to buy animal forage (Lee and Thomas 2008). In addition to chicken farming and fodder harvesting, the families earn income through milk products and ecotourism activities. Processing of milk products, rather than direct selling, enabled increases in income generation. The added value was around 20%, although this activity was found to be labour intensive. Furthermore, the SUMAMAD team actively promotes the restored natural grassland ecosystems as an ecotourism destination and leads efforts to establish a nature reserve in the Hundshandake Sandland. Local families are supported in building small-scale accommodation facilities. This has further helped to diversify household incomes and strengthen the livelihood security of local people in the Hunshandake Sandland.

In the Cholistan region in Pakistan the hyper-arid climate, extreme water scarcity and harsh natural conditions limit agricultural activities and lead to poor living standards. Traditionally, livestock production is the main source of income for the local population, while other livelihood options are limited or lacking. The SUMAMAD project site in Cholistan (see Fig. 2) was managed by the Pakistan Council of Research in Water Resources. In order to provide reliable, year-round water for humans and livestock, the project helped establish modern rainwater harvesting systems through building surface-water reservoirs at topographically suitable locations. Simple sand-based filtration systems were installed.

In addition, the SUMAMAD project team introduced a novel livelihood based on the saline ground water available in the project area: aquaculture in brackish water. The research undertaken by the SUMAMAD team confirmed that several fish species are suitable for aquaculture in brackish water and tolerate salinity ranges between 4,000 and 30,000 ppm (Lee and Schaaf 2008). The fish produced in the brackish water is

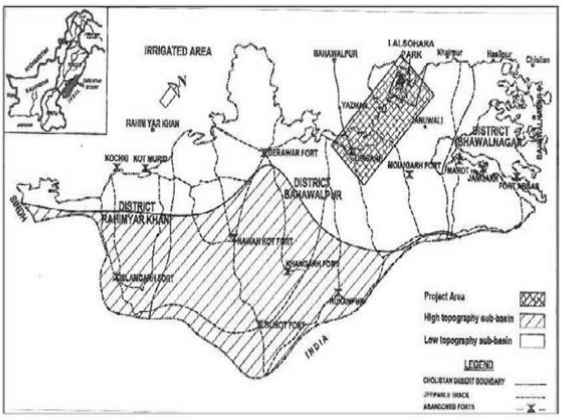

Figure 2. Location map of Lal Sohanra Biosphere reserve and Cholistan Desert. (*Source:* Adeel et al. 2008).

sold in local markets, but is also used for household consumption and, thus, improves the nutrition of the local villagers. The SUMAMAD researches were able to demonstrate that integrated farming-aquaculture systems, such as livestock-fish farming, poultry-fish farming, duck-fish farming, horticulture-fish farming, are economically viable in drylands. The project adopted a poly-culture fish system in order to minimize mortality rates. The success in aquaculture requires an understanding of the nutrition and health/disease requirements of a species, maintaining an adequate water quality in the ponds, developing infrastructure for marketing the fish and intense training of villagers. In addition to dryland aquaculture, the project team also tested irrigation with saline water for vegetable production to diversify livelihoods. The results of the studies demonstrated that the irrigation with moderate to highly saline water enabled the cultivation of salt-tolerant species of vegetables, such as eggplant, pepper, and gourd species, on well drained and fertile soils.

The researchers reported that soil management practices should be adopted, when saline waters are used for irrigation, i.e. adding manure, fertilizers, planting vegetables on ridges and beds etc.

In Egypt project activities were implemented in the Omayed Biosphere Reserve located in an arid, 30 km stretch of land along the Mediterranean coast (see Fig. 3). Several competing human activities, including pastoralism, rain-fed and irrigated agriculture, tourism, and urban development, are concentrated in this area. Bedouin communities, urban vacationers and peasants from the Nile Delta create an unusual mix of people with different interests and needs. The project was coordinated by the University of Alexandria and focused on a wide range of activities, including ecosystem studies, new income-generation opportunities for the local communities and establishing solar-powered desalination plants to generate safe drinking water. In order to support Bedouin women to develop skills and earn money from home, the project helped train women in sewing and embroidery. A rotating micro-credit system was set up, which enabled women to purchase sewing machines and fabric to produce dresses. The products are sold in the community. The researchers demonstrated that this alternative livelihood generated considerable returns on small investments when compared to previous occupations. Bedouin women earn a reported income of EGP 330 (US$62) per month, for EGP 30-35 (approx. US$6.5) invested to purchase sewing machines (Lee and Schaaf 2008). Furthermore, the SUMAMAD researchers supported the development of a new technology for desalination of saline groundwater water using solar powered pumps. Depending on sunlight exposure, the solar-powered desalination units produce about 100–120 litres of water per day, enough water to provide at least five families (40–50 persons) with clean drinking water (Lee and Schaaf 2008).

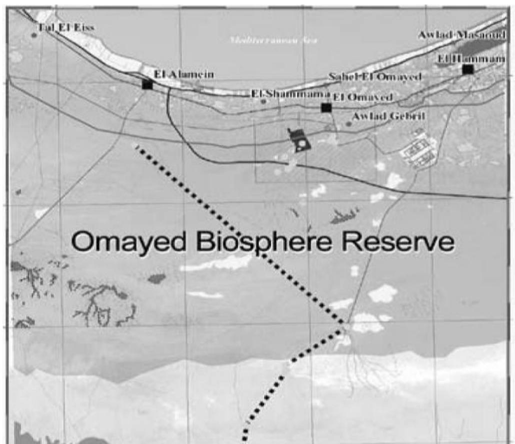

Figure 3. Location of Omayed Biosphere Reserve along the Mediterranean cost. (*Source:* Adeel et al. 2008).

The SUMAMAD research work demonstrated that the investment in the installation of solar-powered units for the desalination of water effectively removed the costs from household expenditures of buying water privately and also led to health improvements through better water quality. Based on the successes of the SUMAMAD project, a company owned by the Egyptian Government started manufacturing solar-powered desalination units for introduction into other parts of Egypt. Another activity of the project to increase livelihood security of the dryland population included the establishment of a factory to dry high quality figs produced in the project area. This enables the local population to sell figs year-round and not only during the harvesting season, when prices are low.

5. Conclusions – meeting the future challenges

Cost-benefit calculations undertaken by the SUMAMAD project highlighted that investments in alternative livelihoods resulted in improved natural resources management and generated a wide range of intangible benefits and higher monetary returns when compared to traditional livelihoods. However, it also became evident that adaptation to innovative, alternative livelihoods and attaining their sustainability requires enabling conditions. In particular, capital investment in dryland development and trade-related infrastructure in remote areas are needed, which in turn depend on governmental policies and effective governance at the local and national levels. Such enabling conditions often do not exist in developing countries with drylands, and particularly in areas that are considered marginal (Safriel et al. 2005). Thus, the first step to be taken on the path to dryland sustainable development is to invest in societal, policy and governance changes, building capacity, and creating an enabling environment that can support emerging alternative livelihoods.

Strong South-South solidarity to collectively address and resolve dryland challenges was identified by the

SUMAMAD project as a key contribution to increase the self-reliance within and amongst dryland countries. The scientific exchange that was strengthened by the project included both experts from both South and North, contributing experiences of working in the dryland environments of the South. Their close collaboration increased knowledge of sustainable dryland management and enabled researchers to recognize alternative solutions and novel ideas that had already been successfully tested in other dryland regions.

The SUMAMAD case studies further underlined that solutions in marginal drylands should build on a broad approach to generate knowledge. The synthesis and integration of different knowledge sources, including locally available traditional knowledge bases, proved to be effective for tackling the complex challenges in an integrated manner. Since local knowledge alone is often not sufficient, it is critical to merge traditional experience with cutting edge scientific research and technology. The right mix between the various knowledge streams depends on the specific circumstances of the dryland site.

The SUMAMAD project highlighted the significance of enabling policies at the national and international level as a key to address challenges faced by communities in marginal drylands. One of the major findings of the project is that enabling national development policies need to strengthen viable livelihood alternatives for dryland populations and integrate dryland management into mainstream poverty reduction plans. A weakness identified by the SUMAMAD project was the divide between research and policy-making. Therefore, policies need to better connect with available research and reinforce data gathering and synthesis to better understand and respond to local challenges. The global development community needs to ensure that national governments have sufficient resources at their disposal to support a sustainable development path in drylands.

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12. Managing current climatic uncertainty and adapting to future climate change in the SAT of Africa and Asia: ICRISAT's approach

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Abstract

Climate variability and change is an important consideration for the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) given its mandate for the improvement of rainfed farming systems in the semi-arid tropics (SAT) of the developing world. Climate change predictions point to a warmer world within the next 50 years. However, the more specific question of the impact of rising temperatures on rainfall distribution patterns remains far less certain. Recognizing this, ICRISAT has developed an Operational Research Strategy (2008–2015) entitled "Adapting to Climate Change in the SAT". This strategy addresses climate change challenges through a two-pronged approach that focuses on: (a) Helping farmers cope better with current rainfall variability as a prerequisite to adapting to future climate change; and (b) Adapting ICRISAT mandate crops to grow in a warmer world. Due to their evolutionary advantage, ICRISAT's mandate crops are better adapted than other major food crops (rice, maize, wheat) to abiotic stresses. Our current breeding strategies have therefore already taken existing high temperatures, low and variable rainfall and subsequent variable moisture stress, as well as soil salinity/acidity into account. Because of this, in prioritizing our crop adaptation strategy for climate change, we are able to draw heavily on current research products and lessons learned in shaping our plan for the way forward.

Introduction

Climate change predictions point to a warmer world within the next 50 years, a trend that is increasingly being supported by 'on-the-ground' measurements. However, the impact of rising temperatures on rainfall distribution patterns in Africa and Asia remains far less certain (IPCC 2007), although in some parts of the world the increasing frequency of extreme rainfall events and droughts appears significant. Satellite data shows that the dry tropics, where rainfed agriculture provides 60% of the world's food and some of the world's poorest live, will be the most vulnerable to climate change (UNDP 2006; IPCC 2007). Data emerging from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) shows that increases in temperature will have a significant reduction (8–30%) in grain yields of dryland crops (e.g. Dimes et al. 2008).

Rainfed agriculture in Africa and Asia: vital for future food security

In the context of continued population growth and predicted climate change, recent studies have envisaged a developing global crisis in the availability of abstracted water (Rosegrant et al. 2002; UNDP 2006). It is suggested that the projected trends in world population growth and dynamics will place substantially greater multi-sectoral demands on water, leading to exacerbated competition between sectors for an increasingly limited supply of abstracted water. This, in turn, will curtail the ability of irrigated agriculture to respond to the expanding food requirements of a global population, particularly those in the developing world. In contrast to the aspirations of the Millennium Development Goals (UN 2005), this raises the specter of a worsening food security crisis (UNDP 2006).

To reverse such a scenario, it has been concluded that much greater emphasis will have to be given to increasing the productivity of global rainfed agriculture which currently provides 60% of the world's food (Rosegrant et al. 2002; UNDP 2006). In such an endeavor, the drylands of Africa and Asia pose special challenges for it is here that some of the poorest and most vulnerable communities live (Tables 1 and 2). These communities manage, and largely rely upon, rainfed agriculture and pastoral systems for their livelihoods and are the custodians of the natural resource base upon which such enterprises depend. Added to the constraints imposed by extreme poverty, health hazards, and often a degrading resource base, is the inherent variability of rainfall amounts and distribution and the risk this imposes on farm production.

Recognizing the importance of rainfed agriculture for both individual as well as national food security, agricultural research increase productivity, but also mitigate the climatically induced uncertainty of production through specific soil, crop and rainfall management strategies. (Cooper et al. 2008).

Table 1. Area of the semi-arid tropics in Asia and Sub-Saharan Africa

Region	**Area (sq. km)**		**SAT %**
	Total	**SAT**	
Asia	7,417,491	1,522,117	20.52
Sub-Saharan Africa	19,306,515	4,977,808	25.78
	26,724,006	**6,499,925**	**24.32**

Table 2. Poverty in Asia and Sub-Saharan Africa (source: Chen and Ravallion 2008).

Region	**Number of people living below poverty line (%)**			
	Below $1	**Below $1.25**	**Below $1.45**	**Below $2**
East Asia and Pacific	9.5	17.9	20.6	39.7
Central Asia	3.4	5.0	6.5	10.6
South Asia	23.7	40.3	52.3	73.9
Sub-Saharan Africa	39.2	50.4	57.9	72.2

Since its foundation in 1972, ICRISAT has provided global leadership in such research. Some examples include:

- Breeding new crop varieties that are better adapted to contrasting climatic conditions (Haussman et al. 2004; Traore et al. 2005; Hiraoka et al. 2006; Mariac et al. 2006);
- Incorporating resistance to pests and diseases (many of which are triggered by specific climate sequences) into our mandate crops (Kishore et al. 2004; Pande et al. 2004);
- Developing and promoting innovative seed supply systems to support the adoption of improved varieties (Sreenath et al. 2006);
- Identifying and promoting affordable input supply systems, such as our work on microdosing (Tabo et al. 2007 ; Twomlow et al. 2008b);
- Low-cost land forming and residue management interventions at the farm and watershed scale that retain scarce

rainfall where it can be most effectively used, such as our work on Zai pits and planting basins (Fatondji et al. 2006; Hatibu et al. 2006; Mazvimavi et al. 2008);

- Developing and promoting more diversified production systems through the incorporation of high value legumes, such as groundnut, chickpea and pigeonpea into crop rotations (e.g. Snapp et al. 2003; Harris et al. 2005; Ncube et al. 2007); and
- Undertaking research on systems and value chains that link farmers to local, regional and global markets (Shiferaw and Bantilan 2004; Shiferaw et al. 2008; Twomlow et al. 2008c).

Such research has already shown great potential on research stations and in farmers' fields, with 'achievable' yields often several times greater than those obtained by traditional farmer practice. However, in general, extensive adoption of these innovations has been low. While 'islands of success' continue to provide hope for the future, little scaling up of such successes has been reported. Widespread impact is not yet evident. Indeed, in many situations, production and the quality of the natural resource base are declining.

Given such a situation, combined with the projected negative impact of water scarcity on the possible extent of expansion of irrigated agriculture, cereal deficits in most of Asia and Africa are expected to increase dramatically by 2025 if the current 'business as usual' rainfed resource management and investment policies are maintained (Table 3) (Rosegrant et al. 2002; UNDP 2006).

In such a scenario, either international food aid must be increasingly called for, an undesirable option, or policies must be put in place and decisions taken to greatly accelerate investment within the agricultural sector beyond the 'business as usual' scenario upon which such projections are based.

Table 3. Current and predicted cereal production and demand in Asia and Africa (source: FAO and Rosegrant et al. 2002)

Country or Region	Current status (million tons)			Predicted status in 2025 (million tons) #		
	Production	Demand$	Deficit	Production*	Demand$	Deficit
Asia	726	794	68	1093 (30)	1228	135
China	358	375	17	542 (26)	581	39
India	175	171	Surplus 4	257 (31)	275	18
S.E. Asia	106	114	8	170 (47)	176	6
South Asia (less India)	51	55	4	81 (14)	102	21
Sub-Saharan Africa	69	78	9	137 (88)	172	35
W. Asia and N. Africa	82	120	38	119 (54)	202	83

Predicted values for the period 2021–2025 according to a 'business as usual' scenario which assumes the continuation of population growth patterns and of current trends and existing plans in water and food policy, resource management and investment. It does not consider the potential impact of climate change.
$ The sum of food and feed demand.
* Figures in parenthesis are the predicted percentage of total cereal production in 2025 coming from rainfed production.

ICRISAT's approach

Charged with a mandate to improve rainfed farming systems and reduce poverty in the dry tropics of the developing world, ICRISAT is employing a two-pronged strategy that will help farmers face the emerging challenges of climate change across a range of time scales, namely:

- **In the short to medium-term:** Helping farmers and their support agents to cope better with current rainfall variability as a prerequisite to adapting to future climate change;
- **In the medium to longer-term:** Adapting our mandate crops (sorghum, millet, groundnut, chickpea and pigeonpea) to grow in a warmer world.

These two strategic initiatives are described in this paper.

Short to medium-term strategic initiative

Current rainfall variability and future climate change is an important consideration for ICRISAT (Cooper et al. 2008) given its mandate for rainfed agriculture upon which some of the most vulnerable communities in the world depend for their livelihoods (Table 2). ICRISAT, together with leading donor support agencies, believes that for vulnerable communities and agricultural stakeholders to adapt to **future** climate change, their ability to cope with the rainfall variability associated with **current** climates must first be enhanced (Twomlow et al. 2008a). ICRISAT, working with partners (Cooper at al. 2008), promotes strategies that span time scales:

(1) Climate risk analysis frameworks that provide a medium-term strategic understanding of the temporal and spatial distribution of current rainfall variability and its impact on performance and profitability of existing and innovative agricultural practices.
(2) Short-term seasonal climate and agricultural forecasting that enables farmers and support agents to 'fine tune' medium-term strategies and thus plan tactically and farm more effectively in the face of seasonally variable weather.
(3) Providing medium to longer-term information on the extent to which climate change is likely to impact on the nature of climate variability, and the implications for rainfed farming systems and their future development and productivity.

To further foster and promote such approaches in sub-Saharan Africa, ICRISAT, with the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), currently facilitates a New Economic Partnerships for African Development (NEPAD)-endorsed consortium of 15 national, regional and international partners entitled *Investing in rainfed farming systems of sub-Saharan Africa: Evaluating the agricultural implications of current climatic variability and planning for future climate change*. Among others, the CGIAR Centers ICRAF, CIAT, IITA, IWMI and ILRI are partners in this consortium.

Through this consortium ICRISAT has partnered with meteorological services, CGIAR Centers and leading climate science researchers worldwide in a series of 'Proof of Concept' projects centered around climate risk management. We blend their deep climate knowledge with our expertise on tropical dryland farming systems. There are currently 10 such projects taking place in sub-Saharan Africa and recently an important project funded by the Asian Development Bank has extended this work to India, Peoples' Republic of China, Sri Lanka, Bangladesh, and Pakistan (Table 4).

Many of these projects focus on mitigating climate-induced risk through making better use of natural resources and identifying those innovations that have a high probability of success in the context of season-to-season weather variability. In this respect, in rainfed farming systems, improved rainfall-use efficiency and soil fertility management are especially important in enhancing food security and income generation.

Table 4. Climate risk management projects. The lead center (LC) is identified

roject title	Project output and date	Project partners
'Providing climate-based decision support for farmers and agricultural concession companies in Mozambique' Funding agent: PROAGRI-MINAG (World Bank)	**2007:** The potential of climate-based decision support systems demonstrated to agricultural concession companies in Mozambique.	ICRISAT **(LC),** Reading Univ., Mozambique Leaf Tobacco, DPA, IIAM, EMPRENDA Alliance, USEBA, SNS and Mozambique Met. Service
'Fertilizer recommendations and policy for smallholder farmers of southern Africa' Funding agent: ACIAR	**2008:** The usefulness of climate driven simulation models (APSIM) in defining climate induced risk in fertilizer use both demonstrated and promoted to farmers and financial institutions in the Limpopo Province, South Africa.	ICRISAT **(LC),** Land Bank of South Africa, Bankers Association of South Africa
'Making the best of climate: Adapting agriculture to climate variability' Funding agent: EU through ASARECA CGS.	**2008:** Innovative strategies for enhancing mitigation of, recovery from, and resilience to climate induced crisis affecting smallholder farmers in the SAT of Kenya, Madagascar and Ethiopia available to farmers and their support agents.	ICRISAT, IRI Univ. Nairobi **(LC)**, KMD, ICPAC, EARO, FOFIFA, SOMEAH
'An aflatoxin risk early warning system to improve nutrition, health and income in west African smallholder farms.' Funding agent: CIDA/CCLF	**2009:** A climate-based aflatoxin risk early warning system developed to improve the nutrition, health and income of West African smallholder farmers.	ICRISAT **(LC),** AGRHYMET IER-Mali, SARI-Ghana, Univ. of Sherbrooke and Univ. of Florida
'Legume diversification in tobacco systems. Climate risk and market opportunities' Funding agent: IDRC – Research in Tobacco Control.	**2009:** The capacity of the National Smallholder Farmers' Association of Malawi (NASFAM) to use climate risk analyses to evaluate and target legume diversification strategies in tobacco producing systems in Malawi enhanced.	ICRISAT, Reading University NASFAM **(LC),** Malawi Met. Services
'Building adaptive capacity to cope with increasing vulnerability due to climate change' Funding agent: IDRC/DfID CCAA.	**2009:** Educational, research and extension competencies to develop strategies that help rural communities adapt to climate variability and change enhanced in Zambia and Zimbabwe.	ICRISAT, CIAT and ZMD Midlands State University, **(LC),** CARE, Dunavant Cotton, CSIRO, AREX, ASP
'Managing uncertainty: Innovation systems for coping with climate variability and change' Funding agent: AfDB through ASARECA CGS.	**2010:** Coping with risks and realizing opportunities associated with climate variability and change enhanced through appropriate strategies and institutional innovation in Uganda, Sudan, and four other selected countries in ECA.	ICRISAT **(LC),** CIAT, ICRAF, Reading Univ. ASARECA Networks, ILRI, ARC-Sudan, NARO-Uganda
'Clues from landraces: Positioning local knowledge on plant management of climate uncertainty at the heart of adaptive agricultural strategies' Funding agent: IDRC/DfID CCAA	**2011:** The capital value of specific locally preserved landrace adaptation traits for the definition of sound adaptive strategies in variable climate demonstrated in Ghana, Mali, and Niger.	ICRISAT-Mali **(LC)**, CIRAD, IUCN, AMEDD, CRA, IER, Univ. of Florida, Univ. of Sherbrooke, SARI
'Managing risk, reducing vulnerability and enhancing productivity under a changing climate' Funding agent: IDRC/DfID CCAA.	**2012:** The impacts of climate induced crises mitigated and resilience improved through the adoption, by small-scale farmers, of innovative strategies that reduce climate risk and manage vulnerability in Tanzania, Kenya, Ethiopia, Eritrea and Sudan.	ICRISAT, ASARECA-SWMNet. Sokoine University of Agriculture, Tanzania **(LC)**
'Vulnerability to climate change: Adaptation strategies and layers of resilience' Funding agent: ADB	**2012:** Provide science-based solutions and pro-poor approaches for adaptation of agricultural systems to climate change for the rural poor and most vulnerable farmers in semi-arid regions of Asia, specifically India, Peoples' Republic of China (PRC), Sri Lanka, Bangladesh, and Pakistan.	ICRISAT **(LC),** CRIDA in India; Chinese Academy of Agricultural Sciences and Guizhou Academy of Agricultural Sciences in PRC; Center for Policy Dialogue in Bangladesh; CARP in Sri Lanka; Pakistan Agricultural Research Council and CLAN
'Community management of crop diversity to enhance resilience, yield stability and income generation in changing West African climates' Funding Agent: BMZ	**2012:** To enhance farm community resilience, production stability and income generation in West Africa (Niger, Burkina Faso, Mali and Ghana) under variable and changing climates by enriching agro-biodiversity management across a climatic gradient.	ICRISAT **(LC)**, Univ. of Hohenheim, farmers organizations and NGOs, IER, Mali; INERA, Burkina Faso; INRAN, AGRHYMET, Niger; SARI, Ghana

ICRISAT is helping farmers devise ways to manage landscapes, soils and crops so that more of the water and nutrient resources are stored and used more efficiently over a longer time period. Using crop growth, soil and water management simulation models, the Institute is quantifying the climate-induced risk associated with such innovations (Box 1).

Medium to longer-term strategic initiative

ICRISAT has identified medium term (20–30 years) priority strategies that will result in crop varieties and cropping systems that are adapted to a changed environment. Key factors considered are:

- Higher temperature tolerance;
- Moisture extremes – both increased moisture stress and risk of temporary flooding;
- Changed distribution and severity of pests and diseases; and
- The 'migration' of our mandate crops into geographical areas already marginal for crops currently being grown there.

Because of their evolutionary advantage, ICRISAT mandate crops are better adapted than other major food crops (rice, maize, wheat) to such stresses. For example, sorghum, pearl millet, chickpea, pigeonpea and groundnut are known to grow in harsh environments where temperatures are quite high and prolonged dry spells are common (ICRISAT 2008).

To get ahead of climate change, ICRISAT has ready-adapted products such as early, extra-early, and super-early chickpea cultivars (Fig. 1).

Our current breeding strategies already take into account existing high temperatures and

ICCV 96029	ICCV 2	KAK 2
Super-early	**Extra-early**	**Early**
75-80 days	**85-90 days**	**90-95 days**

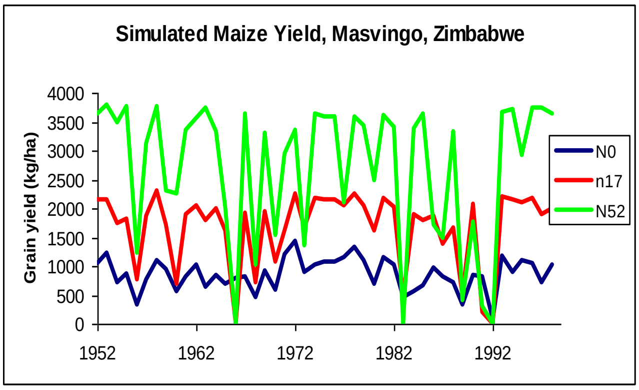
Figure 1. Get ahead of climate change - ready adapted products: Development of early, extra-early and super-early chickpea cultivars at ICRISAT.

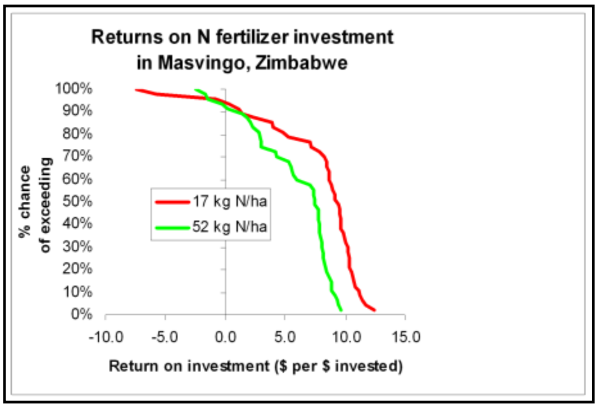
low and variable rainfall, and variable moisture stress. Because of this, in prioritizing ICRISAT's 'Crop Adaptation Strategy for Climate Change', we are able to draw heavily on current research products and lessons learned in shaping the way forward.

ICRISAT already has on hand crops that are adapted to heat, high soil temperatures, knowledge and understanding of photoperiod-sensitive flowering, information on genetic variation for transpiration efficiency, short-duration varieties that escape terminal drought, and high yielding and disease-resistant varieties. What we now need is to better understand the physiological mechanism underlying heat tolerance, identify wider gene pools from which to develop crops of wider adaptability, and develop more effective screening techniques of germplasm for desired traits. To help guide our crop adaptation work we are using crop growth simulation models such as APSIM to examine the disaggregated impact of a range of climate change scenarios on our mandate crops across the SAT of the world (Boxes 2 and 3).

Box 1. A recent successful example of risk assessment and management using the APSIM model (Dimes 2005)

In southern semi-arid Zimbabwe, where nitrogen deficiency is widespread in maize and yields are low and variable, nitrogen fertilizer use is recommended at a rate of 52 kg/ha, but is seldom adopted by farmers. It is considered too risky and expensive. Researchers therefore asked farmers how much fertilizer they could afford and would actually be prepared to use under such conditions and were told about 17 kg N/ha, one third of the recommended rate. Forty-six years of daily climatic data from Masvingo, a local meteorological station, were used to simulate maize yields with 0, 17 and 52 kg N/ha. The results of this simulation confirmed farmers' perception of quite variable nitrogen response, but also suggested useful responses to 17 kg N/ha. The outputs of this simulation were then calculated as 'economic rates of return' to fertilizer use and expressed in terms of probability of success. Except in very bad years, rates of return to the farmer-preferred rate of 17 kg N/ha were substantially better than the recommended rate. The outputs of this simulation gave farmers, fertilizer traders, extension staff, NGOs, donors and researchers the confidence to successfully evaluate this 'microdosing' rate of N with 170,000 farmers in Zimbabwe in the 2003/04 cropping season. Despite poorer-than-average rains, microdosing increased maize grain yields by 30–50% and almost every farmer achieved significant gains. The initiative is ongoing and expanding, enabling farmers to adapt their attitude toward fertilizer use as well as allowing their support agents to adapt their fertilizer recommendations.





The way forward: Implementing ICRISAT's strategy

ICRISAT recognizes that managing climatic uncertainty and adapting to change in the SAT cannot be a separate agenda or an end in itself. It must be seen as an integral part of all that we do. The probability of biophysical and economic success of all that we do within our Integrated Genetic and Natural Resource Management (IGNRM) framework (Twomlow et al. 2008c) will be influenced by seasonally variable climates and future changes in the nature of that climate. If we are to see the successful development, targeted promotion, adoption and impact of

Box 2. Disaggregated effects of predicted changes in temperature and rainfall on sorghum yields in the SAT.

In preliminary cropping simulation exercises to assess the impacts of climate change on sorghum yields in the SAT of Africa and Asia the following three scenarios were examined: current cropping constrained only by climate; current climate modified for temperature change for the region; current climate modified for both temperature and rainfall change for the region. (The impacts of CO_2 rises cannot be adequately accounted for with the currently available cereal modules.)

Future changes in temperature and rainfall in the SAT

(Based on regional predictions for A1B scenario for the end of the 21st century)

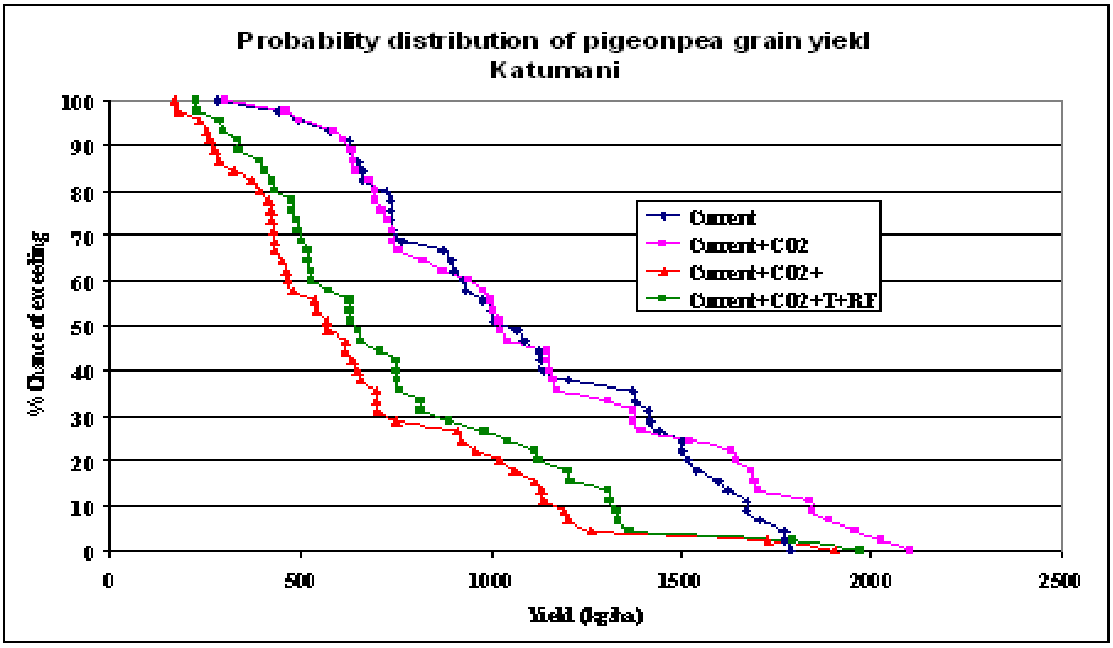
Region	Season	Temperature response (°C)	Precipitation response (%)
East Africa	Oct, Nov, Dec	3.1	11
	Mar, Apr, May	3.2	6
Southern Africa	Oct–Mar	3.1	-10
West Africa	Jul–Oct	3.2	2
South Asia	Jun–Feb	3.3	11

Disaggregated effects of climate change on % change in sorghum yields

Region	Potential grain yield (kg ha^{-1})	Rainfall effect on yield	Temp. effect on yield	CC effect on yield
East Africa short rains	3244	+10%	+11%	+21%
East Africa long rains	2232	+6%	+42%	+48%
Southern Africa	2753	–6%	–16%	–22%
West Africa	1896	+6%	–20%	–14%
South Asia	2800	+1%	–38%	–37%

- Initial simulations clearly showed that for any given climate change (CC) scenario, the impact of CC will vary both in nature and magnitude from location to location, from crop to crop, from cultivar to cultivar and from season to season.
- The % of seasons in which climate change is either a 'good' or 'bad' thing are very relevant to the needs and choices that risk-averse farmers might wish to make in their adaptation strategies, and how ICRISAT responds as an Institute with both a crop and ecological mandate.

Box 3. Probability distribution of predicted changes in temperature and rainfall on pigeonpea grain yield



Pigeonpea is commonly grown in the semi-arid tropic of Kenya. Medium-duration varieties are currently favoured. They are sown in the October, November and December rainy season and flower and fill their grain in the rains of March, April and May. Using 45 years of historical daily climatic data from Katumani and the crop growth simulation model, APSIM, we examined the impact of disaggregated climate change scenarios which comprised a 3°C increase in temperature, a 10% increase in rainfall and a CO_2 level raised to 700ppm (IPCC 2007). We compared the outputs with the probability distribution of yields under the existing climate. While we observed an expected CO_2 fertilization effect, this was more than offset by temperature increases. Temperature increases effectively shorten the duration of crop growth, resulting in the crop flowering and starting to fill grain before the onset of the March, April, May rains. The resultant greatly increased moisture stress during this critical period is clearly reflected in much reduced yields. While this was partially offset by a 10% increase in rainfall, yields under the climate change scenario examined remained much reduced.

agricultural innovations, then the climate-induced risk and the probability of success of those innovations must first be determined for the contrasting SAT environments that we serve.

To address the impacts of this overriding development challenge, ICRISAT has developed an Operational Research Strategy (2008–2015) entitled *Adaptations to and Mitigation of Climate Change in the Semi-Arid Tropics* (ICRISAT 2008) and that complements ICRISAT's other Operational Research Strategies (Fig.2). Six key factors were recognized as being fundamental in the SAT and provide the framework within which we address climate change:

1. In the medium- to long-term, rainfed farming systems will remain vital for future food security, but investment in them will have to be greatly increased.
2. Such increased investment by risk-averse farmers and stakeholders will only take place through a better quantification of climate risk that enables the identification, targeted promotion and implementation of investment innovations that have a high probability of success in the context of variable climates.
3. Climate change is likely to make rainfed agriculture even more risk prone in the rainfed systems of the SAT. Farming systems will need to adapt to these changes; however, the exact nature of these changes still remains uncertain.
4. The livelihood resilience and adaptive capacity of impoverished and marginalized rural communities must first be improved in the context of current climate variability if they are to have any hope of adapting to future climate change.
5. Climate driven tools, when linked with spatial bio-economic models such as 'IMPACT' will allow the development of integrated climate risk management strategies that will facilitate targeted investment innovations.
6. Adapting ICRISAT mandate crops to current and future vagaries of climate is, and will continue to be, an essential component of our work.

In pursuance of furthering our research agenda, ICRISAT must capitalize on its initial portfolio of climate change projects (Table 4) and ensure that it continues to play a major role in the development of gender equitable agricultural adaptation and mitigation strategies as an integral part of agricultural development in the most vulnerable areas of the SAT in sub-Saharan Africa and Asia.

Expected International Public Goods from this portfolio of projects include:

- Improved understanding of climate variability and adaptation-coping strategies for the rural poor;
- Best practices and institutional innovations for mitigating the effects of climate change; and
- Strategies to address socioeconomic problems relating to changing weather patterns and availability of a range of initiatives for their alleviation.

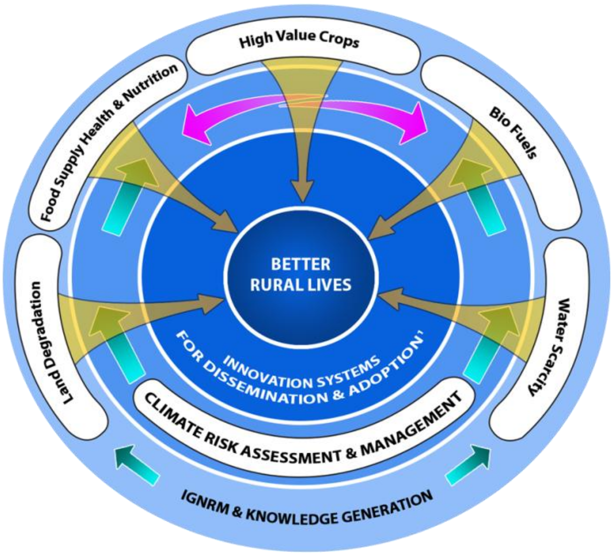


Figure 2. Integrating climate risk management into ICRISAT's integrated genetic and natural resource management.

To achieve this ICRISAT will help build capacity within the national agricultural research and extension systems (NARES) of sub-Saharan Africa and Asia to undertake climate risk analyses from both biophysical and socioeconomic perspectives. ICRISAT has identified a set of four tools to analyze climate data and produce high-quality information and products tailored for agricultural applications and to quantify the relationships between climate, crop, soil and water resources, and economic drivers for use in the strategic and tactical management of agricultural systems. The suite includes:

- INSTAT and GENSTAT– statistical analytical tools with special features for analyzing climate data;
- MARKSIM – a stochastic weather generator for generating synthetic daily weather data by estimating the third-

order Markov model parameters from interpolated climate surfaces;

- APSIM/DSAT – modelling frameworks that provide capabilities via component modules to simulate cropping systems over variable time periods; and
- MARKSIM - a regional modelling framework that provides capabilities to simulate production systems over variable time periods.

Conclusion

ICRISAT is well aware of the seriousness of climate change and has positioned itself to respond to the challenges that it poses for the farming communities of the SAT in Africa and Asia. Our response is centered around a two-pronged strategy that focuses on increasing the livelihood resilience and adaptive capacity of the rural poor and adapting our mandate crops to grow in a warming world. This strategy is resulting in recognition by our partners and support agents that ICRISAT is becoming a committed leader in this field in serving the farmers of the SAT.

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13. Climate change and geomorphic processes in deserts: insights for the future from the record of past climate change

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Abstract

Dune systems in current arid and semiarid regions provide a sensitive indicator of past, present, and future climate change and variability. Studies of dune field response to past climate changes provide information on the range of change that can be expected on decadal to millennial timescales. Variations in temperature and precipitation on all time scales result in changes in vegetation cover and sand mobility. These changes can be modeled using the dune mobility index and the effects of future climate changes can be assessed on a regional scale. Predictions for many desert regions indicate widespread increased dune mobility in the late twentyfirst century, leading to severe disruption of many arid and semiarid ecosystems.

Introduction

Climate change is an ongoing and complex natural process that has occurred on a variety of timescales throughout Earth's history. Irrespective of the causes of climate change (natural vs. anthropogenic), the effects of changes in temperature and precipitation have direct and significant effects on landscapes and ecosystems. Understanding these effects is a major area of climate change research, with great implications for public policy and decision making for land management. The importance of water to human and natural systems in deserts makes them very sensitive to those changes in climate that affect the amount, type, timing and effectiveness of precipitation. Observational data show that changes in seasonal and annual temperature, precipitation, runoff, groundwater recharge, and evapotranspiration are occurring today in many desert regions (e.g. Trenberth et al. 2007) and climate models predict that they are likely to continue in the future, leading to expansion of desert areas and increased aridity in others, in addition to greater severity and duration of periods of drought. Many arid areas have already experienced significant increases in temperature and a reduction in rainfall over the past two decades, manifested in extended droughts in such areas as the SW USA and southern Australia. These ongoing and future climate changes will likely have significant geomorphic impacts, including changes in flood magnitude and frequency, the occurrence and severity of dust storms, and the activity of sand dunes.

Understanding of geomorphic responses to climatic change is based on two approaches: (1) studies of the response of geomorphic systems to modern and historical climatic variability (e.g. El Niño events; extended droughts). Observations enable threshold conditions to be identified and well-constrained process - response models to be developed; and (2) studies of Quaternary sediments and landforms, which provide information on the response of landforms to climate changes of greater amplitude and duration than experienced in the observational record, including those of Glacial-Interglacial cycles, as well as greater extremes in more recent times (e.g. the Little Ice Age). These studies help to understand the range and magnitude of possible responses to climate change.

In this paper, I discuss the application of these approaches to studies of desert sand dunes, as an example of the effects of climate change on arid lands and their geomorphic processes. For a full discussion of the effects of climate change on desert geomorphic processes and landscapes see Lancaster (2009); Meadows and Thomas (2009) cover tropical semi arid regions in the same volume.

Principles of dune system response to climate change

Desert dune systems occupy up to a third of the area of low and mid latitude arid areas (Fig. 1) and form important landscapes and ecosystems (Lancaster 1995). Dune systems are dynamic geomorphic and sedimentary environments that respond to climate change and variability on a variety of temporal and spatial scales. Principal responses to climate change are: (1) activation and stabilization of individual dunes and areas of dunes; (2) formation of new areas of dunes; and (3) erosion of existing dune areas.

Geomorphic studies indicate that sand dune areas tend to accentuate the effects of both dry and wet phases (Rognon 1982). In periods of increased rainfall, the high infiltration capacity and porosity of dune sands favors the growth and persistence of vegetation (Thomas and Tsoar 1990), which may lead to the partial or complete stabilization of the dunes and soil formation (Fig. 2). If the periods of increased rainfall are of sufficient magnitude and duration, then water tables may rise, leading to the formation of pond and marsh deposits in interdune areas. In contrast, periods of aridity will give rise to a very unfavorable biotic environment within the sand sea, with low water tables and active sand movement preventing the growth of vegetation.

The overall state of the dune system is governed by sediment supply, availability and mobility (Kocurek and Lancaster 1999). In turn, sediment supply, availability, and mobility are determined in large part by regional and local climate. Sediment supply is the emplacement of sediment that serves as a source of material for the dune system. It may be affected by variations in flood magnitude and

Figure 1. Dune systems of the world (after Sun and Muhs 2007).

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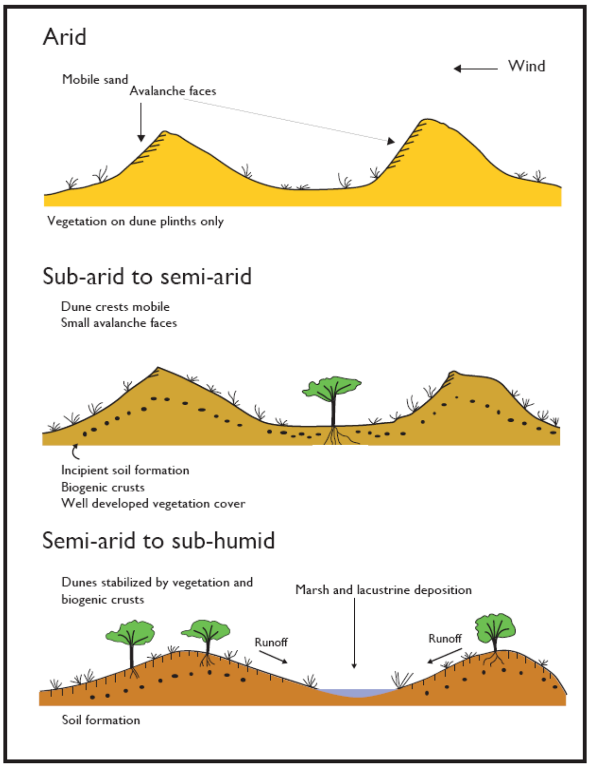

Figure 2. Conceptual model for dune system response to climate change (after Rognon 1982).

frequency, river sediment load, lake and sea levels, and rates of bedrock weathering that affect sediment source areas. Climatic changes impact sediment availability (the susceptibility of a sediment surface to entrainment of material by wind) primarily via the effect of vegetation cover, which protects the sand surface and partitions wind shear stress between the sand surface and the vegetation roughness, and soil moisture. Sediment mobility (sand transport rates) is affected by climate change via changes in the magnitude and frequency of sand transporting winds.

The relations between sediment supply, availability, and mobility at any point in time, as well as their variation through time, define a series of states of the system (Lancaster 1999). They also determine the response of the system to external forcing factors such as climate change so that the system may be described as:

(1)Transport limited, in which actual rate of sand transport (Qa) equals the potential rate (Qp) and the system is limited only by the capacity of the wind to move sediment from source zones. Such systems are potentially affected by climate changes that result in reduced wind energy.

(2)Availability limited, in which Qa < Qp and the system response is controlled by vegetation cover. Changes in vegetation cover as a result of changes in rainfall or disturbance have a major effect on the dynamics of such dune areas, which are widespread in desert margin areas.

(3)Supply limited, in which Qa << Qp and the system is starved of sediment. Climate changes that enhance sediment supply, such as increased flooding of river systems or ephemeral lakes (playas) may affect such systems.

Dune activity

The conventional view of dune systems is that their formation or reactivation indicates periods of aridity and therefore increases in aridity will result in enhanced sediment availability and/or mobility leading to increased dune activity (larger areas of mobile sand, increased rates of dune migration or extension). Recent work however suggests that this is an oversimplification of the complex and often non-linear relationships that exist between desert dune activity and climate (Chase 2009; Hugenholtz and Wolfe 2005; Yizhaq et al. 2008).

Dunes have been classified as ‘active’, ‘inactive’, ‘mobile’ or ‘stable’ (Lancaster 1994), without a clear definition of these states. ‘Active’ and ‘inactive’ dunes represent end members of a continuum of dune dynamics that ranges from mobile (rapidly migrating) barchan dunes to linear or crescentic dunes that are stabilized by vegetation (Thomas 1992). Geomorphic and sedimentary criteria can be used to classify dunes as active, dormant, or relict forms (Katra et al. 2009; Lancaster 1994). Active dunes are characterized by contemporary and widespread surface sand transport, erosion, and deposition. Depending on their morphological type, active dunes may be migrating in the net transport direction (crescentic or transverse dunes), extending (e.g. linear dunes), or vertically accreting (e.g. star dunes) (Thomas 1992; Thomas and Shaw 1991). The degree of aeolian activity may vary seasonally, annually or decadally in response to changes in sand supply, wind velocity, vegetation cover, and moisture content (Bullard et al. 1997). Dormant dunes are those on which erosion and deposition of sand is currently absent or at a low level as a result of low wind energy or vegetation cover; these dunes may revert to an active condition as a result of minor climatic changes (e.g. prolonged regional drought) or disturbance (grazing, fire). Relict dunes do not experience significant sand movement in present-day conditions and are clearly a product of past climatic regimes or depositional environments and have been stabilized by vegetation for a period of at least 10^3 years. Relict dunes may revert to an active state only as a result of major climatic changes.

The temporal and spatial scales on which dune activity occurs are important. Dunes may be seasonally active (e.g. in the dry season), or only active during and after periods of drought (Muhs and Holliday 1995; Thomas and Leason 2005). Periods of above normal rainfall (e.g. El Nino years) may result in germination of annual or ephemeral vegetation and thereby stabilize dunes for months or years. Changes in wind energy across dunes may result in some dunes being active in crestal areas that are more exposed to the wind, whereas lower, less windy areas are stabilized by vegetation (Livingstone and Thomas 1993).

Thresholds for dune activity

Some workers have sought to identify precipitation limits for active dunes. In many desert regions, active dunes occur where mean annual rainfall is 100 - 150 mm or less (Fig. 3), but the situation is much more complex because of the non –linear relations that exist between wind energy, effective precipitation and sand movement or dune activity. Vegetation cover thresholds for active sand transport have been determined empirically from field studies which suggest that a vegetation cover of 14-17% is sufficient to restrict sand transport on sand surfaces (Allgaier 2008; Lancaster and Baas 1998; Wiggs et al. 1995). Studies in Australia, however, suggest that in this area, the threshold vegetation cover may be as much as 35% (Ash and Wasson 1983), although recent field studies suggest a greater range of vegetation cover restricts sand movement (Hesse and Simpson 2006) . In many areas, biological crusts may interact with vegetation cover to promote stabilization of sand surfaces (Kidron et al. 2000)

Dune mobility

Models for the response of dune systems to climate change at various timescales have concentrated on the relations between vegetation cover, wind energy, and effective precipitation. These relations are captured in part by the widely used dune mobility index (e.g. Lancaster 1988; Lancaster and Helm 2000; Hugenholtz and Wolfe 2005). This index provides a measure of potential sand mobility (M) as a function of the ratio between the annual percentage of the time the wind is above sand transport threshold (W) and the effective annual rainfall (P/PE), where PE is the potential evapotranspiration.
$M = W/(P/PE)$.

Empirical thresholds for different levels of dune activity suggest that dunes and dunefields are fully active when the index has a value of >200; 100 - 200, dunes active, but interdunes and lower dune slopes are vegetated; crest areas, but not interdunes are active at a mobility index 50 - 100; and dunes are inactive and completely stabilized by vegetation when the index has a value of <50 (Fig. 4). The

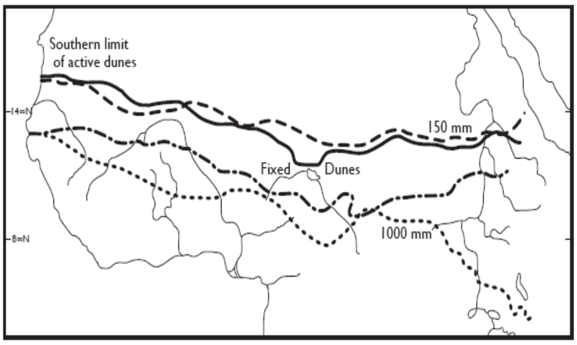

Figure 3. Rainfall limits for dune activity in the Sahel region of Africa.

index has been tested empirically in a number of dune areas (e.g. Muhs and Maat 1993; Lancaster and Helm 2000), and also tested against data on climatic variables and measured sand transport rates. Although not a good predictor of the rate of sand transport from year to year, probably because of the lagged response of vegetation cover to rainfall changes, the index does represent the overall state of the system well, and can therefore be used to assess decadal and longer term responses to climate change (Bullard et al. 1997). For example, dune mobility can vary as a result of changes in wind energy or effective precipitation. Modifications to the index that address lags and seasonal effects (Thomas et al. 2005) represent a valuable advance, but are untested outside the region to which they were first applied.

Recently developed models (e.g. Hugenholtz and Wolf 2005 and Yizhaq et al. 2007) stress that the response of dunes to climate and vegetation change on annual to decadal time scales is non-linear (Fig. 5). In general, the process of stabilization of dunes by the establishment and growth vegetation occurs more slowly than the (re-) activation of dunes as a result of decreased vegetation cover. The result is a bi-stable state of dunes – active or stabilized by vegetation - that is dependent on the energy of the wind regime. In places with very low wind energy, dunes have only one stable state, which is vegetated and fixed; at intermediate levels of wind energy, both active and stabilized dunes can co-exist; whereas, active dunes are the stable state in

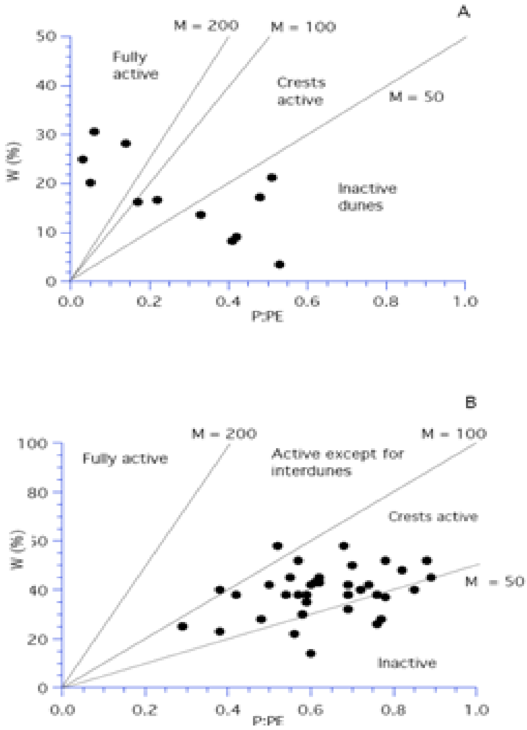

Figure 4. Values of the dune mobility index for (A) southern Africa and (B) Great Plains (data from Muhs and Maat 1993). Note that dunes can change activity level as a result of changes in effective precipitation and or wind strength.

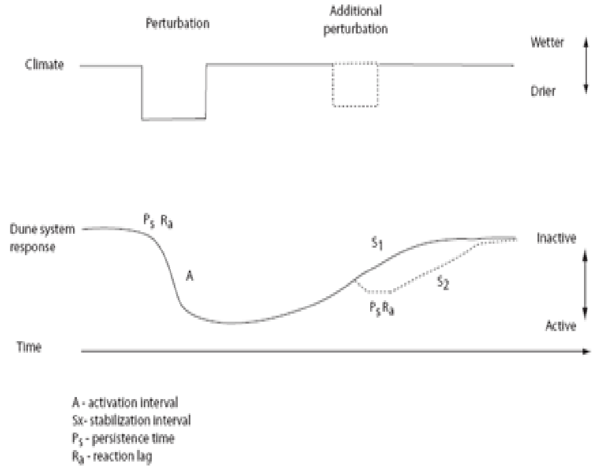

Figure 5. Conceptual model for the response of dune systems to climate change (after Hugenholtz and Wolfe 2005).

areas of very high wind energy (Yizhaq et al. 2007).

Response of dune systems to climate change

A number of empirical studies have documented the response of dune systems to climate change on a variety of timescales. Most relevant to understanding the response of dune systems to future climate changes are those that have occurred during the past 2000 years, when atmospheric circulation patterns resemble those of today. All the dune systems discussed below originally formed in past climate conditions of much more extended aridity and in some cases greater wind energy as a result of glacial-interglacial climate changes. The effects of such changes are discussed in reviews by Lancaster (2007) and Sun and Muhs (2007). In most cases, the same constraints on system response that applied at these time scales also apply to late Holocene and historical changes in dune system dynamics.

Availability limited (Vegetated) dune systems

At Great Sand Dunes (Colorado), Marîn et al. (2005) documented migration rates of parabolic and barchan dunes over a period of 70 years using satellite images and aerial photographs (Fig. 6). They found that migration rates were up to six times higher in drought episodes compared to intervening wetter periods. More than 50% of the movement of parabolic dunes occurred during periods of drought that occurred between 1936 and 1941; 1953 and 1966; and 1998 and 1999. They identified a threshold condition with a Palmer Drought Severity Index (PDSI) value of less than -2 (equivalent to a reduction in summer and fall precipitation of 25%,) for increased dune activity. This assessment is supported by the long-term perspective provided by correlations between decadal-scale drought episodes recognized in tree ring records from the area and periods of aeolian deposition dated by luminescence methods (Fig. 6), suggesting an overall control of dune activity by sediment availability, determined by rainfall and vegetation cover, in this area (Forman et al. 2006).

In Australia, low wind energy over much of the area covered by desert dunes limit dune activity (Ash and Wasson 1983), but recent studies emphasize the importance of vegetation cover in limiting sand movement and dune activity (Hesse and Simpson 2006). These authors note that dune activity is more widespread after vegetation disturbance as well as after periods of extended drought. The record of dated aeolian depositional episodes during the Holocene supports the concept of increased dune activity in dry episodes (Hesse et al. 2004).

Dune systems in semi-arid, desert margin areas appear to be particularly sensitive to climate change and variability. On the Great Plains of the USA and Canada, many of these dunes are partially or completely stabilized by vegetation in current climatic conditions (Muhs and Wolfe 1999). Reports from early explorers and surveys of the Great Plains of the USA indicate however much more widespread dune activity, probably as a result of drought conditions, in the nineteenth century (Muhs and Holliday 1995).

Studies of dune stratigraphy have identified and dated many periods of past activity of these systems in the recent past. For example, six periods of dune activity have been recognized in the area of the Nebraska Sand Hills during the past 1500 years and correlated with evidence of drought episodes elsewhere in the region (Forman et al. 2005; Sridhar et al. 2006). These periods occurred around 1390, 670, 470, 240, 140, and 70 years ago. The most significant of these periods of activity was coincident with a widespread and extended drought (megadrought) that occurred in the sixteenth century. In addition, sand accumulations related to the 1930's drought can be recognized. Elsewhere in this region, a major period of linear dune formation occurred 700-1000 years ago coincident with a period of widespread drought during the Medieval Warm Period (Mason et al. 2004; Sridhar et al. 2006). During this episode of dune formation, winds shifted direction so that summer southeasterly flow of humid air was replaced by dry southwesterly flow.

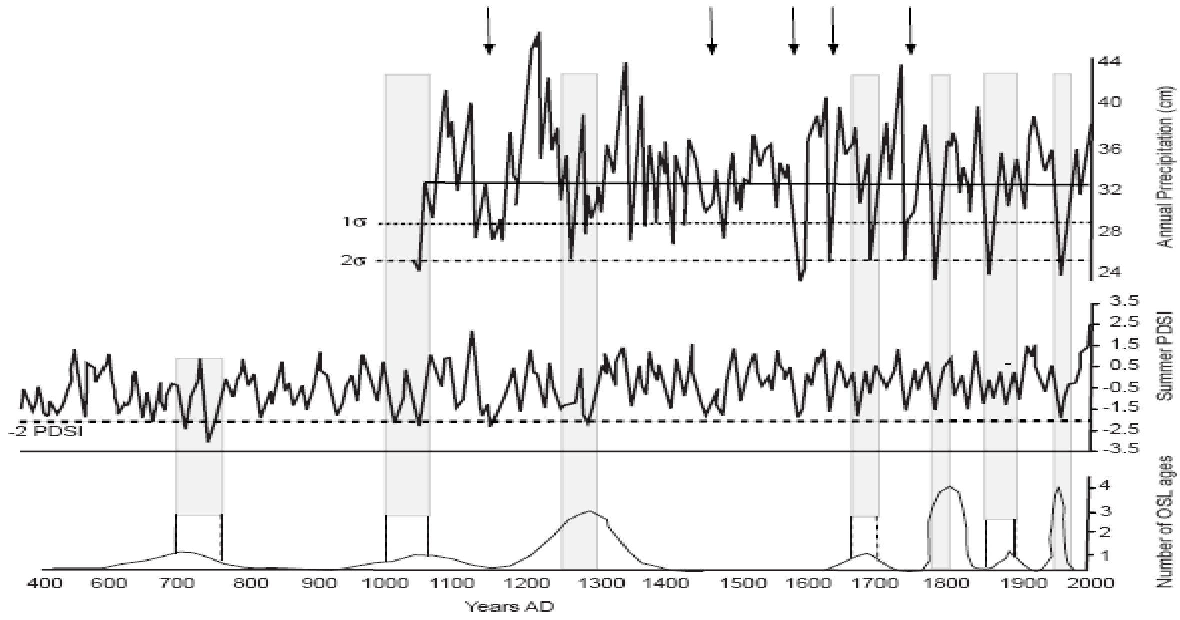

Figure 6. Relationships between (a) records of inferred precipitation, (b) summer Palmer Drought Severity Index (PDSI) from tree ring data, and periods of OSL-dated dune activity at Great Sand Dunes National Park, Colorado (after Forman et al. 2006). Vertical grey bars indicate periods of possible correspondence between aeolian and tree ring records; Arrows indicate periods of drought indicated by tree ring records, but for which there is no equivalent aeolian record.

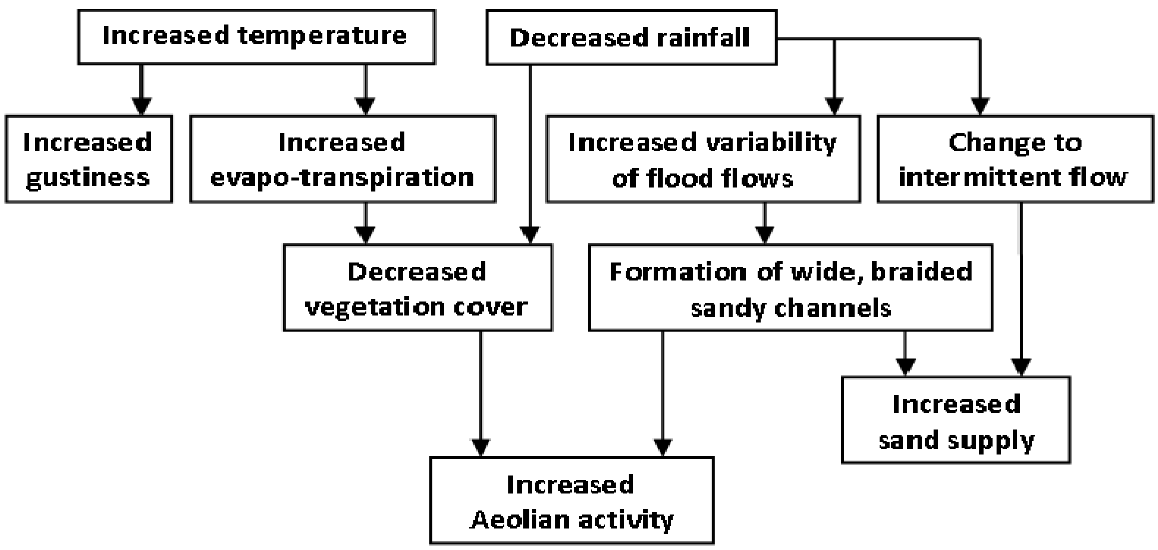

Figure 7. Conceptual model for response of aeolian systems to climate change and sediment supply (after Muhs and Holliday 1995).

Supply limited systems - Effects of sediment supply variations

Many of the Great Plains dunefields lie immediately downwind of sand sources in the flood plains of braided rivers that cross the region. Muhs and Holliday (1995) recognize interactions between reduced precipitation and augmented sediment supply during drought periods, as a result of reduced and/or more variable river flows and more extensive sandy areas in floodplains, which provide a source of sand for adjacent dunefields (Fig. 7).

In the Mojave Desert, dune areas close to terminal areas of river systems appear to have responded sensitively to changes in the magnitude and frequency of flood events, which affected sediment supply to sand source areas. Multiple, short-duration episodes of late Holocene aeolian accumulation are recorded close to modern sand source areas. Ages for sediments in the Kelso Dunes sand transport system (including the Cronese basins) cluster between 0.14 – 0.20, 0.4 – 0.5, 0.7 - 0.85, 1.4 – 1.7, 2 – 3, 3.5 – 4.2, and 5.4 – 6.7 ka (Clarke and Rendell 1998; Lancaster and Tchakerian 2003). These episodes of aeolian deposition correlate well with the record of major floods in the Mojave River system and elsewhere in the region (Ely et al. 1993; Enzel et al. 1989; Enzel et al. 1992) and therefore likely reflect the effect of enhanced sediment supply from the Mojave River, in a similar way to aeolian system response to modern floods such as those that occurred in 1993 and 2004.

Prospects for the future

Given the sensitivity of dune systems to modern and historical climate variability, it is to be expected that future climate change will have similar or enhanced effects on these areas. The effects of such changes in climate (especially increased temperatures) may be explored using the dune mobility index.
Examination of climatic data and values of the Lancaster dune mobility index (Muhs and Holliday 1995; Muhs and Maat 1993) for the Great Plains of USA indicate that the main control of dune mobility in this region is effective precipitation (P/PE), which determines vegetation cover. Wind energy is generally more than sufficient for active sand transport. Therefore any change in the P/PE ratio as a result of increased temperatures and/or decreased precipitation will lead to higher values of the mobility index and increased potential for sand mobility. Modeling of future climatic conditions for the Great Plains and the Colorado Plateau (Fig. 8) suggests that increased temperature and reduced precipitation predicted by climate models will lead to widespread reactivation of dunes and sand sheets in this region (Muhs and Maat 1993).

The Kalahari region of southern Africa contains extensive vegetated sand sheets as well as linear dune systems, which were formed in past conditions of greater aridity (Lancaster 1981; Telfer and Thomas 2007). Field observations (Wiggs et al. 1995) and satellite images (Thomas and Leason 2005) indicate that these dunes, especially in the drier, southwestern Kalahari are very sensitive to vegetation reduction as a result of climate variability or disturbance and become much more active when vegetation cover is reduced below 14%.
In China, Wang et al. (2009) adopted a similar approach to Thomas et al. (2005), and used an unmodified dune mobility index in a range of future climate scenarios

Thomas et al. (2005) have used a modified version of the Lancaster dune mobility index that incorporates monthly data, with additional moisture lag and seasonality components in conjunction with information on temperature, rainfall, and wind speed from global climate models (GCM) under a range of future emissions scenarios to model the response of the Kalahari region to future climate change. Regardless of the scenario or GCM, the dune areas of the Kalahari become progressively more active in the twentyfirst

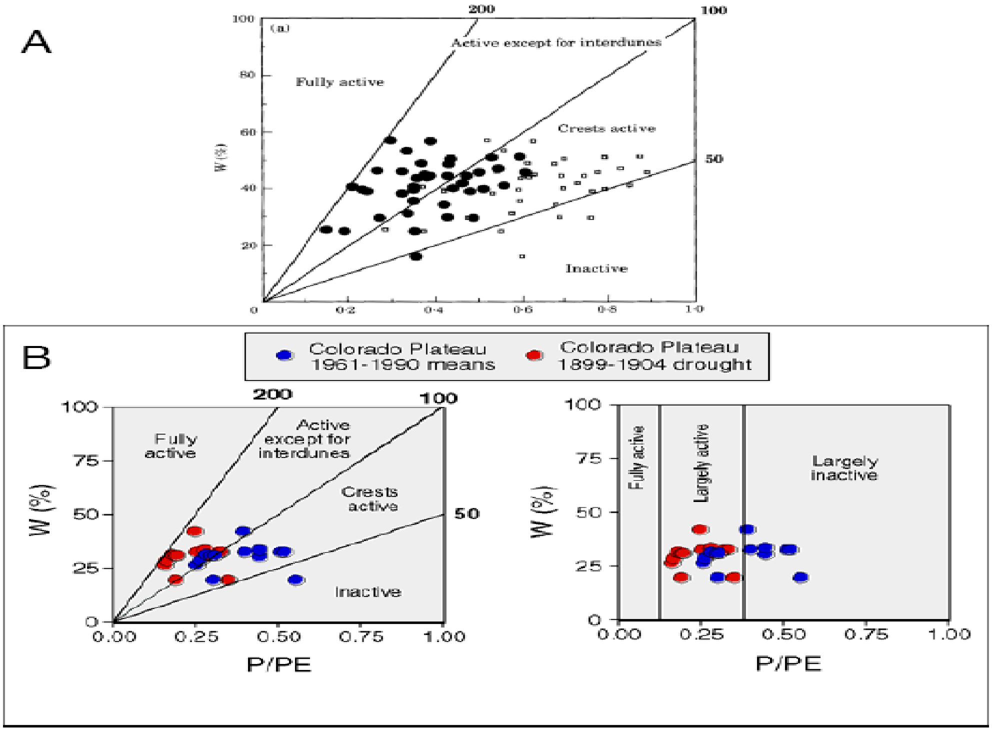

Figure 8. Response of dune systems on the Great Plains and Colorado Plateau to future climate change as indicated by values of the dune mobility index (in part after Muhs and Maat 1993).

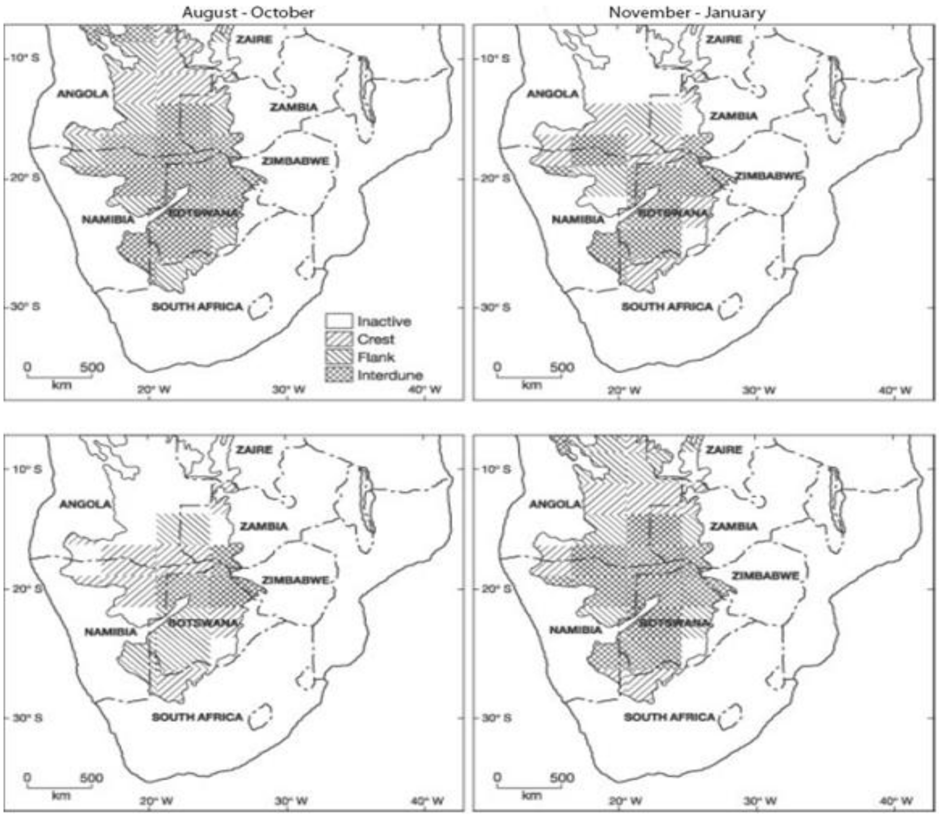

Figure 9. Response of Kalahari dune systems to future climate change (after Thomas et al. 2005).

century, becoming fully active by 2070 (Fig. 9).The implications for the current land use and economy of this region (dominantly extensive cattle raising) are obvious and severe.to estimate future trends in dune mobility in China. Given the vast extent of dune systems in China and the different climatic
conditions they experience today,a complex spatial and temporal pattern is evident, with some regions experiencing decreased dune activity in coming decades. Dune activity increases in most regions after 2040 as a result of higher temperatures and less effective precipitation which give rise to reduced vegetation cover.

Conclusions

Studies of the response of dune systems to historical climate change and variability indicate the sensitivity of these systems to changes in vegetation cover as a result of changes in effective precipitation. These observations can be used in conjunction with simple models for dune activity to understand the response of dune systems to future climate change. The results of such

studies show that many arid regions will experience more widespread and more intense dune activity in coming decades, with important implications for human settlement and land use in many arid and semiarid areas.

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14. Sustainable desert development as a means for combating global warming and overcoming global food reduction

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Abstract

The twenty-first century is facing a number of challenges due to both environmental and economic factors. Burning of fossil fuel has resulted in the release of huge amounts of CO_2 in the atmosphere, a major cause of the climate change phenomena. This concern as well as the depletion of oil reserves and increasing oil prices has prompted some countries to restrict their export of food grains and convert them into biofuels. This is causing a major problem for countries that do not enjoy food sufficiency even though they might have necessary funds for imports. The above changing environmental and socio-economic conditions can be dealt with by ensuring the sustainable development of desert lands based on a holistic approach where agricultural, technological, socio-economic and environmental concepts are implemented. This is achieved through: 1) Changing the cropping patterns in newly reclaimed desert lands to satisfy food self-sufficiency rather than food security; 2) Encouraging tree planting as well as other plant species in the desert and promoting no-till agriculture; 3) Implementing new measures to rationalize use of and develop water resources (water pricing, recycling, desalination, new irrigation and pumping techniques); 4) Promoting the use of energy efficient as well as solar / wind technologies, and designing housing to save energy and attract new residents. Facilities such as schools, hospitals, clubs, and other services should be equipped with super-efficient lighting and appliances and professionally operated in order to attract those who will have to migrate from their homes because of the effects of global warming or due to expected population increases; and 5) Building nuclear power plants in the desert to replace fossil-fuel based power plants to decrease CO_2 emissions.

Introduction

The twenty-first century is facing a number of challenges which are due to both environmental and economic factors. While on the one hand, the tremendous increase in the burning of fossil–fuel in developed and some developing countries has resulted in the release of huge amounts of CO_2 and other green house gases in the atmosphere which has been considered the major cause of the climate change phenomena. On the other hand, the depletion of oil reserves, as well as increasing prices of oil, has prompted some countries to convert food grains into ethanol or other biofuels and thus restricting the exports of their grain production causing a major problem for countries which do not enjoy food sufficiency even if they have necessary funds for importing their food needs. These changing environmental and socio-economic conditions can be dealt with by ensuring the sustainable development of desert lands based on a holistic approach where agricultural, technological, socio-economic and environmental concepts are implemented.

Desert development requires mobilizing vast material and human resources, including farmers, laborers, agricultural specialists, physical scientists, social scientists, engineers, and managers, embracing in integrated manner many fields of knowledge, resources and responsibility. The means that make land productive must be in harmony with, and reinforce, those that support related socially desirable and economically viable activities and can sustain permanent human communities. All of these must confront two of the most important limiting factors for self–sustaining desert development namely water and energy.

Desert development

Proper development of a desert area requires coordinated efforts in many disciplines related to the natural resources, technological aspects, and community aspects appropriate for a specific desert area. This integrated approach is the basis for different types of desert development systems. The natural resources include soil and water appropriate for desert agriculture, mineral resources (including oil and gas) for mining and related activities, raw materials for industrial and agro-industrial activities, and historical, religious and / or scenic resources for local and international tourism. Good quality water is a limiting factor in most of these activities. Technological aspects are based on the type and quality of natural resources, associated developmental activities, and the level of education and culture of the original residents or new settlers in the community. Energy (conventional or renewable) is one of the major constrains in dealing with these activities. Environmental aspects, based on environmental impact assessment studies (EIA), have to be taken into consideration when selecting the appropriate technology to be used. Community aspects deal with infra-structure, socioeconomic base, desert architecture and aesthetics; all of which are very important factors in attracting some of the inhabitants of the overpopulated cities to desert communities.

The socioeconomic base of desert communities depends on one or more of the following activities:

1) Agriculture, including crop and animal production.
2) Mining, including oil, gas, and other raw materials.
3) Industry, including cottage industries, agri-business as well as small and major industries, constituting the economic base of new cities in the desert.
4) Tourism, including religious tourism (e.g. Saint Catherine, Wadi El Natroun in Egypt), historical tourism (e.g. Gamalia, east of El Minya, Egypt), and environmental ‘scenic’ tourism (e.g. Red Sea, Sinai, Matrouh, etc. in Egypt).

The above mentioned activities, contribute to the socioeconomic base of desert communities.

Sustainable desert development

Sustainable development, or environmentally sound development, implies that environment and development are closely linked and are mutually supportive. In other words, there will be no sustained development or meaningful growth without a clear commitment at the same time to preserve the environment and promote the rational use of resources. Sustainable development argues that the real improvement cannot occur unless the strategies being formulated and implemented are ecologically sustainable over the long term, are consistent with social values and institutions, and encourage public participation in the development process. As the primary objective is to provide lasting and secure livelihoods that minimize resource depletion, environmental degradation, cultural disruption, and social instability, this process can be viewed as an interaction among three systems: (a) The biological and resource system; (b) The technological system; and (c) The socioeconomic system. The general objective is to maximize the goals across all these systems through a dynamic and adaptive process of trade-offs.

In 1990 a task force, sponsored by the United Nations Development Programme (UNDP) and coordinated by the author (Bishay et al. 1992), was assigned the responsibility to propose strategies for sustainable development for Egypt. Based on the findings of the UNDP Task Force, the author developed a framework structure , as shown in Figure 1. This was discussed with peers in the Fourth International Conference on Desert Development under the theme 'Sustainable desert development for our common future', organized by the International Desert Development Commission in Mexico city, 25-30 July 1993.

As shown in this figure, in order to achieve sustainable development (and self reliance), a balance should be reached between economic growth and social development, resource management, and environmental protection. This is a dynamic system which would require appropriate management (especially under micro/macro crisis conditions), necessary finances, and research and development with emphasis on optimization between the ecological and economic dimensions of development. Public participation (social and political) and necessary infrastructure and support services are of utmost importance in implementing the different strategies proposed for achieving sustainable development. These strategies were grouped into four sets: (a) Public policy and legislation; (2) Information management, monitoring and public awareness; (c) Technical support (research and development, training); and (d) Institutional and international cooperation.

According to the UNDP Task Force, the proposed strategies should be prioritized as follows:

- To place human development programs at the center of development, including education and training; youth and empolyement; health and nutrition; women's role and status; public participation.

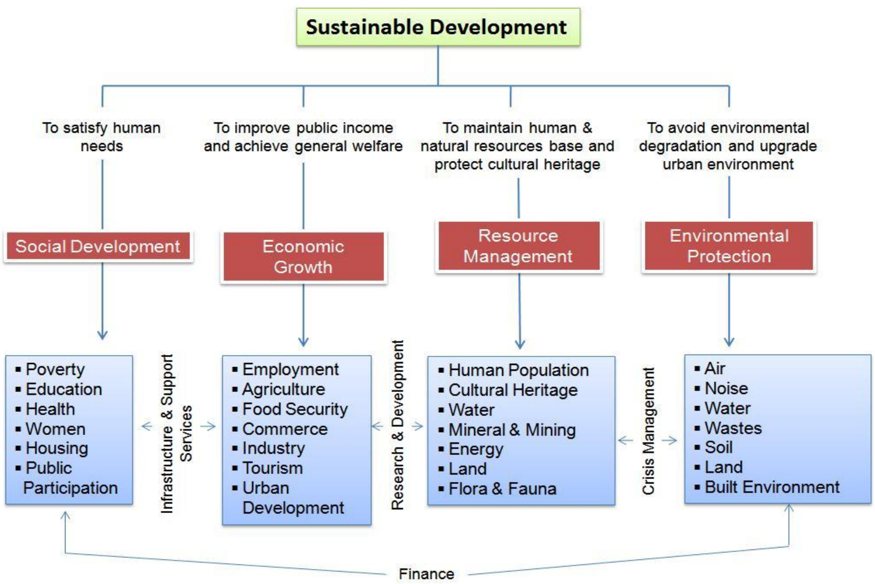

Figure 1. Sustainable development in Egypt.

- To control population growth rates and to achieve better redistribution of the people (10 percent of the population to live in the desert) and to deal with human resources as an asset for development.
- To rationalize long term use and development of freshwater, marine, land, and energy resources while minimizing associated pollution and/or degradation.

Three major factors should be considered when planning sustainable desert development. These are (a) Population increase and uneven distribution; (b) Water scarcity: and (c) Energy limitations.

Population increase and uneven distribution: Egypt's population in 1990 was about 55 million. In 1997 the population was about 63 million, and it reached 66 million in 2000 and about 80 million in 2008. In the year 2017-2020, the population is estimated to reach 90-95 million. At present, about 98% of the population lives on less than 5% of the land (mainly in the Nile Valley and Delta) that is not desert. What is needed is to promote birth control, and to achieve a better distribution of population over the entire area of the country (approximately 10% of the population living in the desert).

Water scarcity: Water is the most important ecological factor in the desert and represents the most critical resource in Egypt. In general, rainfall in Egypt is insignificant; only the northern stretches of the land, for a short distance inland, receive an annual rainfall of up to about 200 mm, and this is used for sporadic cultivation along the coasts. The Nile is Egypt's most important water source, at present supplying the country with most of its water requirements. The discharge of the Nile fluctuates from year to year, with an average annual discharge of 86 billion m^3. Egypt's annual share of the Nile water is 55.5 billion m^3, which is consumed around the year at the rate of 926 m^3 per sec during the winter months and 2660 m^3 per sec during the summer months. An additional 2.0 billion m^3, which were expected to accrue to Egypt in the year 2000 after the completion of the Jonglei Canal to divert the Upper Nile in southern Sudan and thus avoid excessive losses in the Sudd region, represent all the surplus that Egypt can obtain from the Nile. In addition, the annual rate of reuse of agricultural drainage water was 4.9 billion m^3 in 1997 and according to the Ministry of Irrigation should increase gradually to 8.40 billion m^3 by the year 2017.

Ground water is another valuable source for use in land reclamation projects. The main groundwater aquifer lies in the Western Desert and consists of a thick sequence of sandstones with clay lenses overlying basement rocks. The system is confined by a thick clay sequence in the oases and their vicinity. This produces artesian conditions and results in free-flowing wells in the depression areas. The regional hydraulic gradient is from the southwest. Studies indicate that this water has been stored from the old rainy ages and accordingly should be considered as fossil water, i.e., nonrenewable. Based on a simulation model as well as technical and economic feasibility studies, one billion and five hundred thousand m^3 of this water can be used annually to irrigate about 143,000 feddans (acres) distributed among the different Western Desert oases: Kharga, Dakhla, Farafra, and Bahariya. This is in addition to the land which can depend on rainfall for part of its water supply (the North-West coast and Siwa Oasis). For the last fifty years, groundwater extraction in the Kharga and Dakhla depressions has exceeded natural recharge with resultant head decline and falling free flow discharges. The groundwater reservoir is immense, but the availability of water is essentially limited by the pumping head. On the other hand, the groundwater in the southern part of the Western Desert is considered to be enough for cultivating about 250,000 feddans (acres) in East Oweinat and around the High Dam Lake.

Study of the Water Master Plan reveals that in the year 1997, Egypt required 66.34 billion m³ of water. In the year 2017, when Egypt's population is expected to reach over 95 million, the situation is questionable since Egypt's water needs would reach about 86.74 billion m³ if we continue the planned rate of expansion in land reclamation and if the current mismanagement of water resources is not corrected. Some drastic measures and innovations are needed now, especially that the effects of global warming on water availability from different sources are not easy to predict.

Energy limitations: Energy is another critical resource. Apart from small quantities of coal in Sinai, fossil fuels in the form of oil and gas are known around the Gulf of Suez and the northern parts of the Western Desert. Egypt is currently self-sufficient in both of these, and this favorable situation may last for some time. Thus, while in 1991-1992 Egypt's production of oil and gas was 55.1 million tones oil equivalent (MTOE), the consumption was only 31.9 MTOE, leaving a balance of 23 MTOE. Production in 2004-2005 reached 69.7 MTOE while consumption was 43.7 million, leaving a balance of 26 MTOE. It should be noted, however, that about 50 percent of the production is the share of the foreign partner. Accordingly, the given balance will just about pay the partner's share. According to a report of the Egyption National Specialized Councils, the requirements will reach 70 MTOE in the year 2019-2020, while the production is expected to be 104 MTOE. The balance will not be enough to satisfy the share of foreign partners.

In recognition of the above, the UNDP sustainable development program in Egypt proposed the following strategies, some of which are currently being adopted by the government of Egypt (GOE):

1) Increase tariffs of liquid fuel and electricity to rationalize their use.
2) Conduct intensive explorations for petroleum and natural gas to increase known reserves.
3) Maximize the use of new and renewable energy resources (through introduction of incentives).
4) Improve mass transport facilities to decrease car use.
5) Develop coal and oil shale resources and convert oil burning systems to gas.
6) In industry, use energy efficient equipment and conduct waste heat recovery.
7) Develop fuel technologies to substitute leaded fuel.
8) Increase public awareness with strategy issues and renewable energy applications.
9) Interconnect the national network to Middle Eastern, African, and European networks.

The food price crisis

The food price crisis is a global phenomenon with several commonly accepted drivers. According to the IMF 2008 World Economic Outlook, the diversion of food crops to the production of biofuels is responsible for almost half of the increase in the prices of major food crops in 2006-2007. Speculative behavior in commodity markets also contributed to the crisis. After the real estate bubble burst in mid–2007, investment and hedge funds moved into commodity markets in order to compensate for their losses in the property market, driving prices up as a result. Moreover, transport costs rose dramatically as world oil prices increased by about 90 percent, from $64 in May 2007 to more than $135 in May 2008. Rising world oil prices also increased the cost of agricultural inputs for farmers. Other factors affecting food prices include rising living standards in China, India, and other developing countries, which increased demand for livestock and feedstock (Ibrahim 2008).

The proposed scenario

To achieve sustainable desert development, i.e. desert development for future generations, we have to work within the constraints of water scarcity, energy limitation, and population increases, as already indicated earlier. But, we have to consider three additional important factors:

1. Problems caused by a change in strategies of grain exporting countries due to the use of their excess food grains to convert into bio-fuels instead of exporting to countries which do not enjoy food sufficiency. While embarking on large desert development projects, this limitation will have to be considered by changing the cropping patterns in newly reclaimed desert lands to achieve food self sufficiency rather than food security.
2. Problems facing the graduates, who were allocated 5-6 feddans of desert land each, and small farmers. These problems include marketing, inputs, appropriate technology, credit facilities, etc.
3. Lack of coordination between different players in a certain region, including industry, agriculture and domestic activities. Special emphasis is needed on integrated water management within a certain basin as well as rationalization of water use and development (pricing, recycling, desalination, new irrigation and pumping techniques).

In order to solve the above mentioned problems, it is proposed to create viable multipurpose communities based on a particular water basin. These communities would occupy reclaimed desert land and involve industrial, agro-industrial, and urban activities in addition to agricultural activities. In other words, we should have rural, industrial and urban communities intermingled in such a way that they would benefit from each other economically, socially, and environmentally, within the needs of the country as a whole.

To achieve the above, it is proposed to create holding companies, which would represent graduates, small farm owners, business owners and other investors and players in the area. Each holding company and its specialized divisions must work together towards supporting and developing the proposed multipurpose communities. The mission of the Holding Company should be to help in solving the problems of graduates and small investors, to support and develop proposed multipurpose communities, and to work towards achieving sustainable development for the zone as well as satisfying food and other needs of the country as a whole through:

1. Integrated management of natural, human and historical resources.
2. Environmental protection against all types of pollution (air, water, soil, noise, visual, etc).
3. Community development (providing necessary services and amenities: education, health, employment, etc) with emphasis on public participation.
4. Proper planning and management of financial resources and providing credit services to small investors and graduates, which they may use in purchasing inputs, marketing and/or processing agricultural products.
5. Food production to ensure food self sufficiency for the whole country based on a strategic plan adopted by a high level Food Council concerned with overcoming food deficit and the food price crisis.

Global warming

Global warming is caused by an increase in the earth's greenhouse effect due to increases in CO_2 levels in the atmosphere as a result of increased burning of fossil fuels. In order to mitigate the dangerous impacts of global warming, we need to reduce CO_2 levels in the atmosphere through decreasing fossil fuel use and absorbing emitted CO_2 by forest eco-systems.

The effects of global warming on Egypt's water resources are not accurately predictable. However, an increase in temperature is expected to raise rates of water evaporation, thus leading to slight decreases in available water for agriculture, industry and domestic uses. Further more, the changes in rainfall locations, delivery rates and seasons, may result in the loss of some of the rain water used in agriculture and domestic uses in case of continuing activities at the north shore. However, since it is expected that a major part of the north shore will be covered with sea water as a result of global warming, these activities would have to be moved away from the sea, probably to desert lands developed to take care of this situation as well as migration of its inhabitants and increased population growth occurring because of the failure of population control measures.

Climate change may also result in decreases in the productivity of some agricultural crops such as wheat and barley. Because of the diversion of food grains to biofuel production in the traditional grain exporting countries, there would be difficulty in procuring food grains in deficit countries like Egypt. When preparing the 1992 UNDP supported “Strategies for sustainable development in Egypt”, it was stressed that food self-sufficiency is not expected nor aimed for (Bishay et al. 1992). It was then suggested that what is needed is to achieve self reliance within the agricultural sector by shifting emphasis to high value, low water demanding crops which have high export potentials. Furthermore, since agriculture uses 84% of Egypt’s water resources, more emphasis should be given to other income generating, low water demanding sectors (e.g. industry and tourism) ; and it was then concluded that food security can be achieved through the income generated from all these sectors. Development of the “desert village” as an agro-industrial complex is the umbrella under which institutions should serve. Small scale relevant and clean industries were also recommended for the newly reclaimed areas.

Now, in the year 2008, with the extreme changes in food prices coupled with the difficulty of importing corn and other food products, we must revise the earlier concept of ‘food security’ and work towards ‘food self-sufficiency,’ which can be achieved through the sustainable development of our deserts as well as by a revision in the cropping patterns recommended for the Delta, the Nile Valley and the reclaimed desert lands.

Global warming, global food reduction, and sustainable desert development

The burning of fossil fuel results in the release of huge amounts of CO_2 in the atmosphere causing the climate change phenomena. This situation is expected to raise the level of sea water which could cover different areas of land resulting in loss of lands used for housing, agriculture and industrial activities. It is suggested that a 0.5 meter sea level rise in the delta would cause migration of more than two million individuals, loss of more than 214,000 jobs and a value loss of more then $40 billion. This phenomena as well as the tremendous increase in the price of fossil fuels and the fact that they are unsustainable and concentrated in certain areas of the world (like the Middle East), encouraged countries to convert crops into biodiesel as well as promote other renewable energy systems (solar, wind, etc.).

The above changes in environmental and socio-economic conditions facing the world can be dealt with in countries such as Egypt by ensuring the sustainable development of its desert lands based on a holistic approach where agricultural, technological, socio-economic and environmental concepts are implemented, taking into consideration the effects of global warming and the need for its mitigation as well as the increasing price of fossil fuels. This can be achieved through:

1. Changing the cropping patterns in newly reclaimed desert lands to satisfy

food self-sufficiency rather than food security.

2. Encouraging tree planting in the desert, not only as wind breaks, but also for absorbing CO_2, as well as other crops for sequestering carbon.
3. Promoting no-till agriculture and optimizing energy use in agricultural management.
4. Implementing measures to rationalize the use of, and developing, water resources (water pricing, recycling, desalination, new irrigation and pumping techniques).
5. Promoting the use of energy efficiently as well as solar / wind technologies, and designing housing to save energy and attract new residents. Facilities such as schools, hospitals, clubs and other services should be equipped with super-efficient lighting and appliances and professionally operated in order to attract those who will have to migrate from their homes to developed desert lands because of effects of global warming or due to expected population increases.
6. Building nuclear power plants in the desert to replace fossil-fuel operated power plants would decrease CO_2 emissions. This, however, will depend on solutions to nuclear waste disposal and ensuring that these plants can run without accidents.

Conclusions

In 1978, I had a dream of founding a for Desert Development Center (DDC) at the American University in Cairo (AUC), based on the holistic approach. This was successfully demonstrated at the AUC, DDC in Sadat City and South Tahrir. The success of this experiment encouraged us, in 1992, with UNDP support, to use it as the basis for strategies proposed for sustainable development in Egypt. Later, in 1997, when the concept was applied to desert development, it was proposed to create viable multipurpose communities, involving agricultural, industrial, agro-industrial and urban activities, with the creation of holding companies to implement the program. Now, in 2008, this proposal is needed more than ever, since these holding companies should be responding to the implementation of activities that promote food self sufficiency in Egypt and reduce the effects of climate change. Naturally, this would imply the creation of a high level Food Council, which would monitor the implementation activities of the holding companies to ensure a balance between the different needs of the country, as a whole. This food council must have supreme executive powers to implement all necessary steps needed to rationalize the use of water. It is time to start changing the tradition of flood water irrigation to drip or sprinkler or other suitable systems. Also there is a need to impose severe penalties on those who use flood irrigation in the desert and on those who cultivate rice or other high water demanding crops in the desert areas.

We should promote and even subsidize the use of renewable energy. The present system of giving 5 acres of land holding in the newly reclaimed areas to some university graduates has not achieved its goal of encouraging agricultural production, improved livelihoods and overall development because the graduates face many problems. The proposed holding companies should help them face their problems as well as plant appropriate crops.There should thus be a system devised to ensure that food self sufficiency is reached by well designed agriculture suited to the available natural resources in the country. These are alarming times, which necessitate very strong measures.

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15. Climate change and the Egyptian agriculture conundrum

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Abstract

The growing information from climate change studies indicates that agriculture is one of the most vulnerable human activities under the projected changes. Agriculture represents one of the most important human activities in Egypt. Agriculture is key sector for the socio-economic development, and it plays a significant role in the Egyptian national economy. Moreover, agriculture has importance in the social structure of rural regions in Egypt, and it is responsible for their social stability. Egypt is fairly unique in the distribution of its population, high crop productivity, land-use change, agricultural management efficacy and economical impacts, which make it extremely vulnerable to any potential impact on climate, water resources and coastal zone. Climate change impact studies predict a reduction and change in crop productivity in Egypt. These reductions in cereal crops are likely to affect the national income from agriculture, increase food gap, and affect the standard of living of the people. Also competition between water demands for domestic sector and agriculture sector is predicted to intensify due to population increase and the growing demands for irrigation water to overcome climate change impacts on cultivated crops. Development of adaptation plans is therefore one of the top priorities of sustainable development of agriculture sector in Egypt. Adaptation plan for agriculture sector should be characterized as integrated, sustainable, economically efficient, continuous and long term plan. However, complicated relationships amongst various components of agriculture sector and between the agriculture sector and the other sectors accentuate the difficulties in adaptation planning.

Climate change - the growing challenge

In a high level conference of FAO held in Rome in June 2008, the delegates asserted that agriculture, as a fundamental human activity, is not only at risk from climate change, but it is a major driver of environmental and climate change itself. It contributes to the largest anthropogenic impact on land and water resources (FAO 2008). Although there is still certain level of skepticism about climate change, recent thorough studies have concluded that warming of the climate system is unequivocally occurring as is evident from the observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising average sea level (IPCC 2007b).

IPCC (2001b) identified ‘Climate change’ as a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to the natural factors or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC 1992), where climate change is referred to a change in climate that is attributed directly or indirectly to human activity altering the composition of the global atmosphere, and that is observed over time periods in addition to natural climate variability. IPCC (2001b) defines the term 'climate variability' as variation in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or due to the variations in natural or anthropogenic external forcing (external variability).

The scientific evidences attribute climate change to the energy imbalance occurring in the global energy cycle, the so called 'greenhouse effect' phenomena (IPCC 2007c). This imbalance is attributed to the fast increase in the concentrations of greenhouse gases (GHGs) and aerosols in Earth's atmosphere. GHGs and aerosols affect climate by altering incoming solar radiation and out-going infrared (thermal) radiation that are part of Earth's energy balance (IPCC 2007c). GHGs concentrations increased dramatically since the start of the industrial era (about 1750) as a result of the fast human development based on easy access to fossil fuel energy and the extensive change in land use patterns. The human impact on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions.

The recent climate change studies (IPCC 2007c) have concluded that global surface air temperature increased by 0.76 °C from the year 1850 to year 2005. The linear warming trend over the last 50 years is recorded to be 0.13°C per decade. Rising sea level is consistent with the warming of air. Global average sea level has risen since 1961 at an average rate of 1.8 mm/yr (range 1.3 to 2.3) and since 1993 at the rate of 3.1 mm/yr (range 2.4 to 3.8), because of thermal expansion, and melting of glaciers, ice caps, and the polar ice sheets. Additionally, an increase in the frequency and the intensity of the extreme weather events of tropical cyclones and storms, heat and cold waves, floods and droughts, is strongly observed. Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.

Khalil et al. (2008) have observed a general trend of warming in Egypt in the last 30 years, based on a comparison between air temperature parameters of years 1975 and 2004. Comparison with the average historical normals up to 1975 revealed a general trend of increase in mean temperature by 0.46 °C. Furthermore, the average trends of minimum, maximum and mean temperature from 1990 to 2004 were higher than those observed between 1975 and 1989.

The most likely trend of future global change indicated in the fourth assessment report of IPCC (IPCC 2007c) for the next two decades is a warming of about 0.2°C per decade projected for a range of SRES emission scenarios. The projected warming will be associated with a precipitation increase very likely in high latitudes, and decrease in most subtropical land regions. The frequency and the intensity of the extreme events, expansion of the areas affected by drought and floods, and the incidence of extreme high sea levels are all predicted to increase.

The historical climate records for Africa show warming of approximately 0.7°C over most of the continent during the twentieth century (Desanker 2002). More over, all of Africa is very likely to warm during this century, and the warming is very likely to be larger than the global warming (IPCC 2007a). Additionally, climate data gathered in North Africa region during the twentieth century indicated an increase in the temperature by more than 1 °C in the last 40 years (Agoumi 2001).

Why climate change is such critical issue for agriculture?

The projected climatic changes will be one of the most important challenges for agriculture in the twenty-first century, especially for developing countries and arid regions (IPCC 2007a). The risks associated with agriculture and climate change is a result of the strong complicated relationships between agriculture and climate system, plus the high reliance of agriculture system on the natural resources. The first face of this complicated relationship is the fact that agriculture plays an essential role in hydrological cycle, carbon cycle and global energy cycle. On the other hand, agriculture is one of the important human activities that accounts for about 13.5 to 15 per cent of total global GHGs emissions. Agricultural activities contribute directly to emissions of GHGs through enteric fermentation from domestic livestock, manure management, agricultural soils, rice cultivation, and the burning of savanna and agricultural residues (IPCC 1996). Forty five per cent of agricultural GHGs emissions are attributed to methane emissions (WRI 2000), and 10% to rice cultivation; these together account for 1.5 per cent of global GHGs emissions. In Egypt, the agriculture sector is the second largest source of GHGs emissions accounting for 15% of total national GHGs emissions (EEAA1999). It is the main source of methane emissions, mainly from rice cultivation and animal wastes.

Agricultural sector of Egypt: the impacts and the vulnerability

Globally, climatic changes are projected to produce serious impacts on agriculture production. The most projected global impacts over agriculture system could be summarized as a serious change in crop productivity, change in cropping patterns and cultivation seasons, increase in irrigation requirements, the increase in the intensity and the severity of pests and diseases, loss of agriculture land due to sea level rise (SLR), and agricultural soil degradation (Bazzaz and Sombroek 1996; IPCC 2007a). The magnitude of these impacts will differ depending on the level of vulnerability of the region and the adaptation capacity of the local agricultural systems.

The agriculture sector in the Med-latitude region and in the arid and semi-arid regions is exposed to high vulnerability because of the projected impacts of climate change. At the regional level of analysis, the future impacts are predicted to affect agriculture system in the Mediterranean countries, and increase its vulnerability to environmental and social hazards (Iglesias 2002). For the African continent, agricultural production, including access to food, in many African countries is projected to be severely compromised by climate variability and change. Additionally, yields from rain-fed agriculture in Africa could be reduced by up to 50% by 2020, and the projected sea-level rise will affect low-lying coastal areas with large populations, the cost of adaptation for which could amount to at least 5-10% of GDP.

The impacts of climatic changes on Egyptian agricultural sector have been investigated in only a few studies. (Table 1) presents the results of some important studies on the impact of future warming on the production of some major field crops in Egypt. The overall conclusion of the most studies is that there will be a general trend of reduction for the most major field crops. Crop-water requirement is one of the important considerations in agriculture production; hence the impact of climate

Table 1. Projected changes in crop production of some major crops in Egypt under climate change conditions

Crop	Change %		Reference
	2050s	2100s	
Rice	-11%		Eid and EL-Marsafawy (2002)
Maize	-19%		Eid et al. (1997b)
	-14%	-20%	Hassanein and Medany (2007)
Soybeans	-28%		Eid and EL-Marsafawy (2002)
Barley	-20%		Eid et al. (1997b)
Cotton	+17%*	+31% **	Eid et al. (1997a)

* Temperature increased by 2°C
** Temperature increased by 4°C

change on this attribute has been studied at the national level. The results indicate that the future warming will lead to increase in potential evapotranspiration (ET_o) over Egypt. This increase will be uneven depending on regions and seasons. Potential irrigation demands are projected to increase by 6.4-16.0% by 2100s (Attaher et al. 2006). Under the projected change in the ET_o in Egypt, the crop-water demand is projected to face significant changes that may vary according to the crop type and the season of cultivation (Attaher et al. 2006). (Fig.1) illustrates the change in crop-water requirements of major crops due to the change in temperature and CO_2 levels based on IPCC SRES scenarios of A1 and B1 for years 2025s, 2050s and 2100s (Attaher and Medany 2008).

The impact of climate change has been studied on some such important diseases at the national level, as pear early blight (Abo Elmaaty et al. 200?), potato late blight (Fahim et al. 2007), and wheat rust (Abo Elmaaty et al. 2007).

The vulnerability of the agricultural sector in Egypt

Füssel and Klein (2006) identified the 'vulnerability' of the systems to climate change as the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, the adverse impacts of climate change. Generally speaking, Egypt is located in the arid region that can be affected greatly by the adverse effects of climate change (IPCC 2007a). Egypt is fairly unique in the distribution of its population, land-use and agriculture, and economic activity which makes it extremely vulnerable to any potential impacts on its water resources and coastal zone.

Agriculture represents one of the most important human activities in Egypt. Agriculture is key sector for the socio-economic development in Egypt, and it plays a significant role in the Egyptian national economy. About 50% of the Egyptian population relies on it for income generation and job opportunity creation, and it accounts for about 17% of GDP. The agricultural sector employs more than 30% of the labor force, and provides about 20% of the country's exports and a large portion of the important processing industries depend on raw materials produced by the sector. The role that agriculture plays in Egyptian economy and the high environmental pressures to which it is

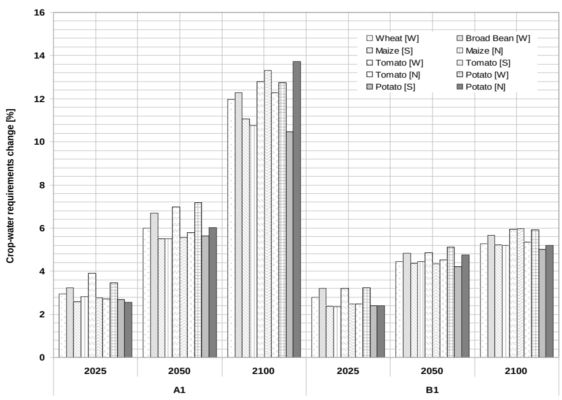

Figure 1. Projected percent change between the current and the future values (for years 2025s, 2050s and 2100s) of seasonal crop-water requirements of some major field and vegetable crops in Egypt (Source: Attaher and Medany 2008).

already exposed are the reasons that motivate the agriculture community to conclude that Egyptian agriculture is highly vulnerable to future climate changes (Attaher and Abou Hadid 2003).

The agricultural land area in Egypt does not exceed 3.3% of the total Egyptian land area and it is confined to the narrow strip which boarders the main course of the River Nile and the Nile Delta. The cultivated land area of Egypt in 2000 was about 8 million Feddan. The fertile ‘Old lands’ in the Nile Valley and the Delta region account for 80% of agricultural area, and the remaining 20% is accounted for by the newly reclaimed in the desert regions. The intensity of cropping ranges from 178.5 to 179.5% and it the highest in the world. Egypt is also unique in the world in irrigated agriculture as about 95 to 97% of the agricultural area is fully irrigated, and about 90% of the remaining 3 to 5 % area that is rainfed receives supplementary irrigation. The productivity of field crops in Egypt is on of the highest in the world because of the adoption of new cultivars, application of modern technologies and improved management practices (Fig. 2).

Agriculture in Egypt is less sensitive to climate variability, due to heavy reliance on irrigation. However, heat and cold waves cause severel harmful impacts on crop productivity, especially on fruit and vegetable crops. The intensity of the heat and cold waves has increased in the past 20 years, exposing growers to greater risks. El-Raey et al. (1999) report that the increase in temperatures and the frequency of extreme events will reduce crop yield, and change in average temperature will induce changes in the spatial distribution of crops.

Agriculture puts a serious pressure on water sector. Several factors are responsible for this: (i) 85% of total available water is consumed in agriculture; (ii) 95% of the cultivated area is under fixed irrigation system, where water-use efficacy is low

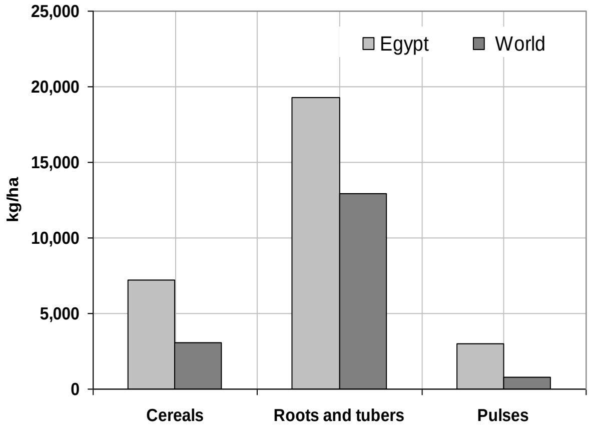

Figure 2. A comparison of the productivity of major groups of field crops in Egypt with the world average (source: FAO 2007).

compared to the other water consumption sectors, and (iii) about 80% of cultivated land has surface irrigation system, which is low in efficiency (less than 60%); and this is coupled with poor irrigation management (Abou Zeid 2002). The overall national development policy for Egypt, in the period 1997 to 2017, aims to add 3.5 million Feddan to be irrigated by 2017. However, under current water situation, reclamation projects face a lot of problems due to water shortage, soil quality and lack of investments. The ongoing expansion of irrigated areas will reduce the capacity of Egypt to cope with future fluctuations in the flow of water (Conway 2005). Moreover, the profitability of the new lands is predicted to decrease under climate change, due to water shortage problems, high production cost, and soil degradation (Eid et al. 2001). Also the competition for water demand between domestic-use sector and agriculture sector is predicted to intensify due to population increase and climate change pressures on water resources. This will produce more stress on the standard of living of people in Egypt (Conway 2005).

Due to high demographic pressure, about 80% of the old cultivated area is accounted for by holdings of less than five Feddan per owner (CAPMAS 2001). These areas are owned by farmers who have limited capacity for investment; as a result they follow less efficient management systems with low technology level. This is one of the important limitations in improving traditional agricultural systems. Moreover, it also increases the risk of farmers to environmental and economical pressures. The fertility and the quality of the old lands is adversely affected by poor water management and agricultural practices. Salinity and water logging problems are common in many locations in the Delta region (Amer et al. 1997). The estimated reduction in crop productivity and changes in cropping patterns in Egypt due to climate change are likely to affect the national income from agriculture, and increase food gap, and affect the standard of living of the people.

The Nile Delta region is the most important agriculture region in Egypt, as it has about one half of the total cultivated area (about 4.3 million Feddan), and about 93 % of its land is 'old land'. The overall agricultural system in Delta region is considered as one of the most intensive and complicated agriculture systems in the world. With the rise in sea-level because of climate change about 12-15% of the existing agricultural land in the Delta region could be lost (Abd El-Wahab 2005). The region has most fertile agricultural lands and cities that have high population, important industries, high infrastructure, etc. All these will be exposed to sea level rise and salt water intrusion and soil salinization (El-Raey et al. 1999). Medany and Attaher (2008) report that the northern part of the Nile Delta region could be the most vulnerable sub-region in the Nile Delta region because of sea level rise, soil and water degradation, limited cropping-pattern, yield reduction, and poor irrigation and drainage management. Urbanization and the reduction in the size of land holdings were the main causes of vulnerability in south Delta sub-region.

Agriculture plays an important role in social structure of many rural regions in Egypt, and it is responsible for social stability in these regions. In less developed rural regions, agriculture is taking the shape of 'family business'; so it encourages the union inside the large families, and reduces the tendency for emigration from the rural to urban cities. As the family business in agriculture requires large families, it tends to negate family planning and adds to demographic pressures on the resources.

Marketing pressures are also increasing gradually for agricultural products, due to international trade fluctuations and export restrictions and protocols (e.g., Eurogap). The current level of agricultural management, high production cost, and failure to meet export quality standards contribute to low income. Local markets have significant fluctuations in the pricing of crop produce from year to year. Besides prices fluctuation, farmers also face serious problems in transporting the agricultural products to the local markets. Furthermore, the level of knowledge of farmers represents one of the important limitations in agricultural development and adaptation. The knowledge level of farmers, in term of modern management practices and technologies, is low. Also, the lack of dissemination of information in rural areas is limiting the management development efforts. The current agriculture information systems are still traditional and are not suitable enough for enhancing the knowledge level and meet the knowledge requirements of farmers. On the other hand, the extension services have problems in acquiring the information from appropriate sources (research centers and administration), and they are therefore unable to meet the farmers requirements in many rural areas in Egypt.

Mitigation and adaptation: the real challenge!

IPCC defined 'adaptation' as any adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities and regions to climate change and variability (IPCC 2001a).

In developing countries, the priority for adaptation plans to climate change is for the systems that are highly vulnerable. As climate change is projected to have serious impacts on agricultural sector in Egypt, modest efforts are being made in scientific research, for developing mitigation and adaptation strategies. A large number of adaptation measures could be addressed in order to overcome the adverse effect of climate change in agriculture production under Egyptian conditions. Table 2 presents measures that were suggested in the first national communication report of Egypt (EEAA, 1998). In a recent study conducted in order to investigate the effect of stakeholders' engagement in adaptation planning in Egypt, changing the crop patterns and varieties, and improving irrigation management were primary adaptation measures suggested by the stakeholders, reflecting the problems related to the current cropping patterns and use of varieties (Medany et al. 2007). Designing and application of adaptation strategy for the agriculture sector is currently suffering from the limitation of gaps in scientific knowledge, policy perceptions, poor adaptive capacity of the rural community, lack of financial support, and absence of appropriate institutional framework.

Medany et al. (2007) suggested that designing adaptation strategy for agriculture sector should consider the simple and low cost adaptation measures that may be inspired from traditional knowledge, and meet local conditions and are compatible with sustainable development requirements. Solutions based on high level of technology and high initial costs might not work. Addressing climate change mitigation and adaptation as an integral part of development strategies can increase their efficiency and durability. Medany et al. (2007) made following suggestions to enhance the planning of adaptation and mitigation strategies for agricultural sector under Egyptian conditions

Table 2. Climate change priorities for mitigation and adaptation measures in the agriculture sector, 1999

Priority sector	Measures
Mitigation	- Reduction of rice cultivated area - Improved management of rice cultivation - Improved nutrition on small farm - Widespread use of small on-farm digesters - Planting of shelter belts on Northern Coast
Adaptation	- New cultivars
	- Less water consuming crops
	- Change cropping patterns

Source: EEAA (1998)

- Improve the scientific capacity should be in the top priorities of development planning.
- Political and financial adoption of adaptation strategies.
- The bottom up approach of planning and implementing adaptation and mitigation strategies.
- Developing community-based measures by stakeholders' involvement in adaptation planning, and improving the adaptive capacity of the different human sectors.
- Increase the public awareness and improve the concept of climate and its relation to environmental and human systems.
- Improve adaptive capacity of the community based on a clear scientific message and strong governmental support.

Attaher et al. (2009) studied the farmers' perception for adaptation planning in the Nile Delta region and concluded that farmers have a real initiative to act positively to reduce the impact of climate change. As community engagement in adaptation planning is very important, the scientific evaluation should take in account more practical sets of adaptation measures based on traditional knowledge.

Conclusion

Agriculture represents one of the most complicated and important human activities in Egypt. It is a key sector for the socio-economic development, and it plays a significant role in the Egyptian national economy. Moreover, it plays important role in social structure of rural regions in Egypt, and is responsible for their social stability. Climate change impact studies predict a reduction in the productivity of cereal crops, which is likely to reduce the national income from agriculture, increase food gap, and adversely affect the standard of living of people in Egypt. Climate change will also have a serious impact on agricultural water-demands in Egypt, causing more stress on standard of living of the people. Adaptation planning is one of the top priorities for sustainable development of agriculture sector in Egypt. Complicated relationships amongst the various components of agriculture sector and between agriculture sector and other sectors accentuate the difficulties encountered in adaptation planning. Adaptation plans should be integrated, sustainable, and economically efficient long term plans.

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16. Combating aeolian desertification in drylands of China

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Abstract

Aeolian desertification is a land degradation through wind erosion, mainly resulting from the excessive human activities in arid, semiarid and some sub-humid regions in Northern China. Camparing the results of analyses of remote sensing data of late 1950, 1975, 1987 and 2000, one can conclude that the development of aeolian desertified land in Northern China has being accelerating in the last 5 decades, as the annual expansion rate was 1,560 km^2 during late 1950 and 1975, 2,100 km^2 between 1975 and 1988 and 3,600 km^2 between 1988 and 2000. The impact of human activities on the process of desertification is much more strong than the natural one. Changes in the landuse pattern (from rangeland to farmland) and increase in the landuse intensity (over-cultivation, over-grazing and over-fuelwood collection) have been the main anthropogenic factors. The natural vegetation has been destroyed by excessive human activity and that has accelerated the process of desertification. For example, such human impact can increase wind erosion 4 to 10 times in contrast to that occuring naturally. Along with increased desertification, there is also acceleration of loss of soil fertility, bio-diversity and bio-production, 3 to 10 folds or more because of human factors in contrast to the natural process. China has made much progress in understanding and combating the process of desertification through many efforts for decades and many projects have been carried out. One of them is the National Project of Grain for Green Program and 1060 counties in 22 provinces have been included in this project. The objective is to take away 3.67 million ha of dry land farming and degraded steppe area, and 5.13 million ha of aeolian desertified land and rehabilitate it by reforestation and revegetation by the end of the Program. There are about 8 million ha of lands under the threat of aeolian desertification and this will be brought under control in the next ten years and 26.67 million ha of windbreaks will be planted. The total financial input is estimated to be about 75 billion Yuan (11 billion US$) to be provided by the central government.

Introduction

According to the United Nations Convention to Combat Desertification (UNCCD 1994) and the actual situation in China (Wang 2004), desertification is a very serious environmental and socio-economic problem facing the world. The desertification can be classified into several major types, namely aeolian desertification, soil and water erosion and salinization. One of the main manifestations of desertification in Northern China is aeolian desertification.

Aeolian desertification is caused by imbalance between environment and development. It not only results in the destruction of resource-environment system and increase in poverty, but also endangers the social stability and sustainable economic development. Therefore, it has attracted widespread attention of international community. China is one of the countries suffering from severest desertification in the world, especially the rapid aeolian desertification in Northern China. Its tremendous impact on environment, society and economy has received considerable attention. Aeolian desertified lands are mainly distributed in the arid, semiarid, and parts of sub-humid regions of Northern China, including the Inner Mongolia, Ningxia, Gansu, Xinjiang, Qinghai, Tibet, Shaanxi, Shanxi, Hebei, Jilin, Liaoning and Heilonjiang provinces (Zhu and Liu 1989). According to the actual situation in China and the studies conducted over the past 30 years, the aeolian desertification is mainly resulting from the excessive human activity in the arid, semiarid and some parts of sub-humid regions of the country (Wang 2008).

China has launched a multidisciplinary and comprehensive research program to combat aeolian desertification. Over the last 50 years, researchers have made some encouraging progress in this field of study, and much work has been conducted in the regions with fragile eco-environmental conditions and excessive human activity as indicated by a high man/land ratio. Through remote sensing monitoring of aeolian desertification along with field investigations in large regions, we have achieved a good preliminary understanding of the causes, distribution, and types of aeolian desertification and damage caused by it in Northern China. Through multidisciplinary research of aeolian desertification developmental processes, including blown sand dynamic processes, biological processes and anthropogenic processes, the role of human and natural impact on the aeolian desertification processes has been clarified and a multi-level comprehensive indicator system of aeolian desertification with blown sand activity as the main indicator has been put forward (Wang, Zhao and Xiao 1999).

Spatial-temporal distribution of aeolian desertification in Northern China

Between 1950’s and 2000, aeolian desertification has developed mainly in the agro-pastoral zones of the Northern China (Fig. 1) and to some extent in the marginal lands outskirts of deserts and low reaches of inland river basins in the Western China. The total aeolian desertified land in China was 0.137 million km^2 in 1955; it increased to 0.176 million km^2 in 1975, 0.334 million km^2 in 1987, and 0.386 million km^2 in 2000. During last 50 years, aeolian desertified land expanded with an annual rate of increase of 1,560 km^2 from late 1950s to mid 1970s, 2100 km^2 from mid 1970s to late 1980s and 3600 km^2 during 1990’s. The total area of aeolian desertified land in the Northern China was $38.57\times104km^2$. The aeolian desertified lands lost huge amount of soil which was carried by dust storms to the Eastern China, such as Beijing, and even to Korea and Japan. The direct and indirect economic loss by the aeolian desertification is estimated to be around 45 billion Chinese Yuan (USD $5.6 billion) per year affecting nearly 300 million people in Northern China.

Aeolian desertified lands in China, in 2000, covered a total area of 38.60×10^4 km^2 and form a discontinuously distributed as arcic belt from Northeast China to North China and to Northwest China. Of this total area, 29% is distributed in the mixed farming-grazing regions and rainfed farming regions in the eastern part of semiarid zone and part of sub-humid zone (mainly in the Otindag aeolian land, Horqin aeolian land, Bashang region of Hebei province and Houshan region in Inner Mongolia) with wind erosion and sand sheet as the striking features; 44% is distributed in the middle and western parts of semiarid zone and desert steppe zone (mainly in the middle of

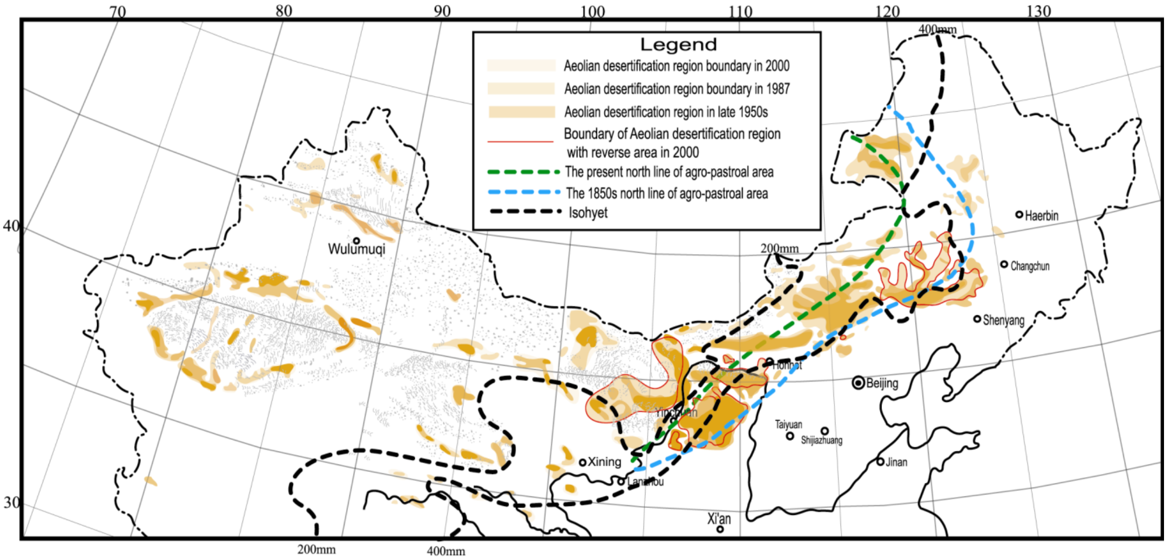

Figure 1. Spatial distributions of aeolian desertified land in Northern China in 1950s, 1987, and 2000. Human activities have also pushed the agro-pastoral boundary northwards by approximately 200 km from 1950s to 2000.

Inner Mongolia) with reactivated fixed dunes and shifting sand spread as the main features; and 27% is distributed at the margin of oases in arid zone and lower reaches of inland rivers (mainly in the Alxa region of west Inner Mongolia, northern part of Hexi Corridor region in Gansu and lower reaches of the Tarim River in Xinjiang) with reactivation of fixed dunes as the main feature.

Rapid expansion of aeolian desertified land not only seriously endangers the eco-environment and socio-economicconditions but also greatly hinders the 'Ecological Construction of the Twenty-first Century' and the implementation of the Western Development in China, especially hampering the development and the improvement of people's living standard in the regions.

Combating aeolian desertification in Northern China

China has made much progress on understanding and combating the process of desertification through many rersearch and development efforts since 1950's and many projects have been carried out. According to the natural and economic conditions of arid and semiarid regions and aeolian desertification developmental trends in Northern China as well as some typical experiences in aeolian desertification control, combating aeolian desertification has to take into consideration ecological, economic and social benefits. It has also to follow the ecological principles of moderate utilization of natural resources and harnessing complementation to contain landuse during the combating processes (Wang 2004). In order to improve the ecosystem of the whole arid and semiarid regions we should undertake an overall planning and adopt comprehensive combating strategies. In respect of economic development the principle of diversified economy dominated by forestry has to be practiced, while the attempts are made to control population growth. The arrangements for implementing projects to combat desertification should include three components: (a) research organizations mainly undertake aeolian desertification control experiments in the experimental plots; (b) research organizations in cooperation with production departments conduct experiments in the demonstration plots; and (c) production departments and local people popularize successful techniques.

In the mixed farming-grazing region where residential areas, cropland and grassland are scattered all over, using ecological household as an unit, such measures as prohibiting grazing, readjusting rainfed farming-dominated landuse structure, increasing forest and grassland area, intensive management of land with better water and fertility conditions, establishing farmland forest net and patchy forests (shrub) in interdune depressions have to be adopted to control aeolian desertification spread and contribute to economic development. In the grazing grassland a rational stocking rate and rotational grazing system has been established, in addition, efforts should be made to construct artificial grassland and forage base, rationally arrange drinking water wells, define grazing density and build roads. In the arid zone, an overall planning should be worked out with basin as an ecological unit, to formulate rational water allocation plan, construct farmland forest net inside oases and sandbreak tree-shrub belt around the oases, in combination with mechanical sand fence and sand-fixing plants inside sand fences grids to form a perfect protective system. In addition, the transportation lines in the dense sand dune regions should be protected by mechanical sand fences and sand-fixing plants, laying emphasis on fixation in combination with blocks.

The Chinese government has issued ‘The Law of Desertification Control of the Peoples Republic of China’ in 2002, which is the first and the only national law in the world up till now. This Law assures that all of the projects on combating desertification can be carried out successfully.

Since the implementation of the Western Development strategy, China has taken the desertified region as a top priority of ecological construction. Since 2000, the central government has invested a total of 217.22 billion Chinese Yuan, and had implemented a series of ecological construction projects, such as the Project of Natural Resources Conservation, the Project of Returning Farmland to Woodland or Grassland Forest, the Project of Sandstorm Source Control surrounding Beijing and Tianjin Area, the project of the Three-North Shelterbelt System Construction, the Project on Wildlife Protection and Nature Reserve Construction, the Project of Wetland Protection and Restoration, etc. These projects greatly accelerated the western region's ecological protection and construction process. Forest coverage in the western region in 2008 had reached 17.05%, an increase of 6.73% over what was there 10 years ago.

According to the State statistics, in the past 10 years since the implementation of the western development strategy, the western region has a total of 30.65 million ha of planted forests. According to the seventh national forest resources inventory data issued recently, forest reserves in the western region amounted to 8.27 billion cubic meters,an increase of 1.3 billion cubic meters compared with the data reported in the fifth inventory 10 years ago. The increase in the forest cover effectively controlled soil erosion and aeolian desertification. Shaanxi, Gansu, Ningxia, Inner Mongolia and other provinces across the country achieved for the first time the historic change from the status of "sand advancing and human retreating" to the status of "human advancing and sand retreating". In Mu Us Sandy Land, aeolian desertification status has achieved a fundamental change and the area has started to enter a new phase of desertification control and use of this Sandy Land. About 0.15 million km^2 of land has been protected from soil erosion on the Loess Plateau and the annual deposition of silt and sand sediment into the Yellow River has been reduced by more than 300 million tons.

In the last 10 years, the Central Government dedicated a total of 10 billion Chinese Yuan in wildlife protection, and on state-level nature reserve construction projects. The forestry sectors has built 395 new nature reserves with an area of 39.72 million ha in the western region, and has formed a preliminary network of nature reserves system. The Central Government has alsoimplemented 55 wetland protection and restoration projects in the western region, and effectively protected an area of 6.59 million ha of wetlands. In forestry ecological construction program in the western region, the forestry sector has combined forestry and water conservation with combating poverty. The sector is promoting economic use of forests through timber cultivation, production of flowers, deep-processing of wood and bamboo resources, eco-tourism and other forestry industries, and realized the priority of ecological benefits, and the harmonization of economic and social benefits. The forestry industry output value in the western region reached 294.02 billion Yuan in 2008, which according to comparable prices, is an inrease by 2.6 times of that in 1999. Based on the success of the pilot project, the Central Government has established a forest ecological benefit compensation fund, and is giving the support for the western region in the compensation of the land area taken out of cultivation and put under forest. Until 2009, the Central Government had compensated 44 million hectares of land under public forest in the western region, and cumulatively arranged the forest ecological benefit compensation fund of 11.17 billion Yuan. From 2010, the Central Government will improve the the subsidy rate of national-level public forest from 75 Yuan to 150 Yuan per ha every year.

The biggest national project developed for combating desertification is the 'Grain for Green Program' (1997—2012) and 1060 counties in 22 provinces have been included into this project. The objective is to withdraw 3.67 million ha of dry land farming area and degraded steppe, and 5.13 million ha of aeolian desertified land suited for reforestation and revegetate and rehabilitate these areas by the end of the Program. About 8 million ha of land under the threats of aeolian desertification will be brought under control in the next ten years and 26.67 million ha of windbreaks will be planted. The total financial input is estimated to be 75 billion Yuan (11 billion US$) to be provided by the Central Government. Thanks to many efforts from the central and local governments, the local people in the aeolian desertified regions have been able to decrease the pace of aeline desertification by 1280 km^2 annually during the last years.

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17. Imperatives of global climate change for agricultural research in Asia-Pacific

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Abstract

The 2007 assessment report of the Inter-Governmental Panel on Climate Change (IPCC) has revealed glaring global climate changes that are expected to affect agriculture (crops, soils, livestock, pests etc.) and hence our global food security. The IPCC report has further indicated the vulnerability of developing countries in Asia-Pacific, the region which is home for more than one half of the world population. The rapid and continuing increase in population and economy implies increased demand for food, which will have to be produced from same or even shrinking land resource due to increasing competition for land and other resources by non-agricultural sectors. Alleviating poverty and attaining food security would thus be the major challenges to most countries in the region during the twenty-first century. Producing enough food with reduced resources in adverse environmental scenario would be a daunting task before most of the Asian nations. Concerted efforts would be needed to maximize food production, minimize environmental degradation and attain socio-economic development through reorientation of agricultural research that would comprehensively address all concerns of adaptations to and mitigation of climate change. It is with this background, that the Asia-Pacific Association of Agricultural Research Institutions (APAARI) had recently organized an Expert Consultation on "Imperatives of Global Climate Change for Agricultural Research in Asia-Pacific" at Tsukuba, Japan in collaboration with JIRCAS, GFAR, CIMMYT, ICARDA, ICRISAT and AVRDC. The main objective had been to review the current state of understanding of the climate change, especially in the developing countries of the region, and to analyze the available scientific, technological and policy options for adaptation and mitigation to climate change and their possible implications on food security and agriculture in the region. This paper provides the highlights and major recommendations for research reorientation to enhance adaptive capacity and mitigation potential of agriculture in the Asia-Pacific region.

Introduction

The major challenges in the twenty-first century are the rapid increase in the world population, the degradation of agricultural land and other natural resources and above all the emission of greenhouse gases (GHGs) in the atmosphere that contribute to climate change. Hence, the growing threat of food insecurity (Brown 2008; FAO 2006, 2007), rapidly engulfing poor and under-privileged population leading to increased poverty across the globe (FAO 2007; Anon. 2008), will be exacerbated by the projected threats to agriculture due to climate change (Cline 2007).

Emissions of GHGs, like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), resulting from human activities, are substantially increasing the average temperature of Earth's surface. Fifty percent of the increase in global warming, since the industrial revolution, is considered to be the consequence of an increased level of carbon dioxide and other gases in the atmosphere (Lal 1999). The concentration of CO_2 in the atmosphere increased from 285 ppm at the end of the ninteenth century, before the industrial revolution, to about 366 ppm in 1998 (equivalent to a 28 % increase) as a consequence of anthropogenic emissions of about 405 (± 60) giga tonnes of carbon (C) into the atmosphere (IPCC 2001). Of this increase, industrialization (fossil-fuel combustion and cement production) contributed 67 % and the remaining 33 % by the land-use change. The increase in GHGs in the atmosphere is now recognized to contribute to climate change (IPCC 2001).

Asia is the home for more than one half of the world population living on 1/3rd of global land. The rapid and continuing increase in population and economy implies increased demand for food in the region. It is estimated that by 2020, food grain requirement in Asia would be 30-50% more than the current demand which will have to be produced from same or even less land, that too with inferior quality of other natural resources. Hence, the world food situation will be strongly dominated by the changes that would occur in Asia because of its huge population, changes in diet pattern and associated increased demand for food, feed, fibre, fuel etc.

Alleviating poverty and attaining food security under adverse environmental scenario due to global climate change and spiraling cost of inputs, as experienced in the recent past, would be a major challenge in the twenty-first century to most of the countries in the Asia-Pacific region. Agriculture, consisting of cropland, pasture, and livestock production, presently contributes 13% of total anthropogenic greenhouse gas emissions. This does not include indirect sources relating to agricultural inputs such as fertilizer, food processing industries and other energy requiring operations.

Also the direction that Asian countries would embark to meet their energy needs during the coming 30 years will have profound impacts on global climate change and energy security for the region and the world. Asia currently accounts for about 26% of global CO_2 emissions, and its share of emissions is projected to increase to nearly 50% by 2030 (USAID 2007). By 2009, China is expected to surpass the United States as the world’s largest emitter of GHGs - a decade earlier than anticipated (IEA 2006). In addition, the burning of coal to meet Asia’s energy needs is projected to increase five-fold by 2030, accelerating GHG emissions and further contributing to global climate change (IEA 2006). Increasingly, Asian countries are importing fossil fuels to sustain their rapid economic growth, and this is raising concerns for further energy security. By 2030, it is expected that 80% of Asia’s oil will be imported from the Middle East (Saha 2006). Reserves of natural gas in Asia (a cleaner burning fossil fuel) are limited, and 40-75% of natural gas will have to be imported by 2030 to satisfy demand (APERC 2006). This future dependence on imported fossil fuels raises legitimate concerns for Asian countries about price volatility and shocks, and supply disruptions. Also the majority of the world’s most polluted cities are in Asia and the impact of urban air pollution on health and mortality in Asia is severe. Urban air pollution in Asia is linked to 500,000 premature deaths every year, accounting for 65% of premature deaths from air pollution worldwide (UNEP 2006).

Above facts draw global concerns and urgency to address the options by which threats to Asian agriculture due to climate change can be met successfully in the near future. On positive side, the agriculture sector also provides significant potential for the GHG mitigation and adaptation to climate change effects. This, however, would demand reorientation of agricultural research that would comprehensively address all urgent concerns of climatic change through well defined adaptation and mitigation strategy which could help maximize food production, minimize environmental degradation and attain socio-economic development.

Impact of climate change on agriculture

The climate change is projected to impinge on sustainable development of most developing countries of Asia as it compounds the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation, and economic development. The impact of climate change on agriculture is now real and without adequate adaptation and mitigation strategies to climate change, food insecurity and loss of livelihood are likely to be exacerbated in Asia. In this regard, the fourth assessment report of the inter-governmental panel on climate change (IPCC), released in 2007, has clearly revealed that increases in the emission of GHGs have resulted in warming of the climate system by 0.74°C between 1906 and 2005. It has further projected that temperature increase by the end of this century is likely to be in the range 2 to 4.5°C. It is expected that future tropical cyclones will become more intense, with larger peak wind speeds and heavier precipitation. Himalayan glaciers and snow cover are projected to contract. It is also very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent. Increases in the amount of precipitation are expected more in high-latitudes, while decreases are likely in most sub-tropical regions. At the same time, the projected sea level rise by the end of this century is likely to be between 0.18 to 0.59 meters. The freshwater availability in Central, South, East and Southeast Asia, particularly in large river basins, is projected to decrease due to climate change which, along with population growth and increasing demand arising from higher standards of living, could adversely affect more than a billion people by the 2050s.

Such climatic changes are affecting agriculture through their direct and indirect effects on crops, soils, livestock and pests, and hence the global food security. IPCC report has particularly indicated vulnerability of developing countries of the Asian region, especially its megadeltas to increasing climate change and variability due to its large population, predominance of agriculture, large climatic variability, and limited resources to adapt. There are likely to be negative effects also on livestock productivity due to increased heat stress, lower pasture productivity, and increased risks due to animal diseases. Increase in sea surface temperature and acidification will also lead to changes in marine species distribution as well as production.

Extreme events including floods, droughts, forest fires, and tropical cyclones have already increased in temperate and tropical Asia in the last few decades. Runoff and water availability are projected to decrease in the arid and semi-arid regions of Asia. Sea-level rise and an increase in the intensity of tropical cyclones is expected to displace tens of millions of people in the low-lying coastal areas of Asia with expectation of around 17 % land getting inundated in Bangladesh alone. On the contrary, the increased intensity of rainfall and contraction of monsoon period would increase flood risks in temperate and tropical Asia.

The Asia-Pacific Association of Agricultural Research Institutions (APAARI) which has been instrumental in promoting regional cooperation for agricultural research in the Asia-Pacific region has been organizing series of expert consultations for debating on emerging issues vis-à-vis agricultural research and development (ARD) concerns in the Asia-Pacific region. In this endeavor, 'biofuel' and 'climate change' were identified as major themes during the expert consultation on "Research Need Assessment" organized by APAARI during 2006. Accordingly, the issue of climate change and its imperatives for agricultural research in the Asia-Pacific region was deliberated in an International Symposium organized jointly by APAARI and JIRCAS. Participants representing national agricultural research systems (NARS), CGIAR, IARCs, GFAR, ACIAR, JIRCAS, advanced research institutions (ARIs), universities and regional fora from 30 countries came out with agricultural research priorities for adapting agriculture to climate change in the form of "Tsukuba declaration on adapting agriculture to climate change" (APAARI, 2009) described below:

Tsukuba Declaration on Adapting Agriculture to Climate Change

- Asia-Pacific region sustains almost half of the global people, with high rates of population growth and poverty. Agriculture continues to play a critical role in terms of employment and livelihood security in all countries of the region. At the same time, this region has the largest concentration of hungry and malnourished people in the world. Droughts, floods, heat waves and cyclones occur regularly. Climate change is likely to raise regional temperatures and lead to decline in fresh water availability, sea level rise, and glacial melting in the Himalayas. The IPCC has considered the developing countries of the Asia-Pacific region, especially the mega-deltas of Asia, as very vulnerable to climate change.

- Attainment of Millennium Development Goals (MDGs), particularly alleviating poverty, assuring food security and environmental sustainability against the background of declining natural resources, together with a changing climate scenario, presents a major challenge to most of the countries in the Asia-Pacific region during the 21st century.
- Water is a key constraint in the region for attaining food production targets and will remain so in future as well. Steps are, therefore, needed by all the stakeholders to prioritize enhancing water use efficiency. In addition, measures for water storage using proven approaches such as small on–farm ponds, large reservoirs, groundwater recharge and storage, and watershed approach managed by the farming communities require attention.
- It was fully recognized that increasing food production locally will be the best option to reduce poor people's vulnerability to climate change variations. Available agricultural technologies can help increase the yield potential of crops that has not yet been tapped in many countries of the Asia-Pacific region. Hence, a concerted effort, backed by policy makers at the national level, would be the key to enhance food security as well as ensuring agricultural sustainability.
- New genotypes tolerant to multiple stresses: drought, floods, heat, salinity, pests and diseases, will help further increase food production. This would require substantial breeding and biotechnology (including genetically modified varieties) related efforts based on collection, characterization, conservation and utilization of new genetic resources that have not been studied and used. CGIAR Centers, Advance Research Institutes (ARIs) and the National Agricultural Research Systems (NARS) of the region have a major role to play in this context. This will require substantial support in terms of institutional infrastructure, human resource capacity and the required

political will to take up associated agricultural reforms. We, therefore, fervently call upon the national policy makers, overseas development agencies (ODA), other donor communities as well as the Private Sector to increase their funding support for agricultural research for development in the Asia-Pacific region.

- It was also recognized that a reliable and timely early warning system of impending climatic risks could help determination of the potential food insecure areas and communities. Such a system could be based on using modern tools of information and space technologies and is especially critical for monitoring cyclones, floods, drought and the movements of insects and pathogens. Advanced Research Institution, such as JIRCAS, could take the lead in establishing an 'Advance Center for Agricultural Research and Information on Global Climate Change' for serving the Asia-Pacific region.
- The increasing probability of floods and droughts and other climatic uncertainties may seriously increase the vulnerability of resource-poor farmers of the Asia-Pacific region to global climate change. Policies and institutions are needed that assist in containing the risk and to provide protection against natural calamities, especially for the small farmers. Weather-crop/livestock insurance, coupled with standardized weather data collection, can greatly help in providing alternative options for adapting agriculture to increased climatic risks.
- Governments of the region should collaborate on priorities to secure effective adaptation and mitigation strategies and their effective implementation through creation of a regional fund for improving climatic services and for effective implementation of weather related risk management programs. Active participation of young professionals is also called for.
- It was recognized that there are several possible approaches to enhance carbon sequestration in the soils of the Asia-Pacific region such as greater adoption of scientific soil and crop management practices, improving degraded lands, enhanced fertilizer use efficiency, and large scale adoption of conservation agriculture. To be effective, these would require simultaneously improved use of inputs such as fertilizers, crop residues, labor and time. This soil carbon sequestration has the added potential advantage of enhancing food security at the national/regional level. We do urge the global community to ensure appropriate pricing of soil carbon and related ecosystem/environmental services in order to motivate the small farmers to adopt new management practices that are linked to proper incentives and rewards.
- APAARI has been instrumental in stimulating regional cooperation for agricultural research in the Asia-Pacific. Global climate change and its implications for agriculture underline the need for such an organization to become even more active at this juncture. APAARI, in collaboration with its stakeholders, especially CGIAR Centers, ARIs, GFAR and other regional fora, should continue facilitating regional collaboration in a Consortium mode and take advantage of new initiatives such as Challenge Program on Climate Change for building required capability to adapt and mitigate the effects of climate change and ensure future sustainability of all concerned in the region.

  The deliberations also led to identification of research priorities and both adaptation and mitigation strategy to deal with the challenge of climate change.

Research strategies for coping with global climate change

Coping with global climate change is a must and for that there are two strategies (i) Adaptation through learning to live with the new environment (e.g., time of planting, changing varieties, new cropping systems, etc.) and (ii) Mitigation through offsetting the causative factors such as reducing the net emission of greenhouse gases.

Adaptation strategies: The potential strategies and actions for adaptation to climate change effects could be as follow-

1. New genotypes
   - Intensify search for genes for stress tolerance across plant and animal kingdom
   - Intensify research efforts on marker aided selection and transgenic development
   - Develop genotypes for biotic (diseases, insects etc) and abiotic (drought, flood, heat, cold, salinity) stress management either by traditional plant breeding, or genetic modification
   - Attempt transforming C3 plants to C4 plants
2. New land use systems
   - Shift of cropping zones
   - Critical appraisal of agronomic strategies and evolving new agronomy for climate change scenarios
   - Exploring opportunities for maintenance /restoration/ enhancement of soil properties
   - Use of multi-purpose adapted livestock species and breeds
3. Value-added weather management services
   - Developing spatially differentiated operational contingency plans for temperature and rainfall related risks, including supply management through market and non-market interventions in the event of adverse supply changes
   - Enhancing research on applications of short, medium and long range weather forecasts for reducing production risks.
   - Developing knowledge based decision support system for translating weather information into operational management practices
   - Developing pests and disease forecasting system covering range of parameters for contingency planning and effective disease management.
4. Integrated study of ‘climate change triangle’ and ‘disease triangle’, especially in relation to viruses and their vectors.
5. Documentation of indigenous traditional knowledge (ITK) and exploring opportunities for its utilization.
6. Reforming global food system.

Mitigation strategies: The basic strategies for mitigating climate change effects are reducing and sequestering emissions. However, before jumping to band-wagon of mitigation strategies, the following points should be considered for effective implementation of mitigation strategies.

- Improve inventories of emission of greenhouse gases using state of art emission equipments coupled with simulation models, and GIS for up-scaling
- Evaluate carbon sequestration potential of different land use systems including opportunities offered by conservation agriculture and agro-forestry
- Critically evaluate the mitigation potential of biofuels; enhance this by their genetic improvement and use of engineered microbes
- Identify cost-effective opportunities for reducing methane generation and emission in ruminants by modification of diet, and in rice paddies by water and nutrient management. Renew focus on nitrogen fertilizer use efficiency with added dimension of nitrous oxides mitigation
- Assess biophysical and socio-economic implications of the proposed GHG mitigating interventions before developing policy for their implementation

1. Reducing emissions: The strategies for reducing emissions includes-

- Avoiding deforestation
- Minimizing soil erosion risks
- Eliminating biomass burning and incidence of wild fires
- Improving input use efficiency (e.g., fertilizers, energy, water, pesticides)
- Conservation Agriculture

2. Sequestering emissions: The stored soil carbon is vulnerable to loss through both land management change and climate change. There are numerous agricultural sources of GHG emissions (Duxbury 1994) with hidden C costs of tillage, fertilizer, pesticide use and irrigation. In general, net C sequestration must take into account these costs. The important strategies of soil C sequestration include restoration of degraded soils, and adoption of improved management practices (IMPs) of agricultural and forestry soils. For example in India, the potential of soil C sequestration is estimated at 39 to 49 (44 ± 5) Tg C/y of which 7 to 10 Tg C/y for restoration of degraded soils and ecosystems, 5 to 7 Tg C/y for erosion control, 6 to 7 Tg C/y for adoption of IMPs on agricultural soils, and 22 to 26 Tg C/y for secondary carbonates (Lal 2004). Therefore, agricultural practices collectively can make a significant contribution at low cost to increasing soil carbon sinks and reducing GHG emissions. A large proportion of the mitigation potential of agriculture (excluding bio-energy) arises from soil carbon sequestration, which has strong synergies with sustainable agriculture and generally reduces vulnerability to climate change. A considerable mitigation potential through sequestration is available from reductions in methane and nitrous oxide emissions in some agricultural systems. However, there is no universally applicable list of mitigation practices and the mitigation through sequestration practices need to be evaluated for individual agricultural systems and settings (e.g. conservation tillage). The biomass from agricultural residues and dedicated energy crops can be an important bio-energy feedstock, but its contribution to climate mitigation to 2030 depends on demand for bio-energy from transport and energy supply, on water availability, and on requirements of land for food and fibre production. Hence, widespread use of agricultural land for biomass production for energy may compete with other land uses and can have positive and negative environmental impacts and implications for food security.

Epilogue

Impact of climate change on agricultural production in Asia Pacific is real. Hence, immediate action at national level to understand and address the issues of climate change becomes a priority. Strategy around both adaptation and mitigation is called for, which would require research reorientation and major policy interventions. Regional and global collaboration would help in addressing these concerns and for building both institutional and human resource capabilities being the two cradles for sustainable agriculture.

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18. Improving agricultural water productivity: A necessary response to water scarcity and climate change in dry areas

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Abstract

Water resources in the dry areas are limited. Most of the available water is tapped and only limited new water is expected from non-conventional sources. As more water will be needed for other priority sectors, less water will be available for agriculture. This decline comes to challenge the attempts to increase food production and to enhance food security. Climate change adds to this challenge in the dry areas as precipitation is expected to decline and drought to intensify. Agriculture as a result must cope with the increasing demand for food, feed, and fiber, but with less water. It is, therefore, essential that substantial changes be made in the way water is valued and managed to help overcome water shortages. The logical response is to produce more with less water; that is to improve water productivity (WP) which is the return for a unit of water consumed or depleted. WP in the dry areas is generally low and there is a great potential for its improvement. There are three primary ways to enhance agricultural WP: (a) Reduce non productive water depletion; (b) Improve plant, animal, etc. productivity per unit of water beneficially consumed; and (c) Allocate water to the more water productive options. Substantial and sustainable improvements in agricultural water productivity can only be achieved through integrated management at all scales. On-farm water-productive techniques include deficit irrigation, supplemental irrigation, water harvesting and precision irrigation. Improved techniques if coupled with improved irrigation management, better crop selection and appropriate cultural practices, improved genetic make-up, and timely socioeconomic interventions will help to achieve this objective. Conventional water management guidelines should be revised to ensure maximum water productivity instead of land productivity. Policy reforms and empowered new institutional setups can ensure sustainable improvement in water use in agriculture.

Introduction

The availability of freshwater is one of the great issues facing humankind today. Water shortage and needs are increasing, and the competition for water among urban, industrial, and agricultural sectors is growing more intensive. Mining groundwater is now a common practice in the dry regions risking both water reserves and quality. In many countries securing basic human water needs for domestic use is becoming an issue not to mention the needs for agriculture, industry and environment. The average annual per capita renewable supplies of water world-wide is about 7000 m^3. The threshold for water poverty level is 1000 m^3 which looks ample for countries like Jordan, where the annual per capita share has dropped to less than 200 m^3 (Margat and Vallae 1999).

With rapid industrialization, urbanization and population increase, economic realities seem certain to reallocate water increasingly away from agriculture to other sectors. Moreover, opportunities for large captures of new water are now few. Most river systems suitable for large-scale irrigation have already been developed. Unacceptable depletion of the flow to downstream users will become increasingly difficult to avoid.

The water scarcity situation in the dry areas is deteriorating every day. Over the coming years, this situation will worsen with increasing demand, given the fact that the possibility of new supplies is limited. If the world's population keeps growing at the current rate (about 90 millions each year), we are facing the challenge of feeding 8 billion people very soon – in 2025. More than 80% of these people will live in developing countries. This implies that with nearly the same water and other natural resources base we must produce food for 2 billion more people while at the same time meeting the expanding domestic and industrial water needs. The increasing pressure on this resource will, unless seriously tackled, escalate hydroplitical conflicts and seriously damage the already fragile environment in the region.

Agriculture is by far the largest user of water, accounting for about 70 percent of all withdrawals from rivers, lakes, and aquifers, and up to 95 percent in many developing countries. The water needed for crops amounts to 1,000 – 3,000 cubic meters per tonne of cereal harvested. It takes 1 – 3 tonnes of water to poduce1kg of grain. Furthermore, it is estimated that only 45% of the water used in agriculture is effectively used by crops (UN/WWAP 2003). The other 55% is partially lost by either evaporation or by losing quality while joining salt sinks, recharges aquifers, or flows downstream to be reused. Therefore, agriculture is not seen as the most efficient water user. The ever-growing competition among water-using sectors is certainly forcing agriculture to give up part of its share to higher priority uses, especially the domestic and industrial sectors. Meanwhile, agriculture must cope with the increasing demand for food, feed, and fiber, but with less water. It is, therefore, essential that substantial changes be made in the way water is valued and managed to help overcome water shortages. Under these circumstances it is crucial that the role of water in securing food supply is understood and the potential for improving overall agricultural productivity with respect to water fully realized.

It has been widely accepted that the most promising option to achieve food security and sustain acceptable standard of living in the water scarce areas is to improve the efficiency of water use or productivity. There are three primary ways to enhance agricultural water productivity: 1) to increase effective use through improved water management; 2) to increase crop yields through agricultural research; and 3) to reform policies and increase investment, particularly in rainfed areas. Improving agricultural water productivity implies getting more output or return per unit of water used. However, sustainability issues must be carefully taken into consideration. Water will be the key agent in the drive to raise and sustain agricultural production. Therefore, agriculture policies and investments will need to become much more strategic. They will have to unlock the potential of agricultural water management practices to raise productivity, spread equitable access to water and conserve the natural productivity of the water resource base.

Water efficiency and productivity concepts

Irrigation efficiencies:

The term **'***efficiency'* in general reflects the ratio of output to input. It is widely used in irrigation systems design, evaluation, and management. Farm irrigation performance is based on three fundamental and interrelated efficiency terms: conveyance, application, distribution and storage efficiencies (Hansen et al.1980 ; Jensen et al. 1981; Walker and Skogerboe 1987; James 1988; and Keller and Bliesner 1990). Water Conveyance Efficiency (WCE) is the ratio of water diverted from the source to that delivered to the farm. It reflects water losses from the conveyance system mainly in seepage, evaporation and weeds consumptive use. Irrigation Application Efficiency (IAE) is the ratio of the water stored in the plant root zone to that applied to the field. It mainly reflects losses of water in deep percolation and in runoff. Irrigation Distribution Efficiency (IDE) refers to how uniformly the water is distributed in the plants root zone. It however does not indicate any water losses or how the full root zone is. Irrigation Storage Efficiency (ISE) is the ratio of water stored in plans root zone to the amount needed to fill it. It reflects how full the root zone is but does not indicate how uniform is irrigation or how much water is lost in deep percolation and/or runoff.

These irrigation related efficiencies are engineering terms necessary for sound design, monitoring, and performance evaluation of irrigation systems. The output (numerator) and input (denominator) components of these irrigation-based efficiencies use the same units and are expressed in percentage (%) with a maximum value of 100%. Values less than 100% imply *losses* during the process.

Losses of water reflected in the above irrigation efficiency terms are mostly paper not real losses. Seepage from irrigation canals and field deep percolation losses are largely recoverable through joining ground water or springs. Runoff losses can be recycled in the fields downstream. Drainage water is also recycled and used several times before becoming too saline. Despite the fact that most of these losses are recoverable, engineers strive to minimize them as reuse implies some costs to the user and probably other side implications. In addition efficiency terms do not indicate how productive irrigation water is.

Water-use efficiency:

Water Use Efficiency reflects how good water is used in agricultural production. The term has been defined in the literature in various ways by hydrologists, physiologists and agronomists depending upon the emphasis that one wishes to place on certain aspects of the problem. In general it is the ratio of the yield to the unit of water used. The most confusing aspect in this term is the evaluation of the unit of water used. Some use applied water; others use evapo-transpiration or even transpiration alone. The term is restricted to biophysical return to water ignoring other types of return such as socioeconomic or environmental. Production could be grain, biomass or any other entity. It makes it difficult to compare efficiencies at different places or under different practices unless the production and the water used are well defined and evaluated (Hansen et al. 1980; Hanks 1983; Howell et al. 1990; Gregory 1991; Joshi and Singh 1994).

Water productivity:

As mentioned before, irrigation and water use efficiencies, although useful in addressing many aspects of water management, do not reflect well the various types of return to water and the water used in the production. Water productivity defined as the return per unit of water consumed in the production can overcome those deficiencies. The return to water can be:

a) Biomass, grain, milk, meat, etc
b) Economic benefits (i.e. net income)
c) Environmental benefits (i.e. carbon sequestration)

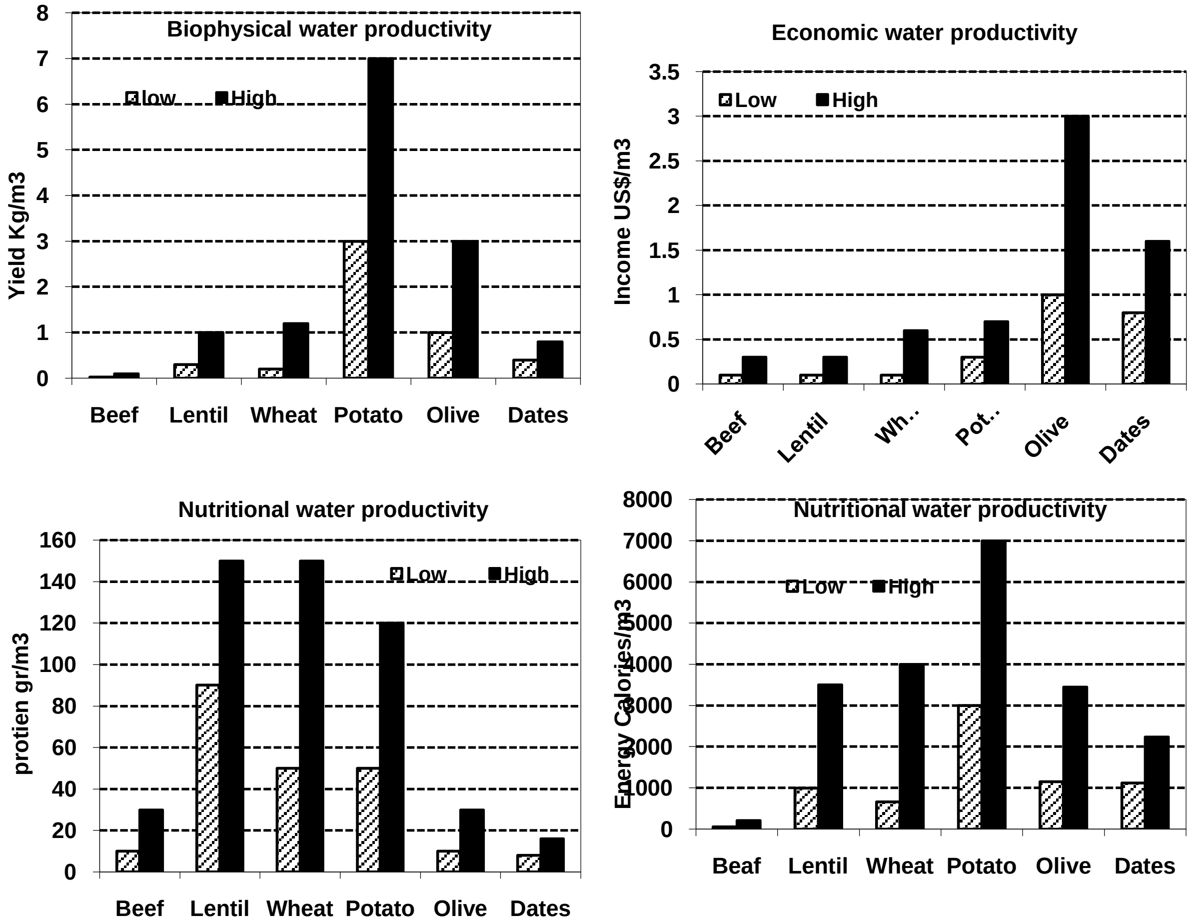

Figure 1. Estimates of a range of water productivity values (from low to high) of some agricultural products; (a) biophysical WP, (b) economic WP, (c) nutritional WP (protein) and (d) energy WP. (Molden and Oweis 2008)

d) Social benefits (i.e. employment)
e) Energy (i.e. calories)
f) Nutrition (i.e. protein)

The water consumed is meant to be the water depleted from the production system giving the return. Water depletion is the use or removal of water (from a domain, particularly a basin) that renders it unavailable for further use. Water may be depleted by evaporation, flows to sinks (such as sea or saline groundwater), or incorporation into products (such as bottled water). Therefore, it is important to distinguish between water depleted and water diverted or applied, because not all water diverted (or supplied) to irrigation is depleted. Recoverable losses (such as surface runoff, deep percolation, etc.) from any domain's boundaries can be reused within the same domain or higher levels. More specifically, depleted water includes: evaporation, transpiration, water quality deterioration, and water incorporated in the product or plant tissues. Water recycled in the farming system may not be totally lost as implied by evaluating irrigation efficiencies. Water quality is important as water with various qualities has different productivity. It is now well understood that the issue of water productivity is a multidisciplinary and scale or level-dependent (Molden and Oweis 2008; Molden 2003; Molden 1997).

Agricultural water productivity (WP)

Figures 1-4 show a range of water productivities for some agricultural products based on biophysical, economic, nutrient and energy returns (Molden and Oweis 2008). The wide range of values, from low to high, reflects the great potential for improvement. The figures show that depending on the production purpose and local conditions the selection of the product can make great deference in the return for the water. One can also notice the low water productivity in producing beef compared to crops.

It is important to note that WP is not only scale and user specific, but also site and management specific. A cubic meter of water is expected to produce more biomass in a cool than in a hot dry environment. Soil type, water quality, crop variety, production input, water and crop management are among the factors impacting WP. Market prices effect economic WP. For meaningful comparison of WP at different locations and/or environments, there is need to normalize the values of WP (Oweis and Hachum 2003).

Scales and drivers

WP is addressed at different scales (plant, farm, project, and basin levels) and a conceptual framework for better understanding of WP and water accounting across scales is introduced. It has been pointed out that highest WP at one scale does not necessarily result in highest WP at another scale. Economic productivity and opportunity cost of water make the undertaking far more complex. Nevertheless, the major drivers at each scale are:

a) At the basin level: competition among uses (agricultural, domestic, environmental, etc.), conflicts between countries, equity issues (upstream – downstream users)
b) At the national level: food security, hard currency, socio-politics
c) At the farm level: maximizing economic return (crop and allocation selection)
d) At the field level: maximizing biological output (maximizing resources productivity)
e) At the plant level: maximizing nutrient content and quality of harvest.

Potential WP improvements

Figure 2a shows worldwide ratio of biomass and yield of common small grain crops to transpiration (T) along with yield/ET ratio for two selected regions. The slope of the second line from top is greater than the slope of the top line that indicates potential improvement in harvest index. The two lower lines in the Figure indicate that improvements in water productivity are possible through improved management that increases the ratio of yield to evapotranspiration (slope of line). But in many of the most productive areas of the world, such as the lower Yellow River Basin, large improvements have already been made and the remaining scope is small. The implication is that for these areas achieving higher yields will require more evapotranspiration. The areas with the highest potential gains are those with very low yields, such as Sub-Saharan Africa and South Asia. These are also areas of extreme poverty, with the largest concentration of poor people and high dependence of the poor on agriculture (Molden and Oweis 2008; Rockstrom et al. 2007).

Crop breeding, targeting early growth vigor to reduce evaporation, and increasing resistance to drought, disease, or salinity could all improve water productivity per unit of evapotranspiration. But there are several indirect means to improve water productivity in which biotechnology can play a role: (a) Targeting rapid early growth to shade the soil and reduce evaporation; (b) Breeding for resistance to disease, pests, and salinity; (c) Boosting the harvest index for crops such as millet and sorghum that have not received as much attention as the

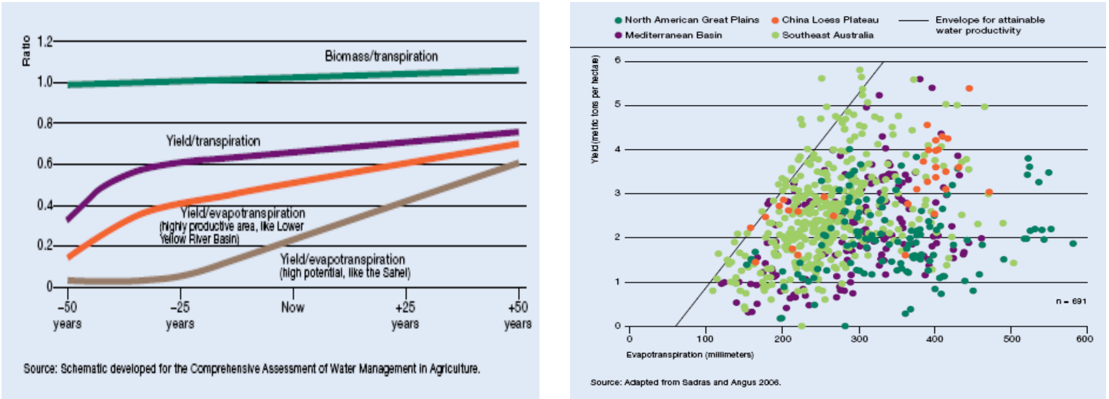

Figure 2. Potential improvements in water productivity. (a) Projected potential improvements of WP with various means and regions, (b) water yield relations of wheat grains in major regions of the world (Molden and Oweis 2008).

green revolution cereals; (d) More value per unit of evapotranspiration can be achieved by improving the nutritional quality of crops and by reducing agrochemical inputs by planting disease- and pest-resistant crops.

Figure 2b illustrates significant variability in yield due to differences in biophysical conditions (particularly evaporation and other climatic conditions) among sites in addition to differences in management of natural resources. Variability due to management practices gives hope for potential improvement in water productivity especially at low yield domain. It shows that the potential to improve WP is substantial in many areas and mainly management can achieve this improvement.

Tradeoffs between water and land productivities:

In conventional irrigation, water is applied to maximize crop yield per unit of land. This is the case when land availability is limiting. In the most of the dry areas, land is not any more the most limiting factor to agricultural production. Rather, water is increasingly becoming the most limiting factor. The objective, therefore, should be maximizing the return per unit of water instead per unit of land. This should yield higher overall production, since the saved water can be used to irrigate new land with higher production. However, high WP does not come without high land productivity (LP). Fortunately, both water and land productivities increase as the on-farm management is improved. However, this does not continue all the way. At high yield level achieving incremental increase requires higher amounts of water to be used. This means that water productivity drops as yield increases near its potential. Figure 3 shows the relationship between LP and WP for wheat in the Mediterranean region. When this relation is curvilinear, maximum WP occurs at less than maximum LP which is not the case for all crops and conditions (Oweis et al. 1998).

Attaining higher yields with improved WP should ensure that increased gains in crop yield are not offset by increased costs of inputs and running costs. The curvilinear WP–yield relationship emphasizes the importance of attaining relatively high yields for efficient use of water. A policy for maximizing yield and/or net profit should be looked at very carefully under water scarcity conditions. Guidelines for recommending irrigation schedules under normal water availability (Allen et al. 1998) may need to be revised when applied in areas with limited water resources.

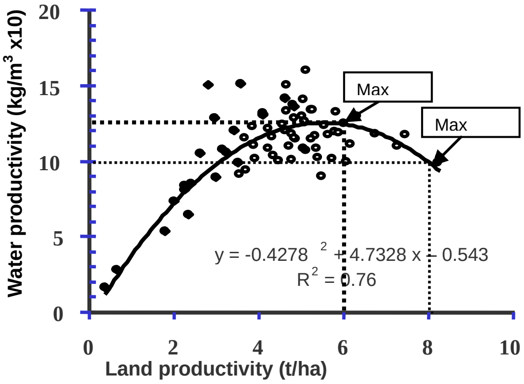

Figure 3. Relationship between water productivity (WP) and land productivity (LP) for durum wheat in Mediterranean environment (Oweis et al. 1998).

When water is short of providing full supplemental irrigation (SI) to the whole farm, the farmer has two options: a) to irrigate part of the farm with full SI leaving the other part rainfed or b) to apply deficit irrigation to the whole farm. In northern Syria, water-short farmers are advised to apply 50% deficit SI to their wheat fields. By so doing, the area under SI is doubled using the same amount of water, and total farm production is higher. A farmer having a 4-hectare farm would on average produce 33% more grain from his farm if he adopted deficit irrigation for the whole area, than if full irrigation was applied to half of the area (table 1).

Approaches for improving water productivity

Following are major approaches for improving agricultural water productivity (Viets 1962; Stanhill 1986; Monteith 1986; Oweis et al. 1998).

Increasing the productivity per unit of water consumed:

- ***Improved crop varieties;*** to grow new crop varieties that can provide increased yields for each unit of water consumed, or the same yields with fewer units of water consumed.
- ***Alternative crops;*** by switching from high- to less-water-consuming crops, or switching to crops with higher economic or physical productivity per unit of water consumed.
- ***Deficit, supplemental, or precision irrigation;*** with sufficient water control, higher productivity can be achieved using irrigation strategies that increase the returns per unit of water consumed.
- ***Improved water management;*** to provide better timing of supplies to reduce stress at critical crop growth stages leading to increased yields or by increasing water supply reliability so that farmers invest more in other agricultural inputs leading to higher output per unit of water.
- ***Optimizing non-water inputs;*** in association with irrigation strategies that increase the yield per unit of water consumed, agronomic practices such as land preparation and fertilization can increase the return per unit of water.
- ***Policy reform and public awareness;*** policies related to water use and valuation should be geared towards controlling water use, reducing water demand, safe use and disposal of water, and encouraging the collective approach in using and managing water.

Table 1. Wheat grain production scenarios for 4-hectare farms with various strategies of supplemental irrigation in Syria (Oweis and Hachum 2003)

Management strategy	Rainfed	Farmer'	Full SI	Deficit SI
Total water applied (m^3)	342 mm	2980	2220	1110
Grain yield (t/ha)	1.8	4.18	4.46	4.15
Water productivity (kg/m^3)	0.53	0.70	1.06	1.85
Possible 4-ha farm production (ton) if water is not limiting	7.2	16.7	17.8	16.6
Total 4-ha farm production (ton) under limited water available (50% of full requirements)	7.2	10.8	12.5	16.6

Reducing non-beneficial water depletion:

- ***Reducing evaporation from water applied*** to irrigated fields through specific irrigation technologies such as drip irrigation, or agronomic practices such as mulching, or changing crop planting dates to match periods of less-evaporative demand.
- ***Reducing evaporation from fallow land***, decreasing the area of free water surfaces, decreasing non- or less-beneficial vegetation and controlling weeds.
- ***Reducing water flows to sinks*** by interventions that reduce irrecoverable deep percolation and surface runoff.
- ***Minimizing salinization of return flows***—by minimizing flows through saline soils or through saline groundwater to reduce pollution caused by the movement of salts into recoverable irrigation return flows.
- ***Shunting polluted water to sinks*** to avoid the need to dilute with freshwater, saline or otherwise polluted water should be shunted directly to sinks.
- ***Reusing return flow*** through gravity and pump diversions to increase irrigated area.

Reallocating water among uses:

- ***Reallocating water from lower- to higher-value uses.*** It will generally not result in any direct water savings, but it can dramatically increase the economic productivity of water. Because downstream commitments may change, reallocation of water can have serious legal, equity and other social considerations that must be addressed.
- ***Tapping uncommitted outflows*** to be used for productive purposes.
- ***Improving management of existing facilities*** to obtain more beneficial use from existing water supplies.
- ***Policy, design, management and institutional interventions*** may allow for an expansion of irrigated area, increased cropping intensity or increased yields within the service areas.
- ***Reducing delivery requirements*** by improved application efficiency, water pricing, and improved allocation and distribution practices.
- ***Adding storage facilities infrastructures*** to store and regulate the use of uncommitted outflows (as is the case during wet years) so that more water is available for release during drier periods.

Highly water-productive technologies

Deficit irrigation:
When water is limiting the production, the rules of scheduling should be modified for improved water productivity. In intensive irrigation development, all efforts including research and advancement in technology development are geared towards achieving yield maximization per unit of land. However, in water scarce areas, water, not land, is the most limiting factor to improved agricultural production. Irrigating for less than maximum yield per unit land (deficit irrigation) could save substantial amounts of water for irrigating new lands and hence producing more food from the available water. Deficit irrigation is not the only practice that has shown good potential, but other ways are available to modify water management principles to achieve more water-efficient practices. New guidelines for crop water requirements and irrigation scheduling to maximize water productivity are yet to be developed for the important crops in the dry areas.

Deficit irrigation is an optimizing strategy under which crops are deliberately allowed to sustain some degree of water deficit and yield reduction in order to maximize the productivity per unit of water used. One important merit of deficit supplemental irrigation is the greater potential for benefiting from unexpected rainfall during the growing season due to the higher availability of storage space in the crop root zone. Results on wheat, obtained from farmers' fields trials conducted in a Mediterranean climate in northern Syria showed significant improvement in SI water productivity at lower application

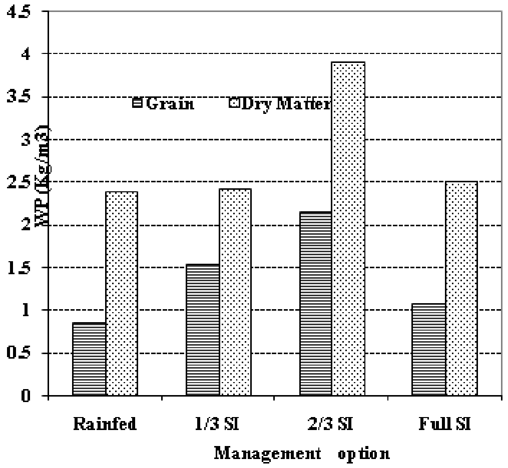

Figure 4. Water productivity (WP) of wheat grains under rainfed, full and deficit irrigation (SI) in northern Syria (Oweis et al. 2003).

rates than at full irrigation. Highest water productivity of applied water was obtained at rates between 1/3 and 2/3 of full SI requirements, in addition to rainfall.

Water harvesting:

The drier environments, the steppe or *badia*, occupy the vast majority of the dry areas of the world. The natural resources of these areas are subject to degradation and the income of the people, who depend mainly on livestock grazing, is continuously declining. Due to harsh conditions, people are increasingly migrating from these areas to the cities, with associated high social and environmental costs. Precipitation in the drier environments is generally low compared to crop basic needs. It is unfavorably distributed over the crop-growing season and often comes with high intensity. As a result, rainfall cannot support economical dryland farming. In the Mediterranean areas, rain usually comes in sporadic, unpredictable storms and is mostly lost in evaporation and runoff, leaving frequent dry periods during the crop growing season. Part of the rain returns to the atmosphere by evaporation after it falls, and part usually flows to swamps or to “salt sinks”, where it loses quality and evaporates (Oweis et al. 1999).

Water harvesting in agriculture is based on the principle of depriving part of the land of its share of rainwater and adding it to the share of another part. This brings the amount of water available to the target area closer to the crop water requirements so that economical agricultural production can be achieved. It is thus the process of concentrating precipitation through runoff and storing it for beneficial use.
Without water harvesting intervention, all rainwater and land production are lost, while with water harvesting part of the land and most of the rainwater are used in production. Thus, rainwater productivity is immensely increased. Notable wealth of indigenous knowledge on water harvesting is available and documented. Indigenous systems such as *jessour* and *meskat* in Tunisia, *tabia* in Libya, *cisterns* in north Egypt, *hafaer* in Jordan, Syria and Sudan and many other techniques are still in use (Oweis et al. 1999 and 2001). Water harvesting may be developed to provide water for human and animal consumption, domestic and environmental purposes, as well as for plant production. Water harvesting is also effective in combating land degradation and desertification.

Unfortunately, the introduction of systems which have been tested under various climatic, soil, land-tenure and socio-economic conditions are usually not accepted by the target groups. The most significant problems and constraints hindering the integration of water harvesting in the agricultural production are:

- Technology inadequacy to meet the local conditions;
- Lack of acceptance, motivation and involvement among beneficiaries;
- Lack of adequate hydrological data and information for confident planning, design and implementation of water harvesting projects;
- Insufficient attention to social and economic aspects such as land tenure, unemployment and return of water harvesting system;
- Inadequate institutional structures, beneficiary organizations and government training programs for farmers, pastoralists and extension staff;
- Absence of a long-term government policy.

Supplemental irrigation:

Shortage of soil moisture in the dry rainfed areas often occurs during the most sensitive growth stages (flowering and grain filling) of the crops. As a result, rainfed crop growth is poor and yield is consequently low. Supplemental irrigation (SI) can, using a limited amount of water, if applied during the critical crop growth stages, result in substantial improvement in yield and water productivity. Therefore, supplemental irrigation is an effective response to alleviate the adverse impact of soil moisture stress during dry spells on the yield of rainfed crops. Unlike full irrigation, the timing and amount of SI cannot be determined in advance owing to rainfall randomness. Supplemental irrigation in rainfed areas is based on three basic aspects (Oweis and Hachum 2003): Water is applied to a rainfed crop that would normally produce some yield without irrigation, irrigation is only applied when rainfall fails to provide essential moisture for improved and stable production, and the amount and timing of irrigation are scheduled to ensure a minimum amount of water available during the critical stages of crop growth.

Average WP of rain in producing wheat in the dry areas of West Asia and North Africa (WANA) ranges from about 0.35 to 1.00 kg grain/m^3. However, water used in supplemental irrigation can be much more efficient. Studies at ICARDA showed that a cubic meter of water applied at the right time (when crops suffer from moisture stress) and good management could produce more than 2.5 kg of grain over the rainfed production. This extremely high WUE is mainly attributed to the effectiveness of a small amount of water in alleviating severe moisture stress during the most sensitive stage of crop growth. This stress usually causes a collapse in the crop development and seed filling and reduces the yields substantially. When SI irrigation water is applied before such conditions occur, the plant may reach its high yield potential.

In comparison to the productivity of water in fully irrigated areas (rainfall effect is negligible) we find greater advantage with SI. In fully irrigated areas with good management, wheat grain yield is about 6 t/ha using a total amount of 800 mm of water. This makes WP about 0.75 kg/m3, one third of that under SI with similar management (Figure 5). This suggests that water resources are better allocated to SI when other physical and economic conditions are favorable

In the high lands of WANA region, frost conditions occur in the winter and put field crops into dormant condition. Usually, the first rainfall, sufficient to germinate seeds, comes late resulting in low crop stand when the frost occurs. Rainfed yields as a result are much lower than when the crop stand pre-frost is good. Ensuring a good crop stand in December can be achieved by early sowing a and applying a 50-100 mm of supplemental irrigation early in the season.

Applying 50 mm of SI to wheat sown early increased grain yield by more than 60%, adding more than 2 t/ha to the average rainfed yield of 3.2 t/ha (Ilbeyi et al. 2006). Water productivity of wheat reached 3.7 kg grain/m3 of consumed water compared to 1 to 2 kg/m3 under traditional practices (Figure5).

Alternative cropping patterns:

Due to increased water scarcity and climate change, current land use and cropping patterns should be modified if more food is to be produced from less water.

Water is likely to be the major constraint and new land use systems that respond to external as well as internal factors must be developed based on available water. This should include adopting water efficient crops, varieties, and sound combinations of crops in the farming system.

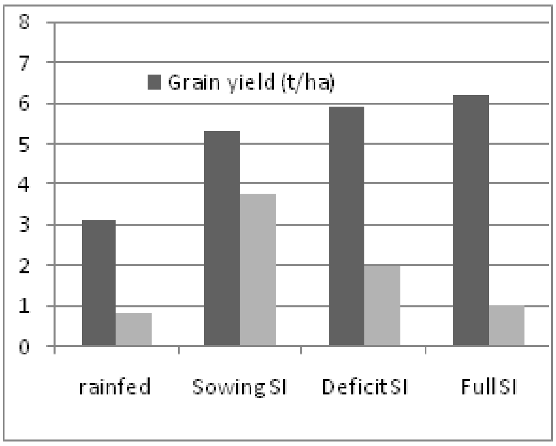

Figure 5. Water productivity and yield of wheat grains under various water management strategies; rainfed, full supplemental irrigation, deficit irrigation and sowing irrigation (Ilbeyi et al. 2006) .

In cases of extreme water scarcity the concept of importing virtual water becomes viable. We do not encourage adopting this concept as a national policy in developing countries as it affects food security. Caution should be taken when evaluating the monetory, social and environmental returns for water and the best crops should be adopted for maximum benefits. Further more, modifications of cropping patterns should be introduced gradually with appropriate policies to encourage adoption.

Precision irrigation:

Improved technologies that already exist may at least double the amount of food produced from present levels of water use. Implementing precision irrigation, such as micro- and sprinkler irrigation systems, laser leveling and others techniques contribute to substantial improvement in water application and distribution efficiency. It is true that water lost during conveyance and on-farm application is not an absolute loss from a basin perspective, but its quality may deteriorate and its recovery comes at a cost. To account for these losses, the size of the irrigation system will significantly increase and this again comes at a very high cost. Policies to implement and transfer these technologies are vital. There is a need to provide farmers with economic and more efficient alternatives to on-farm water management practices with incentives that can bring about the needed change.

Other considerations

Environmental water productivity:

It is now globally understood and accepted that *environment* is a water-using sector, which is strongly linked to the sustainability of water resources development and management. This is a complex issue for both rich and poor countries. It is technically challenging and often entails difficult trade-off among social, economic, and political considerations. Strategies to reduce poverty should not lead to further degradation of water resources and ecology. Environmental water needs and that for food production should be complementary for sustainable livelihoods.

Enabling environments:

Lack of appropriate policies and institutional setups are main obstacles for adoption of improved water management options. Valuating water is essential if productiity is to improve. Socio-political constrains do not allow water pricing, but alternatives to pricing can be developed.

Water trading through goods is an old practice. It can be used in countries with extreme water scarcity to reduce inefficient water use; but agricultural practices of rural communities should be protected. Water management institutions such as user associations and community cooperatives are weak in the region and need strengthening. They should be allowed to participate in the decision making regarding water issues. Training is essential to improve skills and participation. These vital changes are essential in order to unlock the potential of water management in agriculture.

Conclusions and recommendations

In the dry areas, water is the most limiting resource for agricultural production and is increasingly declining. As more food in needed with less water available, the only option available is to increase agricultural water productivity. Focusing on water productivity in addition to land productivity is therefore a recommended strategy. To achieve this, more efficient water management techniques must be adopted. On-farm water-productive techniques should be coupled with improved irrigation management options. Major changes needed would include: water allocation to more water-efficient crops/techniques, more water-efficient land use, water valuation to truly reflect its value, trade policy to import high water demand goods, regional cooporation for combating water scarcity and new policies to address water scarcity issues.

Substantial and sustainable improvements in water productivity can only be achieved through participatory and integrated farm resources management. More investment in rainfed agriculture, in reallocating water resources to higher water efficient options such as SI and WH and in improving WP through appropriate policies and institutional set ups is recommended.

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19. Climate change, water crisis and desertification - role of traditional knowledge to cope with the challenge

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Abstract

People have always had to face the unpredictability of the environment and the variability of the climate. These conditions have allowed us to acquire knowledge appropriate at the local level to deal with adversity, thanks to the techniques of water collection and distribution, the protection of soils, recycling, and to the optimal use of energy. However, it is the first time in the history of our planet that the changes in climate are due to the human intervention and that they are accompanied by two factors that make it difficult to respond to them.The first factor is the speed at which the process that has been set in motion is taking place impeding a progressive, natural and cultural adaptation to the new conditions.The second factor is the state of physical and social deterioration. Soils are exhausted by the agricultural industry and massive urbanisation. Crops are deserted because of waves of emigration, poverty and loss of identity. This is true for all countries in the world, just as much the dry zones as the temperate ones. Where there is water, there is no one who had learnt to manage it with wisdom as in the oases of the desert. Oases are not natural phenomena, a random happening, but the product of human talent. A system tightly connected and completely under the care of the inhabitants. The conditions of oases, where every error has an immediate echo on the survival of the whole ecosystem, provide a lesson that only a common and responsible management can guarantee the survival of the oasis in the cosmos, in the Earth. The paper highlights the value of traditional knowledge of pre-industrial societies in the area of natural resources management. The significance of the practical and cultural dimensions of this knowledge based on a systemic vision of the human-nature interactions taking into account the environmental, economic and socio-cultural aspects of natural resources management is underlined. An emphasis is placed on the history of water management traditional techniques and local knowledge considered as part of cultural history. Special attention is given to water management practices developed in the arid areas of this region and notably to the oases model described as a sustainable development alternative to the hydraulic civilisations model based on an abusive exploitation of water resources. Several examples of innovative use of ancient water management practices for agricultural, architectural and urban development purposes are described.

Intoduction - facing the new global crises

Global warming and climate exasperation set new urgent issues in managing urban and rural areas. Environmental crises on a large scale caused by meteorological extreme factors and sea level rising will have a massive impact on the rural and urban systems, already stressed by a hypertrophic consumption of resources.

Production models today are based on concentrating population on flat and coastal land and abandoning the mountain and hilly areas. The mountain systems are no longer protected and they have lost their capability of absorbing water and mitigating climate. Landslides, rain-wash and flooding are becoming more frequent and affect the plains and coasts where the watercourses have been cemented causing, together with the urbanization process, land disappearance. It is the land, the superficial layer resulting from the continuous interaction of chemical, physical and biological factors with water that makes vegetable life possible, assuring the same land's protection and constant regeneration. Without this protection soil is exposed to the violence of the atmospheric forces and is eroded by wind and rain. The materials carried off add more abrasive particles to the winds and produce sand that contributes to the disappearance of superficial run-off water, worsening dryness. The land degradation and biological and hydraulic impoverishment processes are therefore strengthened in a constantly increasing desertification cycle. Inappropriate human intervention like exploiting the water and vegetable resources, monoculture, aggression to slopes and cementing are all factors that trigger and worsen the process. Appropriate local intervention schemes can instead interrupt the negative circle of desertification and install new sustainable dynamics. This is the direction Traditional Knowledge follows thanks to its long period of adaptation to environmental dynamics.

Traditional Knowledge constitutes the ancient knowledge of humanity, the deepest layer on which our science and culture have developed, the local solutions that have allowed the creation and management of ecosystems and cultural landscapes on the entire surface of the planet. It enables the development of solutions with a low energy and resource use that are able to adapt to environmental variability and to react to emergencies and catastrophes in flexible and multifunctional ways. It has used solar energy and the laws of nature: the principles of thermal insulation for protection from heat and cold, hydrodynamics for water capure and distribution, biology principles to combine and reuse elements for humus and cultivable soil creation. It has managed to control the force of the winds, to use the law of gravity and to exploit the slightest factors of humidity to trigger interactive autocatalytic processes to amplify positive phenomena.

Today, while entire planet systems risk ecological collapse, Traditional Knowledge shows how to interact with the environment enhancing its resource potential without exhausting it. It is the bearer of quality and techniques, widespread on a territorial scale, that have originated from the use of the materials and objects of everyday life. It consists of fragile elements that are subject to the attack of today's transformations, but it also constitutes a still widely adopted system of strong and brilliant devices for energy production and resource recycling, microclimate control and for the management of the earth's soil.

In Nepal, 75% of the irrigated area is managed with traditional techniques, in the Philippines 50%, and in Sri Lanka 40%. In India, it is only 4%, but if we consider the size of the country and that it has 70 million hectares of irrigated agriculture, this is an enormous figure. In the Sahara desert, in extreme arid conditions, the oases make life possible thanks to complex traditional systems of water capture and management, soil maintenance, dunes control and bioclimatic architecture. Vast areas of desert, now completely abandoned, were once covered with gardens and cultivations thanks to these practices. The incredible water distribution systems in Marib, in the heart of the Arabian desert, made the existence of the capital of the Queen of Saba possible for 2000 years, before this civilization was destroyed and covered by the sand. Still today in Algeria, of the date cultivation in the oases, roughly 13.000 hectares having about 2 million date palms are watered thanks to underground tunnels dug artificially. The total surface covered by these channels is of 7,000 Km. We are referring to an ancient technique dating back thousands of years, capable of producing water in the most extreme desert conditions and compatible with the environment's capability of renewing its resources. In Morocco, the intricate net of artificial channels makes the region around Marrakech fertile and has been working for 300 years. In the south of Italy and in the Mediterranean plains, Neolithic societies flourished thanks to embankments, channels and water regulation systems. Until recent times, on the islands and coasts of the Mediterranean, Red Sea and Indian Ocean, potable water was guaranteed thanks to archaic water condensation and gathering systems.

It is wrong to consider traditional knowledge only as a historical reminiscence constituted by marginal practices to the greater economic and technological processes. From a quantitative point of view also its use still maintains most of humanity, distributed in the less industrialized countries. Absurdly in these places where traditional techniques are of common use, they are considered as a manifestation of backwardness in a modernist view, while in developed countries they become elements that create an image and add value. Learning to use this knowledge and disseminate it then does not mean a return to the past but its innovative reintroduction. This is a productive area of research for the development of new technologies based on the same ancient principles, experiencing the possibility of acquiring the most ancient knowledge of humanity and of marrying it with high-tech. This integration between historical experience and modern technological complexity is possible in all sectors, from agricultural to urban systems, landscapes and social practices.

The new role of local knowledge in agriculture

In agriculture, traditional techniques dating back to prehistory are today reintroduced as the best practices for the regeneration of soil, hydraulic savings, and combating hydro- geological instability and desertification. The draining ditches technique of the Daunia, in the southern Italian region of Puglia, dates back 6000 years. More than 3000 villages were surrounded by crescent shaped trenches that drained the water maintaining the earth dry for cultivation during the wet season and having multiple functions as watering place for animals, humus creating patches and water reservoirs in the dry season. Today, the traditional practice has been substituted by automated agriculture and in these places terrible floods take place in winter and drought in the summer. On the Ethiopian planes, along the Rift Valley, many villages still use trench systems with multiple functions for storing and regulating water resources, collecting sewage and producing fertilizer. Water condensation from the atmosphere in caves, from piles of stones and walls of calcareous stones is used in all the ancient societies in arid areas. Today aerial wells, atmosphere condensers that produce water from the humidity in the air, have been created thanks to the application of the same ancient principles and techniques. The practice of installing terracotta jar shaped cisterns or piles of calcareous stones near plants to supply water is reproposed today with innovative techniques and is more functional than the modern dripping irrigation system. These techniques are used for reforestation in arid areas and provide each plant with its own water supply that sustains the tree in its growth period until it becomes able to tap underground water. In the same frame of technologies a company has elaborated enzymatic biodegradable compost called "dry water" which, when placed near the roots, gradually transforms itself giving needed water supply.

Draining water tunnels, underground channels for water capture, are still used in the Sahara but also in China and Iran to produce the necessary hydraulic resources for the oases. The tunnels, dug parallel to the level of the ground, do not reach the aquifers, but they only drain the superficial surface of water, therefore absorbing only a quantity compatible with their regeneration capacity. They therefore constitute a solution that can be reused also in damper countries, as an alternative to wells that draw water directly from the aquifers exhausting them and causing serious pollution problems and salinity. In the Sahara new techniques to ease the hard digging work are being experimented by introducing small machines especially designed. To the same innovative class belongs a series of mechanical equipment ranging from mini-tractors to dig crescent shaped trenches for storing water, to new machines for sustainable agriculture. In this field reintroducing ancient practices enables successful results in combating soil erosion and degradation.

In southern Italy, new practices are being experimented like planting grass and sowing without previous tilling. The first technique consists in letting grass grow under fruit and olive trees creating a protective layer and avoiding tilling which is a cause of erosion. The second technique is based on sowing wheat on land that has not been tilled to preserve soil and save costs. This practice is to be used in situations of drought because the wheat plants grow less in height and need less water and chemical fertilizers.

Traditional techniques and materials in architecture

A series of innovative technologies deriving from tradition are being experimented in the urban sector. Most of the ancient centres were built on the agricultural land, where terracing and hydraulic systems had been created. In their structure, they incorporate and continue using the ancient techniques for gathering rain water, the protected areas and kitchen gardens, the reuse of organic waste for making humus, the passive architecture, climate control for conserving food methods, energy saving and food and waste recycling systems. All the techniques on photovoltaic, solar energy for warming, water captation, compost and waste recycle belong to this category. Several companies now propose roof-gardens, which are becoming mandatory in some cities in the advanced countries, like Tokyo for example, where the grass on the roofs of modern buildings, reminiscence of the ancient hanging gardens of Babylonia, maintains a perfect climate balance in the apartments, collects rain water and constitutes a place for leisure and contemplation. In the recycling system, a vast innovative sector is represented by micro-solutions in the neighbourhood or in each house. Small compost producing units to be placed in the gardens or communal areas are quite common and are effective in absorbing organic waste, transforming it into humus for the gardens. A water-closet composter has also been created, based on a device that is set immediately under the seat that transforms sewage directly into compost. There are some miniature biomass reactors that transform waste in to biogas for use in kitchen and also bigger systems for the heating of the whole house.

Small and large-scale solutions for sewage are available. In Germany for example, modern houses have been provided with vertical swamps, devices that imitate water decantation and filtering processes like those that take place naturally on the marshlands. The same process is reproduced along the walls of the buildings in glass channels where sewage is continually filtered, putrified and recycled. In Calcutta an innovative traditional technique used on a large scale has solved the problem of grey water. Traditionally the wastewater was reused for rice fields, today thanks to the appropriate innovations of the sewage filtering and sterilization processes, the wastewater from being a problem has changed back to being a resource to irrigate and fertilize rice fields.

Another innovative sector is represented by the great quantity of products, materials and know-how used in high-quality architecture. The aesthetical elements we appreciate in the ancient towns, like the beauty of natural materials, the architecture and the space, the organic relation with the landscape owe their success to the intrinsic quality of traditional techniques and to the research for the symbiosis and harmony with the local practices. In this sector numerous companies have started reintroducing materials and processes obtained trough tradition, like quicklime, natural plasters, pozzolana for restoration and new constructions.

Quality produce and landscape protection

Local knowledge is a propelling economic factor in several sectors of production. Tradition persists and has an economic fundamental role in those sectors and countries considered to be technologically more advanced. The values of tradition, the practices and artisan capabilities are the basis on which the added value is founded and constitutes an important economical factor for many modern countries. Typical food production like oil, cheese and wine protect the quality of the landscape both aesthetically and environmentally because the ancient production systems are possible only with the use of the ancient techniques for soil management. In the same sector, the increasing use of organically produced agricultural products including meat demonstrates the growing interest in traditional cultivation and breeding techniques.

The same considerations are true for other sectors, going from utensils to fashion design and for the land and housing markets. The finest companies boast about the traditional techniques they use, and their success is due to their capability of incorporating tradition in their productive processes.In the Vallese regions in Switzerland, in the Loire valley in France, in Tuscany in Italy, maintaining traditional techniques in agriculture has made high quality landscape settlement possible. The high labour costs and difficulties faced are accepted because of the great value attributed to the obtained products, in the case of Tuscany the best example is the production of wine. In the Vallese area, the systems catching water from the stream sources or from glaciers are still functioning. Irrigation from the glaciers is possible thanks to the bisses, superficial channels, built with the right inclination to drain the water with the force of gravity. With this technique mountain slopes at higher altitude than the water streams can be irrigated. A similar technique is reproposed today in Tibet with innovative methods to preserve glaciers endangered by climate change. In the Loire the traditional technique of troglodyte houses with their underground caves is maintained to preserve every meter of land, precious for the production of high quality wine, and to create perfect micro-climate cellars for the processing of the product. In Tuscany the wine production provides sufficient economic resources to preserve one of the most splendid agricultural landscapes, consolidated and stabilized over the centuries.

In Liguria, where one of the most extended systems of terraced slopes in the Mediterranean is preserved, the Cinque Terre, the traditional technique that protects the earth and drains the water has been consolidated with an innovative agricultural mechanisation process. The difficulty of the work in the terraces is the transport. Traditionally, lift transportation facilities had been invented, like sledges pulled up with ropes. At the beginning of the XX century these were already substituted with rack railways. Today the same technique is reintroduced with appropriate monorail systems that enable ascending the slopes without disturbing the surrounding landscape and ecosystem.

Social practices

In Botswana the ‘motswelo’ is a traditional form of cooperative and of banking, ivolving generally fifteen to twenty people. The participants come voluntarily and they contribute what ever they can afford - money, products from their farms, labour, etc. With this, a system of savings, borrowing with no interest, and financing of important activities is created. The production and marketing work are considered as deposit funds. The profits are destined in turn to one of the motswelo members, who uses them to finance his activity or for other social needs like festivals, marriages, house purchasing etc. These practices are reintroduced today by the Ethical banks and micro-borrowing systems, constituting an innovative reintroduction of traditional social practices.

In Burkina Fasso 'zai' is a particular traditional technique that enables the recovery of degraded land. Holes in the ground are made so that in the wet season they fill with water and in the dry season they are filled with waste and manure. This practice attracts termites that digest the waste that can then be assimilated by the plant roots. The termites' activity also enhances the soil porosity. Seeds are then planted in the holes and there is a high productivity. Innovative practices that promote original forms of symbiosis between humans, animals and microorganisms are reintroduced today for restoring degraded land or re-elaborated to make certain areas with extreme conditions more bearable.

In the Balearic Islands, 'feixes' are a type of agricultural organization where irrigation is carried out from underground, providing the necessary quantity of water directly to the plant roots and avoiding any waste of resources. The cultivated fields are separated by superficial channels where water flows. From these main channels a series of smaller ones are dug under the fields and furnished with porous calcareous materials covered by a bed of algae. These tunnels are capable of releasing the right quantity of water depending on the seasonal needs and climatic conditions. The same technique is reintroduced in hydroponic cultivations and in space-stations design.

Guidelines for a new sustainable paradigm

The acquisition and dissemination of this knowledge does not mean a return to the past, but their innovative reintroduction. This a productive field of research for the development of new technologies based on the same ancient principles, experimenting the possibility of acquisition of the ancient knowledge and combining it with high-tech.

In nature, the elements water, air, soil, energy are related to one another in a cyclic manner and nothing is wasted but everything is continually renewed. This principle at the basis of traditional knowledge has determined in the past the beauty of our historical centres and landscape. The shortage of resources is the result of destruction. An enormous quantity of rain water is not stocked and it flows away while precious potable water is put to toilet use. Solar energy has always been used traditionally and today, with the modern photovoltaic techniques, it can solve the energy problems of an entire country. The piles of rubbish and the quantity of wastewater today constitute a problem but may become a resource. With innovative techniques suitable for the environment and the local societies it is possible to create a system to obtain water from the atmosphere, energy from the sun, soil and fertilizers from recycling: a harmonious human development compatible with cultures and nature.

The following guidelines must be developed:

a) in rural areas agriculture must not be considered as a mere productive system but as a necessary action for territorial maintenance;
b) in the urban areas environment and town must be integrated and action plans implemented for an auto-sustainable form of human settlement and a new concept of towns as ecosystems.

The programmes should focus on innovative actions in managing the soil, water and energy resources. Particularly it is necessary to:

- Address financing differently and stop the processes of loss of local knowledge, soil degradation and harmful transformations for the landscape;
- Enhance and promote traditional development of water collection and distribution systems;

- Enhance the adoption of traditional techniques in organizing production in integrated cycles;
- Provide incentives for sustainable programmes in the urban systems;
- Promote integration of production, consumption and waste disposal in the urban areas;
- Enhance people’s participation, re-evaluating the role of the elderly, women, and children and of the marginal strata of society and organize territorial networks between municipalities, territories, basin communities and parks.

The local knowledge and the traditional territorial asset must be reintroduced to protect the typical landscape and safeguard the knowledge itself.

20. Climate change impact on dry areas, a daunting challenge for sustainable agricultural production

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Abstract

The drylands cover about 54 million km^2 of the globe. Although spreading across all continents, they are concentrated in Asia and Africa. Projected global warming there, leading to extreme climate variability and change, is expected to have significant impacts on agricultural production systems and the livelihood of millions. Drought could cause 350 to 600 million Africans to face water shortages by the middle of this century. On the other hand, predicted increase in rainfall in the arid lands of northeast Africa in the next 40 years may lead to dramatic changes in land use bringing more conflicts between farmers and pastoralists. Soil degradation, deforestation, spread of diseases, poverty, environmental refugees, conflicts, and food security are challenging issues for the developing world under the anticipated scenarios of climate change. Sudan, being one of the top 13 countries with more than 1.5 million km^2 of dry lands, is expected to face daunting challenges to adapt to the anticipated climate change. Sudan has suffered from droughts and floods with varying severity during the past and recent years. One study over 12 meteorological stations showed a trend that rainfall will decrease by about 0.5 - 5.0 mm/year for the period 1952 - 1992. A more recent study concluded that the frequency of receiving only 50% of the seasonal long term average rainfall was highest between latitude 18° to 22° N in the northern parts. Analysis of temperature and rainfall for the period 1960-2006 revealed a trend for rising temperatures during the last three decades, while rainfall showed a decline except in south of Kordofan and in the extreme southern parts. Another study projected temperature rise in 2030 in Western Sudan by 0.5 to 1°C while the global prediction is 0.6°C. Consequently, the average annual rate of evapotranspiration would increase from 2773 to 3110 mm. The yield of sorghum and millet in Western Sudan is expected to decline by 13-82% and 20-70% respectively. The paper highlights some of the results of climate change studies and the associated impacts on agricultural production systems together with suggested strategies, tools and practices for increased resilience and/or mitigation of climate change effects in drylands in general and Sudan in particular.

Introduction

Using the definition of aridity provided by the United Nations Convention to Combat Desertification (UNCCD), based on the ratio of precipitation to potential evapotranspiration (P/PET), dryland covers about 34.8% of the terrestrial land (Robin and Nackoney 2003). The drylands fall in the aridity index range 0.05 to 0.65 P/PET which includes arid, semi-arid and dry sub es`dhumid areas. Semi-arid region is the most extensive followed by arid and dry sub-humid areas. On the other hand, the Thematic Program of Work (WoP) on Dry

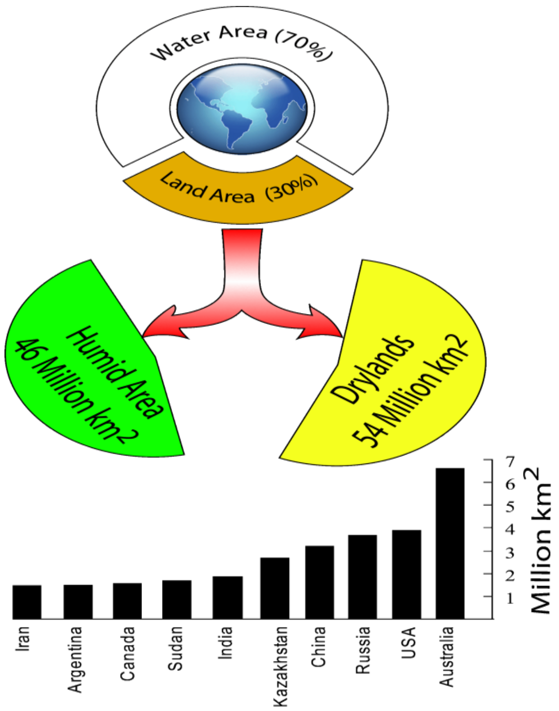

Fig. 1. Global drylands and the top ten countries with more than 1.4 million km^2 of dryland

and Sub-humid Lands of the Convention of Biological Diversity (CBD) defines dry lands to have less than 0.65 P/PET thus extending dryland cover to 41.5% of the terrestrial land. (Fig. 1) shows the extent of dryland cover relative to terrestrial land and the top ten countries with over one million square kilometers of drylands.

More than two billion people live in the drylands. High population densities are concentrated in the semi-arid and dry sub-humid zones of India, dry sub-humid zones of eastern China and in the Middle East. It is beyond doubts now that climate change and variability are affecting the style of living and will continue to affect the way people do business for generations to come. Those living on drylands with low income or below poverty line will be severely affected.

Climate change is a global problem that mankind has to face and a lot of precious time has already been wasted with little useful steps taken to tackle the problem, especially in the developing world. The problem is complicated and confounded by land and environmental degradation and resources overexploitation due to population increase and urbanization. As the drylands are fragile with complex ecosystems that evolved over thousands of years, they will be severely affected, no matter whether in the developed or developing countries, once the fragile balance is disturbed through temperature rise and extreme weather conditions. For example, the two reservoirs, Lake Mead and Lake Powell, providing water for over 27 million people in seven states in the USA are now half full and according to a recent study it is concluded that there is a 50% chance that the two reservoirs will dry-up by 2021. Furthermore, there is a 10% chance that the two reservoirs will run out of usable water by 2013. On the otherhand, a new study co-founded by NASA, indicated that rainfall in eastern Africa (March-May) has declined by 15% since the eighties and the cause is debated to be irregularities of moisture transportation due to rising temperature of the Indian Ocean.

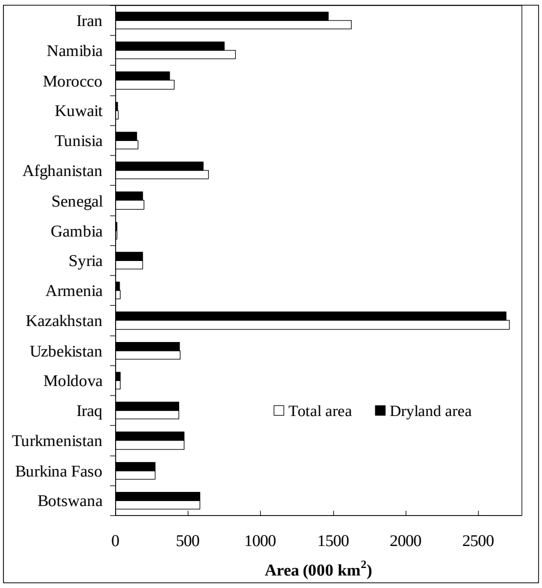

Fig. 2. Dryland extent compared with total area in countries with over 90% of dryland

Table 1. Distribution of drylands by region (000 km^2)

Region	Arid	%	Semi-Arid	%	Dry Sub-Humid	%	All Drylands	%
Asia	6,164	13	7,649	16	4,588	9	18,401	39
Africa	5,052	17	5,073	17	2,808	9	12,933	43
Oceania	3,488	39	3,532	39	996	11	8,016	89
North America	379	2	3,436	16	2,081	10	5,896	28
South America	401	2	2,980	17	2,233	13	5,614	32
Central America & Caribbean	421	18	696	30	242	10	1,359	58
Europe	5	0	373	7	961	17	1,339	24
World Total	15,910	12	23,739	18	13,909	10	53,558	40

Source: UNSO/UNDP 1997

According to Molly Brown of NASA's Goddard Space Flight Center (www.metropolismag.com), who co-authored the study, the decline in rainfall will affect the delicate and sensitive ecosystems of Somalia and eastern Ethiopia. This in turn will have serious impacts on the River Nile and the civilization that continued to nourish around it, because the Blue Nile is one of the live arteries of the River Nile that originates from the Ethiopian plateau.

Drylands and climate change

The amount of web-based information on climate change and variability is enormous with several models and scenarios. Despite the fact that the globe is getting warmer, to date, not all the consequences of climate change have been fully understood. Hence much research efforts are needed todevelop and examine evidences of how this change would be at regional and local levels in general and in drylands in specific. This will necessitate downscaling of the general circulation model (GCM). The process requires long-term daily climatic data and capacity to use them for modeling, which is a constraint in many parts of the developing world. The situation is further aggravated by the on-going challenges already facing sustainable development in drylands even if climate change scenarios were ignored. Theses challenges include population increase, destruction of surface vegetation, poor management of water resources, irrational use of irrigation water, fertilizers and pesticides, bad land use practices, pollution and overexploitation of surface and ground water. In addition, the land degradation is rampant due to overgrazing as some of the highest livestock densities in the world are in the drylands of Asia, Africa, the Middle East, and South America (Robin and Nackoney 2003).

Generally speaking, climate change impacts can be classified in to three categories: impacts on agriculture, impacts caused by rising sea level, and impacts resulting from increased frequencies of extreme weather events. It is difficult to separate the last category from the first one, as it is cross-cutting. The following general impacts on drylands were anticipated:

Impacts on agriculture:
Agriculture is anticipated to be impacted due to changes in local temperature and rainfall patterns. Depending on location, the expected consequences will be reduced crop yields, with longer periods of drought and increased frequency of rainfall storms and floods,. These would be devastating in areas with less adaptation capacities and

plans as is the case in most of the underdeveloped and developing dryland areas. Changes in growing season and on-set of rainfall would imply changes in cropping patterns and land use, which may induce land degradation. Land degradation induced by climate change would lead to loss of agricultural activities leading to famine and mass migration. Civil unrest and conflicts may be caused by increased competition over land and water resources specially in areas with nomadic and pastoralist activities. Darfur dispute is one of the examples. On the other hand, there are opportunities of making use of the extra water if appropriate strategies and adaptation plans are put together and capacities for proper implementation are enhanced. For example, a recent study in the Climate Land Interaction Project (CLIP) indicates that the arid land in the remote northeast part of Africa gets wetter causing dramatic changes in land use, which may cause land disputes between the displaced livestock keepers over limited usable lands. According to Kumar and Parikh (2001), temperature is expected to rise in India by 2.5 to 4.9 °C, which will cause about 32 to 40% reductions in rice yields and about 41 to 52% losses in wheat yields.

Other dimension to the problem of temperature rise and floods will be increased health problems in areas threatened by vector-borne diseases such as malaria and water-borne diseases like cholera in addition to heat stress for elder and young people. For example, malaria is now invading some high lands of Eastern Africa as a consequence of higher temperatures. Another effect related to temperature and rainfall is the reduction in per capita availability of water; it is predicted to be reduced by 50% in the already parched Middle East and North Africa. Remedies include water demand management reforms such as the one lead by the Regional Water Demand Initiative for the Middle East and North Africa (WaDImena). Large technological investment schemes on water transfer from areas of availability to areas of scarcity such as the Libyan Great River Project may also be needed in the future together with cheaper methods for desalination of sea water. Loss of biodiversity and ecosystems such as the loss of climate sensitive indigenous species and invasion of alien species is also expected to occur in fragile ecosystems of the drylands because of changes in the weed flora due to temperature-induced growth of some species and loss of other species due to unfavorable conditions and/or increased incidences of plant diseases. Maintenance of endangered species is necessary through genetic resources conservation programs and genetic engineering techniques.

Effects of rise in the sea level:
Due to melting of glaciers and ice caps the sea level is expected to rise, threatening the low-lying areas and causing loss of usable land and water resources due to intrusion of sea water, damage to infrastructures and impairment of economic activities, especially in the low-lying delta regions in poor countries dependent on coastal fishery and agriculture (Parikh and Parikh 2002). Increased sea level may trigger environmental refugees that would create population pressures around nearby large towns and cities or may increase the pace of land degradation when settling in fragile ecosystems.

Adaptation and mitigation

Adaptation refers to all human activities that aim at reducing the negative impacts of climate change on the quality of life and various human activities. This may include planning, awareness raising, crises management and consideration of climate change in new development plans. Mitigation on the other hand, refers to the actions taken to deal with the root cause of the problem, emission of green house gases (GHG). This may include global treaties on GHG emissions and commitments, change in the lifestyle, reduction of fossil fuel consumption and other industrial activities. It also involves the utilization of alternative and cleaner energy sources such as bio-fuels, wind, waves and solar radiation, the usage of more efficient machines in addition to other activities that result in increased carbon sequestration such as restoration of forests, wetlands and other sensitive ecosystems. However, there are concerns raised by the developing countries that mitigation efforts would be at the expenses of development and economic growth of poor countries even though they were not responsible for the generation of GHG emissions that have caused the problem. Developing countries such as India, often argue that there are considerable actions being taken within the country in terms of policies, programs and projects related to climate change issues while some developed countries fail to fulfill their commitments on GHG cut-back.

Situation in Sudan:

Sudan is one of the top 13 countries with more than 1.5 million km^2 of dry lands and with more than 70% of the population depending on agricultural activities as the main source of income. The country is expected to face daunting challenges to adapt to the anticipated climate change. Although Sudan is very active member of the Intergovernmental Panel on Climate Change (IPCC), the current activities related to climate change are far below the level needed in terms of research activities, development of strategies and policies, and raising the awareness of general public about the threats associated with climate change. The situation in other African countries is not much different. This is directly attributed to the fact that most of the African nations have been deeply involved in either economic crises or civil disputes, which have been dictating their agenda for priority setting with least priority attached to issues related to climate change. On the otherhand, most of the African nations see themselves as victims of the developed world on climate change issues and hence expect that the adaptation capacity-building and related climate change costs must be paid for by the developed world. But, such an opinions should not prevent them from getting actively involved in research and development activities for enhanceing the resilience of their people in the face of the climate change.

With meager resources directed for research in Sudan on climate change, preliminary analysis of data showed that droughts and floods with varying severity have inflicted Sudan several times during the recent years. One study, based on data from 12 meteorological stations, showed that the rainfall was decreasing by about 0.5 to 5.0 mm/year over the period 1952 – 1992 (Table 2).

More recently, a study concluded that the frequency of receiving only 50% of the seasonal long term average rainfall was highest between latitude 18° to 22° N. Analysis of data for the period 1960-2006 revealed a rising trend for temperature during the last three decades, while rainfall showed a decline, except in south of Kordofan and the extreme southern parts. Another study predicted a temperature rise of 0.5 to 1°C by 2030 in Western Sudan, while the global prediction was 0.6°C. Consequently the average annual rate of evapotranspiration would increase from 2773 to 3110 mm. The yield of sorghum and millet in Western Sudan is expected to decline by 13-82% and 20-70% respectively. Abdelhadi et al. (1999) analyzed climatic data between 1966 and 1993 with regards to evapotranspiration and crop water requirements in the Gezira Iirrigation Scheme of Sudan. Results showed that weather trend is inclined towards higher evapotranspiration due to the effects of drought combined with higher temperatures. This implies that more water would be needed during summer time especially under less or no rainfall conditions

Table 2. (a)Yearly Drop in Rainfall. (b) Correlation Coefficient and (c) Level of Significance during 1952-92 in Sudan

Station	A (mm/year)	b	c
Dongola	-0.48	0.56	<0.01
Atabara	-0.56	0.31	<0.05
Shambat	-4.9	0.96	<0.001
Medani	-4.7	0.93	<0.001
Damazine	-5.4	0.88	<0.001
Malakal	-2.6	0.25	<0.05
Gadaref	+0.5	0.04	N.S.
Sennar	-3.03	0.32	<0.05
Kosti	-5.0	0.76	<0.001
Obied	-3.9	0.58	<0.001
Kadugli	-3.99	0.33	<0.05
Nyala	-5.12	0.59	<0.001

Source: Mohamed (1998)

The Agricultural Research Corporation of Sudan is currently involved in three regional projects related to climate change. The first includes Tanzania, Kenya, Ethiopia and Sudan while the second includes Sudan, Kenya Uganda and Eritrea. These two projects involve research activities on selected sites to understand climate change through advanced data analysis and simulation models. The projects also intend to raise public awareness about climate change impacts and build capacities of different stakeholders on the utilization of climate and crop models and weather forecast for better planning and formulation of adaptation strategies. The third project is the CARBOAFRICA project with one monitoring site near El Obeid in Demokeya forest where Sudan is leading the quantification and prediction of carbon cycle and the emission of other GHG in Sub-Saharan Africa. The station started data collection in 2002 and has a measuring system in operation for eddy covariance flux since 2004. It is hoped that through these three projects the region would benefit from the inventory of technologies, strategies and best practices that will be created in the form of participatory multi-stakeholder approach on climate change adaptation in addition to making actual measurements of changes occurring through field monitoring and observations for further research in the area of climate change and impacts.

At national level, Sudan has recently adopted two comprehensive programs, one on mobilization of resources for agriculture and the other on agricultural revitalization. The two programs may indirectly deal with climate change issues through a number of proposed policies, laws and regulations. These include sustainable utilization of land and water resources while protecting and reducing the environmental deterioration due to irrational expansion of mechanized agriculture and other related sectors; combating desertification and desert encroachmen; afforestation programs and promotion of renewable energy sources; introduction and adoption of agricultural insurance system; development of flood early warning system and development of strategic food reserves; revision and improvement of land tenure rules and regulations; formation of Higher Council for Agriculture to deal with agricultural revitalization program; partnership and cooperation with relevant international and regional organizations; and formation of water users' associations and promotion of water savings techniques. However, the agricultural revitalization program is an ambitious program that requires complementary roles and backup of all the institutions at local and national levels to accomplish its mission.

Strategies

The following strategies are needed to deal with climate change issues in the drylands in the developing countries:

1- Capacity building for all the relevant stakeholders for better understanding of climate change scenarios and risk analysis. This includes training of research and meteorological staff on GCM models and downscaling using the available local weather data in addition to crop simulation models.
2- Enhancement of public awareness on climate change issues and implications.
3- Cises management strategies including diversification of livelihood and formulation of strategic food reserves at national and regional levels in addition to improvement of interstate roads and communication facilities for quicker responses at times of emergencies and crises.
4- Technology transfer including modern irrigation technologies, water harvesting, desalination and water transport and recycling of waste water.
5- Afforestation and reclamation of marginal and waste lands with proper incentives for public and private sectors.
6- Active participation and involvement in regional and international forums and research support related to climate change adaptation and mitigation.
7- Utilization of cost-effective-environmental friendly alternative energy sources based on the system of incentives and penalties.
8- Combat desertification and land degradation.
9- Sustainable and integrated water resources management including spending on water storage facilities.
10- Urban development and industrialization projects that are climate-proof.

Acknowledgments

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21. Climate change and water: recommendations for healthier Africa

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Abstract

Coping with climate variability and climate change in Africa is a topic of high interest to many decision makers, water resource specialists, agriculturalists, environmentalists, urban and industrial developers, and scioeconomists. It is widely accepted that climate change will lead to an intensification of the global hydrological cycle and may have major impacts on local and regional water resources. For Africa, impacts are being projected on both ground and surface water supplies for domestic and industrial uses, irrigation, in-stream ecosystems, hydropower generation, navigation, and water-based tourism. The degree of effect of climate change, however, on the available water resources in Africa is muddled with other factors such as transboundary agreements, population growth, changes in water sectors' demands, water management options used, level of technology deployment, vertical and horizontal strategies used for agriculture development, and the level of investment deployed in infrastructure. The 2001 Intergovernmental Panel on Climate Change reported that though changes in the climate may affect the whole continent of Africa, its distribution may vary. Desertification is predicted to increase in the arid northern sub-region of the continent. Rainfall is predicted to decrease in the Sahara and Sahel sub-regions, resulting in soil degradation and an increasing number of dust storms. In northeast Africa, more intense dry periods and shorter wet seasons are expected to affect even huge river systems such as the Blue Nile, leading to water shortages and adverse consequences for the agriculture and forestry sectors throughout the region. In West Africa, more frequent and longer dry periods are expected, again threatening crop failures. East and Central Africa will also see its agricultural capacity decline. Coastal areas may also be affected by rising sea levels and intrusion of salt water into inland freshwater resources. Southern Africa also faces similar threats. Climate change, therefore, is expected to further worsen the food and fiber supply, hence, exacerbate the widespread poverty in the region. This conceptual paper attempts to offer some broad recommendations to the potentially impacted countries within the continent of Africa. The recommendations, nonetheless, aim to advance the constructive dialogue among the stakeholders to navigate priorities to withstand the projected impacts of climate change on water resources for healthier Africa.

Introduction

Coping with climate variability and changes in Africa is a topic of high interest to many decision makers, water resources specialists, agriculturalists, environmentalists, urban and industrial developers, and scioeconomists within Africa continent and elsewhere. It is widely accepted that climate change will lead to an intensification of the global hydrological cycle and may have major impacts on local and regional water resources. For Africa, impacts are being projected on both surface and ground water supply for domestic and industrial uses, irrigation, in-stream ecosystems, hydropower generation, navigation, and water-based tourism.

The degree of climate changes, however, on the available water resources in Africa is muddled with other factors such as transboundary agreements, population growth, changes in water sectors' demands needs, water management options used, technology deployment level, agriculture vertical and horizontal development strategies deployed, and infrastructure investment levels being implemented.

The 2007 Intergovernmental Panel on Climate Changes reported that though changes in the climate may affect the whole continent of Africa, its distribution may vary. Desertification is predicted to increase in the arid northern sub-region of the continent. Rainfall is predicted to decrease in the Sahara and Sahel sub-regions, resulting in soil degradation and an increasing number of dust storms. In northeast Africa, more intense dry periods and shorter wet seasons are expected to affect even huge river systems such as the Blue Nile, leading to water shortages and adverse consequences for the agriculture and forestry sectors throughout the region. In West Africa, more frequent and longer dry periods are expected, again threatening crop failures. East and Central Africa will also see its agricultural capacity decline. Coastal areas may also be affected by rising sea levels and intrusion of salt water into inland freshwater resources. Southern Africa also faces similar threats. A climate change with no focused actions, therefore, is expected to further worsen the food and fiber supply, hence, exacerbate the widespread poverty in the region.

This conceptual paper attempts to offer some broad recommendations to the potentially impacted countries within the continent of Africa. The recommendations, nonetheless, aim to advance the constructive dialogue among the stakeholders to navigate priorities to withstand the projected impacts of climate changes on water resources for healthier Africa.

Dry areas of developing world occupy about 3 billion hectares or 20 percent of total global land area, and are home to one-third of the global population – over 1.7 billion people. According to number of publications, about 16 percent of the populations in these areas live on one dollar a day, particularly in marginalized rainfed areas.

Coping with climate variability and changes in Africa is a topic of high interest to many decision makers, water resources specialists, agriculturalists, environmentalists, urban and industrial developers, and scioeconomists within Africa continent and elsewhere. It is widely accepted that due to climate change, most land areas of our planet is getting warmer, and fewer cold days and nights and more frequent hot days and nights. The published reports indicated that it is very likely over most areas warm spells and heat waves to occur; heavy precipitation events. It likely area affected by droughts increases and intense tropical cyclone activity to increase and an increased incidence of extreme high sea level

It is obvious that dry areas are living with uncertainties and challenges, key challenges facing the dry areas, include:

- Desertification
- Loss of precious agro-biodiversity
- Water Poverty

- Abiotic Stresses: Drought, heat, cold
- Climate change
- Biotic Stresses: e.g. disease and insect pests
- Inadequate National investments in research
- Inadequate policy and institutional support
- Globalization
- Urbanization
- Inadequate empowerment of women
- War and conflict
- Hunger, malnutrition and poverty

Majority of water managers use conventional assumptions for water planning. Climate change, however, may alter the reliability of water management systems. Thus, projection may not reflect the reality of water portfolios. Therefore, an innovative ways in water planning becomes a necessity to account for climate change added constraints. Climate change is being observed, is causing problems, and some changes is unavoidable. The evidence is accumulating and convincing that the climate pattern is already shifting or changing (Fig. 1, 2 and 3).

Some of the worst impacts will be on natural resources such as water the hydrologic cycle will be substantially or in some cases significantly affected. Existinwater natural or human-made water systems will be significantly affected in complex ways. Conventional water engineers, practitioners, managers and planners are not well prepared. There are things we can do now to reduce the risks of impact of climate change. Sole dependence on conventional water management responses is no longer the only option. Best available knowledge related climate changes should be seriously considered in water planning. Remaining uncertainties should not be used to delay taking certain actions now

The Earth has warmed by two-thirds of a degree C since 1900. Precipitation patterns are changing. Glaciers are melting at larger rates in what the historical record shows (Fig.3). Vegetation is blooming earlier in spring and summer and continues to photosynthesize longer in fall. Snow and ice cover are decreasing and melting starting earlier than what used to be. Timing of runoff in some land-snowmelt water basins shows evidence of a change.

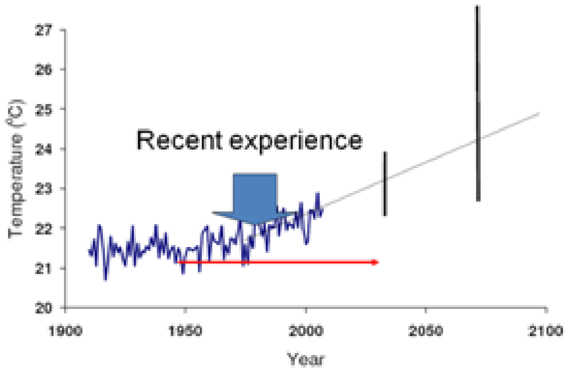

Figure 1. Temperature projections for Australia, Prof Ross Kingwell, University of Western Australia & Department of Agriculture & Food, Western Australia: 1st ICARDA Science Week. Oct.2008.

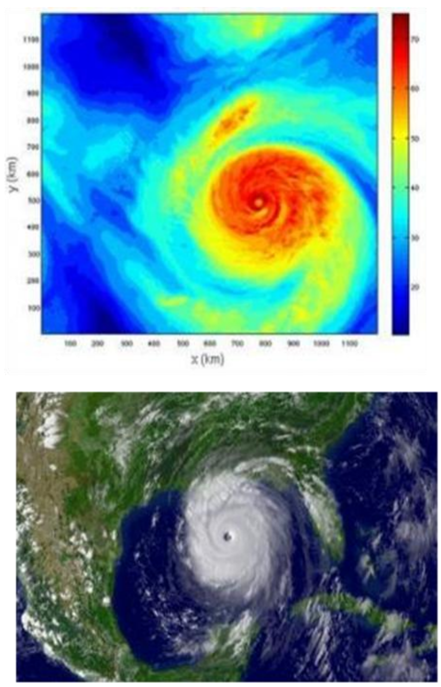

Figure shows an example of a hurricane computer simulation generated by the Rosenstiel School team. The colors indicate water vapor in a vertical column of the atmosphere, where the dark red areas would indicate extremely heavy rainfall. The small size of each pixel, 3 km x 3 km provides remarkably accurate detail in the storm. In comparison, the number of pixels in an image used to represent storms in global climate models are typically 100 km x 100 km, at best. (Credit: UM/RSMAS)

http://www.sciencedaily.com/releases/2008/09/080904145113.htm

Figure 2. Predicated and observed weather extremes

Higher ambient temperatures and reduced snowmelt would compound the problem of providing suitable cold water habitat for aquatic live. Sea level rise would especially affect the numerous coastal areas and likely cause more salinity intrusion and adversely impact wildlife reserves.

With less certainty, there may be an extreme precipitation events, thus, increase in floods risk and inadequate ability to handle storm drainage in facilities designed with historical rainfall depth-duration-frequency data. Slightly higher water use by plants due to higher temperatures would be expected, partially offset by the beneficial effect of higher atmospheric carbon dioxide levels.

Increasing winter evapotranspiration could reduce the excess deep percolation of rainfall for aquifer recharge. Loss of natural water storage in the snowpack would reduce developed project water yields. Less snowmelt runoff would mean lower early summer storage at major foothill reservoirs with less hydroelectric power production. Lower summer reservoir levels would affect recreation adversely.

In summary, there is quite uncertainty and room for debate related to the magnitude. The scientific debate about whether climate change is a problem is over. Although, the political debate of who is causing it, is not! The debate now is:

- What kind of impact?
- How serious is the impact?
- What should we do about it?
- When should we start?
- How much financial resource will it cost?
- How long it would take?
- Who is responsible and who should pay
- and how much?
- What can we expect for water?

- A warmer, wetter world, on average.
- Dramatic changes in land-snowfall and snowmelt dynamics.
- Rising sea-level with impacts on groundwater aquifers and coastal ecosystems.
- Ground overdraft.
- Flooding may be more of a problem.
- More frequent droughts.
- Deterioration of surface and groundwater quality (temperatures, flows, runoff rates and timing, and the ability of watersheds to assimilate wastes and pollutants).
- Poor understanding of specific regional changes

Figure 4 shows the major water basins in Africa where in About 25 percent of the current African population experiences water stress 69 percent live under conditions of relative water abundance (Vörösmarty et al., 2005). Relative abundance: potablity and accessibility only about 62 percent of Africans had access to improved water supplies in the year 2000, One third of the people in Africa lives in drought-prone areas and are vulnerable to the impacts of droughts (World Water Forum, 2000)
In west Africa, a decline in annual rainfall has been observed since the end of the 1960s, with a decrease of 20 percent to 40 percent in the period 1968-1990 as compared to the thirty years between 1931 and 1960 (Nicholson et al., 2000; Chappell and Agnew, 2004.)

Proposed recommendations for water and Africa:

- Optimizing use of water resources by improving water delivery and irrigation efficiency and agriculture drainage water reuse.
- Improving water sanitation coverage for urban and rural areas.
- Development of nonconventional water infrastructure and management to include brackish water use and agriculture drainage water treatment and use.
- Development of clear and appropriate strategies for the countries industrial, urban, and agriculture water sectors with due consideration to human environment health
- Development of focused and specialized human capacity programs
- Development of multi levels educational and outreach programs

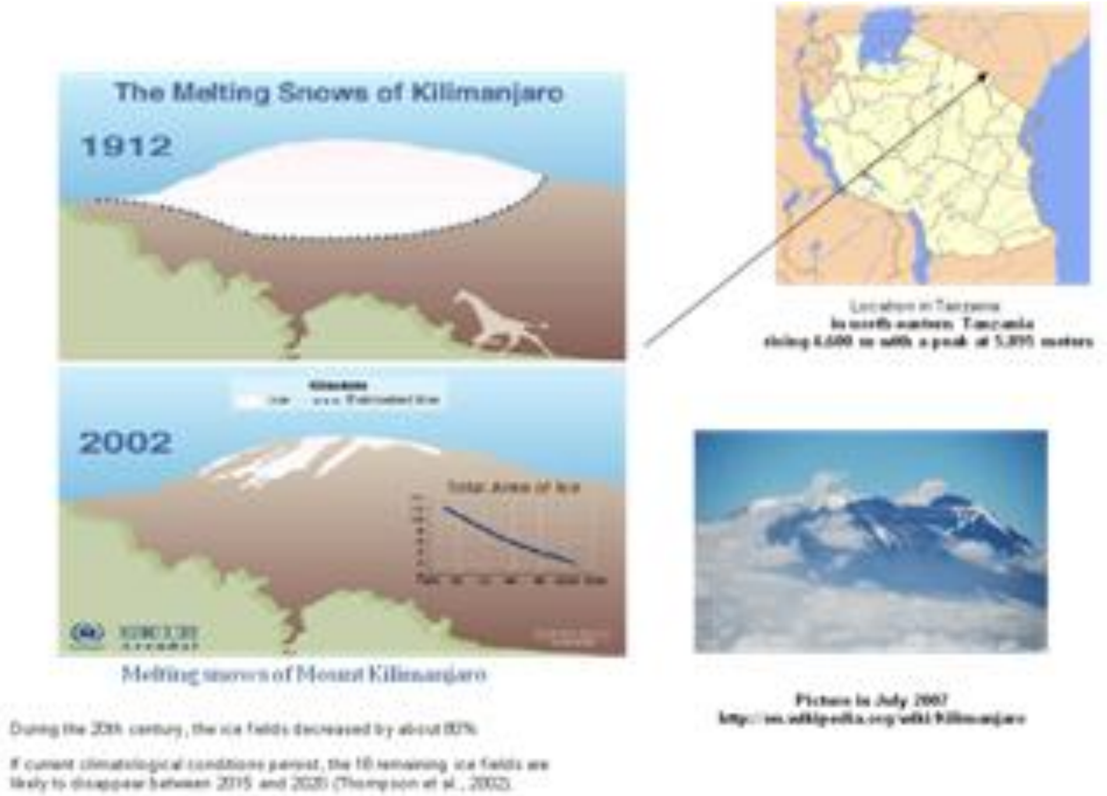

Figure 3. Temporal melting snow of Mount Kilimanjaro, Tanzania.

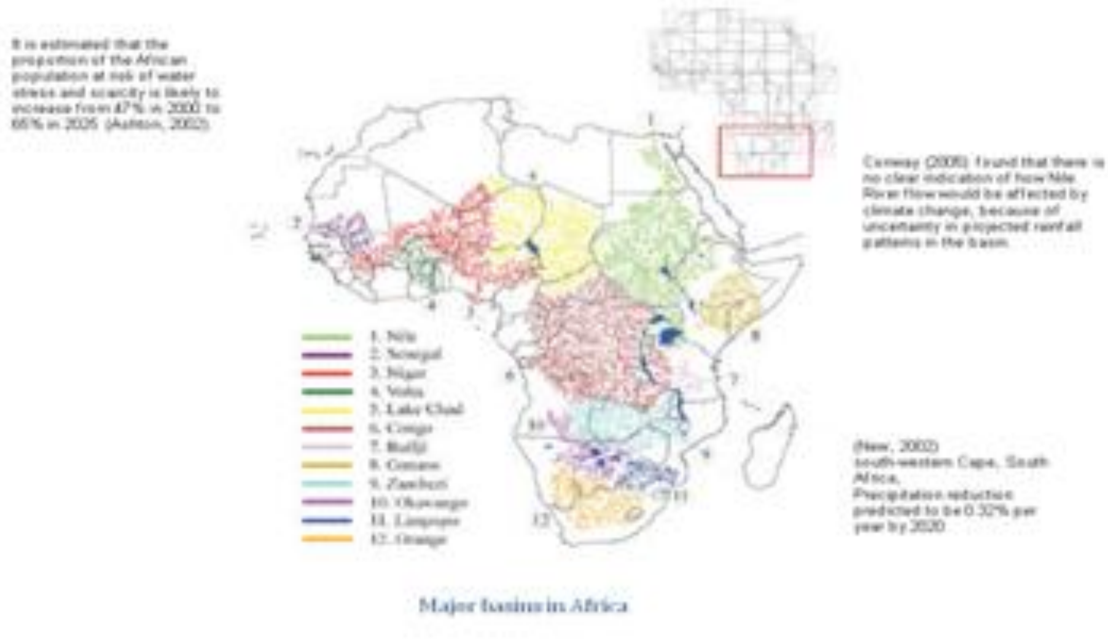

Figure 4: Major water basin in Africa, Adopted from the IPCC, 2007.

- Capitalize on developed technologies to be modified to meet specific localities with incentive/disincentive programs.
- Development for water plans every 5 years to provide options and strategies to balance water resources supply and demand
- Develop applicable water supply management options
- Develop an applicable water demand options
- Development of complementary mechanisms to impalement the proposed programs
- Development of institutional evaluation approaches to evaluate the level(s) of the implementation programs.
- Promote water management relations among the countries of the Region
- Reinforce South-South and North-South cooperation, while promoting the flow of information and practitioners development
- Develop more efficient mechanisms of cooperation and support in order to enhance African countries' integration and adaptation to Climate Change
- Mobilize the necessary brain and financial resources for establishing structured workplans and adaptation strategies and the corresponding plans of action.
- Finally no doubts that the progressive water planners agree with the IPCC conclusion "water demand management and institutional adaptation are the primary components for increasing system flexibility to meet uncertainties of climate change."

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22. Understanding drought-tolerance mechanism in barley and its utilisation for the development of stress tolerant germplasm

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Abstract

The advent of molecular markers has revolutionized the genetic analysis of crop plants and provided valuable new tools to identify chromosome regions influencing tolerance to abiotic stresses. Yield performance under drought is particularly a complex phenomenon, because yield itself is a quantitative trait, and plants exhibit a diverse range of genetically complex mechanisms for drought resistance, including mechanisms of drought escape, drought avoidance, and drought tolerance (e.g., osmotic adjustment). This complexity may explain why most quantitative trait loci (QTL) studies of field-grown barley have so far been performed in favorable conditions, while only a few studies have performed QTL analyses for agronomic performance under drought stress. These studies have shown that developmental genes, notably those involved in flowering time and plant stature have pleiotropic effects on abiotic stress resistance and ultimately determine yield potential. In order to reduce complexity, physiological traits that have influence on yield performance under drought were investigated in several studies on osmotic adjustment, relative water content and carbon isotope discrimination conducted on field-grown barley and under controlled conditions.

In addition, the application of expression analyses and cloning techniques to the analysis of stress response has allowed the detection of a number of candidate genes whose expression is affected under stress. The paper presents QTL studies for agronomic performance (plant height, flowering time, yield, peduncle length, peduncle extrusion) in relation to drought stress. The methodology used here in barley will also be used for bread wheat as part of the global center of excellence for dryland science program. Approaches to improvement in drought tolerance

Introduction

Two contrasting philosophies have been used to breed crops for drought tolerance. The first uses selection under optimum growing conditions, and is based on the assumption that an increased yield potential will have a carryover effect when the improved cultivars are grown under less favorable conditions. The second uses direct selection in the presence of drought within the target environment, and can take two forms: (i) selection for physiological or developmental traits (analytical breeding), and (ii) direct selection for grain yield (empirical or pragmatic breeding).

The first philosophy has failed to produce convincing results. In barley, scientists consistently found a negative relationship between yield potential and yield under stress conditions (van Oosterom et al.

1993). The circumstantial evidence of the absence of a spillover effect is that drought continues to affect negatively agricultural production worldwide, despite the spectacular increases in crop yields obtained through breeding under optimum conditions.

Breeding based on traits associated with drought tolerance has been very popular. Traits investigated include physiological/biochemical and developmental/ morphological traits. The physiological/biochemical traits include osmotic adjustment, osmotic potential, comtent of water soluble carbohydrates, proline content, stomatal conductance, epidermal conductance, canopy temperature, relative water content, leaf turgor, abscisic acid content, transpiration efficiency, water use efficiency, carbon isotope discrimination, and retranslocation of metabolites. The developmental and morphological traits are leaf emergence, early growth vigor, leaf area index, leaf waxiness, stomatal density, tiller development, flowering time, maturity rate, cell membrane stability, cell wall rheology, and root characteristics.

In barley, scientists at ICARDA have found that the traits more consistently associated with higher grain yield under drought are growth habit, early growth vigor, earliness, plant height under drought, long peduncle, and short grain-filling duration (Acevedo and Ceccarelli 1989). The analytical approach has been very useful in understanding which traits are associated with drought tolerance and why. The approach has however been less useful in developing new cultivars that show improved drought tolerance under field conditions. This is because, as mentioned earlier, under field conditions, drought varies in timing, intensity, and duration. Therefore, it is the interaction among traits that determines the overall crop response to the variable nature of the drought stress, rather than the expression of any specific trait (Ceccarelli et al. 1991).

Although breeding for drought tolerance based on direct selection for grain yield in the target environment (empirical or pragmatic breeding) appears intuitively as the most obvious solution, it has faced the criticism because the progress is slow and chances of success are remote. Two of the major problems with selection in stress environments are precision of selection and existence of several target environments. Each environment is characterized by its own specific type of drought and generally a combination of stresses.

The issue of precision of selection under moisture stress conditions has been addressed by several papers, which have focused attention on the magnitude of heritability (Ceccarelli 1994). A review of literature (Ceccarelli 1996a) has shown the absence of a consistent relationship between grain yield (as a measure of the intensity of the stress) and the magnitude of heritability. Recently, vom Brocke et al. (2002) confirmed that in pearl millet, it is possible to detect genetic differences even under severe moisture stress conditions. Furthermore, considerable progress has been made in both experimental design and statistical analysis, which improve the estimate of experimental error (Singh et al. 2003). Therefore, it is possible to combine precision and relevance by conducting trials in the target environment even when it is a stress environment.The second issue is how to deal with the multitude of target environments. This is intimately associated with broad and specific adaptation,a subject that has been debated in plant breeding since the early 1920s and is still highly controversial. One of the causes of controversy is the definition of stress environment, which is different for different crops. For example, in a country like Syria, with a large spatial variability of rainfall, bread wheat, durum wheat, and barley are grown within short distances in progressively drier environments with some overlapping. Therefore, a stress environment for bread wheat is moderately favorable for durum wheat, and a stress environment for durum wheat is moderately favorable for barley and lentil. At the drier end, barley is the only rainfed crop, while the other cereals are only grown under irrigation.

Another cause of controversy is the confusion between adaptation over time and adaptation over space, even though the distinction is of fundamental importance. Adaptation over time (also called stability or dependability) refers to the performance of a cultivar in a given location over several years. If the cultivar performs consistently better than a reference cultivar, it is said to be stable. Adaptation over space refers to the performance of a cultivar in several locations. If the cultivar performs consistently better than a reference cultivar, it is said to be widely adapted. It can be argued that wide adaptation over time (also defined as stability) is more important to farmers than wide adaptation over space. The latter is, for obvious reasons, the major concern of seed producers.

Breeding for specific adaptation is particularly important in crops predominantly grown in unfavorable conditions, because unfavorable environments tend to be more different from each other than favorable environments. Breeding for specific adaptation to unfavorable conditions is often considered an undesirable breeding objective, because it is usually associated with a reduction of potential yield under favorable conditions. This issue has to be considered in its social dimension and in relation to the difference between adaptation over space and adaptation over time.

Choice of germplasm

Landraces are still the backbone of agricultural production in many developing countries, and for crops grown in stress environments. The reasons farmers prefer to grow only landraces or continue to grow landraces even after partial adoption of modern cultivars are not well documented. These include quality attributes, seed storability, and the ability of landraces to produce some yield even in difficult conditions where modern varieties are less reliable.

The value of landraces in barley (Grando et al. 2001) and several other crops (Brush 1999) is well documented in Syria. The comparison between barley landraces and modern cultivars in different conditions, ranging from severe stress (low input and low rainfall) to moderately favorable conditions (use of inputs and high rainfall) has given several indications:

- Landraces produce more yield than the modern cultivars under low-input and stress conditions.
- The superiority of landraces is not associated with mechanisms to escape drought stress, as shown by their heading date.
- Within landraces, there is considerable variation in grain yield under low-input and stress conditions, but all the landrace-derived lines produce some yield whereas some modern cultivars do not.
- Landraces are responsive to inputs and rainfall, and the yield potential of some lines is high, though not as high as modern cultivars.
- It is possible to find modern cultivars that produce yields almost as well as landraces under low-input and stress conditions, but the frequency is very low.

Chromosome regions for drought tolerance and developmental traits in balanced populations

Agronomic performance in balanced mapping populations was tested under drought prone conditions of West Asia, North Africa, and Australia. Baum et al.

(2003) used 194 RILs, randomly selected from a population of 494 RILs, and tested them in the 1996–97 and 1997–98 cropping seasons at ICARDA's research stations near Tel Hadya and Breda in Syria. Total rainfall in Tel Hadya in 1996–97 and 1997–98 was 433.7 and 410.5 mm, respectively, whereas in Breda it was 230.8 and 227.4 mm, respectively. The map extended over 890 cM and contained 189 marker loci, including one morphological marker locus (*btr* = brittle rachis), 158 AFLP loci and 30 SSR loci. Teulat et al. (2001a,b, 2003), Forster et al. (2004), and Diab et al. (2004) used a progeny of 167 two-row barley recombinant inbred lines (RILs), and the two parents Tadmor (selected by ICARDA from Arabi Aswad, a Syrian landrace) and Er/Apm (selected line released in Tunisia), which were grown in three Mediterranean sites (Montpellier, France; Meknes, Morocco and Le Kef, Tunisia). The trial in Montpellier was conducted under two water treatments in 1999; 360.5 and 458 mm. For the two other sites, the plants were grown under rainfed conditions, in Meknes in 2000 (254.6 mm) and 2001 (267.4 mm) and in Le Kef in 2001 (282.8 mm). One hundred and thirty-three markers covered 1500 cM of the genome. Diab et al. (2004) added more candidate genes and ESTs to the available map. Von Korff et al. (2008) phenotyped the Tadmor Er/Apm population in four locations (Tel Hadya and Breda in Syria and Terbol and Kfardane in Lebanon) during four consecutive cropping seasons from 2002 to 2005. Besides marker main effects, also location interactions (M*L) as well as marker by year within location interactions (M*Y(L) were considered in this QTL analysis.

The developmental trait, heading date, in barley is controlled by three genetically independent mechanisms of the photothermal response, i.e., day length (photoperiod), plant response to a sum of temperature over a period (earliness *per se*), and response to a period of low temperature at the 3H (bin 13), *eps4L* on 4HL, *eps5L* on 5H (bin 6), *eps6L.1* and *eps6L.2* on 6H (bin 7, 13), *eps7S* on 7H (bin 3) and *eps7L* on 7H (bin 12) (Laurie et al. 1995). As for vernalization, *Vrn-H1* on chromosome 5H (bin 11), *Vrn-H2* on 4H (bin 13), and *Vrn-H3* on 1H (bin 13) determine the vernalization requirement in barley (Laurie et a. 1995; Dubcovsky et al. 1998).

For days to heading a few major chromosomal locations have been repeatedly identified in the above mentioned populations (Fig. 1). QTL have been identified on 7H (bin 2-3) (Baum et al. 2003), 3H (bin 12) (Baum et al. 2003; Teulat et al. 2001), 2H (bin 3-7) (*Ppd-H1)* (Baum et al. 2003; von Korff et al. 2008) 2H (bin 11-13) (Baum et al. 2003; Teulat et al. 2001), and 5H (bin 6) (Baum et al. 2003). Under better rainfall conditions the location on 3H (bin 12), 2H (bin 3-7) (*Ppd-H1*) and 2H (bin 13) were more important in the Arta/*H. spontaneum* 41-1 population whereas under drier conditions the 7H (bin 3) location was more important (Baum et al. 2003). At the 7H location, *H. spontaneum* 41-1 contributed the drought escape allele. In the Tadmor/ErApm population 2H (bin 13), 3H (bin 12), 5H (bin 11) and 7H (bin 9) were the important loci in North Africa/France location, in the West Asia location the locus with the strongest effect was measured at Qdh-tera.1H.b, which explained 15.8% of the genetic variance, and lines with the Tadmor allele flowered 1.3 days earlier on average.

One of the most important characters for the extreme drought conditions with annual rainfall less than 200 mm is the plant height (under drought stress). Here, alleles form *H. spontaneum* 41-1 become very useful to increase plant height. QTL with major effects have been identified by Baum et al. (2003) on chromosomes 2H (bin 13), 3H (bin 12, *sdw*1), and 7H (bin 3). These might be more specific to *H. spontaneum* 41-1 background. In the Tadmor/ErApm population, major QTLs for plant height were located on 2H (bin 13), 3H (bin 6), 4H (bin 13), 6H (bin 10) (Teulat et al. 2001) in North Africa/France. The QTLs on chromosomes 3H, 4H and 6H were also confirmed in West Asia (von Korff et al. 2008). The Tadmor allele increased height at five out of six loci by maximal 4.3cm at Qph-tera_3H.a, which explained 19.4 % of the genetic variance. No significant interaction effects were recorded for plant height. SCIM analysis corroborated all main effects detected on 3H and 6H and detected a QTLxE interaction effect at $pHva1_{(1H)}$.

Peduncle length and peduncle extrusion were only measured in the Tadmor/ErApm population (von Korff et al. 2008). For both traits, three QTLs were detected on chromosome 3H. The Tadmor allele increased peduncle length and peduncle extrusion at all three loci by a maximum of 1.9 and 1.4%, respectively. Qped-tera_3H.a had the strongest effect on PED explaining 19.0% of the genetic variance, while Qpedex-tera_3H.b was the major locus for PEDEX with 16.3% of the genetic variance explained. Two and one M*Y(L) interaction effects were found for PED and PEDEX, respectively. The marker phva1 explained 8.7% (PED) and 3.6% (PEDEX) of the interaction variance G*Y (L). SCIM supported all three main effects for PED and PEDEX and detected an additional QTL for PED at $Bmag173_{(6H)}$, where Tadmor increased the trait value, and a QTLxE interaction effect at marker $cdo497_{(6H)}$.

In the Arta/*H. spontaneum* 41-1 population, QTLs for grain yield and biological yield have been identified and located at the *btr* location on 3H (bin 3), and the *sdw1* (bin 12) locus in the part of the population with non-brittle lines. In both locations, pleiotropic effects for several other characters were identified. Other grain yield QTLs were identified on 4H (bin 13), 5H (bin 11), and 7H (bin 3) (Baum et al. 2003). Teulat et al. (2001b) identified QTL for grain yield on chromosome 4H (bin 13); further on chromosome 7H (bin 9). In West Asia, six QTLs were identified for grain yield on 3H, 6H and 7H. The ER/Apm allele increased yield at all loci with the strongest effect at Qgy-tera.6H.b. This locus explained 17.6% of the genetic variance, and the ER/Apm allele increased yield by, on average, 192.3 kg/ha. Six loci showed significant interactions with the location with the strongest effects at $pHva1_{(1H)}$ and $Tapk4_{(5H)}$, explaining 7.2% and 6.5% of the G*L interaction variance. At these loci the Tadmor allele increased yield in Breda and Terbol, and the ER/Apm allele increased yield in Kfardane and Tel Hadya. Nine M*Y(L) interaction effects were identified explaining between 1.9 and 3.8% of the interaction variance G*Y(L). The SCIM analysis confirmed the six marker main effects and identified five QTLxE interaction effects which coincided with two M*L and three M*Y(L) effects. Cold and frost tolerance is a necessary requirement for barley production in the Fertile Crescent. In the Arta/*H. spontaneum* 41-1 population, eight QTL for cold damage were identified. For the QTL with minor effects (2H, 4H and 6H), the allele from the *H. spontaneum* line showed the better protection. For all other QTLs, the allele of 'Arta' showed better ability to protect the plant from cold damage. Three of the four alleles with a high effect on cold damage were localized on chromosome 5H at the known locations for frost tolerance QTL (Pan et al. 1994; Reinheimer et al. 2004; Francia et al. 2004). Additionally, a QTL on 7H was identified. This is in agreement with the observation of Karsai et al. (2004), whose survey of *H. spontaneum* accessions of the Middle East origin showed some degree of vernalization response.

Putative traits for drought tolerance: physiological traits

Breeding for drought tolerance based on traits associated with drought resistance, but easier to select for than grain yield, has been and is still very popular. Some

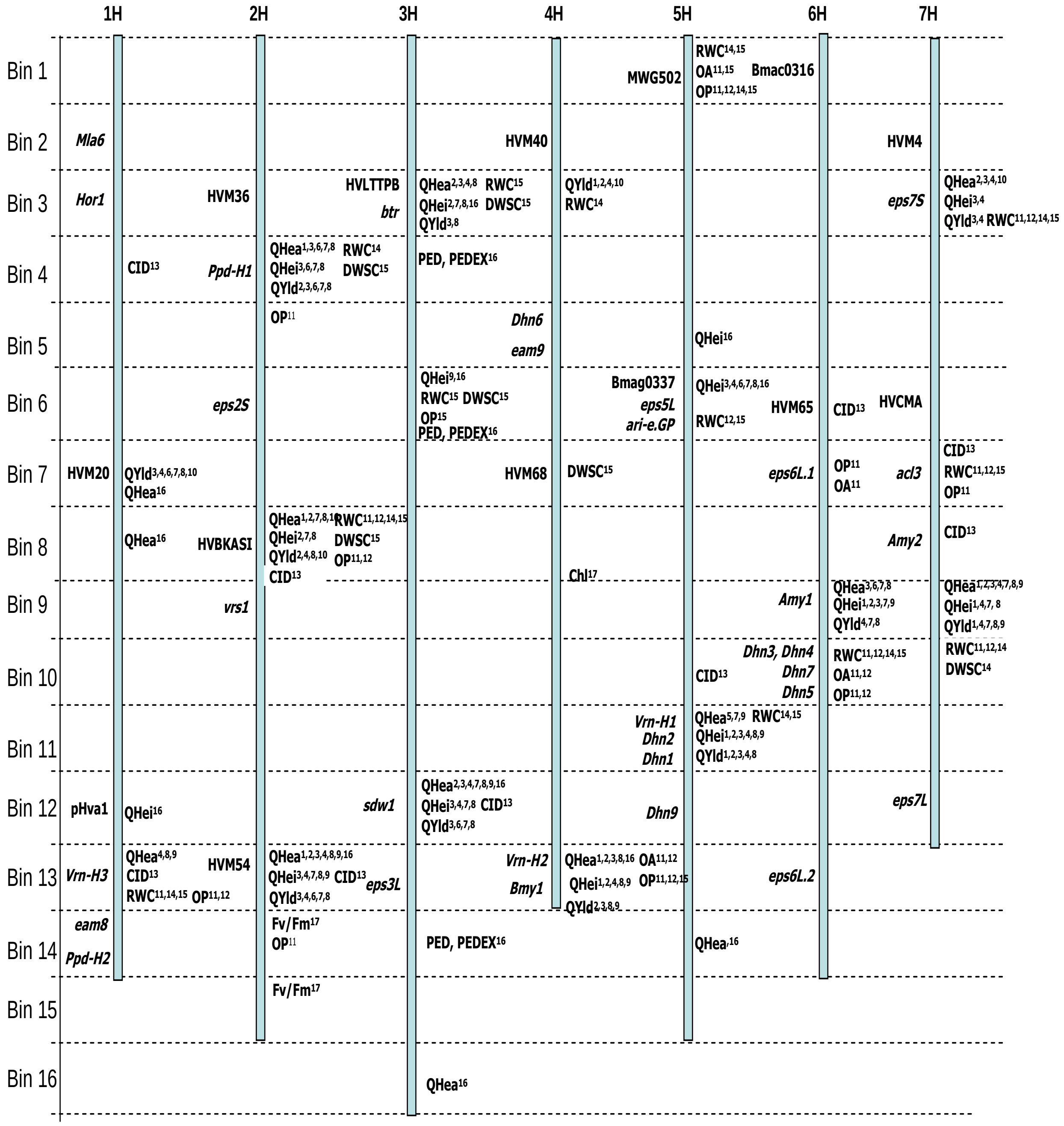

Figure 1. Genetic map of barley with locations for selected QTLs for agronomic and physiological traits (Baum et al. 2007, adapted). The genetic map is based on the Steptoe x Morex bin map by Kleinhofs and Graner (2001). Markers and loci have been assigned to the bin with the help of reference markers. Marker names are given on the left side of the chromosome bar. QTL for agronomic traits and physiological traits are presented on the right side of the bar. Selected QTL are shown for yield (QYld), heading date (QHea), plant height (QHei), physiological traits: relative water content (RWC), osmotic adjustement (OA), osmotic potential (OP), water-soluble carbohydrate concentration (WSC) and carbon isotope discrimination (CID), peduncle length (PED), peduncle extrusion (PEDEX), rate of photosynthesis (Fv/Fm).

References: [1] Pillen et al., (2003), [2] Pillen et al., (2004), [3] Baum et al., (2003), [4] Talame et al., (2004), [5] Hori et al., (2005), [6] Li et al., (2005), [7] Li et al., (2006), [8] von Korff et al., (2006), [9] Teulat et al., (2001b), [10] Long et al., (2003), [11] Teulat et al., (1998), [12] Teulat et al., (2001a), [13] Teulat et al., (2002), [14] Teulat et al., (2003), [15] Diab et al., (2004), [16] von Korff et al (2008), [17]Guo et al. (2008).

physiological responses have been observed in plants induced by drought stress (Ludlow and Muchow 1990). Osmotic Adjustment (OA) has been found to be one of the physiological mechanisms associated with plant tolerance to water deficit (Blum 1988). Relative water content (RWC) is a measure of plant water status resulting from a cellular water deficit. RWC is an appropriate estimate of plant water status as affected by leaf water potential and OA. Carbon isotope discrimination is another method used to screen for drought tolerance. The correlation between water use efficiency and carbon isotope discrimination has been extensively studied in several crops including wheat (Farquhar and Richards 1984; Condon et al. 1987) and barley (Araus et al. 1997).

The chromosomal location of some traits related to drought tolerance is known. Differentially expressed sequence tags related to drought tolerance have been mapped in the Tadmor/ErApm RIL population by Diab et al. (2004). Osmotic potential, OP100 (is the osmotic potential under full turgor) and RWC are components of OA and they are highly correlated (Teulat et al. 1998). For that reason, OA is considered a drought-related trait (Teulat et al. 2001a). Several chromosomal regions related to variation in OA and water status were detected. Two QTLs were identified for OA, one on chromosome 3H and one on 5H (Teulat et al. 2001; Diab et al. 2004) (Fig. 1).

The genomic regions with QTL clusters for physiological traits were found on 1H (bin 13), 2H (bin 8), 5H (bin 1), 6H (bin 10) and 7H (bin 7) (see Fig. 1). For example, QTL for RWC, OA and OP were all mapped to approximately the same chromosomal location on 6H (Teulat et al. 1998, 2001a, 2003; Diab et al. 2004). This locus on 6H matches the location of the candidate genes *Dhn3*, *Dhn4*, *Dhn7*, *Dhn5*, which are expressed during drought and/or cold stress (Cattivelli et al. 2002). Genomic regions with effects on OA, OP and RWC coincided with QTL for flowering time, height and yield as for example on 2H (bin 8) and 4H (bin 13) (Fig. 1). The co-location of the QTL for DWSC100 (difference in water-soluble carbohydrate concentration between well-watered and stressed plants) and RWC in more than one genomic region, 2H (bin 4, bin 8) and 3H (bin 3), under water stress, suggests that the accumulation of WSC (water-soluble carbohydrate) may be important for plants to maintain their RWC. QTL for carbon isotope discrimination (CID) did also overlap with loci identified for RWC, OA and OP (1H, 2H, 7H). In addition, CID was located close to genomic regions with relevance for agronomic performance such as on 2H (bin 8) and 3H (bin 12).

Guo et al. (2008) analyzed QTL controlling chlorophyll content and chlorophyll fluorescence in the Arta/*Hordeum spontaneum* 41-1 population. A QTL for Fv/Fm, which is related to the drought tolerance of photosynthesis was identified on chromosome 2H at 116 cM in the linkage map under drought stress. This QTL alone explained more than 15% of phenotypic variance of maximum quantum yield of PSII, and was also associated with the expression of four other traits. In addition, another QTL for Fv/Fm was also located on the same chromosome (2H) but at 135.7 cM explaining around 9% of the phenotypic variance under drought conditions. The result presented here suggest that two major loci, located on chromosome 2H, are involved in the development of functional chloroplast at post-flowering stage for drought tolerance of photosynthesis in barley under drought stress. A QTL for chlorophyll content was also identified and located on 2H (bin 13) at the same position as the QTLs for Fv/Fm.

Conclusions

Numerous QTL studies for agronomic performance have been conducted in favorable environments using balanced populations. Although drought tolerance has been recognized as one of the prime breeding goals to increase food production in arid areas, only very few QTL studies are available which have analyzed agronomic performance in drought stressed environments. For agriculture in the Mediterranean region barley landraces as well as *H. spontaneum* play a major role as the main source of drought tolerance, and the first results of QTL studies with exotic germplasm look promising. A number of favorable exotic alleles for agronomic performance were detected, in particular, in the studies conducted under drought (Baum et al. 2003, Talame et al. 2004). However, further QTL studies on drought stress using land races and exotic barley as donors are clearly needed to make efficient use of the vast collection of germplasm resources. QTL studies with and without *H. spontaneum* have shown that developmental genes, notably those involved in flowering time and plant stature, show pleiotropic effects on abiotic stress tolerance and ultimately determine yield. Important loci in this regard are the semi-dwarf gene *sdw3* (bin 7 on 2H), the flowering locus *Ppd-H1* (2H, bin 4) and the vernalization requirement locus *Vrn-H2* (4H, bin 13). It was shown that *H. spontaneum* offers novel allelic variance at these loci. These alleles from wild barley can be exploited for the improvement of drought tolerance in elite germplasm by selecting those exotic alleles with the most beneficial pleiotropic effects on drought resistance. Problems associated with the hybridisation of *H. spontaneum* such as alleles with deleterious effects on field performance, i.e. the brittle rachis loci *btr*, could be best addressed in the advanced backcross QTL analysis.

The QTL analysis in the population Tadmor/ErApm demonstrated the significance of crossover interactions in the environments with large differences between locations and between years within locations. Alleles from the parent with the higher yield potential, ER/ Apm, were associated with improved performance at all markers exhibiting main effects for grain yield. The coincidence of main effect QTL for plant height and yield indicated that average yield was mainly determined by plant height, where Tadmor's taller plants, being susceptible to lodging, yielded less. However, a number of crossover interactions were detected, in particular for yield, where the Tadmor allele improved yield in the locations with more severe drought stress. The marker with the highest number of cross-over interactions for yield and yield component traits mapped close to the flowering gene *Ppd-H2* and a candidate gene for drought tolerance *HVA1* on chromosome 1H. Effects of these candidate genes and QTL may be involved in adaptation to severe drought as frequently occurring in the driest regions in the Mediterranean countries. Identification of QTL and genes affecting field performance of barley under drought stress is a first step towards the understanding of the genetics behind drought tolerance.

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23. Strengthening sustainable use of small ruminant genetic resources in the drylands in the WANA region

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Abstract

Genetic diversity in livestock is currently measured in terms of the number of breeds. Breeds have been developed within production systems, which are shaped by the natural resource base and social and economic factors. Thus, changes in the production environment will induce changes in the use of breeds. Small ruminants are a major component of the farming system and an important source of income and dietary protein in West Asia and North Africa (WANA). The WANA region is one of the main centers of domestication for sheep and goats, and is home to 75 sheep and about 32 goat breeds. These breeds are adapted to the climatic extremes of the region, from deserts to humid coastal areas. Many are highly tolerant to heat and cold stress and low quality feeds (converting unusable range resources into animal protein). However, their production levels are low when compared to exotic breeds and their products may not meet emerging consumer demands related to food quality and safety. To ensure sustainable use of livestock diversity, it is essential to improve the productivity of local breeds and the quality of their products responding to the market demands, while retaining their adaptive attributes. To achieve this goal we propose a conceptual framework with three interlinked elements: 1) Analysis of market constraints and opportunities; understanding the effect of market trends on the utilization of species and/or breeds; 2) Characterization of breeds, their production system, and the quality of their products; and 3) Designing community-based, decentralised breeding schemes where farmers are fully involved in defining breeding goals and designing and implementing selection strategies. Conditions in WANA today are similar to those predicted for other regions in the future, as a result of climate change (drier, hotter, erratic rainfall, growing water scarcity). Maintaining and developing the region's rich small ruminant diversity will, therefore, not only improve the livelihoods of millions of rural households, but also provide genetic resources that could help other regions cope with climate change.

The concept of sustainable use

There is broad agreement that sustainable use of animal genetic resources for agriculture and food production (AnGR) is the preferred strategy for maintaining livestock diversity (FAO 2007). Article 2 of the Convention on Biological Diversity (CBD) defines sustainable use as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations."

Many definitions of sustainability in the development literature cover three dimensions – an economic, an environmental, and a social dimension (Rischkowsky 2008). Animal genetic resources exist within production systems that are dependent on the natural resource base – changes in the environment will induce changes in AnGR. Social policies may constrain or support livestock keeping livelihoods; social attitudes affect the decisions of farmers, policy makers and consumers. Developing a concept of sustainable use requires a deeper understanding of AnGR diversity within its economic, social and ecological context. An attempt to develop such a broad concept was made by a multidisciplinary FAO expert consultation in 2006 (Weary et al. 2008).

This paper focuses on management strategies for strengthening the sustainable use of small ruminant genetic resources in the WANA (West Asia and North Africa) region using mainly research studies of ICARDA and its NARS partners as examples.

Small ruminant genetic resources in the WANA region

The WANA region known as the "Fertile Crescent" is one of the main centres of domestication for sheep and goats. ICARDA has been documenting the status and phenotypic characteristics of the sheep and goat breeds in the WANA region jointly with its NARs partners (Iñiguez 2005a, b). Many breeds are shared across the region and have important adaptive traits to dryland conditions. In WANA alone there are 75 breeds of sheep and less precisely (as it has not been well documented) 32 breeds of goats. These breeds are adapted to the semi-arid and arid conditions and climatic extremes of the region; some are thriving in fully deserted areas while others are adapted to Oasis or humid coastal regions, etc. Most of these breeds are known for their tolerance to heat and cold stress, low quality feeds (converting unusable range resources into animal protein) of degraded rangelands.

Most (about 71%) of the sheep breeds in WANA region are fat-tailed, an adaptation that allows them to cope better with fluctuation in feed availability – deposit fat during feed abundance and mobilize their fat depot during feed scarcity. Some examples of livestock adapted to constrained environments are the Barki sheep and D'man sheep, which are found in extremely dry areas of North Africa. In addition, most mountain goats are the only livestock species able to utilize range resources in rugged terrain and landscapes. Some breeds are highly demanded in the region (for example, Awassi sheep and Shami/Damascus goats). The latter is spreading more throughout the region and influencing others – demanded for crossbreeding in North Africa.

Some sheep breeds of the WANA region are threatened by indiscriminate crossbreeding (Atlas Mountain, Beni Guil, Sicilo-Sarde, Bahmei, Baluchi, Kurdi, and Cyprus fat-tailed breeds) and have suffered displacement (e.g. Beni Ashen and Karakul). Others are at risk due to high rate of inbreeding (for e.g. Chal, Moghani, Sanjabi, and Zel) or are just few in number (e.g. Güney Karaman and Gökçeada) and close to extinction (e.g. Ödemiş). Status of many of the goat breeds in the region is largely unavailable; they are threatened by indiscriminate crossbreeding (e.g. Mountain goats, Zaraibi), small population size (e.g. Dihewi, Zaraibi, Norduz, Gürcü and Abaza) or their number is declining (e.g. Angora goat) following abolishing of the government subsidies for their special product, and probably due to low market prices of Mohair and low milk yield of the breed. Other reasons for breeds at risk were absorption by nearby breed, competition with more productive breed, adoption of more profitable irrigated agriculture (in which more attention is paid to dairy cattle), neglect of the breeds because of their low productivity, lack of market for their products, and lack of local institutions e.g. farmers' organization for processing and marketing of their produce (Iñiguez 2005a, b).

Challenges facing WANA's drylands

The recent climate change scenarios show that most of the Near East region will face a decrease in water availability of up to 40 mm per year. The number of dry days is expected to increase everywhere in the region, with the exception of some central-Saharan areas, while the number of frost days is expected to decrease. Once the temperature increases reach 3 or 4°C the length of growing seasons will decrease. Yields of the key crops across Africa and Western Asia may fall 15 to 35 percent or 5 to 20 percent, depending on whether there is weak or high carbon fertilization, respectively (FAO 2008 based on IPCC 2007).

The expected additional stresses from climate change in most of the region will increase the already existing vulnerability to climatic fluctuations in the WANA region. An analysis of the coefficient of variation of the maximum NDVI for the period 1982-2000 showed that there is ample evidence of hotspots of response and vulnerability to climatic fluctuations in the region (Celis et al. 2007). The hotspots include North Africa, from Morocco into Tunisia; the Sahel, from Mauritania into Sudan, Eritrea, northern Ethiopia and turning south into Somalia; and the Fertile Crescent, from Jordan, Syria, Iraq, turning southeast into Khuzistan province in southern Iran. These areas are already currently characterized by severe droughts, degradation of land, water and vegetation resources, and sometimes famines. They are already facing conditions as predicted from climate change (drier, hotter, erratic rainfalls, and fragile water supply, Thomas et al. 2007).

The expected impact of climate change has to be seen also in the background of other trends shaping agricultural environment in general, such as already high and growing populations, persistent reliance on income from agriculture; unstable off-farm income due to political and socioeconomic factors discouraging investment into industry and services, and dwindling water resources due to overuse and lack of policies to protect the resources or use them efficiently (Thomas, 2008).

Small ruminants (sheep and goats) represent a major component of the farming system and are an important source of income and animal protein for the rural poor in the dry areas of WANA (Iñiguez 2004). It is estimated that, assuming a flock size that fluctuates between 20 to 50 heads per family, about 4-10 million families benefit from small ruminants in NENA (Iñiguez 2005a). They require low initial investment and use marginal land and crop residues to produce milk and meat. In particular in pastoral and agro-pastoral systems where extensive grazing is the main resource to produce high-value agricultural products, animals have become an essential aspect of the cultural, social and religious life of the people who depend upon them, and specific breeds adapted to the needs of the people and the environmental stressors have been developed (Scherf et al. 2006).

The increasing demand for animal products results in increasing interactions of small scale livestock producers with markets that provide both opportunities and risks. At present small ruminant producers in the region are targeting local markets for dairy and meat products and regional markets (the Gulf region) for meat. However, the share of the WANA region in meat supply of the Gulf market is decreasing The reasons are health-related trade restrictions for small ruminants, poor market infrastructure, and lack of information about the dynamics of export markets and lack of polices to effectively respond to export market requirements (Aw-Hassan et al. 2005). The incidence and control of zoonotic diseases have received little attention in the region which is already causing difficulties to farmers with marketing and trade. Urban consumers are becoming more demanding with regard to food quality and retailers that demand homogenous, reliable and safe supplies are increasingly entering the markets in WANA. Market structures often lack transparency that limits farmers in their attempt to capitalize market opportunities. Thus, issues of product quality and safety are turning so important that they may restrict the small holders from accessing the markets. Another important trend in the region is the decreasing contribution of rangelands to the small ruminant diets. A survey in the Syrian steppe showed that depending on the mobility of the livestock producers rangelands contributed only 22 to 36% to the sheep diets in 2004, an average rainfall year (Dutilly-Diane et al. 2006).

Strengthening sustainable use of local small ruminant breeds

The indigenous sheep and goat breeds in the WANA region are well adapted to the dry land conditions and are expected to cope better with the consequences of climate change than exotic breeds. Thus, sustaining and improving the use of the indigenous breeds, which have adapted over centuries to the dry and hot areas, is also an important coping strategy for climate change. However, the production levels are low when compared to exotic breeds and their products may not meet emerging consumer demands related to food quality and safety. To ensure sustainable use of livestock diversity, it is essential to improve the productivity of local breeds and the quality of their products responding to the market demands, while retaining their adaptive attributes.

To achieve this goal we propose a conceptual framework with interlinked elements:

- Analysis of market constraints and opportunities; understanding the effect of market trends on the utilization of species and/or breeds.
- Characterization of breeds, their production system, and the quality of their products.
- Designing community-based, decentralised breeding schemes where farmers are fully involved in defining breeding goals and designing and implementing selection strategies.
- Improving production systems.

Analysis of market opportunities: Understanding the effect of market trends on the utilization of species and/or breeds is important for preventing their extinction. In Tunisia a shift towards a thin-tailed sheep at the expense of fat-tailed Barbarin sheep by crossing them with thin-tailed ones was noticed in recent years (Bedhiaf-Romdhani et al. 2008). The study showed that this shift was mainly dictated by butchers and not by consumers. The reason was the difficulty faced by butchers to sell the fat tail, which is estimated to constitute 15% of the carcass. Consequently, the butchers were reluctant to buy fat-tailed animals. Consumers still prefer the meat of Barbarin breed and meat from fat-tailed lambs was superior in tenderness, flavor and smell in sensory tests. However, farmers admitted that butcher’s preference influenced their income because they are paying favorably for thin-tailed sheep. Such trends could relatively rapidly lead to the extinction of breeds with a geographical limited distribution.

Characterization of breeds and their production environments: An integral component in any plan for sustainable utilization is characterization of genetic diversity, i.e. of the small ruminant breeds. This includes developing an understanding of production, functional and adaptive traits. The requirement for improved characterization is particularly great in resource-poor production systems. An improved knowledge of breed characteristics may also serve as a means to identify niche products (Wurzinger et al. 2008). Characterization needs to take into account the effects of spatial and temporal variability within the production system (Rischkowsky et al. 2004). Another factor to consider is the specific characteristics of breeds under consideration that make them unique; for example, adaptive traits such as disease and heat resistance or specific feeding behaviour. Adaptation is complex and difficult to measure. One approach to this problem is to characterize adaptation indirectly by describing the production environments in which a breed has been kept over time, and to which it has probably become adapted. Comprehensive and comparable descriptions of the production environments in which animals are kept are also vital to make meaningful evaluations of performance data and to enable comparative analysis of the performance of different breeds. To address these requirements, a recognized set of 'production environment descriptors' (PEDs) has been developed as a common framework for describing breeds' production environments (Pilling et al. in press).

Genetic improvement programs: The indigenous small ruminant breeds are largely owned by smallholders in marginal dryland areas. Improving their productivity while retaining their adaptive attributes would also contribute towards mitigating climate change. In doing so more can be produced by less number of animals through the culling of mediocre animals, which otherwise will degrade the rangeland and release greenhouse gases contributing to global warming. Genetic improvement of sheep and goat breeds in such systems is constrained by small flock size, lack of animal identification and recording. Attempt so far failed due to a prescribed approach which ignored livestock owners in the planning and implementation of the breeding schemes.

However, breeding plans can be adapted to various conditions ranging from low- to high-input systems and contribute substantially to the improvement of productivity and living conditions of resource poor farmers. For example, village breeding programmes were designed for Llama smallholder farmers in Bolivia (Wurzinger et al. 2005; Wurzinger 2005) and Friesian cattle in Uganda (Nakimbugwe 2005). A few decentralized nucleus schemes handled by smallholders or their organizations have been successfully applied to small ruminants, in particular in Argentina, Perú (Mueller et al. 2002; Mueller 2003) and Morocco (Iñiguez 2005a, b). These programs have, from inception, taken into account the farmers' decisions, ownership and participation, hence their success. ICARDA in collaboration with international partners (ILRI and BOKU) launched community-based participatory and decentralized sheep breeding scheme involving farmers in Ethiopia. This approach is considered more appropriate and successful for marginal environment and socio-economic conditions where communal resources (grazing, watering points, etc) are shared. This research project involves characterization of breeds and their production system, defining breeding goals and designing breeding schemes (including simulation studies), genetic improvement of indigenous breeds, and market constraints and opportunities for the farmers.

A breeding and marketing program that has been implemented for the Sicilo-Sarde sheep breed in Tunisia brought this local breed back from the edge of extinction. The Sicilo-Sarde is the only specialized dairy sheep adapted to dry environments of North Africa. The constitution of the Sicilo-Sarde breed association in 2003, prompted by a visionary farmer, allowed a participatory partnership involving researchers, farmers (through their association) and development agencies that tackled the reduction of production constraints and eventually established the basis for a breeding plan. This breed is being rescued by helping it bounce back to market through effective milk marketing and an efficient genetic improvement program that helped to decrease inbreeding and increase milk productivity. The association was also able to negotiate with policy decision makers for the introduction of a new legislation benefiting dairy sheep production (Djemali et al. in press).

Improving production systems: In reality, genetic improvements and management function together, as changes in management create new opportunities for selection and vice versa. Technical improvements to nutrition, management or animal health can be essential. In the WANA region, managing the production risk caused by the variability of feed availability is the central issue of small ruminant production. The high losses because of droughts and the increasing vulnerability of agropastoral communities led many governments in the region to intervene with various forms of drought assistance, mainly subsidies. These interventions are costly to governments and use resources that could otherwise be spent for development purposes (Nefzaoui et al. 2008). The recent move into producing bio-fuel from crops and crop residues competes directly with feed resources used in livestock production and contributes to increased food and feed prices. The use of cropland for bio-energy may displace livestock and production of livestock feeds. The conversion of grazing lands to crop production may force livestock into previously unused areas leading to forest clearing for livestock grazing. For example in Brazil, sugarcane plantation for bioethanol and soybean for biodiesel on lands previously used for grazing has been noted (CGIAR position paper).

Thus, alternative feeding options become of even higher importance for livestock producers. One option is to prepare multi-nutrient feed blocks from non-conventional and cheap agro-industrial by-products. Agro-industrial by-products tested included molasses, crude olive cake, sugar beet and tomato pulp (Rihawi 2005). Although many by-products can be used, a constraint is that often their production levels do not reach significant volumes to cover the large demand. In order to replace barley in the diets, multi-nutrient feed blocks with molasses and urea were successfully tested for strategic supplementation of ewes during critical periods in the production cycle, namely early mating, late pregnancy and lactation (Rihawi et al. 2007) and for lamb fattening (Iñiguez et al. 2007). However, the delivery of these products and their access by farmers pose difficulties which require due efforts in private sector participation and policy development.

Vast rangeland areas suffer from poor soil fertility, and varying levels of degradation. As a result of overgrazing, severe cutting of trees and removal of vegetation, valuable range species are being replaced by less valuable species unpalatable to livestock. Several shrubs and drought tolerant species have been introduced or used in the WANA region. This includes widely known *Atriplex* and *Acacia* species (Larbi et al. 2008) and cactus (Alary *et al.* 2007). These plants have been found useful to rehabilitate rangelands, alone, in alley cropping, or as ingredients of feed blocks. The plantation and grazing of these shrubs is faced with the inherent difficulties associated with land that is communally owned. The inconsistencies and lack of policies in relation to communal use of ranges and resources leave the communities with little motivation to conserve rangelands, and hinders the development of efficient management strategies to conserve and regenerate them (El Dessougi 2006). Several measures have been proposed and/or tested: reseeding, water harvesting, increasing water use efficiency, enhancing soil fertility, and policy reform on land tenure. The challenge is to implement these measures in poor dryland communities.

For dairy sheep production systems alternative management options for increasing the milk offtake or targeting higher market prices can be economically interesting. For example it is estimated that about 25% of the milk yield of a dairy Awassi ewe is produced during the first 65 days of lactation (Al Jassim et al. 1999). Early weaning through creep feeding of lambs is an interesting option to increase the milk offtake. Feeding experiments showed that, with adequate feeding, lambs can be weaned at an age of 45 days (Rihawi et al. 2008). Out-of season sheep milk production to capture higher market prices is also possible. Although representing additional costs, producing milk out-of season can bring extra benefits to farmers allowing them to recover costs and make a profit because of the better prices of milk products (ICARDA 2005). It is interesting to note that some farmers are already moving into this type of specialized production by their own initiative.

In Syria, national reports have shown that the amount of fresh milk sold has dropped, as a result of the progressive replacement of fresh sheep milk with cow milk (Iñiguez and Aw-Hassan 2004). This trend has apparently triggered an increase in the number of more intensive dairy production systems which process their own milk, particularly yogurt, rather than selling it as fresh milk at a low price. Improving quality, shelf-life and marketability of dairy products is critical for farmers to respond to the market demands of food safety and hygiene. ICARDA researchers and extension workers applied a participatory approach to improve the product quality of Syrian farmers (Hilali et al. 2006). Workshops and trainings (on milk hygiene, improved yoghurt processing and culture management) were held involving women. Low cost interventions such as the use of industrial starters in making yoghurt with improved firmness and appropriate processing methods were developed. As a result the farmers achieved higher market prices for their yoghurt and improved their competitiveness in the market.

Conclusions

Conditions in many areas in WANA today are similar to those predicted for other regions in the future as a result of climate change (drier, hotter, erratic rainfall, growing water scarcity). Maintaining and further developing the region’s rich small ruminant diversity will, therefore, not only improve the livelihoods of millions of rural households, but also provide genetic resources that could help other regions cope with climate change.

To date only few small ruminant breeds are at risk in the WANA region. However, there are still large gaps in the phenotypic and genetic characterization of small ruminant breeds, in particular of goat breeds, and in the documentation of their population status. Adaptive traits of the breeds have not been studied. There is a high potential to improve the productivity of the small ruminant flocks through both genetic improvement and management interventions. The greatest challenge in the near future for sustaining the use of small ruminants will be the supply of adequate feed resources in times of rapidly increasing feed prices and low contribution of rangelands to the diets.

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24. Impact of climate change in dry areas of the Mediterranean region: risk to land productivity and water resources

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Abstract

This paper discusses the current pressures on water scarcity, the climate change projections, and the potential impacts of climate change on land productivity and water. Land productivity and water resources in dry areas are increasingly unstable and vulnerable, but climate change is only one of the determinants of their vulnerability. The issue is even more pertinent where 'at risk' regions and social groups are already economically marginal or at the edge of climate tolerance. To reduce the vulnerability of water resources to climate change in dry areas, robust policy options or adaptation response strategies are required. The risks are not just long term; in the short term, extreme weather events could cause major damage and loss of ecosystems, especially in marginal areas.

Introduction

Many areas of the world are already struggling today with the adverse impacts of an increase in global average temperature, especially dryland areas. The scientific literature suggests that there is an increase in the frequency and intensity of extremes in weather events (drought, floods and heat waves). The alarming numbers of these events during the last five years may be the consequence of climate change and suggest that climate change is resulting in the increase in natural climate disasters, at least in some regions.

Agriculture and water are closely interlinked in dry areas and shape the social development in the rural areas there. Societies, cultures and economies have evolved adapting to mean climatic conditions. The sustainable development of dry areas depends on the ability to adapt to climate change. This is determined by the economic, social, and environmental vulnerability.

The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC 1992) imposed certain reductions of greenhouse gases (GHGs) production on the ratifying countries, since the accumulation of GHGs in the atmosphere was found to increase global temperatures and changes in the climate (IPCC 2007). Two main policy interventions have been identified for combating climate change – mitigation and adaptation. According to the UNFCCC (1992), there is a clear difference between mitigation (reduction of greenhouse gas emissions and carbon sequestration) and adaptation (ways and means of reducing the impacts of, and vulnerability to, climate change). Until recently, UNFCCC negotiations have focused primarily on mitigation; however, it is now clear that the objectives of human well-being in the future should be addressed, stressing the importance of adaptation. Regardless of international progress to reduce emissions of the greenhouse gases, the climate system will continue to adjust for the next few decades to past and present emissions. This will bring unavoidable impacts on natural and human systems, presenting the challenge of a second response to climate change – adaptation – to prepare for and cope with these impacts.

In contrast to this clear understanding of the concepts of 'climate change' and ‘mitigation’, the concepts of impacts, vulnerability, risk and adaptation are not defined in either the UNFCCC or the Kyoto Protocol; the terms are used loosely by many scientific and policy communities. It has been observed that interpretation of some of these key terms by scientific groups or policy makers can be quite different, which may lead to varied or false expectations and responses (Levina and Adapmas 2006). Nevertheless, understanding and quantifying the impacts, risks and adaptation responses to climate change are key issues for current and future policy determinants to the economic impacts to society.

This paper discusses the current pressures on water scarcity, the climate change projections, the potential impacts of climate change on land productivity and water, potential adaptation strategies and some recommendations for adaptation policy.

Current pressures on land productivity and water

Mediterranean agriculture faces limited and variable rainfall and water availability. Irrigated agriculture is a small fraction of the total agriculture but it provides more than half of the food consumed, and half value of the total agricultural earnings especially exports. Because water resources are limited, the use of water for irrigation competes with other uses such as those for industrial, municipal and ecosystem needs; this often results in social and environmental conflicts.

The pressure on land productivity and water arises mainly from the following factors:
1. *Population*: Over the 20th century, global population has tripled while water withdrawals have increased by a factor of about seven.
2. *Pollution*: The development of industry and agriculture intensification have resulted in major pollution problems in many regions of the world; this is linked to the degradation of aquatic ecosystems.
3. *Governance*: Poor governance has been a result of fragmented and uncoordinated management, top-down institutions and increased competition for finite resources.
4. *Climate change*: The impacts of climate change on freshwater resources affect all sectors of society.

Rainfall and water resources are limited and difficult to predict from year to year. In many countries demand largely exceeds the available water resources in most Mediterranean countries (Table 1). The potential water availability per capita and year considering the total freshwater resources in southern Mediterranean countries is less than 1000 m^3. Real available water resources is a small fraction of the total water resources in all cases. For example in Spain real available water resources are less than half of the total freshwater resources and the potential use of surface water under natural regime is only 7% (Iglesias et al., 2007).

Water demand is raising due to demographic shifts, economic development and lifestyle changes. Water use for agriculture accounts for more than 50% of total water use in all the countries in the region except France. Nevertheless, other economic and social water demands are rapidly increasing, such as tourism and ecosystem services (Iglesias et al. 2007). A commonly shared concern in the region is the ability to reach the targets of the Millennium Development Goals (MDGs), especially to halve by 2015 the proportion of people who do not have access to safe drinking water.

Table 1 Total freshwater resources, available resources, use, and water availability in selected Mediterranean countries

Country	Total area (km2) [Population (million)]	Rainfall (mm/yr)	Total [Internal] renewable water resources (km/yr) (*)	Total water use (% Renew-able)	Potential total renewable water resources (m/capita per year)	Agricultural value added / GDP (%)	Irrigated cropland (%) 2006 [1961]
Algeria	2,381,740 [32]	89	14.32 [13.90]	40	473	13.3	6.8 [3.2]
Egypt	1,001,450 [72]	51	58.30 [1.80]	106	859	15.1	100 [100]
France	551,500 [60]	867	203.70 [178.50]	17	3,439	2.7	13.3 [2.4]
Greece	131,960 [11]	652	74.25 [58.00]	11	6,998	6.9	37.2 [11.6]
Israel	22,000 [6.5]	435	1.67 [0.75]	103	254	1.3	45.8 [34.3]
Italy	301,340 [57]	832	191.30 [182.50]	22	3,325	2.7	24.9 [15.4]
Libyan Arab J.	1,759,540 [6]	56	0.60 [0.60]	954	113	n.a.	21.9 [6.1]
Morocco	446,550 [31]	346	29.00 [29.00]	42	971	16.8	14.5 [12.6]
Spain	505,990 [41]	636	111.50 [111.20]	32	2,794	3.3	20.2 [9.4]
Syrian Arab R.	180,000 [18]	252	26.26 [7]	100	1,403	23.5	24.6 [8.7]
Tunisia	163,610 [10]	313	4.56 [4.15]	57	482	12.1	7.8 [2.4]
Turkey	770,000 [71]	593	213 [227]	18	2,800	12.1	18.3 [5.2]

(*) The values refer to both regulated and unregulated water. Real available water resources in all cases are a fraction of these values. Source of data: FAO 2008.

The evolution of irrigation in all the Mediterranean countries has been remarkable over the last half century, but northern and southern Mediterranean countries have varying rates of expansion of irrigated land and have been using different irrigation technologies. New irrigation technologies have increased water productivity up to 30% or 40% (Causape et al. 2005; Luquet et al. 2005) and this has given a competitive advantage to many Mediterranean crops in European markets.

These technologies ensure the best results when combined with efficient irrigation schedules or supplemental irrigation.

Intensive extraction of groundwater is a recent strategy to cope with the increasing water demand and has been undertaken in most Mediterranean countries. In most cases, almost all groundwater extracted is used for irrigation (Garrido and Iglesias 2007; Fornes et al. 2005). The pressure on groundwater resources in the last decades has partially arisen from the rapid expansion of intensive irrigated agricultural areas but as well from the growth in urbanisations. Groundwater resources play a vital role in meeting water demands, not only in terms of quality and quantity, but also in space and time, and are of critical importance for alleviating the effects of drought (Llamas 2000; Llamas and Martinez-Santos 2005). A common problem of aquifers in the Mediterranean region is the degradation of the groundwater quality due to multiple stresses: excessive pumping in relation to average natural recharge, return flow from irrigation water with intense use of agrochemicals, leakage from urban areas (land fills, septic tanks, sewers, mine tailings, among others) (Barraque 1998; Fornes et al. 2005). In addition, drought episodes contribute in a significant way to the degradation of groundwater quality (Iglesias et al. 2007).

Many Mediterranean freshwater and groundwater resources are shared among countries. River Nile is an example. Within the countries, shared water among administrative units is also common. Disputes exist, especially during drought conditions, and potentially will increase due to the increasing water imbalances. Policies of a single government or water basin unit cannot resolve issues over shared water bodies, and local interests are likely to diverge. International institutions play a key role as formal mechanisms to deal with water related conflicts in the region. Nevertheless, there is weak cooperation among different institutions related to agricultural and water management, and the roles of the country and its administrative regions are fragmented that can result in conflicts (Iglesias et al. 2009c).

Soil degradation is a major threat to the sustainability of Mediterranean land resources and may impair the ability of Mediterranean agriculture to adapt successfully to climate change. Mediterranean soils are currently experiencing a range of conservation problems, including high erosion rates (and erosion-derived agro-chemical pollution of waterways), declines in soil organic matter and vulnerability of soil organic carbon pools. These are linked to site factors and changing land management practices and are being exacerbated by climate change and the increasing incidence of extreme weather events. Increased intensity of precipitation is likely to change patterns of erosion and accretion, increase the occurrence of storm flooding and storm damage and lead to greater incidences of waterlogging.

Wetland ecosystems depend to a significant degree on the sustainability of agro-ecosystems in Mediterranean countries (Llamas and Martinez-Santos 2005; Llamas 2000; Gerakis and Kalburtji 1998) and they have been seriously affected by irrigation schemes and individual farmers using groundwater resources. In some countries conservation of habitats and agriculture are becoming irreconcilable interests (Hellegers et al. 2001).

Climatic conditions and sea level rise projections

Scientific projections of potential impacts of climate change in the Mediterranean agriculture are uncertain and subject to numerous hypotheses. Climate change scenarios project higher than the global average increases in temperature and changes in the hydrological cycle (IPCC 2007; Giorgi and Lionello 2008). The projections indicate a decrease of precipitation up to -40%, by the 2050s compared to 1961-1990 levels in some areas, with changes in the annual precipitation patterns. In all cases, temperature increases of about 1.5^{o} C are expected by the mid 2050s, and thereby increased evaporation and reduced soil moisture. There is also a growing concern about the impacts of climate change on magnitude and frequency of drought in the Mediterranean region (Giorgi and Lionello 2008) with severe implications for future water availability (Hisdal et al. 2001; Iglesias 2002; Iglesias et al. 2002; Lloyd-Hughes and Saunders, 2002).

Increased sea level will affect agricultural production and water resources in the low-lying coastal areas, unless measures to protect vulnerable land or other land management schemes are put in place. Changes in climate variability and extremes are likely to be at least as important as changes in mean climate conditions in determining climate change impacts and vulnerability. Increased frequency of extremes events could result in higher insurance fees. The application of risk management techniques can contribute to increased private coping capacity of farmers in these areas. But the ability of agricultural strategies to adapt to changes in climate and climate variability depends on the magnitude of such increase, the system being impacted, and the adaptation options, as discussed below.

Impacts on land productivity and water resources

An increasing number of studies have shown the effect of current climate variability and extremes in agricultural production, especially in areas where crops are cultivated near their climatic limits. There are several studies of the potential impacts of climate change on agriculture in the Mediterranean, using many different approaches (Iglesias et al. 2000; 2009a; Quiroga and Iglesias 2009; Iglesias and Quiroga 2007; El-Saher et al. 1997). The studies focus on particular issues (e.g. soil erosion, biodiversity, and farm income), time-frames (e.g. 2020s, 2050s, and 2100), scenarios (e.g. SRES) and spatial scales (from local to regional). The results of the studies are diverse and sometimes contradictory due to different assumptions and approaches. Here we outline the main potential impacts of climate change in Mediterranean agriculture. The impacts reported here have the following characteristics: (1) are highly certain (the majority of studies agree); (2) exacerbate the social vulnerability differences (and therefore social inequality); and (3) may be addressed by adaptation policy. This analysis aims to guide the selection of policies for adaptation.

All studies point to definite and significant impact of climate change on further deterioration of water resources in the Mediterranean region. The demand for water would increase in all areas due to increases in crop evapotranspiration in response to increased temperatures. Increased water shortages, particularly in the spring and summer months, would imply conflicts over water uses especially in southern countries (Döll 2002). Reduced water quality due to higher water temperatures and lower levels of runoff in some regions, particularly in summer, would impose further environmental stress in irrigated areas. All this surely leads to increasing restrictions on irrigation in agriculture.

There have been several studies into the potential impacts of climate change on water resources, with many different approaches (e.g. physical modelling, econometric analysis) and definitions (e.g. impacts, vulnerability, risk, adaptation). Studies have focused on particular issues (e.g. agricultural water pressure, ecosystem services), timeframes (e.g. 2020s, 2050s and 2100), scenarios (e.g. IPCC SRES, 2001) and spatial scales (with a focus on national and global scales). Consequently, our knowledge of the potential impacts is diverse and fragmented. Nevertheless, the projected impacts pose challenges for many water-dependent activities and magnify the regional differences in Europe’s natural resources and assets. Although there is a large variation in projected impacts in each EU region, overall the studies are consistent in the direction of change and the spatial distribution of effects. In general in the northern areas, most sectors of the economy are benefited by climate change, providing that projected extremes do not become catastrophic events. However, these potential opportunities will only be possible if water requirements are met. In most of the central and southern areas of Europe water availability is projected to decrease under all scenarios considered. In addition, concurrent altered carbon and nitrogen cycles may have significant implications for soil erosion and water quality.

The effects of climate changes on major water management determinants and expected social and ecological consequences are summarized in (Table 2).

Most studies agree that climate change is likely to have the following common consequences across the Mediterranean region:

- Increased demand for agricultural water in all regions due to expected increases in crop evapotranspiration in response to increased temperatures. The potential for decreasing water demand due to the direct effects of CO_2 on the crop have been challenged (Long et al. 2006).
- Increased water shortages, particularly in the spring and summer months, therefore increasing the water requirement for irrigation.
- Increased deterioration in water quality due to higher water temperatures and lower levels of runoff in some regions, particularly in summer, imposing further stress in irrigated agricultural areas.
- Increased risk of flooding in winter due to the expected concentration of precipitation in this period, affecting significant areas of the Mediterranean region. The major flood events experienced in recent years (notably 2002 and 2007) demonstrate the vulnerability to floods. In addition, the projected increases in sea level will also affect flooding in low-lying coastal areas.

Change in precipitation is probably the most important factor determining the likely impacts in the Mediterranean region. A decrease in water availability is predicted together with an increase in water demand, leading to potential conflicts between users. Decreasing water resources in some areas may affect soil structure, while reduced soil drainage may lead to increased salinity. However, an increase in the frequency and intensity of floods is predicted in some areas where significant increase in winter rainfall is likely to occur. These changes are expected to reduce the diversity of Mediterranean species. In the Mediterranean region, irrigation accounts for over 60 per cent of the pressure on water resources. Box 1 provides an example of the potential impacts of climate change on irrigation in this region, based on a number of studies.

Adaptation

Defining adaptation:

Adaptation is about preparing people and their assets for the impacts of climate change. It is concerned with minimizing adverse effects, or maximizing new opportunities, through taking actions which either anticipate or react to changing climatic conditions. The focus of these actions is on managing risk. Investments in risk-based actions are fundamental to reducing the environmental, social and economic costs of climate change.

The need for an adaptation policy stems from the overwhelming scientific consensus that climate change is a significant threat facing the world, its people, environment and economy. Strong mitigation measures are essential to make deep cuts in the greenhouse gas emissions. However, as aconsequence of present and past emissions of greenhouse gases and the inertia of the climate system, we are already committed to several decades of climate change that cannot now be avoided. Adaptation to cope with the impacts of unavoidable climate change is therefore also necessary as a complementary action to efforts to reduce emissions. In its fourth assessment report, the IPCC (2007) recognizes that some adaptation action is occurring but on a very limited basis, and affirms the need for extensive adaptation across nations and across sectors to address impacts and reduce vulnerability.

Various types of adaptation can be distinguished. Recent studies have highlighted the distinction between ‘autonomous adaptation’ and ‘policy-driven adaptation’. Autonomous adaptation describes actions taken ‘naturally’ by private actors, such as individuals, households, businesses in response to actual or expected climate change, without the active intervention of policy.

Table 2 Effects of climate change on main water management determinants and expected social and ecological consequences

	Expected intensity of negative effects	Potential consequences for agro-ecosystems and rural areas	Confidence level of the potential agricultural impact
Water resources	Changes in hydrological regime. Differences in water needs. Increased water shortage.	Variations in hydrological regime. Decreased availability of water. Risks of water quality loss. Increased risk of soil salinization. Conflicts among users. Groundwater extraction, depletion and decrease in water quality.	High
Irrigation requirements	High in areas already vulnerable to water scarcity	Increased demand for irrigation. Decreased yield of crops.	High
Changes in water and soil salinity and erosion	High for southern countries.	Decrease in water quality from nutrient leaching. Decreased crop yields. Land abandonment. Increased risk of desertification. Loss of rural income.	High
Land use	Depends on region.	Shift in optimal conditions for farming. Deterioration of soils. Loss of rural income. Loss of cultural heritage. Land abandonment. Increased risk of desertification.	High
Increased expenditure in emergency and remediation actions	High for regions with low adaptation capacity.	Loss of rural income. Economic imbalances.	Medium
Biodiversity loss	High for vulnerable regions.	Loss of natural adaptation options. Modified interaction among species.	Medium

Box 1 Potential impacts of climate change on irrigation in the Mediterranean region

Background: Irrigation accounts for over 60 per cent of total water withdrawals, is used on about 10 per cent of the agricultural area, and gives rise to about 90 per cent of the total value of crop production. Water resources vary greatly among basins.

Problem: The studies focus on the evaluation of the potential impact of a change in climate on the potential crop production and irrigation demand. They also aim at examining the potential increase in irrigation demand in areas already vulnerable to water use conflicts.

Methods: Several methods including process-based agronomic models were used to estimate crop yields and crop water requirements at site and regional levels. Crop yield and irrigation demand functions were derived from the validated site results to evaluate spatial water demand and potential change in irrigation areas. Each of the models used in the study was validated against local data.

Scenarios: The current baseline adopted for the socioeconomic projections was 1990 and the climatic baseline 1951–1980. Scenarios of climate change were projected for the 2050s with several global climate models driven by a range of socioeconomic conditions.

Impacts: Under climate change, irrigation demand is expected to increase in all southern Mediterranean regions, especially the ones with the largest current irrigaed areas. The increase in irrigation demand is due to a combination of increased temperature that leads to higher evapotranspiration and decreased precipitation.

Adaptive responses: Improvements in water delivery systems are able to supply the demand for increases in irrigation supply and the projected increase in the irrigated area in the northern half of the region, but do not achieve the same results in the south-eastern part of the region.

Source: Bindi et al. 2000; Iglesias et al. 2000; Tubiello et a. 2000; Iglesias 2002; Iglesias et al. 2002; Tubiello et al. 2002; Iglesias 2003; Moriondo et al. 2006;Salinari et al. 2006; Iglesias et al. 2007b, 2008a

Autonomous/endogenous adaptations are taken naturally but their extent, direction and effectiveness are a function of existing conditions, infrastructure and technologies, that are in turn a result of existing policies, not necessarily intended for adaptation. In contrast, policy driven adaptation is 'the result of a deliberate policy decision'. Policy-driven adaptation is therefore associated with public agencies, either in that they set policies to encourage and inform adaptation or they take direct action themselves, such as public investment (Stern 2006). Planned policy adaptation actions focus on the vulnerability reduction of people and societies.

Adaptation strategies are put in place to deliver adaptations. An adaptation strategy is a broad plan of action that is implemented through policies and measures. Adaptation strategies are not only reactions to posed threats of climate change, but can comprise, at the same time, a large number of technical, social, economic and environmental challenges (Olesen and Bindi, 2002; Iglesias et al. 2007a, 2007c).

Integrating adaptation and sustainable development:

The capacity to adapt to environmental change is implicit in the concept of sustainable development. Climate change will add to the many economic and social challenges already being faced by sustainable development in Europe, increasing the vulnerability of marginal areas and populations. Climate change is a real concern for sustainable policy development, raising major issues about the adequacy of current water and land resource management, both globally and within the EU. The unavoidable impacts of climate change put current activities, certainly at the level of individual land and water managers, at significant risk, therefore making imperative the development of both private and public adaptation strategies. These strategies must evolve taking into account the overall strategy for development in the EU.

Over a decade ago, most countries joined an international treaty – the United Nations Framework Convention on Climate Change (UNFCCC) – to begin considering what can be done to reduce global warming and to cope with whatever temperature increases are inevitable given that climate change is already happening (IPCC 2007). Recently, a number of nations have approved an addition to the treaty, the Kyoto Protocol, which is an international and legally binding agreement to reduce greenhouse gases emissions worldwide (entered into force on 16 February 2005).

The Earth Summit in Rio (1992) ensured that the sustainable development strategy became a goal for governments around the world, by signing the Agenda for the 21st Century. This Agenda (known as Agenda 21) recognizes that broad public participation in decision making is one of the fundamental prerequisites for the achievement of sustainable development. Agenda 21 was one of the first initiatives relating to sustainable development and climate change, establishing actions and identifying actors to implement strategies on poverty alleviation, the provision of basic education and public services, environmental protection and components of sustainable development that have links with addressing climate change such as the rational use of energy and promotion of ecologically sound technologies.
Adaptation to climate change is an essential step towards the process of sustainable development, but the policy priorities for such adaptation in the different social sectors are often fragmented, unformulated and contradictory. The EEA provides an excellent example of a clear definition of policy priorities and adaptation strategies in relation to adaptation in the water sector (EEA 2007). The policy priorities include: (i) reduce the vulnerability of people and societies; (ii) protect and restore the

ecosystems; and (iii) close the gap between supply and demand. The adaptation strategies include: (i) sharing the loss; (ii) preventing the effect; and (iii) research and education. The EEA recognizes the value of high quality information in order to formulate concrete strategies and the role of regulatory and institutional actions. The missing components of all current strategies are: (i) a lack of guidance related to responsibilities for implementing the strategies and actions; and (ii) a lack of a protocol for policy evaluation.

Climate change policy is a specific policy that needs to be coordinated with the EU and national sustainable development strategy processes. Climate change and sustainable development policies should be mutually enforcing, but this challenge has not been fully addressed.

Challenges:
Evidence for limits to adaptation of socio-economic, agricultural, water systems in the Mediterranean region can be documented in recent history. For example, water reserves were not able to cope with sustained droughts in the late 1990's and early 2000´s in some areas, causing many irrigation dependent agricultural systems to cease production. In addition, effective measures to cope with long-term drought and water scarcity are limited and difficult to implement due to the variety of the stakeholders involved and the lack of adequate means to negotiate new policies. The combination of long-term change and greater extremes can have decisive impacts on water demand, limiting further ecosystem services.

Integrated adaptation options at the local level and regional level are extensive. For example, at the local level adaptation initiatives may combine water efficiency initiatives, engineering and structural improvements to water supply infrastructure, agriculture policies and urban planning/management. At the national/regional level, priorities include placing greater emphasis on integrated, cross-sectoral water resources management, using river basins as resource management units, and encouraging sound and management practices. Given increasing pressures on resources, and the considerable time and expense required to implement many adaptation measures, the agriculture and water resources sectors in many areas and countries will remain vulnerable to climate variability.

Agricultural and water management is partly determined by legislation and co-operation among government entities, within countries and internationally; altered water supply and demand would call for a reconsideration of existing legal and cooperative arrangements. In most cases, there is likely to be a need for costly investment in new technologies and infrastructure. Assessing adaptation options involves subjective value adjustments that can be controversial; therefore there are no widely accepted methods for evaluating local adaptation. Finally, the development of adaptation scenarios needs to include stakeholder participation since they are both the demand-drivers and end users of adaptation analysis.

Conclusions

Land productivity and water resources in dry areas are increasingly unstable and vulnerable, but climate change is only one of the determinants of their vulnerability. The issue is even more pertinent where 'at risk' regions and social groups are already economically marginal or at the edge of climate tolerance. To reduce the vulnerability of water resources to climate change in dry areas, robust policy options or adaptation response strategies are required. The risks are not just long term; in the short term, extreme weather events could cause major damage and loss of ecosystems, especially in marginal areas. The proportion of the rural population with limited water resources is highest in dry areas of the Mediterranean region – areas that are projected to face the greatest risks and have the fewest opportunities (from climate change). These regions are the most vulnerable. If climate changes continue to intensify, many dry areas may become increasingly unstable and vulnerable to changing climate patterns and extreme events.

Development policies should incorporate climate change. Adaptation is unlikely to be facilitated through the introduction of new and separate policies at the national level, but rather by the revision of existing local policies that undermine adaptation and the strengthening of policies that enhance it. If adaptation is to become 'mainstreamed', it will be necessary for relevant National policies, such as desertification and sustainable development, to address the issue more directly. Existing agreements also have a part to play.

Existing policy instruments can be used to stimulate and facilitate adaptation and other mechanisms must also be utilized, such as insurance, capacity building, networks and partnerships. Adjustments to the current agricultural and water policies could provide opportunities to examine how to integrate adaptation into agriculture support programmes. Consideration might be given to the extent to which the local agricultural and water policies can promote good farming practices that are compatible with changing climatic conditions.

To minimize the negative impacts of climate change and to take advantage of the potential benefits, adaptation efforts will need to be introduced at all levels and may need to be coordinated across the countries. Adaptation often involves combined effort across many sectors. Water resources are sensitive to responses in other sectors, particularly agriculture, tourism and biodiversity conservation. Adaptation measures for water resources should take account of policies in other sectors. Wider influences on water resources, such as changes in non-climate driven pressures, must be considered alongside climate change. It is important to consider whether adaptations are sustainable, or rendered irrelevant by other drivers. This holistic approach should also ensure that adaptation decisions and investments are both cost effective and proportionate to the risks or benefits that may be incurred. The main challenge of climate change policy in dry areas is a clear definition of multiple priorities and responsibilities for implementing the strategic measures.

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25. Sustainable production intensification for food security in drylands

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Abstract

Agriculture production is under pressure to feed an increasing population while contributing to meet a growing energy demand. In drylands agricultural production is further challenged by the limited availability of water resources, the increasing variability of extreme climatic events, the predicted changes in mean temperatures with the expected associated changes in distribution and movement of plant pests and animal diseases. Unless the sector is able to become more resilient and efficient through the use of adequate policies and technologies, the livelihoods of rural populations in drylands, already vulnerable to food insecurity, will be further affected. Efficiency in agricultural production could be achieved through sustainable production intensification, but only when technological, socioeconomic and environmental aspects relevant to the drylands are taken into consideration.

Sustainable intensification and its adaptation to local conditions and challenges is knowledge intensive and requires continuous improvement of capacity at different levels., from the improvement of field knowledge to the implementation of relevant national and regional policies. Proven approaches like 'Farmer Field School' could be the starting point to enhance knowledge base of land users. Worldwide there is already experience with the implementation of agronomic practices that result in more efficient agricultural production and preservation of the resource base: e.g. more resistant varieties, soil and water conservation technologies, integrated nutrient management, conservation agriculture, integrated pest management, diversification of cropping pattern, etc. The challenge is how to integrate, transfer and apply to local conditions. Efficient agricultural production systems require coordinated efforts of different sectors of society – land users, field technicians, research institutions, academia, non-governmental organizations, national governments, etc. This paper discusses the different aspects of sustainable production intensification, its application in drylands and the role of FAO in facilitating and achieving it.

Introduction

Recurrent droughts and migration from rural to urban areas have decreased the contribution of agriculture to the GDP of many countries with drylands. Nevertheless, many of the poorest countries rely on agriculture and face increasing challenges to sustain their crop production (Morawski et al. 1999). Naturally, several constraints impair crop production in dryland areas, including short length of growing periods, water scarcity, salinization, erosion, decreased soil organic matter, low soil water holding capacity, deficiency of nitrogen, phosphorous and some micronutrients (van Duiven et al. 2000). The occurrence of intermittent droughts frequently exacerbates the challenges facing crop production. Productivity gaps are particularly large in rainfed areas. This is attributed mainly to the variability of soil features, negligible control of water, weak technology adaptation or adoption, refinement and diffusion mechanisms, and poor institutional support. Still, there are several success stories of bridging the gaps at various levels, which should be analyzed to identify the underlying drivers of change. They could be used as examples for scaling up.

The effects of climate variability and change add to the current challenges for crop production in drylands. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, many semi-arid areas (e.g. the Mediterranean Basin, western United States, southern Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change (IPCC 2007); in some regions, demand for irrigation will increase and precipitation patterns will vary highly. The Central and West Asia and North Africa (CWANA) region is expected to be particularly affected by more frequent droughts, increased evapotranspiration, changes in rainfall patterns and associated wind erosion, increased salinization and decreased carbon mineralization. Paradoxically, an increase in heavy precipitation events is likely to increase risks of both flooding and drought for the main crops in this region (Thomas 2008).

In addition to abiotic stresses, climate change is expected to alter the distribution of plant pests and diseases as well as the vulnerability of agroecosystems to pests and diseases. To date, there is still only limited information on the effects of climate change on specific agroecosystems, although it is accepted that the sensitivity of each agroecosystem will depend on the crop varieties, pest and disease species involved (in particular their phenotypic and genotypic flexibility), their trophic levels and geographical locations. The prediction of disease outbreaks, as well as long-term predictions on the movement of plant pests and diseases, will be more difficult under rapidly changing climate and unstable weather (Bale et al. 2002; Fuhrer 2003).

For drylands, there are still many questions unanswered. It is known that extremes like droughts or floods are important triggers for the outbreak or wider spread of soil-borne pathogens (Fuhrer 2003). In the past few years, a new virulent strain of the wheat stem rust disease (UG99), caused by a fungal pathogen, emerged in East Africa and spread, reaching Iran in late 2007. The regions of the Near East, Eastern Africa and Central and South Asia at immediate risk account for some 37 percent of global wheat production. Although the impacts of climate variability and change in the proliferation of UG99 are still not clear, scientists expect that climatic stresses imposed on wheat when coupled to stem rust, especially where it is rainfed, will cause severe yield losses (FAO 2007).

Altogether, increased demand for crop production for food, fibre and non-food products (such as biofuels), the growing concerns of ecosystem degradation (including resource base degradation and loss of biodiversity), changes in consumer preferences and the projected impacts of climate variability and change, are creating a need to rethink agricultural systems. To fulfil the demand for agricultural products, about 80 percent of the increase in land-based agricultural production is expected to derive from increased input use and improved technology on existing agricultural land; the other 20 percent is expected from expansion of arable lands in parts of South America and sub-Saharan Africa (FAO 2003). Intensification will be the main way forward, but this time it will need to take a more sustainable route. In order to feed a growing population while maintaining or restoring ecosystems' health and functions, there is a need to promote strategies and technologies for crop production that: are environmentally friendly, culturally adapted, produce socioeconomic benefits, take into account adaptation to climate change and result in good quality and safe products. This paper focuses on the vision of FAO to achieve sustainable production intensification, while recognising the important contributions of many other stakeholders working towards sustainable agriculture.

Promoting efficient and ecologically sound production systems: Sustainable production intensification

Bearing in mind the need for more sustainable production systems, FAO, in particular the Plant Production and Protection Division (AGP), is promoting sustainable production intensification (SPI), as a set of choices locally adapted to increase the output per land area while considering socioeconomic and ecosystem health factors. These choices will require careful consideration of past failures and promising policies, approaches and technologies, often resulting in increasingly integrated systems. The support that FAO will provide to member governments to design and implement strategies and policies for sustainable production intensification will be underpinned by the research of the Consultative Group on International Agricultural Research (CGIAR) centres and strong national agricultural research centres; FAO also will rely on partnerships with different institutions, regional programs and donors.

Technical components of sustainable production intensification relevant to drylands

The implementation of SPI choices in dryland countries will depend on the particular conditions and aims of governments and land users. Areas with more constraints could be earmarked for diversification and production of other ecosystem services which, in the long term, will result in more benefits for local communities, countries and regions. Areas with more potential should benefit from integrated approaches that altogether result in sustainable production intensification. Examples of the different technical components that could be part of planning for sustainable production intensification in drylands are mentioned below. Links to specific information on each topic are provided in (Table 1).

Using nutrients efficiently for improving soil fertility, crop yields and environmental resources quality: A fundamental part of sustainable production intensification is the appropriate management of soil and plant nutrients. In drylands, where soils are normally low in nutrients, increasing soil fertility should be the first step towards SPI. Sustainable production intensification builds on the experience with Integrated Plant Nutrient Management Systems (IPNS), which promote the use of sources of plant nutrients more relevant to local conditions (mineral fertilizers, organic or biological materials) and approaches that take into consideration nutrient balances at the farm and larger landscape levels. This should allow optimization of nutrient application to increase soil fertility, reduce pollution and altogether result in lower production costs. The careful consideration of economic returns resulting from input use and minimization of risks are fundamental in the design of nutrient management plans.

Seed security and seed systems: Seeds are an important agent in agricultural change, technology transfer and development. Seed quality and availability are fundamental to guarantee the success of sustainable production intensification and food security. Seed quality implies genetic, physiological, analytical and sanitary quality. Farmers should have a wide range of seed of adapted crops and

Table 1. Selected links with examples of the different activities of FAO that can contribute to sustainable production intensification

Topic	Link
Sustainable Production Intensification	http://www.fao.org/agriculture/crops/core-themes/theme/sustainable-production-intensification/en/
Using nutrients efficiently	http://www.fao.org/agriculture/crops/core-themes/theme/sustainable-production-intensification/fertilizer-and-plant-nutrition/en/
Seed security and seed systems	http://www.fao.org/agriculture/crops/core-themes/theme/seeds-and-plant-genetic-resources/en/
Managing water	http://www.fao.org/nr/water/ http://www.fao.org/nr/water/activities_iptrid.html
Combating erosion	http://www.fao.org/nr/lman/lman_en.htm http://www.fao.org/agriculture/crops/core-themes/theme/biodiversity-and-ecosystem-services/soil/en/
Genetic resources to increase the resilience of agroecosystems	Same as seed; http://km.fao.org/gipb/; http://www.fao.org/ag/cgrfa/default.htm
Controlling salinization	http://www.fao.org/agriculture/crops/networks/en/ http://www.fao.org/agriculture/crops/core-themes/theme/biodiversity-and-ecosystem-services/soil/en/
Promoting diversification	http://www.fao.org/agriculture/crops/core-themes/theme/horticulture-and-industrial-crops/en/ http://www.fao.org/ag/agn/index_en.stm#; http://www.fao.org/forestry/50667/en/
Environmentally sound pest management programmes	http://www.fao.org/agriculture/crops/core-themes/theme/pest-and-pesticide-management/en/
Soil rehabilitation	http://www.fao.org/nr/lman/lman_en.htm; http://www.fao.org/agriculture/crops/core-themes/theme/biodiversity-and-ecosystem-services/soil/en/; http://www.fao.org/world/Regional/RNE/
Grassland rehabilitation	http://www.fao.org/agriculture/crops/core-themes/theme/biodiversity-and-ecosystem-services/grasslands-and-rangelands/en/; http://www.fao.org/world/Regional/RNE/
Promoting the provision of other ecosystem services	http://www.fao.org/agriculture/crops/core-themes/theme/biodiversity-and-ecosystem-services/en/
Agrobiodiversity	http://www.fao.org/biodiversity/biodiversity-home/en/
Human nutrition	http://www.fao.org/ag/agn/index_en.stm#
Empowering farming communities (including monitoring)	http://www.fao.org/docrep/006/ad487e/ad487e02.htm; http://www.fao.org/nr/edu/edu_en.htm; http://www.fao-ilo.org/; http://www.fao.org/nr/lten/lten_en.htm; http://www.fao.org/nr/ext/ext_en.htm; http://www.fao.org/nr/lman/lman_en.htm; http://www.fao.org/nr/lada/; http://www.fao.org/sd/EIdirect/EIre0071.htm; http://www.fao.org/world/Regional/RNE/morelinks/Publications/English/Aljouf%20project%20overview.pdf; http://www.fao.org/ag/AGP/agpc/doc/publicat/field2/TCP0067.htm; http://www.fao.org/ag/AGP/AGPC/doc/Present/FAO/Baas.htm

varieties during normal operations and during (or immediately after) extreme climatic events. In drylands, climate change threats will often require adaptation of seed distribution systems, to ensure that farmers have access to good quality seeds that help them to adapt their agroecosystems and reduce the loss of local germplasm.

Managing water for more efficient production systems: The focus should be on: modernizing existing irrigation systems; implementing efficient systems in new irrigated areas; using better adapted and more efficient crop varieties; promoting soil moisture conservation practices; improving drainage; encouraging the use of improved water harvesting technologies (including microcatchments, macrocatchments and flood water diversion); preventing salinization; preventing sodification and paying attention to social and environmental problems associated to water allocation and abstraction of non-renewable sources. The Investment Briefs produced by the Conference on *Water for Agriculture and Energy in Africa: the Challenges of Climate Change* could be useful to identify investment needs in this region.

Combating erosion using approaches that improve the acceptance of soil conservation technologies: The approaches used in the past for soil conservation only achieved limited success as farmers often see them as additional costs and abandon them at the end of projects. As a result, soil erosion has in general not been controlled and productivity continues to decline in areas affected by erosion. Experience has shown that erosion can be reduced by increasing the quantity and continuity of soil cover and by improving the structure and porosity of soil. In this way, soil-raindrop impact and runoff, the two factors most responsible for soil erosion, are greatly reduced.

The role of genetic resources to increase the resilience of agroecosystems: The resilience of agroecosystems can be increased by promoting indigenous agrobiodiversity (more diverse systems have greater potential for adaptation to stress) and by breeding and selecting species which have more possibilities of adapting to stress (for example tolerance to drought, heat stress, salinity, flooding and pest and disease resistance). In this context, FAO facilitates the Global Partnership Initiative for Plant Breeding Capacity Building (GIPB) to strengthen the national capacities of developing countries to breed stress resistant crops. In addition, FAO, together with other partners, also promotes the use of indigenous and locally adapted plant and animal diversity.

Controlling salinization, the contribution of biosaline agriculture: Salt affected soils are often found in drylands, either naturally or as the result of inappropriate agricultural practices. While the aim is to prevent salinization, in areas where there are already problems, biosaline agriculture may be an option to keep productivity and diversify income. Biosaline agriculture is defined as crop production on saline soils where, in most cases, seawater or brackish/saline groundwater are the only sources of irrigation water. Biosaline agriculture in general uses plants which are more tolerant to salts or halophytes.

Promoting diversification: Diversification is a useful means to increase crop output under different conditions. With the increasing demand for fruits and vegetables, herbal medicines and botanicals, and for organically produced food, aquaculture and other products, countries can develop specific production and distribution patterns for their speciality commodities, including for specific markets such as certified production and organic products. The protected cultivation of vegetables could be an option in semi-arid and dry-subhumid areas, provided a permanent source of water is available for irrigation. The protected cultivation of vegetables needs careful feasibility studies.

Promoting efficient and environmentally sound pest management programmes: The widespread introduction of pesticides (insecticides, fungicides and herbicides) changed the outlook on pest control as part of agricultural intensification. The application of pesticides in drylands varies from region to region, from smallholders (who traditionally apply small amounts and through a combination of approaches) to wider regional applications of pesticides, especially during outbreaks. Today, environmental and health concerns have heightened and few countries have now established programmes to reduce pesticide use, like Integrated Pest Management (IPM), which uses approaches that increase the role of ecosystem processes in pest management and reduce the use of pesticides.

Rehabilitating soils and grasslands and using their potential for carbon sequestration: Enhancing carbon sequestration in degraded drylands could have direct environmental, economic and social benefits for local people. It would increase farmers' benefits and help mitigate global warming. Estimations suggest that the ecotechnological scope for soil carbon sequestration in dryland ecosystems is about 1 billion tonnes of carbon per year (Lal 2004). Investments in improved land management leading to increased soil fertility and carbon sequestration can also be justified in many cases because they can be a win-win situation with higher agronomic productivity and contributing to national economic growth, food security and biodiversity conservation.

Promoting the provision of other ecosystem services and biodiversity conservation: Improving the supply of environmental services can be an important component of agricultural development strategies in drylands, depending on the existing natural resource base and the type of farming system in place. This requires the adoption of policies and agricultural production systems that generate environmental services. In land abundant areas, and areas where off-farm employment opportunities have drawn populations out of rural areas, the potential for setting aside land for non-agricultural uses is high. The conversion of non-used agricultural lands to forests, grasslands and areas of conservation of endemic species (supported through tourist income), contribute to carbon sequestration, watershed protection and biodiversity conservation. In land scarce environments, the trade-off between agricultural and non-agricultural services is high. In such environments, ecosystem services would have to be complementary to food and fibre production. Not every country or region has the potential to realize an economic benefit from supplying ecosystem services, and environmental and socioeconomic conditions (e.g. property rights, food security, and low transaction costs) are important determinants of the returns (Lipper et al. 2006).

Using energy efficient technologies: Sustainable production intensification will necessarily need to consider energy efficiency at all the steps of production. Agriculture at different scales can contribute to reducing the consumption of fossil fuels and other non-renewable sources of energy. Even when smallholders in drylands may not currently be the larger consumers of energy, it is clear that under intensification, provisions need to be made in order to optimize the outputs per unit of energy used. This area requires more research, application at field level and technology transfer. For example, charcoal production in arid and semi-arid zones needs policies to prevent major deforestation of sparse woody vegetation.

Considering human nutrition concerns when planning for SPI in drylands: Drylands are areas where human nutrient deficiencies are common due to many factors, including high percentages of staple foods in the food basket, low micronutrient content of agricultural products and limited access to food. Sustainable production intensification should also consider local human nutrition concerns. In this sense, SPI can contribute to combating deficiencies by promoting crop diversification (and therefore opportunities for expansion of the food basket) and the use of varieties that have a higher nutritional value, like those that are being bred in CGIAR centres under the *Harvest Plus Challenge Program*.

Introducing environmental impact assessment in development projects: The cost of environmental impact assessment (EIA) of agricultural activities may still be high for small farmers in drylands, but the potential impact of intensification should be an integral part of development projects. By introducing environmental impact assessment in development projects, farmers may also have the opportunity to become acquainted with EIA tools. FAO is developing tools for different stakeholders to support projects and beneficiaries to introduce EIA.

Empowering farming communities to monitor their natural resources: Monitoring the impacts of agriculture on the environment is much more difficult than monitoring most other sectors. Farmers are stewards of land resources, and monitoring the impacts of their land use decisions is a major undertaking. It is important to empower farmers to adopt criteria and methods to assess the impact of their practices on ecosystems and to encourage monitoring of dryland degradation (Sivakumar 2006). At the farm level, the use of simple visual soil assessment tools that integrate soil physical, chemical and biological characteristic seems to be having some success.

Matching practices to local circumstances: Experience has shown that it is better to tailor practices to local situations rather than to apply prescriptions for one cropping system to another. A fundamental pillar of SPI is the assessment of the local situation and needs and then the promotion of practices that respond to these needs and agroecological conditions, specifically under climate change threats. The combination of new scientific knowledge with indigenous knowledge may have better chances of acceptance and success under local conditions.

Examples of integrated practices contributing to sustainable production intensification

There are already several examples of integrated practices that, in the future, may play an important role in sustainable production intensification. These practices have started to consider the capacity of land to provide other environmental services, like carbon sequestration, nutrient cycling, water infiltration, pollination and biodiversity conservation, among others. Building on these practices and improving them in order to achieve more integrated practices under SPI will be the challenge of the next few years, if the production capacity of the land is to be continued and the health of ecosystems (including human health) maintained or restored. Examples of practices that FAO has been promoting and that can be adapted for SPI are included in (Table 2).

The role of early warning systems for crop production in drylands

Investments in early warning of potential droughts as well as pest and disease proliferation monitoring systems will be a key to avoiding the higher costs of production losses and deterioration of farmers' livelihoods. Coordinated research,

Table 2. Effects of climate change on main water management determinants and expected social and ecological consequences

Integrated practice	Basics	Benefits	Lessons learnt
Conservation Agriculture (CA)	Based on three principles: minimum tillage, keeping soils covered and crop rotations (FAO, 2007). Not a single technology but a wide set of specific technologies. Over the last two decades, the set of technologies have been improved and adapted for nearly all farm sizes, soils, crop types and climatic zones	Enhances natural biological processes above and below ground; provides additional ecosystem services: soil carbon sequestration, water infiltration; increases watershed quality; reduces pollution from agrochemicals; preserves soil moisture; reduces labour costs; reduces fuel consumption compared with conventional tillage-based agriculture.	Start-up incentives and training are needed to encourage farmers to adopt CA and overcome potential problems such as weed proliferation, balance the short-term costs (e.g. the use of crops for covering the soil instead of feed or fuel) or to improve management skills.
Integrated Production and Pest Management (IPPM)	The four principles of IPPM are: 1) cultivation of a healthy soil and crop; 2) conservation of natural enemies; 3) observation of fields; and 4) farmers becoming expert IPPM practitioners	Emphasizes the growth of healthy crops with the least possible disruption to agroecosystems; encourages natural pest control mechanism; farmers and the farming systems are the focus of technological innovation; interventions are kept to levels that are economically justified and reduce or minimize risks to human health and the environment; contributes to enhancing other ecosystems services such as pollination.	IPPM training programmes in Benin, Burkina Faso, Mali, Senegal, Sudan, Tanzania, Zambia and Zimbabwe are showing that the concepts and methodologies used for IPPM are adaptable to African conditions.
Agroforestry	Involves deliberate combination of trees, agricultural crops and/or animals on the same land management unit in some form of spatial arrangement or temporal sequence.	In many cases can be considered as a form of diversification; it can control soil erosion; ameliorate the environment for food production through shelter belts and windbreaks; contribute to feed for livestock and supplement the diet of the rural population, both directly in the form of fruits, nuts and leaves, and indirectly through honey and wildlife. The promotion of date palm in arid and semi-arid areas is an example (Table 4).	The viability of such systems is dictated by water availability and management capability.
Integrated crop and livestock systems	The integration may be achieved through consortium; either as succession or rotation with annual crops such as forages. Innovative systems include incorporation of CA.	The benefits of the crop-livestock integration include: recuperation and maintenance of the soil productive capacity; product diversification and higher yields at less cost; ecological reduction of crop pests and; more uniform income distribution as the livestock and crop activities separately concentrate income generation.	Degree of integration will depend on objectives: the rehabilitation of degraded pastures, the maintenance of high pasture production and, mainly, sequential crop/pasture production.
Urban and peri-urban agriculture (UPA)	Urban and peri-urban agriculture have been used as a household strategy to respond to both chronic and emergency food insecurity. It often involves the direct use of urban waste and the re-utilisation of resources after they have been used in urban sectors.	Farm households are less dependent on gifts and transfers of food; major shares of household food consumption may be self-provided in some cities, especially among low-income families; the demand for fresh and perishable goods may be better met by urban production than rural (FAO, 2000); represents an opportunity to produce more food in an efficient manner. Protected cultivation of vegetables may be an option.	Factors that negatively affect the contribution of UPA to household food security are land tenure problems, high water cost in many urban areas and theft (FAO, 2001 Egal). In addition the opportunity to use carefully treated urban waters could add reduce the costs of production in dryland countries if due attention to food safety is considered.

Table 3. Examples of networks and initiatives facilitated by FAO that promote information and technology transfer for sustainable production intensification (SPI) in drylands

Network/programme	Website
Conference on Water for Agriculture and Energy in Africa: The Challenges of Climate change	http:/www.sirtewaterandenergy.org/
Date Palm Global Network	http://dpgn.uaeu.ac.ae/
FAO-ICARDA International Technical Cooperation Network on Cactus	http://www.cactusnet.org/
Global Partnership Initiative for Plant Breeding Capacity Building (GIPB)	http://km.fao.org/gipb/;
Globally Important Agricultural Heritage Systems	http://www.fao.org/sd/giahs/
Land Degradation Assessment in drylands (LADA)	http://www.fao.org/nr/lada/
Locust Watch – Desert Locust monitoring and early warning	http://www.fao.org/ag/locusts/en/info/info/index.html
Salinization Prevention and Productive Use of Salt Affected Soils (SPUSH)	http://www.fao.org/agriculture/crops/networks/en/

including programmes related to climate change and food security will be needed to improve the range of options available to countries. Examples of warning systems are already available from many institutions, e.g. the FAO Global Information and Early Warning System. FAO, through its Wheat Rust Disease Global Program (WRDGP), is promoting global action to prevent a potential wheat production crisis. The WRDGP covers 29 countries in the regions of East and North Africa, the Near East, Central and South Asia. Experience from the tracking outbreak of other diseases is being incorporated in FAO's efforts, e.g. the movement of Yellow Rust (Vir-Yr9). In addition, FAO has many years of experience with the monitoring of desert locust, which is being used as a model for monitoring the movement of other pests and diseases.

Examples of policy issues related to SPI in drylands

The careful consideration of the local needs for policy support will create better opportunities for farmers and consumers to benefit from SPI; in fact, experience shows that, if appropriate support is not available for smallholders, technology is not successful. There are many policy issues that are specific for each country and region. We have selected only two: drought mitigation plans; and payments for environmental services as examples. However, when planning for SPI, there is a need to assess which strategies and policies would better support the aims of SPI under local conditions.

Drought mitigation plans:
The traditional approach of responding to drought is the provision of emergency assistance to alleviate the impacts, although it has been demonstrated that preparedness for drought is more cost-effective than responding to it. Planning can reduce the effects of drought and the needs for assistance. To reduce the impacts of climate variability and change, sustainable production intensification should consider the preparation of drought mitigation plans, which would need the support of governments and different sectors of society.

Adequate drought mitigation plans should include a component with provisions for implementation during normal conditions (proactive measures to reduce risks) and a contingency plan for rapid implementation during drought (carefully thought-out emergency responses). Developing these components at the same time would ensure that contingency plans consider actions that will lead to long-term development. Examples of the actions for crop production during normal periods that can be incorporated into drought mitigation plans include (Bazza 2001):

- Encouraging water conservation measures, such as supplementary and deficit-irrigation.
- Improving water efficiency in agriculture; installing flow meters and introducing crops with shorter seasons and/or lower water requirements.
- Increasing water collection and storage opportunities, for both surface and underground excess water.
- Breeding for drought- and heat-tolerant varieties or breeding short season varieties.
- Training farmers on the use of agricultural practices that increase and conserve soil moisture and allow crops to use water efficiently.

Upon the onset of drought, little can be done to save crops that are already in the field, especially when water is not available for irrigation. This highlights the importance of mitigation measures during regular periods. Some of the actions that can result in saving part of the production as part of contingency plans are:

- Making available supplementary irrigation where water can be allocated on an emergency basis.
- Adopting cultural practices that conserve soil moisture.
- Reducing the use of nitrogen fertilizers to avoid the increase of biomass and the requirement for more water.
- Mulching and shading to reduce evapotranspiration.
- Reducing crop density.
- Weeding to avoid competition for water.

Payment for environmental services (PES):
Even if drylands have the potential to provide several environmental services, farmers may not consider them as a priority without incentives, especially if benefits are more obvious off-site than on-site. Opportunities to incorporate the provision of environmental services into land use strategies in drylands seem to be arising: there is an increasing willingness on the part of external beneficiaries to pay for environmental services and there is increasing recognition of the importance of environmental services in sustainable agricultural management (as well as the high costs of their depletion).

The source of PES depends upon the beneficiary of the service; payments could come from government or private funds. Perhaps the most important requirement for integration of environmental services into drylands development strategies is the incorporation of their potential value into national agricultural and economic development strategies. Creating the institutional framework to promote PES is also fundamental. The first step is to gather and disseminate information on the potential demand for and supply of environmental services from a given country or region to alert policy makers and planners of these possibilities (Lipper et al. 2006; FAO 2007). FAO has been working to promote different modalities of PES which can be incorporated into sustainable production intensification (Table 1).

Technology and information transfer

Sustainable production intensification is knowledge intensive and it needs efficient means for information and technology transfer at different levels, from the authorities to the land users. Mechanisms for information and technology transfer can include networks, strengthening of farmers' associations and farmer field schools (FFS).

Examples of some of the networks facilitated by FAO are included in (Table3) Participatory approaches for technology transfer such as farmer field schools can increase the capacity of farmers to respond adequately to changing farming situations. Farmer field schools traditionally cover the crop production practices, but they can include other aspects of SPI. The role of FAO in FFS development is not to directly deliver FFS, but to pilot test and then facilitate the transfer of this approach and development of training materials for trainers, to enable and empower the wide array of local initiatives that are working in close collaboration with farmers.

The socioeconomic picture: empowering smallholders

Sustainable production intensification can only be successful if farmers, in particular smallholders, are empowered to participate in the opportunities and benefits that SPI may offer. Smallholders need to be the focus of technology transfer and policies and these should reflect and improve the conditions under which they work in the drylands. Empowering smallholders to choose and apply efficient crop production technologies; identifying opportunities for diversification or provision of other ecosystem services; estimating economic benefits and recognising the impacts of their practices on the environment and health are fundamental. At the same time SPI should consider mechanisms to improve the access of smallholders to fair credits and markets.

Need for coordinated action

Climate change adds to the multiple development threats faced by drylands. These can only be overcome by developing a common agenda where different actors can see their roles clearly. It is also important to build on success stories and make sure that they continue to be successful under new constraints. Regional partnerships, such as TerrAfrica, which are already active, can be important platforms for the dissemination of SPI. Land users are central to sustainable production intensification; they need to recognize the indirect and external benefits of sustainable intensification if they are to manage their resources in a more sustainable way. It is clear that, under new threats, they will need more support from field technicians, researchers and policy makers.

Agronomic research will continue to play an important role by improving the understanding of the impacts of climate change on crop production; developing (or improving) adaptation options; and improving the understanding of the consequences of different adaptation options on further climate forcing. The results of research can only be effective if the capacity of field technicians is strengthened to transfer knowledge and provide feedback to scientists on the adoption rates and needs of farmers. Field technicians also need to work with a wide range of other disciplines, and across sectors of the food industry, to contribute to the development of the necessary new approaches and paradigms to better link research on food production to food security issues (Ingram 2008).

Finally, without the support from appropriate policies, efforts to introduce SPI in the drylands will result in the same failures that many separate initiatives have suffered over the years. If SPI is to be effective in improving the livelihoods of dryland people under climate change threats, there is a need for further support from policy makers.

The experience of FAO in drylands makes it a key resource for the exchange of technical information, national capacity building, planning and organizing of mitigation plans, natural resources management and agricultural development. FAO can also contribute to facilitating financial support from international or bilateral donors. FAO will continue to promote partnerships with those working towards the development of drylands, including research, field technicians, academia, intergovernmental bodies, non-governmental organizations, farmers' and producers' associations, national and international development agencies, UN sister organizations and others.

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26. Climate change in arid western India

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Abstract

Global climate change due to emission of anthropogenic greenhouse gases into the atmosphere is now a reality that is increasing the temperature and bringing in large-scale changes in other climatic parameters. Several simulation studies with global and regional climate models have shown that the hot arid zone of India, located mostly in the country's western states of Rajasthan and Gujarat (accounting for 81.5% of the total arid areas in India), will also experience large changes in climate that will impact agriculture and allied activities, and in turn the socio-economic conditions of the people. Annual temperature, as well as the summer and winter temperatures, would increase by 3-5°C by the last quarter of this century. Annual rainfall may increase by 10-15% in the eastern fringe, and by 20-40% in the south, but the northwest will experience up to 30% reduction in rainfall. Rainy days will possibly decline across the region. Since biophysical resources of the region are already in a delicate balance with prevalent climate, and pressure on land resources are very high, the region is becoming more vulnerable to natural process acceleration and usurpation of resources by humans. Yields of some crops may decline by 20-50% unless remedial interventions are made. For example, simulation studies show that pearl millet grain and biomass production may decline, respectively by 21% and 12% if rainfall is 20% less and increase by 8% and 2% if rainfall is 20% more than at present but without any change in temperature. If the above rainfall changes are associated with 2°C rise in temperature both grain and biomass production would be reduced by ~40%, and if the rise is 4°C, the reduction would be by >50% (even if rainfall increases by 20%). This calls for strengthening of research on water use efficiency of crops, stress tolerance in plants, maintenance of green cover to reduce wind erosion and soil nutrient loss, water conservation technologies, and livestock production system that fares well under a drier environment and under drought. The CAZRI, based on its 50 years' research experience, is gearing up to face the challenges.

Introduction

The hot arid region of India covers an area of 317,090 km^2, which is spread over seven states viz., Rajasthan, Gujarat, Haryana, Punjab, Maharashtra, Karnataka and Andhra Pradesh. Rajasthan and Gujarat accounts for 81.5% of the total arid area in India. Besides the extreme weather conditions, the climate change and the rapidly increasing human and livestock population are causing an acute biotic pressure on natural resources of this northwest arid region

The Intergovernmental Panel on Climate Change (IPCC) projects that the global mean temperature may increase between

1.4 and 5.5^{0}C by 2100. This unprecedented increase is expected to have severe impacts in the global hydrological system, ecosystems, crop production and related processes. The climate change impact would be particularly severe in fragile arid eco-system like northwest India, changing the behavioural pattern of monsoon rainfall influencing crop production, land and water resources. About 80 to 90% of the rainfall is brought by southwesterly monsoon current. The monsoon depressions, which originate from the Bay of Bengal, while moving farther reach northwest arid India, where they become dry resulting in little or no rain. Besides, the Indian arid zone being located in the semi-permanent belt, often resists the vertical cloud development and precipitation process.

Combating droughts and desertification in the hot Indian arid zone was started way back in 1952 with the establishment of Desert Afforestation Station which became full-fledged institute in 1959 designated as the Central Arid Zone Research Institute (CAZRI). This multi-disciplinary institute is located at Jodhpur and has regional research stations at Pali, Bikaner, Jaisalmer and Kukma (Bhuj) to cater the need of the hot arid regions of India**.** The current and predicted climate change scenarios of the arid western India and various strategies adopted for mitigation of climate change are discussed below.

Climate change and its impacts in Indian arid region

Rainfall trends:

The arid phase of northwest India has a history of about 3000 years (Pant and Maliekel 1987). Winstanly (1973 a,b) analyzed the rainfall at Bikaner and Jaisalmer and reported that the monsoon in the arid region of northwest India was favourable during 1700 to 1930 and has been unfavourable since 1970. The studies conducted on secular changes in rainfall and air temperatures of northwest India (covering the meteorological sub-divisions of Punjab, Haryana, west Rajasthan and west Madhya Pradesh) showed that there was a marginal increase in the rainfall by 141 mm in the past 100 years (Pant and Hingane 1988) and more so in irrigated belts of Sri Ganganagar region, particularly during the past three decades (Rao 1996).

The physiographic rainfall variations across arid western plains and Marusthali during 1813 to 2006 showed a decline in annual rainfall in the region, but showed a marginal increase in the June and decline in the July rainfall. Across different seasons, an increase in rainfall during summer (March-May) and post-monsoon (October-December) and a decline in winter (January and February) and monsoon rainfall (June-September) was observed (Sontakke et al. 2008). However, the long-term trends of average annual rainfall of 12 arid districts of Rajasthan during 1901 to 2006 showed that there was no significant change in annual rainfall (except +20 mm increase in the past 100 years) (Fig.1). However, the climate change studies along the tracts of irrigated arid region showed that the area of Ganganagar which is exposed for long period to irrigation, showed an increase in annual rainfall at a rate of 1.0 mm year^{-1}. Introduction of irrigation from *Indira Gandhi Nahar Parjyojana* (IGNP) canal water in the Indian arid region resulted in changes in micro-climate, flora and fauna of the area over the past years. However, such an increase was not observed in areas where irrigation has been introduced in the past two decades at Bikaner and one decade at Jaisalmer (Rao 1996).

Simulations using PRECIS (Providing Regional Climates for Impact Studies) regional climate model, developed by the Hadley Centre for Climate Prediction and Research, was applied for India (Rupa Kumar et al. 2006) to generate the climate for the present (1961-1990) and a future period (2071-2100) for two different

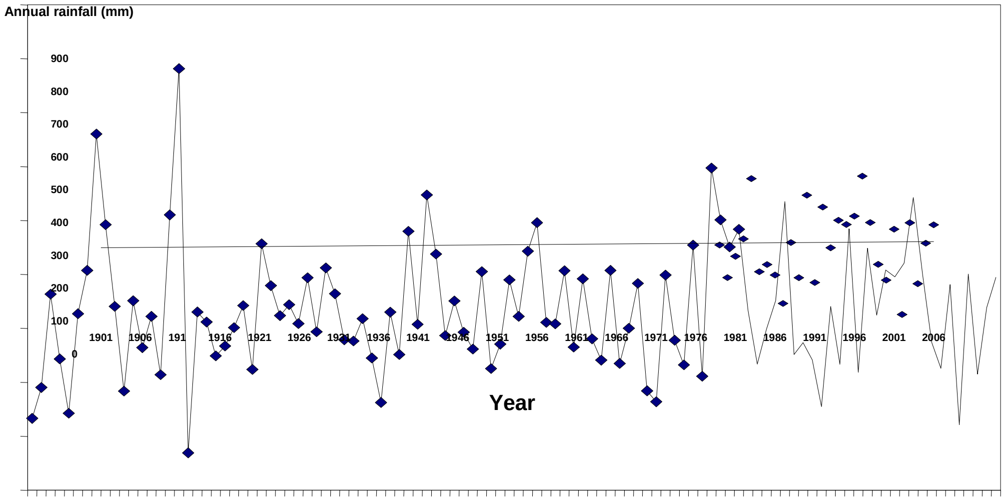

Figure 1. Long-term Rainfall trend of Arid Rajasthan

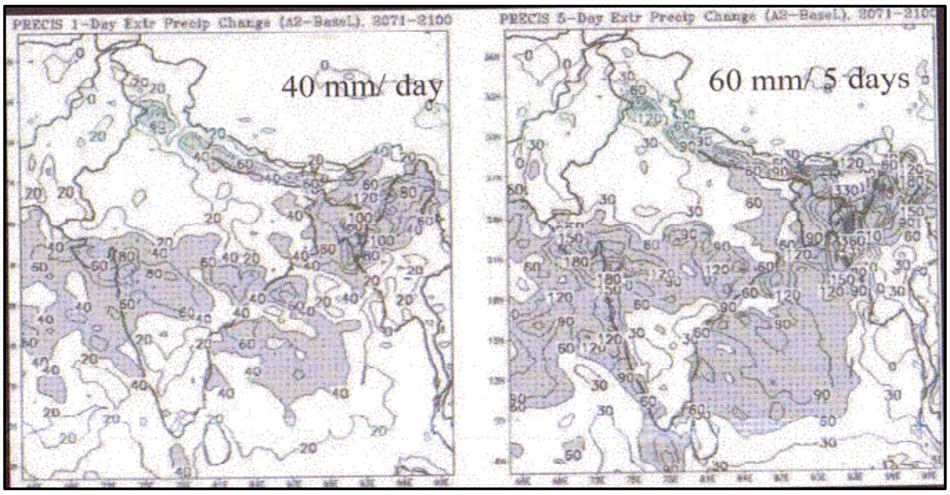

Figure 2. Future projections of extremes in daily precipitations. Shaded portions indicate changes exceeding 40 mm for 1-day precipitation (left) and 60 mm for 5-day precipitation(right) (Rupa Kumar et al. 2006).

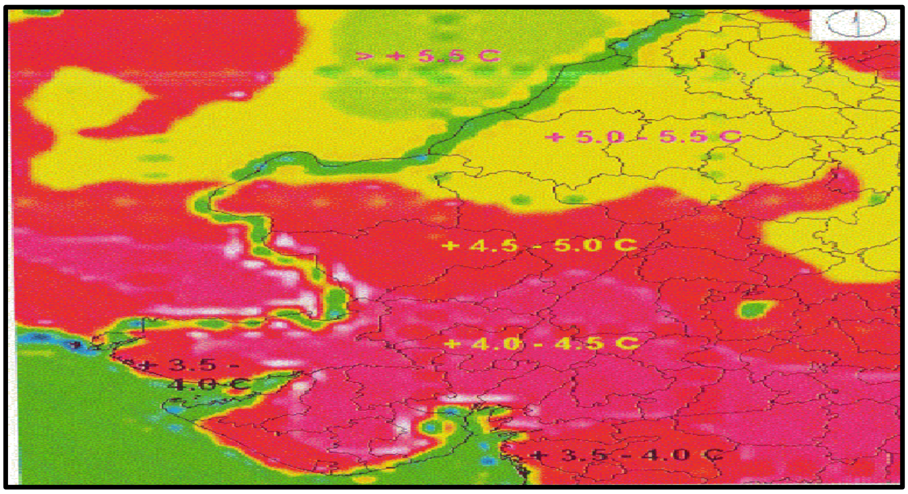

Figure 3. Likely changes in annual temperature in northwest India by the year 2071 using PRECIS RCM for A2 scenario (Source: Hadley Centre, U.K).

socio-economic scenarios both characterized by originally focused development but with priority to economic issues in one (A2 scenario) and to environmental issues in theother (B2 scenario). The model predicted an increase in rainfall across India by 15-40% except in Rajasthan, Punjab and Tamil Nadu which showed a decline. For the Indian arid region, the model predicted for an increase in annual rainfall by 10-15% in the eastern fringe and by 20-40% in the south, but a reduction up to 30% in the northwest (Fig..2). Rainy days were predicted to decline across the region. Based on these results, three broad zones emerge: (1) the hotter and very dry north-west Rajasthan and adjoining Punjab, (2) the warmer and moderately wetter arid Gujarat and adjoining south Rajasthan, and (3) the hotter and slightly wetter eastern fringe of arid Rajasthan and adjoining Haryana (Fig.2).

Extreme precipitation events exceeding 40 mm/day and also 60 mm/5 days were predicted to substantially increase over the northern parts of arid Gujarat (Fig. 2).

Temperature trends:

The PRECIS model of Hadley Center, U.K (Rupa Kumar et al.2006) for India, using IPCC scenarios, showed an increase in an annual mean surface temperature by 3 to 5^0C under A2 scenario and 2.5 to 4^0C under B2 scenario, with warming more pronounced in the northern parts of India by the end of the century (Fig. 3). Warming is predicted to be more in winter (December-February) and post-monsoon (October-November) seasons compared to southwest monsoon season (June-September).

The PRECIS model (Rupa Kumar et al.,2006) also predicted that Indian arid region would experience both more warm nights as well as warm days, whereas other parts of India would experience only warmer days (Fig.4).

Further, the PRECIS model (Rupa Kumar et al.,2006) showed more extremes in maximum and minimum temperatures in the arid India. Diurnal variations in air temperatures are also expected to increase. (Fig 5).

Drought and floods:

Global climate change is likely to influence regional weather systems like monsoon by causing erratic rainfall distribution, delayed onset and prolonged dry spells during the cropping season, often resulting in water stress conditions at different growth stages leading to decline in food production. Droughts in India are attributed to temporal and spatial variability in monsoon rainfall. Historical record of droughts in the region show no definite pattern or interval. The arid areas are subjected to almost permanent drought. Between 1901 and 2008, western Rajasthan experienced 58 moderate to severe droughts (Fig. 6). There were five occasions when drought occurred in successive years: 1903-05, 1957-60, 1966-71, 1984-87 and 1998-2000. Droughts of 1918, 1987 and 2002 were most severe, when rainfall departure from the normal was -81, -65 and -70 %, respectively. The 2002 drought during July was unique with reference to its climate anomalies and their impacts as well as the institutional responses.

The districts of Jaisalmer, Barmer, Bikaner and Ganganagar have the maximum probability of drought occurrence, in one place or the other, even in good rainfall years. Production of pearl millet during *kharif* is reduced by 10-30% during mild drought, 35-60% during moderate drought and 75-90% during severe droughts. Surface water availability also declines during drought years with the drought severity creating drinking water problem. Fodder scarcity, which is a deficit by 20-30% of the demand during normal years, reaches 80-100% during severe droughts. During the current decade (2001-2008),

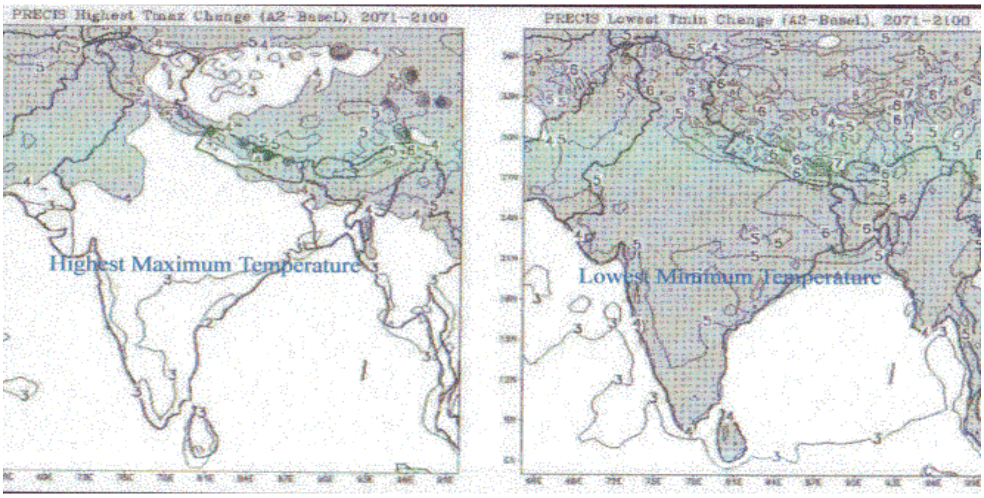

Figure 4. Future projections of extremes in daily maximum (left) and minimum temperatures(right), 2071-2100 (Shaded portions indicate warming above 4^0C).

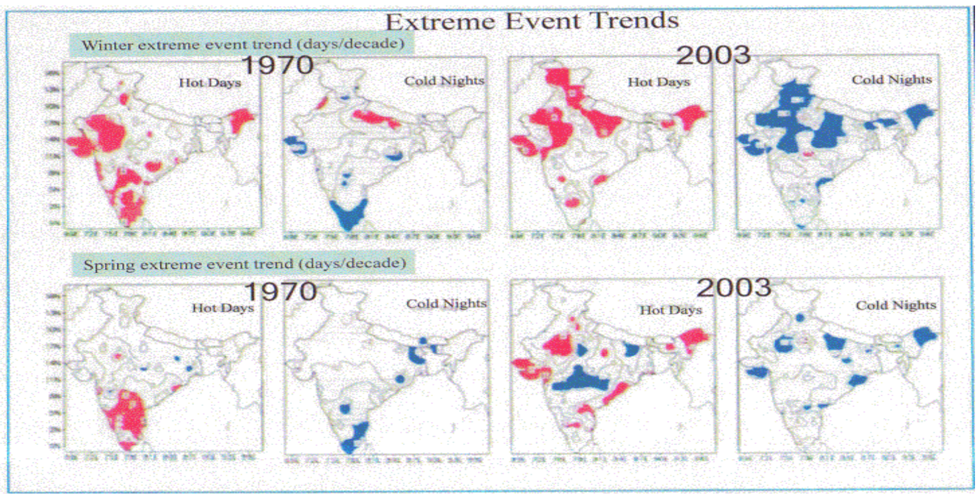

Figure 5. Spatial patterns of trends in seasonal (winter and spring seasons) extreme temperature events (hot days and cold nights). Shaded area indicates trend significant at 5% level, red for increasing and blue for decreasing, 1970-2003.

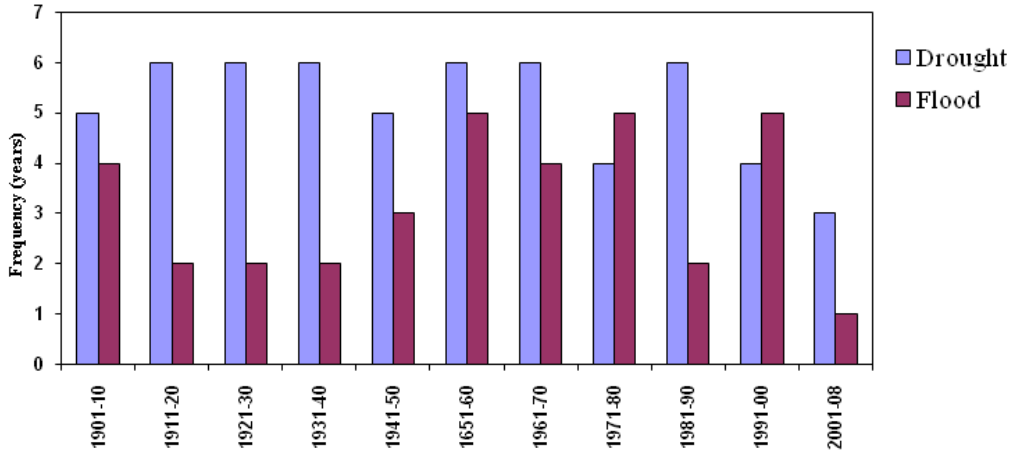

Fig.7 Decade-wise frequency of drought and flood occured in the arid western India

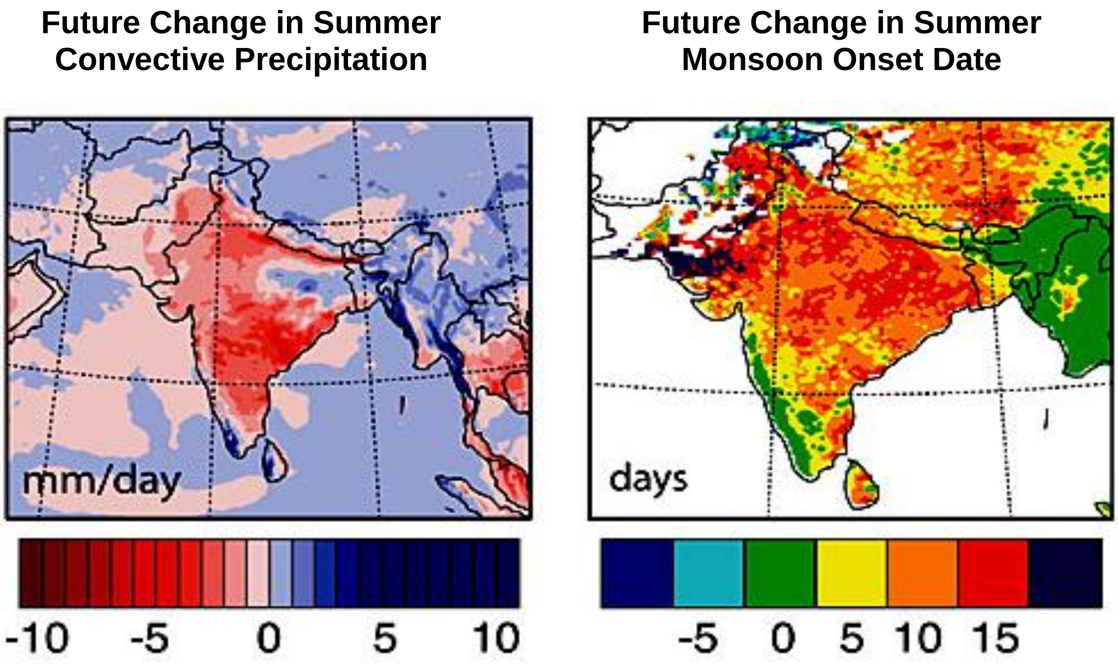

Figure 7. Future change in summer convective precipitation and in Monsoon onsetdate in the Indian region. (Source: Purdue University, USA and Geophysical Letters)

except for 2002, the drought frequency was lower compared to previous decades (Fig.6).

Floods in Indian arid region are rare, but do occur with a less frequency and mainly during the monsoon season (July to September). The decadal flood frequency in twelve arid districts of Rajasthan showed that they occurred (Fig.6) with an average frequency of 2 to 3 times in each decade. The decades 1911-1920, 1941-1950 and 1981-1990 were notable for severe floods. Severe and widespread floods occurred in the region during 1908, 1917, 1944, 1975, 1983, 1997 and 2006.

Climate change and Indian Monsoon

Global warming is intensifying the monsoon in Central India. Monsoon rains in Central India between the years 1981 and 2000 were more intense and frequent than in the 1950s and 1960s, and increased by 10 per cent since the early 1950s. The frequency of severe rains doubled over the same period while moderate rains were fewer. The seasonal mean rainfall did not show a significant trend, because the contribution from increased numbers of heavy events did offset the decrease caused by reduced number of moderate events. A substantial increase in hazards related to heavy rain is expected over Central India in the future (Goswami 2006).

A study at Purdue University indicated that the GCM model projected a delay in the start of monsoon season from 5 to 15 days by the end of the 21st century and an overall weakening of the summer monsoon precipitation over South Asia. Increasing temperatures in the future would strengthen some aspects of large-scale monsoon circulation but weaken the fine-scale interactions of the land with the moisture in the atmosphere, which could lead to reduced precipitation over the Indian subcontinent (Fig.7).

Climate change and desertification

In arid Rajasthan, where annual rainfall is less than 250 mm, wind erosion and sand dune movement are widespread. Salinity/alkalinity and water logging have resulted mainly due to excessive irrigation and presence of impervious strata. Over-grazing and indiscriminate felling of trees has resulted in the degradation of vegetative cover. In high rainfall areas, water erosion is a serious problem affecting the biological productivity of different ecosystems. In case these problems continue unchecked, large areas of agricultural land will be affected in future

In arid Rajasthan, the requirement of fuel-wood has increased by 178% and fodder deficit by nearly 100% (from 14.9 million tones to 28.2 million tones) during the last three decades. This has resulted in over-exploitation of vegetation and other natural resources in this fragile arid ecosystem. Land use statistics of arid Rajasthan revealed an increase in net sown area by 54.1% from early 1950’s to early 1980’s, which increased by further 11.7 percent in the last decade. The areas affected by desertification in arid Rajasthan are shown in Fig. 8. Nearly 75% of the area in the region is affected by wind erosion, 11% with water erosion, 0.7% with water logging and 5% with salinization (Kar et al. 2007).

The studies on climatic change over Jodhpur region showed that the rainfall and air temperatures were favourable, but the increase in human population (by 400%) and livestock (by 127%) during the twentieth century was resulting in a major shift in land use pattern and putting tremendous pressure on surface and groundwater resources. These were the main causative factors for desertification conditions in the region (Rao and Miyazaki 1997).

Impact of climate change on food production

Some of the projected impacts of climate change in India, using dynamic crop models, indicate a decrease in yield of crops as temperature would increase in different parts of the country. However, at the moderate rise in temperature this decrease would be offset because of increase in the carbon dioxide level. However, at higher level of warming, the negative impact on crop productivity is projected due to reduced crop duration.

Climatic impact assessment using BIOME-3 model and climate projection for the year 2085 show 77% and 68% of the forested grids in India are likely to experience shifts in forest types at A2 and B2 scenarios, respectively. The projection shows a shift in the dry forests to wetter, resulting from shift in rainfall patterns (Jayant Sathaye et al. 2006).

Climate change and pearl millet productivity:

Pearl millet is an important cereal crop of arid region. Performance of pearl millet under no water stress (potential yield) and water limited condition (rainfed crop yield) was assessed through CERES-Millet model at Jodhpur (Central Thar), Pali (Eastern Thar) and Jaisalmer (Western Thar). Daily weather data of 10 years was used for Jodhpur and Pali and of 7 years for Jaisalmer. Change in climate was simulated through rise in temperature by 1 to 4^{o}C, with or without 10 and 20% increase or decrease in rainfall. The date of sowing was taken as the normal onset date of rainfall (1st July) to determine the potential yield. The sowing date of rainfed crop was between 15th June to 15th August based on the onset of sowing rains. The earliest sowing was on 15th June at all the three locations. The latest sowing was on 25th July at Jodhpur, 1st August at Pali and 15th August at Jaisalmer, except one year when crop could not be sown at Jaisalmer due to lack of rains. Mean seasonal rainfall is 396 mm at Jodhpur, 463 mm at Pali and 158 mm at Jaisalmer.

Under present weather conditions, mean potential biomass and grain yields were highest at Jodhpur (6677 and 2814 kg ha^{-1}, respectively), followed by Jaisalmer (6026 and 2553 kg ha^{-1}) and Pali (4467and 1927 kg ha^{-1}). Low yield levels at Pali were due to more cloudiness resulting in less solar radiation compared to other two locations. Biomass and seed yields under water limited condition (rainfed crop) were also higher at Jodhpur (4912 and 1697 kg ha^{-1}, respectively). Contrary to potential yields, biomass and grain yields under water limited condition were much lower at Jaisalmer (1157 and 387 kg ha^{-1}) as compared to Pali (3181 and 1194 kg ha^{-1}) because of less seasonal rainfall at Jaisalmer. Biomass and seed yields declined linearly with rise in temperature at all the three locations (Table 1).

Under rainfed condition, biomass yield decreased by 12.4-13.5% and seed yield decreased by 12.5-15.5% in Thar desert with each ^{o}C rise in temperature (Fig 9-11). The adverse effects of temperature rise were more pronounced if seasonal rainfall also declined. However, even increase in seasonal rainfall by 20% was not able to reduce the adverse effect of temperature rise on pearl millet production significantly.

Sand dune stabilization and wind erosion control

Wind erosion in northwest arid India is due to strong prevailing winds, sparse vegetation cover and intense human activities on the dominantly sandy terrain. In 100 to 250 mm rainfall zone, the stabilized sand dunes and sandy plains are reactivated during summer. In western Rajasthan, moderate to severely wind-erosion affected area is about 8.74 million ha (Venkateswarlu and Kar 1996).

Stabilization of sand dunes in the Thar region was successfully tried by various governmental agencies by planting selected tree and grass species. CAZRI developed several effective techniques comprising three distinct processes viz. (a) protection against biotic interference by fencing of the area, (b) establishment of micro-wind breaks on the windward side of a dune in 5 m parallel strips or in a 5 m chess board pattern, and (c) sowing of grasses and transplanting (with the onset of the monsoon) of adopted tree and shrub species raised in earthen bricks, on the leeward side of the micro-wind breaks and management of re-vegetated sites. The presence of adequate moisture in unstabilized dunes (Ramakrishna et al. 1990, 1994) also helped in initial establishment of trees and grasses. The dunes are largely owned by private farmers and success of sand dune stabilization programme in these lands would depend upon their participation. For sand dune stabilization, small shrubs and grasses are better binders than the trees. But, because of uncontrolled grazing on the dunes and sandy plains, bio-fencing using locally non-palatable species is a cheaper and more effective form of barrier (Anonymous 1988; Muthana1982; Harsh and Tewari 1993).

Pasture grasses like *Cenchus ciliaris, C. setigerus* and *Lasiurus sindicus,* if pelleted and seeded on slopes of partially stabilized dunes at 10 to 20 m interval across the slope, were found useful for stabilization of dune. In the extreme arid region of Jaisalmer, grasslands with gravelly shallow soils were protected with ditch and mound fencings (about 500 m apart) followed by construction of contour furrows spaced 8-10 m apart. Mounds of contour furrows trapped the naturally blowing sand and led to regeneration of *L. sindicus* (Mertia 1992). The government of Rajasthan is adopting the sand dune fixation techniques as a governmental program, the shelterbelts virtually have been the road side plantations.

Modification of wind regime and microclimate by shelterbelts (Rao et al. 1983) and micro-crop shelterbelts (Ramakrishna 1982, 1985) provided favourable conditions to improve agricultural productivity from the arid region. Tree shelterbelts made up of *Acacia tortilis* and *Cassia siamea* at CAZRI Farm, Jodhpur were found to decrease wind speeds by 30% to 50% at 2 H to 5 H distance (H indicates the height of shelterbelt in meters), decreased soil loss through wind erosion by 65% resulting in considerably higher grain production in the leeward side (Rao et al. 1983).

Conclusions

Indian hot arid zone, having high population density, is largely dependent on climate sensitive sectors like agriculture and animal husbandry. Further, the adaptive capacity of desert dwellers is poor due to socio-economic conditions. Various studies on future climate of Indian arid region showed an increase in annual temperature by 3-5°C by the last quarter of this century. Annual rainfall may increase by 10-15% in the eastern fringe, and by 20-40% in the south, but the northwest will experience up to 30% reduction in rainfall. Since biophysical resources of the region are under pressure due to increasing population and frequent drought, the region is becoming more vulnerable to climate change. Food production from pearl millet may decline by 20-50% unless remedial interventions are made.

The Central Arid Zone Research Instittue, based on its 50 years' research experience, is gearing up to face the challenges imposed by climate change and the following strategies have been suggested for the Indian arid zone:

Crops:
Water-use efficiency should be increased with thermophilic plants with biotechnological interventions. Mixed

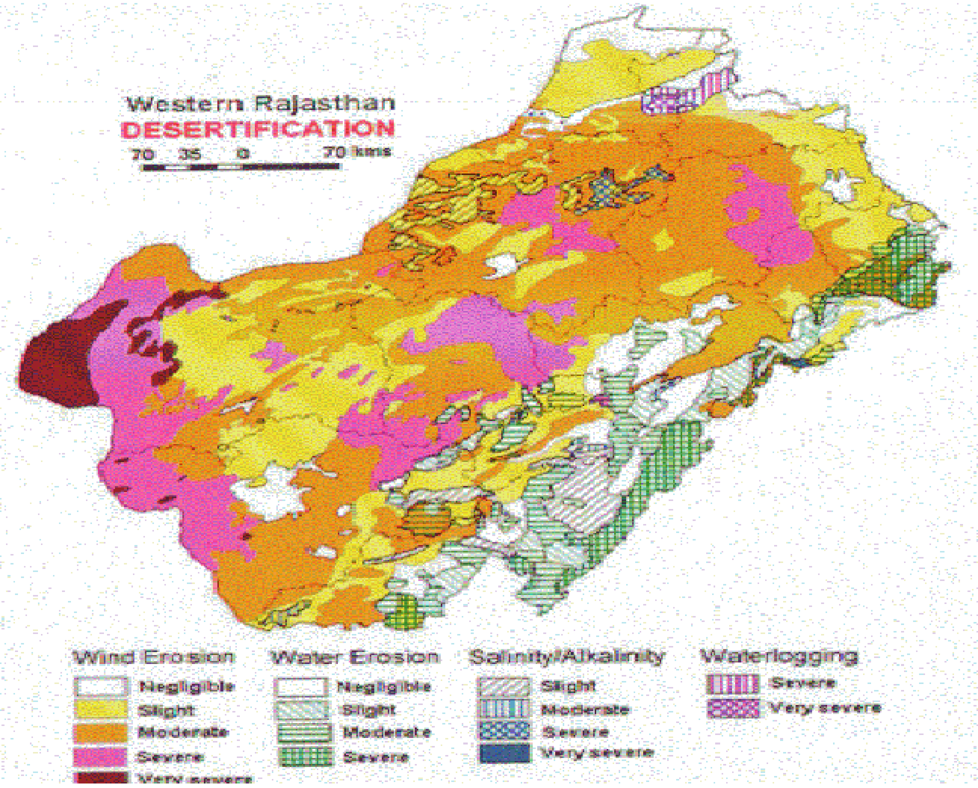

Figure 8. Areas affected by desertification in arid Rajasthan

Table 1. Response of pearl millet to rise in temperature in Thar desert

Yield (kg ha^{-1})	Yield as a function of rise in temperature (^{o}C)	R^2
Biomass yield		
Jodhpur	y = 5365 - 637x	0.9789
Pali	y = 3436 - 401.55x	0.9676
Jaisalmer	y = 1265.4 – 141.97x	0.9835
Seed Yield		
Jodhpur	y = 1868.5 – 203.99x	0.9910
Pali	y = 1297.1 – 149.44x	0.9723
Jaisalmer	y = 428.5 - 59.3x	0.9745

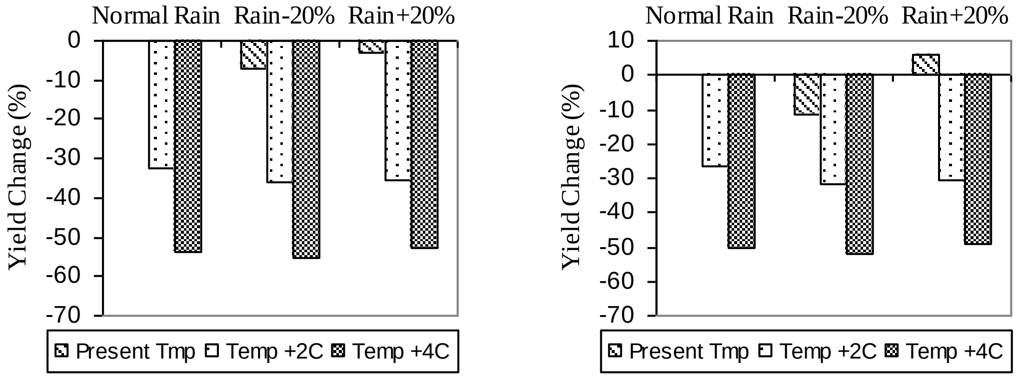

Figure 9. Change in biomass (a) and seed yield (b) of pearl millet in Central Thar with climate change

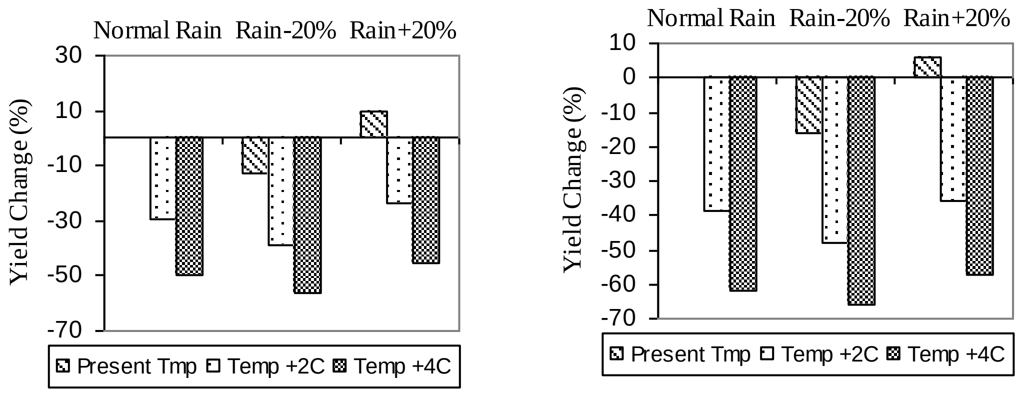

Figure 10. Change in biomass (a) and seed yield (b) of pearl millet in Western Thar with climate change

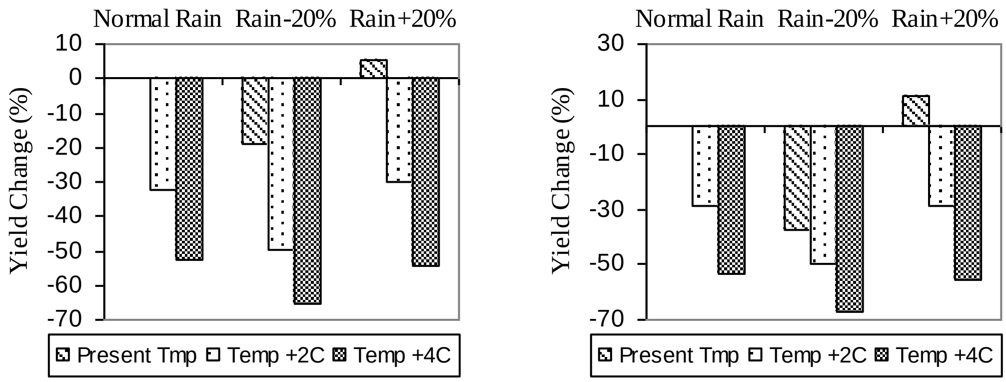

Figure 11. Change in biomass (a) and seed yield (b) of pearl millet in Eastern Thar with climate change

cropping may be increased to minimize the risks due to vagaries of weather

- Glas- house agriculture using water harvesting technologies and indigenous technical knowledge may be adopted
- Precision agriculture using agro-advisories
- Matching the cropping pattern with season changes
- Development of a sound land and water use policy to arrange provisions and evolve permanent land base assets like silvipastures, common grazing lands,
- water harvesting and re-use structures with participation of people
- Adoption of forest conservation, reforestation can contribute to conservation of bio-diversity.
- A comprehensive early weather warning system as a critical component of a state or regional plan. Use of medium and long terem predictions for initiating suitable mitigation measures against weather induced risks.
- Adoption of coping mechanism based on traditional wisdom and innovations

Fodders:

- Biomass is likely to be less affected. Hence new fodder crop strategies to be developed
- Pastoralism may become intensive part of larger community
- *Lasiurus sindicus* may offer new opportunity with its ability to survive under meager resources of rainfall/soil

Livestock:

- Less thermal sensitive local breeds to be upgraded to adapt easily to changing environment
- Use of various species with different feeding habits. Hence, a resilience is maintained between trees, shrubs and grasses

Energy management:

- Shift to renewable sources of energy, some of which are already cost-effective,

The above strategies are cost-effective and can be easily adopted by the arid zone farmers with governmental support for policies and finances. The climate change issue is a part of the larger challenge to sustainable development of arid regions. The impacts of climate variability and change, climate policy responses, and associated socio-economic development will affect the sustainable development of arid regions.

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Concurrent Session Presentations

Theme 1. Climatic change in arid lands and impact of global climate change on the natural resources of land, water and biodiversity in the dry areas

1.1. Climate change and water resources management in arid and semi-arid regions

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Abstract

The ever growing population and the recent droughts are exerting a lot of pressure on the water resources and calling for new approaches for water planning and management if the rainfall will continue to decrease and the temperature will continue to rise. The climate of the Mediterranean region is characterised by hot dry summers and mild wet winters. The region suffers frequently from years of low rainfall and several parts of the region have experienced periods of severe drought. The UK Hadlley Centre's Global Climate Model has been run on monthly basis for the Mediterranean countries to predict the percent change in rainfall and temperatures with respect to mean monthly values. The results show that by the year 2050, for the wet season (October to March) rainfall could increase in central and eastern Spain, north of France, north of Italy and in the Alps by up to 15% while in the southern Mediterranean, the rainfall will decrease by about 10% to 15%. For the same period, the temperature in the northern Mediterranean will increase by 1.25 to 2.25 degrees while in the southern Mediterranean the temperature will increase by 1.5 to 2.5 degrees. The temperature of the coastal areas will usually increase by less than that of the inner regions. Results also show that, for the dry season (April to September) by the year 2050, rainfall is likely to decrease over much of the Mediterranean countries particularly in the southern parts where it could decrease by up to 25%. The decrease is more pronounced in the south than in the north of the Mediterranean. This decrease in rainfall is accompanied by temperature rise between 1.5 to 2.75 degrees in the northern part and between 1.75 and 3.0 degrees in the southern part of the Mediterranean. Coastal areas have less increase than inner regions. The decrease in rainfall during summer time has a great impact on both irrigation and tourism, as both activities take place in summer time and require more water supplies. Given the above mentioned facts, in order to meet the water demands in the next century, new dams and water infrastructure will have to be built in some countries and a new paradigm by rethinking the water use with the aim of increasing the productive use of water will have to be adopted. Two approaches are needed: increasing efficiency with which current needs are met and increasing the efficiency with which water is allocated among different uses.

In addition, non-conventional sources of water supply such as reclaimed water, recycled water and desalinated brackish water or seawater is expected to play an important role.

Introduction

Over the past century, population growth, industrial development and expansion of irrigated agriculture have increased dramatically. World population has grown from 1,600 million in 1900 to 6,000 million in 1995 while land under irrigation increased from around 50 million hectares to over 250 million hectares for the same period. In addition to other factors these have led to a nearly seven fold increase in fresh water withdrawals. The latter have increased from 580 km^3 yr^{-1} in 1900 to 3,580 km^3 yr^{-1} in 1990 and are estimated to be 3,940 for year 2000. At present, 54% of accessible runoff on earth is in use and it is expected that future population growth could make use of 70% of the accessible runoff by the year 2025 (Gleick 1998; Shiklomanov 1997). Because of the expected increase in population, agricultural production and per-capita water use, planners and policy makers have expected a rise in water demand. It is expected to exceed the actual water supplies and it will be a water management problem as to how to bridge the gap.

Water has always been the central concern to life in the south Mediterranean (SMED) and Middle Eastern (ME) countries. Early civilisations emerged along the Nile, Tigris and Euphrates and the struggle for water shaped the life of desert communities. The ever growing population and the recent droughts in this part of the world are putting a lot of pressure on the water resources. New approaches for water planning and management are therefore needed if escalating conflicts are to be avoided and environmental degradation is to be halted and reversed.

According to the World Bank (1993), the minimum water required to sustain human life is about 25 l day^{-1} (10 m^3 yr^{-1}). A reasonable supply to maintain health may be 100-200 l day^{-1} per capita (40-80 m^3 yr^{-1}) though in developed countries domestic use can exceed 300-400 l day^{-1} per capita (up to 150 m^3 yr^{-1}or more). By year 2025 renewable water resources in four SMED and ME countries will barely cover the basic human needs in Jordan, Libya, Saudi Arabia, and Yemen. At present, the water exploitation index, taken as percentage of renewable annual water resources, for Tunisia is 83%, Egypt 92%, Israel 140%, Gaza 169%, Libya 644% (because 84% comes from non-renewable fossil water from beneath the Sahara), Syria nearly 50%, Lebanon about 25%, Algeria 20%, and Morocco nearly 40% (Pearce 1996).

The world's leading scientists consider that we are now on the verge of changing our climate due to human activities that cause the greenhouse effect. The latter has great impact on water resources. According to the IPCC (1996), the global average temperature in the year 2100 is likely to be 2°C warmer than at present. This increase might not look significant but a difference of only 1°C in average global temperature is all that separates today’s climate from that of the Little Ice Age in the period from the fourteenth to the seventeenth century. An increase of 2°C would bring the average global temperature beyond anything experienced in the past 10,000 years (Gleick 1998). Therefore, water managers, policymakers and public must think about long-term water planning and management. There have already been some significant changes in the Earth’s climate. Since the late 19th century, the global mean surface temperature has increased by 0.3°C to 0.6°C and that was enough to make the past decade to be the warmest decade in the period of instrumental record. Precipitation has increased in the high latitudes of the northern hemisphere, particularly during winter. Global sea level has risen by 10 cm to 25 cm over the past 100 years.

The Mediterranean region suffers frequently from years of low rainfall. Most of the region was hit by severe drought in 1989-1990 and some have seen poor rainfall. Tunisia suffered severe drought from 1987-1989, while Morocco has suffered continually since 1990. Because countries are using their water resources with growing intensity, poor rainfall increasingly leads to national water crises as water tables fall and reservoirs, wetlands and rivers run dry.

Generally, the climate of the Mediterranean region is characterised by hot dry summer and mild wet winter. The coasts of Algeria and Libya normally have seven dry months, receive only around 200 mm of rain in an average year and have typical July temperatures of 30°C. When rain does fall, it tends to arrive as heavy storms; falls of over 125 mm in a day, often with thunder, are not uncommon and records for individual sites include more severe storms such as Tripoli (130 mm) and Haifa (183 mm) (Acreman 2000). Thus, some areas receive their total annual rainfall in a few days.

There is a growing debate about whether these droughts are simply another manifestation of the notorious variability of Mediterranean rainfall or a sign of a long term shift in rainfall patterns perhaps linked to global warming. There has been a decrease in rainfall throughout the region over the past century. In summer, rainfall is now 20% less than at the end of the 19th century. In Tangiers, rainfall has dropped by 100 mm in 40 years and at Ifrane, in the Moyen-Atlas Mountain in Morocco, by 400 mm in 30 years. Such changes create uncertainty. Are long term averages of rainfall or river flow any longer valid as a basis for planning water resources use? The Greek hydrologists were forced to reconsider their estimates of average flows in the 220 km River Acheloos, the country's longest river and scheduled for a major diversion project to irrigate fields (Pearce 1996).

Global warming could unleash further changes, further variability and further uncertainty on the region. Several computer models of climate change suggest that the region will continue to become drier and hotter, with reduced rainfall and increased rates of evaporation. Some models suggest more than 5% decrease in rainfall by mid-21st century if the world warms by 2°C.

The objective of this work is to highlight the issue of the increasing demand on the limited water resources in the SMED and ME countries, to predict the possible future climate change up to the year 2050 and to suggest possible means to manage this limited water resources under the possible impact of climate change on water resources.

2. Water resources in SMED and ME countries

The total annual renewable water resources in SMED and ME countries average about 350 billion m^3 (1,436 m^3 per head), of which some 120 billion m^3 is accounted for by river flows from outside the region. In 1990, of 18 countries only seven had per capita availability of more than 1000 m^3 per year. Between 1960 and 2025, per capita renewable supply is expected to fall from 3,430 m^3 to 667 m^3 and in several countries of the region renewable fresh water resources will barely cover basic human needs into the next century (World Bank 1993; FAO 1997). Irrigation accounts for about 80% of withdrawals. However the demand is expanding very rapidly in urban areas. Withdrawals in Libya, Saudi Arabia, the Gulf States and Yemen are already exceeding the renewable supplies while Egypt, Israel and Jordan are essentially at the limit. In addition, Algeria, Iran, Morocco and Tunisia face sever regional deficits even if in total they are in surplus. Water transfers are sometimes feasible but can be very expensive and sometimes impractical. Only Iraq and Lebanon appear to have renewable supplies adequate to their relatively small population.

2.1 Surface water resources

Major water resources in SMED and ME are shared between countries. The Nile, Jordan and Euphrates and Tigris River Basins are shared (Gischler 1979). Large aquifers underlie North Africa and Arabian Peninsula,which could be shared by several countries but agreement on abstractions does not exist. (Table 1) gives some information on the renewable water resources, annual river flows, and renewable water resources per capita in the SMED and ME countries; while (Table 2) shows the distribution of the water resources between the different sectors.

Deteriorating water quality is an increasingly serious issue in SMED and ME countries. This is due to combination of low river flows, inadequate treatment, agricultural runoffs and uncontrolled effluent from industry. The decline in water quality affects directly the utility of the water resources and increases the treatment costs. Seawater intrusion into coastal aquifers is a critical issue in these regions.

Water quantity and quality are inseparable since there is a certain water quality level associated with each water use. Water management and planning must therefore deal appropriately with both aspects in an integrated approach.

According to Shahin (1996) the average flow, in 10^6 m^3 yr^{-1}, of the Nile is 85.5, Tigris is 48.7 and Euphrates is 29.0. There is a River Nile water agreement signed in 1959 between Egypt and Sudan (Gishler 1979) stipulating that Sudan's share is 18.5 billion m^3 and Egypt's share is 55.5 billion m^3. It is worth noting that evaporation losses from Lake Nasser are 10 billion m^3 per year.

The Euphrates originates in Turkey where it receives 94% of the flow, 4% is added in Syria with no significant amount added in Iraq. The Tigris receives 40% of its flow from Turkey, 50% from Iraq and 10% from Iran (World Bank 1993). The two rivers join together to form Shatt Al-Arab waterway before entering the Persian Gulf. Some 80% of the withdrawal is for irrigation.

The Jordan River flow at its entry to Lake Tiberias is 580 million m^3 and is reduced to 60 million m^3 at its entry at Dead Sea. Yarmuk River starts in Syria and forms the present boundary between Syria and Jordan for 40 km before it becomes the border between Jordan and Israel for 12 km. The Yarmuk discharge is about 450-475 million m^3 (Kliot 1994).

2.2 Groundwater resources

Many countries in the regions mine groundwater. This is a non-renewable resource and cannot continue indefinitely. Several very large aquifers underlie SMED and ME countries. Examples are the Eastern Erg, the Nubian and the Saq/Disi aquifers (Kliot 1994). The Eastern Erg is located south of the Atlas Mountains in Algeria and extends into Tunisia. It covers an area of

Table 1. Water availability SMED and ME countries (World Bank 1993)

Country	Total annual	Annual river flows		Net annual renewable	Renewable resources per capita		
	Renewable water resources	From other countries	To other countries	Resources	1960	1990	2025
	B m^3	B m^3	B m^3	B m^3	m^3 yr^{-1}		
Algeria	18.90	0.20	0.70	18.40	1,704	737	354
Bahrain	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Egypt	1.8	56.50	n.s.	58.30	2,251	1,112	645
Iran	117.5	n.s.	n.s.	117.50	5,788	2,152	1,032
Iraq	34.00	66.00	n.a.	100.00	14,706	5,285	2,000
Israel	1.70	0.45	n.a.	2.15	1,024	467	311
Jordan	0.70	0.40	n.s.	0.90	529	224	91
Lebanon	4.80	n.a	0.86	3.80	2,000	1,407	809
Libya	0.70	n.a.	n.a.	0.70	538	154	55
Morocco	30.00	n.a.	0.30	29.70	2,560	1,185	651
Oman	2.00	n.a.	n.s.	2.00	4,000	1,333	421
Qatar	n.a.	n.a.	n.s.	0.00	n.a.	n.a.	n.a.
S. Arabia	2.20	n.a.	n.s.	2.20	537	156	49
Syria	7.60	27.90	30.00	5.50	1,196	439	161
Tunisia	3.75	0.60	n.a.	4.35	1,036	532	319
U.A.E.	0.30	n.a.	n.a.	0.30	3,000	189	113
Yemen	2.50	n.a.	n.s.	2.50	481	214	72
MENA	228.45	152.05	31.86	348.30	3,430	1,436	667
Africa	4,184	n.a.	n.a.	4,184	14,884	6,516	2,620
Asia	10,485	n.s.	n.s.	10,485	6,290	3,368	2,134
World	40,673	n.a.	n.a.	40,673	13,471	7,685	4,783
Cyprus	0.9					1213 (1995)	

Table 2. Water resources availability and uses in SMED and ME countries (Gleick 1998)

Country	Annual renewable water resources	Total fresh water withdrawal	Domestic use	Industrial use	Agricultural use	Irrigated area
	$km^3 yr^{-1}$	$km^3 yr^{-1}$	%	%	%	10^3 ha
Algeria	14.3	4.5	25	15	60	555
Cyprus	0.9	0.21	24	2	74	40
Egypt	86.8	55.1	6	8	86	3,265
Libya	0.6	4.6	11	2	87	470
Morocco	30.0	11.04	5	3	92	1,258
Sudan	154.0	17.8	4	1	94	1,946
Tunisia	4.1	3.08	9	3	89	352
Bahrain	0.1	0.24	39	4	56	3
Gaza St.	0.06	0.12	40		60	12
Iran	137.5	70.03	6	2	92	7,264
Iraq	96.4	42.8	3	5	92	3,525
Israel	2.1	1.9	16	5	79	193
Jordan	0.9	0.98	22	3	75	73
Kuwait	0.0	0.54	37	2	60	5
Lebanon	4.8	1.29	28	4	68	88
Oman	1.0	1.22	5	2	94	62
Qatar	0.1	0.28	23	3	74	13
Saudi A.	2.4	17.02	9	1	90	1,473
Syria	46.1	14.41	4	2	94	1,082
Turkey	200.7	31.6	16	11	72	4,186
U.A.E	0.1	2.11	24	9	67	67
W. Bank	0.4	0.10	6.5		93.5	10.4
Yemen	4.1	2.93	7	1	92	481

Table 3. Total desalinization capacity in some SMED and ME countries (Shahin 1996)

Country	Capacity	Percentage of total
	$m^3 d^{-1}$	%
Algeria	204,312	1.841
Bahrain	315,197	2.841
Egypt	87,044	0.785
Iraq	333,093	3.002
Jordan	8,445	0.076
Kuwait	1,523,210	13.731
Libya	677,750	6.110
Morocco	15,325	0.138
Oman	162,096	1.461
Qatar	582,074	5.247
S. Arabia	5,020,324	45.257
Sudan	1,776	0.016
Syria	7,703	0.069
Tunisia	50,914	0.459
U.A.E.	2,081,091	18.760
Yemen	37,188	0.335
Total	11,093,008	100
Cyprus	6,275	

400,000 km^2, largely artesian, only 0.4% of its volume is recharged annually and its volume is about four times the average annual renewable supply of SMED and ME countries. The Nubian sandstone aquifer runs under Egypt, Libya and Sudan extending over an area of 1.8 million km^2 of which 150,000 km^2 are under artesian conditions. The Nubian aquifer is estimated to contain 6000 billion m^3, which is twenty times the average annual renewable supply of the whole region. The renewable rate is ~2.5% of its volume. There is a massive exploitation in south-eastern Libya and the water is transferred to Libyan coastal regions via the 'man-made river' project. There is a fear hat this may reduce the groundwater reserves in neighbouring countries quite substantially. The Saq formation (Disi aquifer in Jordan) covers an area of 106,000 km^2 and extends from Jordan to the east and south to Saudi Arabia. There is a concern that the low-return wheat cultivation in Saudi Arabia will reduce availability for higher priority uses in Jordan and Saudi Arabia. These aquifers are often at great depth and pumping costs rises as the water tables decline.

In the Gaza strip, the irrigated area is about 20,000 ha; the rainfall ranges from 200 mm to 300 mm in the north and from 300 mm to 400 mm in the south. Natural replenishment of the aquifer is 60 million m^3 where the demand is 100 million m^3 leaving a deficit of 40 million m^3. The gap between the demand and supply is met by over-abstraction. Future deficit will have to be met by importing water from outside the region and by desalination. In the West Bank, the cultivated area is 200,000 ha. Rainfall ranges between 500 to 800 mm in the mountain and 200 mm in the semi-arid southern part. The usable (naturally replenished) reserves have been estimated at 400 million m^3 of water. The Palestinian quota of 130 million m^3 represents 20% of the rechargeable groundwater reserves. Irrigated land is 10,400 ha from 50,000 irrigable land. The total demand is 300 million m^3 to irrigate the 50,000 ha.

2.3 Nonconventional water resources

Non conventional sources will become increasingly important. The region already accounts for more than 60% of the total world desalination capacity (Shahin 1996). Given its cost (~2$ per m^3) it is only for domestic use and partly for industrial use in the oil rich countries. Two thirds of the world desalination plants exist in the SMED and ME countries (Table 3). Within the region, wastewater (Table 4) will play an increasing role.

3. The climate of SMED and ME countries

3.1 The variability in temperature, rainfall and potential evapotranspiration

The SMED and ME countries enjoy large variations in their climatic conditions. These variations could be significant within a single country. Countries like Algeria, Libya, Egypt and Tunisia exhibit large variation between their north Mediterranean regions and their deserts in the south. There is also a large difference between the Gulf and the Mediterranean countries in terms of rainfall, temperature and evapotranspiration (ET_p), as shown in (Table 5) The ET_p values vary from 100 mm per year along the Mediterranean coast of northwest Africa to more than 2200 mm y^{-1} in the desert between Libya, Egypt and Sudan. The Gulf States and Egypt seem to have the lowest rainfall.

3.2 Carbon dioxide emissions

The Middle East may contribute a large fraction of the world's oil but through their own energy consumption produce only 6% of global CO_2 emissions (Marland et al. 1994) from fossil fuels and cement. Due to the CO_2 emitted during the oil field fires, Kuwait exhibited a dramatic increase in

Table 4. Use of non-conventional sources of water in selected countries (FAO 2000)

Country	Mean Temperature in January °C		Mean Temperature in July °C		Mean annual rainfall	Mean annual Pot. Evapo-transpiration
	Max	Min	Max	Min		
Algeria	16-20.2	5-9	28-40.5	21-25.1	23 - 818	1000 - 2450
Bahrain	20	13.9	37.2	29.4	74	1900
Cyprus		9	35 (Aug.)		503	
Egypt	17.7-22.2	6.2-9.8	28.7-40.6	20.6-25.8	25 - 190	1580 - 2300
Iraq	12.8-15.6	1.1-3.9	38.3-43.3	21.1-24.3	107 - 717	1600 - 2000
Jordan	12.2-13.4	3.8-3.9	31.5-32.2	18-19	100 - 625	1640 - 1960
Kuwait	16.1	9.4	39.4	30	100 - 141	2000
Lebanon	16.5	10.5	30.5	23	559 - 765	1250 - 1400
Libya	16-20.5	6-8.5	29.5-43	21-24	1 - 577	1350 - 2450
Morocco	9-17	-5-9	26-31	12-19	103 - 654	1000 - 1700
Oman	25-27.2	17.8-18.9	27.8-36.1	23.9-30.6	54 - 99	1700 - 3000
Qatar	20.5-21.5	10.5-10.8	38.7-42.4	26.3-27	60 - 100	1850
Saudi. A.	21.1-28.9	7.8-18.9	37.2-41.7	25.6-26.1	37 - 193	1700 - 2300
Sudan	24-32	7.8-19.9	38.5-41.2	24.9-28.1	64 - 777	2020 - 2450
Syria	11.7-12.9	1.3-2.2	35.5-38.7	18-23.7	100 - 1147	1425 - 1650
Tunisia	14-16	4-6	32-37	21-22	96 - 864	1200 - 1650
U.A.E	23.3	12.2	37.8	27.8	n.a.	2400
Yemen	24.1-29	0.5-22	31.5-37.2	14.1-28	117 - 864	2050 - 2200

Table 5. Mean values of temperature, rainfall and potential evapotranspiration for some countries in SMED and ME countries (Shahin 1996)

Country	Total water withdrawal		Desalinated water		Reused treated wastewater		Use of desalinated water and treated wastewater	
	Year	million m^3 per year	Year	million m^3 per year	Year	million m^3 per year	million m^3 per year	as % of total withdrawal
ALGERIA	1990	4 500,0	1990	64,00		-	64,00	1,422
BAHRAIN	1991	239,2	1991	44,10	1991	8,03	52,13	21,793
CYPRUS *	1993	211,0		-	1995	11,00	11,00	5,213
EGYPT	1993	55 100,0	1990	25,00	1993	200,00	225,00	0,408
IRAN	1993	70 034,0	1991	2,90		-	2,90	0,004
IRAQ	1990	42 800,0		-		-	-	-
JORDAN	1993	984,0	1993	2,00	1991	50,30	52,30	5,315
KUWAIT	1994	538,0	1993	231,00	1994	52,00	283,00	52,602
LEBANON	1994	1 293,0		-	1991	2,00	2,00	0,155
LIBYA	1994	4 600,0	1994	70,00	1990	100,00	170,00	3,696
MALTA	1995	55,7	1995	31,40	1993	1,56	32,96	59,174
MOROCCO	1991	11 045,0	1992	3,40		-	3,40	0,031
OMAN	1991	1 223,0	1995	34,00	1991	26,00	60,00	4,906
QATAR	1994	284,9	1995	98,60	1994	25,20	123,80	43,454
SAUDI ARABIA	1992	17 018,0	1995	714,00	1992	217,00	931,00	5,471
SYRIA	1993	14 410,0		-	1993	370,00	370,00	2,568
TUNISIA	1990	3 075,0	1990	8,30	1993	20,00	28,30	0,920
TURKEY	1992	31 600,0	1990	0,50		-	0,50	0,002
UNITED ARAB EM.	1995	2 108,0	1995	385,00	1995	108,00	493,00	23,387

* ***Cyprus*:** The figure for total water withdrawal refers to the government controlled area; other figures refer to the whole island.

CO_2 emission in 1991. The 1991 Kuwaiti oil field fires resulted in 130 million metric tons of carbon being emitted to the atmosphere, more than the total CO_2 emission of the 8th largest national emitter, Canada. The three major fuel consumers discharge 62% of the region's CO_2; they are Iran (60.7 million metric ton of carbon in 1991), Saudi Arabia (58.7 million metric tons) and Turkey (38.9 million metric tons). Gas flaring has been a major source of regional emission. Per capita emissions underwent rapid growth until 1973 but have changed little since then. Qatar has the highest national per capita CO_2 emission rate in the world, 12.2 metric tons of carbon per person. In Africa, South Africa contributes 41% of the continental total while another 40% come from Egypt, Nigeria, Algeria, and Libya combined. These are the only five countries with annual CO_2 emission in excess of 10 million metric tons of carbon. Libya has annual CO_2 emission of 2.5 million metric tons carbon.

4. Possible future climate change in SMED and ME countries

As mentioned earlier, the expectations for SMED and ME countries are that summers will be dryer and hotter. The UK Hadley Centre's Global Climate Model is shown in (Fig. 1) The model comprises several layers into the atmosphere and below soil surface and accounts for most of the essential /dominant hydrological processes. The model runs at spatial scale of 2.5° × 3.75° grid squares for rainfall predictions and 0.5°× 0.5° grid squares for temperature. Version two (HadCM2) of this model accounts only for CO_2 impact, it does not account for the aerosols impact. All the scenarios are for the time horizon 2050. They are expressed as percentage rainfall change or temperature change compared to the CRU climatology corresponding to the baseline period of 1961-1990 (New et al. 1999). The model has been run on monthly basis for the SMED and ME countries to predict the % change in rainfall with respect to mean monthly values. The results are shown in Figure 2 for the dry season (April to September) and for the wet season (October to March) up to the year 2050. Temperature changes in absolute °C are shown in Figure 3 for the dry and the wet seasons.

Figure 2 shows that by the year 2050 northern Africa and some parts of Egypt, Saudi Arabia, Iran, Syria, Jordan and Israel are expected to have reduced rainfall amounts, up to 20 to 25% less than the present mean values. This decrease in rainfall is accompanied by a temperature rise in those areas between 2°C and 2.75°C, as shown in Figure 3. For the same period, the temperature in the coastal areas of SMED and ME countries will rise by about 1.5°C. In wintertime, the rainfall will decrease by about 10% to 15%. In the winter time, the temperature in the coastal areas will also increase but by only 1.5°C on average while inside the region it will increase by 1.75°C to 2.5 as shown in Figure 3.

4.1 Uncertainties in climate change predictions

The climate models used to generate estimates of future climate conditions are in need for refinement and improvement in many areas (Gleick 1998). Gaps in data and basic understanding of fundamental climatological processes slow any progress. Moreover, future unexpected large and rapid changes in climate as those of the past are very difficult to predict.

These unpredictable events are attributed to the non-linear nature of the climate system (Gleick 1998). According to Jager and Ferguson (1991) the uncertainties in climate predictions arise from our imperfect knowledge of: (a) Future rates of human-made emissions; (b How these will change the atmospheric concentrations of greenhouse gases; and (c) The responses of climate to these changed conditions.There are many uncertainties associated with timing, direction and extent of these climatic changes as well as about their implications for societies. These uncertainties have great influence on the rational water-resources planning for the future. These uncertainties should not paralyse policy makers and water managers and stop them from rethink and re-evaluate current policies.

4.2 Climate change impact on the hydrological cycle

Climate change has always been associated with the increase in temperature through the 'Greenhouse effect'. However some of the most severe impacts of climate change are likely to come, not from the expected increase in temperature, but from the changes in precipitation, evapotranspiration, runoff, and soil moisture which are crucial factors for water planning and management. The hydrologic system affects, and is affected by, the climatic condition. Changes in temperature affect evapotranspiration rates, cloud characteristics, soil moisture, storm intensity, and snowfall and snowmelt regimes. Changes in precipitation affect the timing and magnitude of floods and droughts, shift runoff regimes and alter groundwater recharge rates. Vegetation pattern and growth rates and the changes in soil moisture regime are also affected.

Some regions can expect an increase in the amount of precipitation, which will lead to changes in agriculture production and the natural ecosystem (IPCC 1988, IPCC 1990). In other areas soil moisture may diminish, especially where a moisture deficit in the soil is already experienced such as in Africa. A 1-2°C rise in air temperature accompanied by a 10% reduction in the amount of precipitation may cause a 40% to 70% drop in mean annual river runoff, which will substantially affect agriculture, water supplies and hydropower.

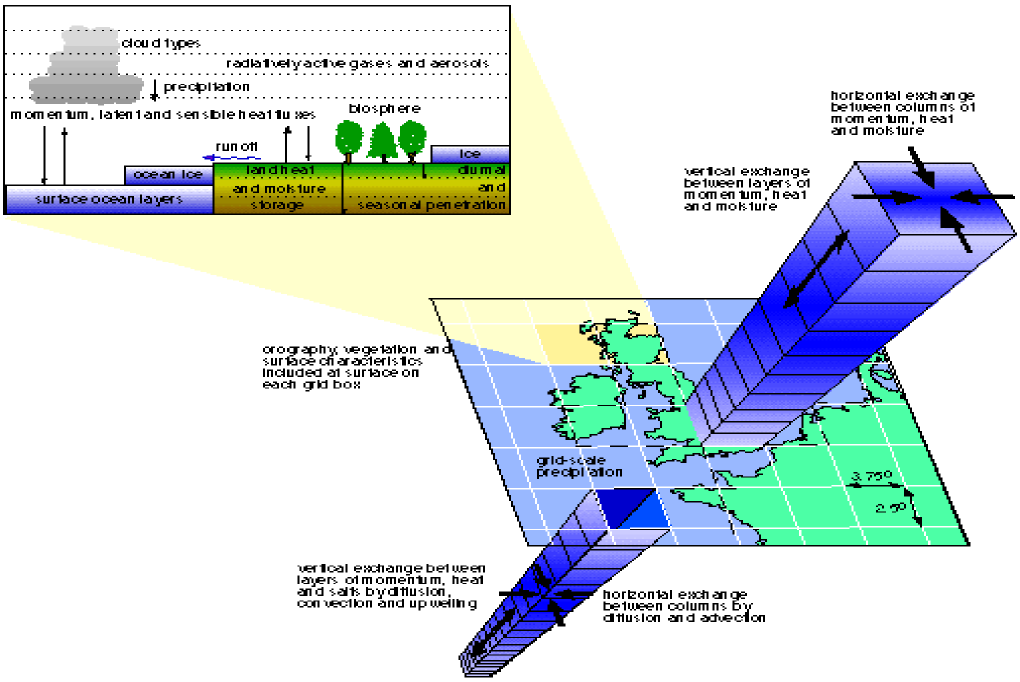

Figure 1. Conceptual diagram of HadCM2 (Ragab and Prudhomme 2002).

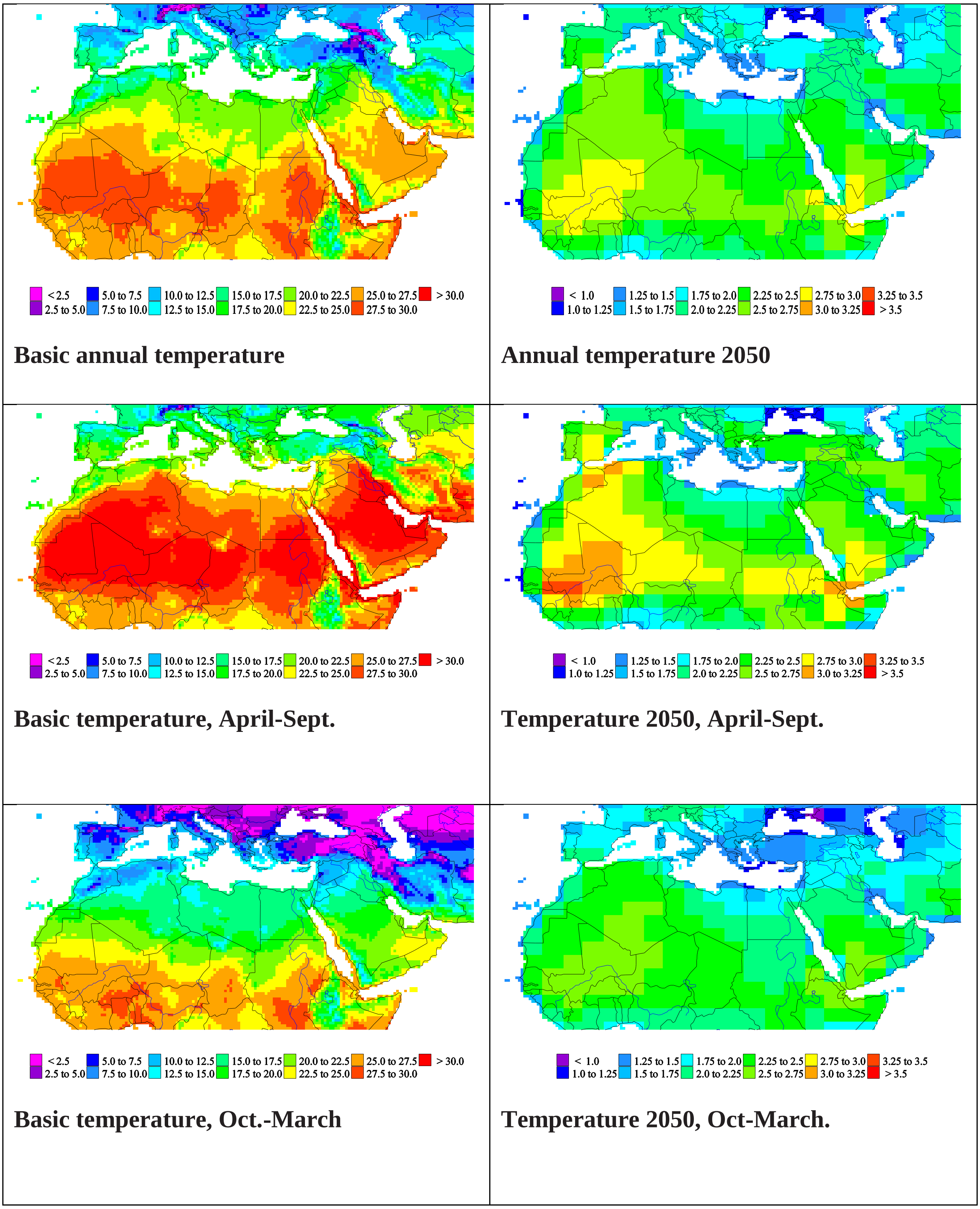

Figure 2. Basic precipitation based on 1961-1990 data and percent changes in precipitation for the dry (April to September) and the wet (October to March) seasons of the year 2050 according to the HadCM2 Scenario-GHGX (Ragab and Prudhomme 2002).

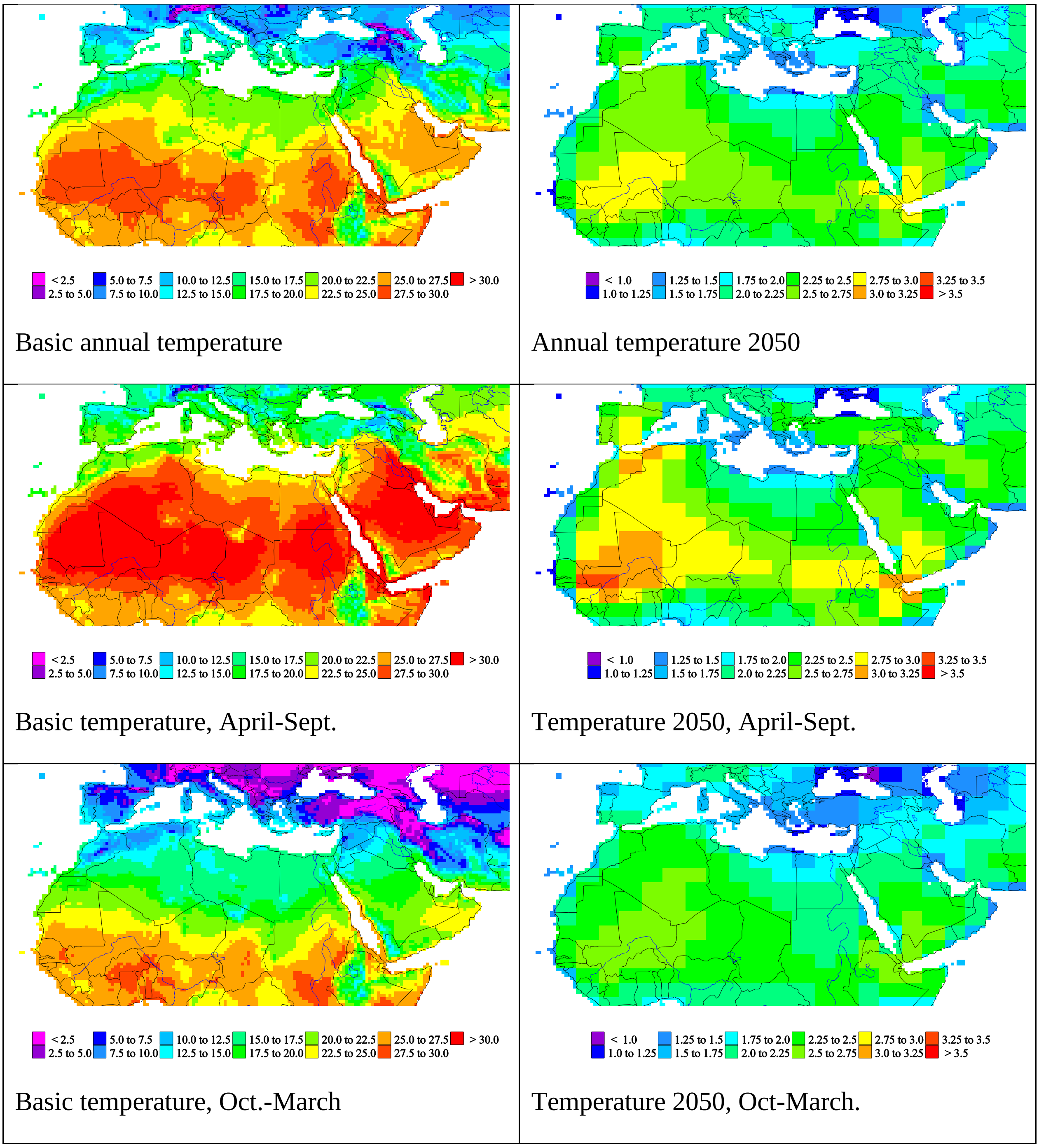

Figure 3. Basic temperature based on 1961-1990 data and changes in temperature (°C) for the dry (April to September) and the wet (October to March) seasons of the year 2050 according to the HadCM2 Scenario-GHGX (Ragab and Prudhomme 2002).

With respect to agriculture in the SMED and ME regions, the impact (Jager and Ferguson (1991) could be as follows:

- The growing season will increase, which might benefit the crop yield.
- Increased CO_2 may also benefit crops.
- Increase in disease and pest incidence could occur.
- The demand for irrigation water will increase.
- In terms of the hydrology cycle the impact could lead to:
- Changes in precipitation with significant variation and remarkable inter-annual variability.
- Change in evaporation and transpiration. With temperature
- rise, the available energy for evaporation and the atmospheric demand for water from land and water surfaces increase.
- Changes in soil moisture. Changes in climate in terms of precipitation patterns and evapotranspiration will directly affect soil moisture status, surface runoff and groundwater recharge.
- Changes in snowfall and snowmelt.
- Changes in storm frequency and intensity.
- Changes in runoff, flood and droughts.

5. What are the possible solutions and choices?

5.1 The conventional solutions

It seems that the SMED and ME region is geared primarily to conventional solutions especially in the North African countries (Pearce 1996). Algeria believes it will need another 5.5 km^3 of water a year by 2010, 50% for irrigation and 50% for domestic and industrial uses. It plans 50 more dams and 10 diversion canals and will tap non-renewable fossil water beneath the Sahara. Tunisia is already using 90% of its surface water in the north and all of its groundwater. It will build new large dams and develop a network of pipes and canals to transfer water between river basins. It will have the capacity to transfer more than 50% of the water captured behind dams in the northern regions. Morocco intends to double the proportion of its river flow controlled by dams and extract more groundwater. It will build 60 large dams, sink boreholes with a total length of 100 km and build 280 km of water-transfer-structures involving huge expenses. Water infrastructure already accounts for more than 20% of public sector investment in Morocco and Tunisia and 12% in Algeria. Libya is planning to tap more under-groundwater and transporting it to the coastal aquifers such as Jefara, which have been destroyed by over-abstraction.

5.2 Innovative solutions

New solutions to harvest rainwater could be based on old techniques used in the past, especially in the deserts. Desalination of seawater by reverse osmosis is electricity consuming while evaporation method using solar/wind energy is less expensive. The cost of desalination is three to five times the cost of tapping groundwater. Brackish water could be desalinated but a cheaper solution is to develop salt tolerant crops that can be irrigated with this water either as such or diluted with fresh.

5.3 The alternative solutions

5.3.1 Reducing demand: Water policies have to be directed toward cutting the demand by using the advanced technology as a key factor. Present computer systems can monitor flows and pressure, detect leaks and prevent water wastage both in industrial and urban water-distribution networks. Market-oriented approach to water should be adopted using price incentive to encourage savings. Leaks and evaporation should be reduced; these could amount to 60% in urban areas. This loss is 30% in Damascus, 65% in Malta and 45% in the cities in Greece. An evaporation rate in North Africa is 2 m per year and losses from surface waters and reservoirs can be great. Evaporation losses from Lake Nasser are 14%.

5.3.2 Efficient irrigation systems: Surface irrigation is the common practice in the region, accounting for more than 50%. Sensors linked to a computer system can control flow of water in pipes and irrigation can be applied at night to reduce evaporation losses. The capital costs are high but the saving in water is substantial, between 30% and 50%. Drip irrigation is widely used in Israel, Jordan, and to a less extent in other countries.

5.3.3 Recycling: Treated wastewater of cities and farms can be recycled or reused for irrigation. This is already taking place in Morocco, Egypt, Libya, and Tunisia, as well as in Israel.

6. Epilogue – a need for sustainable vision for fresh water resources

As world population grows from the present six billion, more water will be required to satisfy the basic needs. The climate change prediction for the Southern Mediterranean and Middle East regions indicates a drier and hotter climate. The limited water resources at present will get even more limited in the future. The needed water in the future might come at a high financial and ecological price. Although, there is some uncertainty in predicting the climate change, these regions are already experiencing a dryer and hotter climate each year, as per the climate change predictions for these regions. Based on the society's needs and choices, policy makers can set goals for water use that are both sustainable and achievable. Policies with some positive vision, and some thoughts about what truly sustainable water use means, are very much needed.

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1.2. Adaptation measures for productive drylands to cope with possible climate change in Egypt

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Abstract

Climate change scenarios are becoming a reality with varied impacts in the different climatic zones of the world. Possible climate change impacts vary with respect to temperature rise, change in rainfall rates and patterns, sea level rise, salt water intrusion, effects on land and water-resource use, and crop productivity, and performance of biota, among other impacts. Egypt exhibits four agro-ecological zones with varied attributes pertinent to productive lands and use of available resources. These include: a) Alluvial and desert soils irrigated through the use and reuse of Nile water as well as drainage water; b) Rangelands mainly in the northern coastal areas with marginal cultivation depending on limited rainfall, use of water-harvesting techniques, water storage and seasonal cultivation; c) Dry valleys in Sinai and the eastern Desert based on the use of groundwater of varied quality; and d) Desert lands cultivated with the huge groundwater resources of Nubian Sandstone Aquifer mainly of good quality in the western Desert (e.g. New Valley and East Owinate). Climate change impacts will vary considerably throughout these zones. Adaptation measures are proposed to cope with possible climate change include modified management practices of soil and water resources, changes in cropping patterns based on use of crops having appropriate water requirement and adaptation traits, innovative approaches to land and water use, conservation and use of environmentally adapted germplasm, in addition to capacity building, awareness campaigns, advanced extension services, and demand-driven research activities.

1. Background

Climate change is attributed to the enhanced emission of global warming gases, foremost among which is the CO_2 due to disturbance of the natural carbon cycle through adverse human activities. IPCC (2000) reported that if the trend of CO_2 emission continues at the present rates, it is anticipated that the average global temperature of Earth's surface and sea water surface, could increase by 1.5-6.0 ^oC (3.0 ^oC is most probable) by the end of the present century. Other climate change impacts would include alteration of rainfall rates and patterns, occurrence of drought spells, and changes in energy exchange patterns between the global atmosphere and Earth's surface. Such changes would have definite impacts on the components of the ecosystem, including soil, water, plant, micro flora and human inhabitants. This paper will focus on the impacts of possible climate change scenarios on the productive drylands in Egypt and suggest adaptation measures to cope with such changes.

2. Main attributes of productive lands in Egypt

There are four distinct agro-ecological

zones in Egypt with varied geomorphological, micro-climatic, plant cover, soil and water attributes, in addition to varied human activities and management systems of the available resources. The four agro-ecological zones are: Northern Coastal Areas, the old Nile Valley and the adjacent reclaimed desert soils, Inland Sinai and the Eastern Desert, and Western Desert. Aside from the natural variations typical of dry ecosystems, global climate change scenarios are anticipated to have varied impacts in the four agro-ecological zones.

2.1. Northern coastal areas

The Northern Coast area extends in a narrow strip of about 20-30 km. width along the Mediterranean coastal line in two major sub-zones, i.e. the Northwest Coast extending from form Amria to the western boarders, and the North Coast of Sinai extending from the Suiz Canal till the eastern boarder.

Elevation: Coastal areas elevatios ranges from the sea level or below to 50-200m asl., in a distance of few kilometers. The succession of land forms start in most areas by flat or elevated depressions with gentle or intermediate slopes. These relatively low lands lead rapidly, in all cases, to short transition areas of foot-hills and undulating areas of higher levels which in turn lead to the edge of plateaux and mountainous areas in Sinai or North-Western Costal area (NWCA). Many dry valleys dissect the escarpment and foot-hills of the plateau, especially in the NWCA.

Climate: The zone is characterized by dry Mediterranean climate with relatively rainy, cool winter. Averages of seasonal rainfall (autumn and winter) are about 250 mm/y, in general the highest in Egypt, with the highest on the North-Eastern part of Sinai. The average rainfall on the rest of the areas varies between 110-200 mm/y. Rainfall decreases sharply to 50 mm at a distance from 20-70 km inland. Natural variation of rainfall is highly variable between seasons and within the season. These areas experience the highest wind speed in Egypt, especially in the winter season, when it could reach up to18.5 km/hr.

Soil: Soil types and properties are highly influenced by geomorphic and pedological factors. The main dominant soil units could be depicted as follows:Deep and moderately deep soils, soils of alluvial fans and outwash plains, saline soils of lagoons and depressions, coastal oolitic dunes, inland sand dunes and wind blown formations (El-Bagouri et al. 1982; GTZ 1993).

Water: Water resources are mainly rainfall and groundwater, the latter is limited in quantity and usually of low quality, especially, with varied salinity content and composition. (JICA 1992).

Land use: Rangelands dominate in this zone with an area of over 6.5 million feddans (1 feddan = 0.4 ha) mostly in the North-West Coast (3.75 million feddans). The annual carrying capacity of rangelands, averaging 1.5 million heads of sheep, goats and camels, varies considerably according to seasonal rainfall. Economic returns from animal production and related cottage industry represent the main source of income to Beduins. Rainfall, harvested and stored, are used to cultivate winter cereals(barley and wheat) and vegetable crops (tomatoes, cucumber and melons) (Dames and Moore 1983; ICARDA 1995). Total cultivated area is around 350,000 feddans. Drought resistant fruit trees (mainly olives and figs) number 700,000 trees.

Human resources: Agro-pastoralists with tribal traditions are the main dwellers of rangelands. Lately, touristic villages have been established all along the Mediterranean Sea Coast enhancing human resources affiliated to these villages and resorts.

Anticipated climate change impacts: The physiographic and climatic features of this agro-ecological zone combined with the main attributes of land and water resources make this zone most liable to climate change impacts, which are listed below:

- The climate change could lead to drought spells because of the projected reduction in the average rainfall (FAO/RONE 2001) and, therefore, reduced productivity of rangelands and cultivated areas. The presently degraded rangelands would face serious constraints of regeneration of plant cover and suffer reduction in the carrying capacities. Related activities of cottage industry and crafts byproducts would be reduced.
- Drought spells and reduced rainfall would also enhance the soil erosion. Efficiency and amounts of harvested rainwater are anticipated to be significantly reduced, threatening the success of cultivation of field crops. In the drought affected areas in the North African countries, under similar conditions, cereal crops give any yield only once every 2-3 years. The increase of heat stress would be more significant in this zone affecting the composition of the natural plant communities, favoring heat tolerant plants. Cultivated field crops might also suffer more from certain plant diseases.
- Climate change scenarios predict a rise of about one meter by the end of a few decades. Areas laying below the sea level in the eastern part of the NWCA and the western part of the Northern Coast of Sinai (Teana Plain) will get inundated. There will be enhanced salt water intrusion in the shallow groundwater aquifers, necessitating the cultivation of salinity tolerant plants and halophytes, and adopting appropriate salt water desalination techniques.
- The above changes will have significant impacts on the income and livelihood of the Beduins, farmers and other dwellers of the coastal areas. Loss of job opportunities and migration of personnel especially youth to urban areas will cause social problems. The shoreline touristic villages adjacent to the Mediterranean Sea shore will lose touristic revenues.

Adaptation measures*:* The following measures are proposed to address the possible impacts:

- Rangelands management to secure sustainable development is of priority. This will require improved collection of harvested water and its use to secure the regeneration of rangelands, using native drought tolerant species available in the Sheikh Zuaid gene bank of the Desert Researech Center. Harvested water and its storage in large cisterns would be of help in the production of adequate feed for the animal herds. Use of the limited brackish groundwater resources for irrigation of the salt-tolerant forage shrubs during the dry months of the year would reduce pressure on rangelands. Planting of the field crops in this area will have to be avoided.
- To reduce soil erosional processes by wind and water the regeneration of plant cover of rangelands, application of appropriate techniques to stabilize active sand dunes, cultivation of appropriately spaced hedges and wind breaks formed of drought resistant and salt tolerant indigenous species are recommended.
- Cultivation of winter cereals and vegetables should be limited to areas with available canal irrigation water and intensity adjusted to match the yearly estimated amounts of available water.
- Groundwater resources are limited in this area. The thin layers of low brackish water floating over more dense saline water has to be carefully extracted. Appropriate and feasible techniques of water desalination could be applied for use of saline water, especially, with the availability of abundant solar energy. Integrated planning for relocating the

people affected by inundation of coastal areas will be necessary.

- Timely implementation of the proposed adaptation measures would greatly reduce the adverse impacts on dwellers of the area. It is important to secure the stakeholder participation in planning and implementation of the adaptation measures with appropriate immediate initiation of awareness and capacity building programs.

2.2. The Nile Valley and the reclaimed desert fringes

This agro-ecological zone is the largest contributor to food security, agricultural trading activities and national economy. It is also most densely populated. Through the last four decades vast areas at the desert fringes of the Nile Valley and Delta have been reclaimed and used for agriculture using Nile water.

Physiographic and climate features: The Nile Valley with vastly level areas extends through gentle slopes from Aswan in the south to the Coastal lines in the North over a distance of about 940 km. The Nile Valley in Upper Egypt extends in the eastern and western directions to elevated desert areas through varied river terraces. The southern areas of the Nile Valley are characterized by hyper-arid conditions of high temperatures and very low rainfall. There is significant variation in the average temperatures in the direction to the northern coastal areas of moderate climate. This has significant impacts on biodiversity, cropping systems and cultivated varieties.

Soil and water: Soils include the fertile deep alluvial soils of the Old Nile Valley, in addition to the soils at the fringes of the Old Valley including desert calcareous and non-calcareous soils with low soil fertility and inferior soil physical, chemical and biological properties (El-Bagouri 1992). Egypt's share of the Nile water is 55.5 billion m^3/ year. The High Dam provids perennial storage of excess Nile water in Lake Nasser. About 80% of the Nile water is used for irrigation of the Old Valley and the newly reclaimed soils in its fringes. Sizable amounts of the agriculture drainage water of the Old Valley are recycled in the water conveyance system and mixed with the fresh. In addition to the Nile water, a huge ground water aquifer extends under the Nile Delta which is continually recharged by the excess of the Nile water used for irrigation. Large amount of water (4.8 billion cubic meters) is extracted yearly from this aquifer.

Land use: The highly fertile alluvial soils over 5.8 million feddans permit the highest cropping intensity in the Arab region. Through the last four decades, over two and half million feddans were reclaimed in the desert fringes of the Old Valley and Delta using mainly Nile water.

Human resources: Over 95% of the Egyptian population lives in this area. Aside from urban dwellers of mega and major cities, the rural populations comprise of traditional farmers, young graduates and investors of varied economic status, mainly in the reclaimed desert areas.

Anticipated climate change impacts: Due to the rich and extensive land and water resources of this agro-ecological zone, the possible climate change impacts are varied in space, magnitude and significance:

- The most significant impact is the anticipated changes in the yearly supply of water resources from the River Nile (IDRC 1985). Several studies were carried out to forecast the possible changes of Nile water in its basin through the use of mathematical models (Conway and Hulme 1993; IPCC 2000; Sayed et al. 2004). Investigations concluded that there were significant correlations between recorded temperatures, through the previous 35 years, and rainfall rates and gave different [rojections for changes in rates of rainfall ranging between -10.3 - +27.2% by the year 2030. The overall anticipated change of Nile water supply is most probably negative.

- Using several mathematical models Mowafy et al. (2004) forecasted that water requirements of the main field crops would be enhanced by 10% for maize, 9% for wheat and 12% for cotton by the year 2050. Possible heat stress due to enhanced average temperatures would reduce the productivity of most cultivated crops to varied extents.
- Considerable low laying areas could be inundated especially in the areas south of Manzla Lake in the east and areas around Lake Idku and Lake Maryut to the west. It is anticipated that the areas of northern lakes would expand limiting the areas of wetlands which could enhance fishing resources while reducing wild life habitats including birds and other unique wild life species. Expansion of Lakes and inundated areas would also be at the expense of productive cultivated areas and its inhabitants who will have to migrate to other non threatened areas.
- Sea water intrusion is anticipated to have impacts on the salt balance of the huge groundwater aquifer laying under the Nile Delta. Major water quantities are extracted from this rather shallow aquifer to supplement irrigation of certain areas of the Old Nile Valley and many areas of the newly reclaimed desert soils in the fringes of the Old Valley.
- There will be serious economic and social impacts on human resources including migration and relocation of dwellings, reduced income, loss of job opportunities and possible change of livelihood patterns.

Proposed adaptation measures: Following measures are proposed:

- The possible reduction of the water supply of the Nile River would represent a major impact that has to be addressed with prompt immediate integrated planning. Water losses through conveyance and through on-farm use, estimated to be over 30% (El-Bagouri 1992), should be curtailed to the maximum extent. The Ministry of Water Resources and Irrigation (MWRI) is taking steps to minimize conveyance losses. Adoption of appropriate irrigation methods especially in reclaimed desert areas, improving the awareness of farmers to conserve irrigation water through proper irrigation management and scheduling to prevent over-irrigation and deep percolation losses will reduce onfarm losses.
- Development and use of drought resistant varieties of the major crops, appropriate alteration of the farming systems and cropping patterns to maintain food security while curtailing water demands, assessing the possibilities of alternatives to crops of high water demands (eg. rice and sugarcane) and restricting the total cultivated areas of these crops according to the bare minimum requirements, and availability of water requirements. To deal with the anticipated reduction in the quality and quantities of agricultural drainage waters, which are partly reused alone or in mixture with the fresh Nile water, the cultivation of salt tolerant crops and appropriate halophytes will have to be promoted.
- Adaptive measures for increased heat stress will necessitate research to develop varieties of major crops that are resistant to heat and less susceptible to plant diseases, as well as, to introduce appropriate alterations to cropping patterns and horticultural activities. Such measures should be implemented through proper application of forecasting models for temperature changes.
- To cope with inundation with water in the lowlying areas projects will have to be formulated. Fishing industry might

help in securing livelihoods. Losses of productive lands should be addressed through prior reclamation of new lands and establishing appropriate industrial and commercial activities to cope with migration of affected population.

2.3. Inland Sinai and the Eastern Desert

Physiographic and climatic features: This zone has vast areas of elevated and mountainous areas which are dissected by dry valleys that lead to low laying coastal areas (near sea level) adjacent to Gulf of Suez, Gulf of Aqaba and the Red Sea. The very low rainfall characteristics of inland Sinai (30-50 mm/year) falling on vast catchment areas gets collected through the dry valleys causing occasional strong flash floods towards the gulfs of Suez and Aqaba, leading to soil water erosion. Similar flash floods occur especially in the southern areas of the Eastern Desert, where rainfall rate is high due to seasonal storms, and cause water erosion. Average temperatures vary greatly with elevations and increase in the southern direction. Wind speed, especially in the winter season, frequently exceeds 8-10 m/sec.

Soil and water resources*:* The soils of inland Sinai differ widely according to their landforms, including sabkhas and wadi alluvial soils. Despite the very low rainfall, the geomorphic factors, combined with the intensity of infrequent rain showers, lead to flash floods, which cause soil-erosion, have adverse effect on infrastructure and touristic installations, and result in loss of water to the adjacent marine areas.
Land use*:* Rangelands of rather limited carrying capacity are spread in many areas of the zone. Cultivated areas are sparse and limited to the dry valleys and their deltas, where groundwater resources are available in qualities appropriate for cultivated plants (El-Bagouri 2004). In the southern mountainous area of the Eastern Desert unique natural plants grow on seasonal summer rainfall providing a wealth of biodiversity.

Human resources: Human resources are diversified with Beduin pastoralists dominant in Sinai and South Eastern Desert areas. Urban dwellers are mainly in towns and touristic villages, in addition to workers in industrial, mining and oil field sectors.

Anticipated climate change impacts: Possible reduction of rainfall in Inland Sinai and elevated lands in the Eastern Desert would affect the productivity of rangelands although they arecomposed mainly of drought resistant plant species. The areas under cultivated lands dependant on rainfall and supplemental irrigation through the limited groundwater resources will be reduced. Salt content of the shallow groundwater wells is expected to rise with pronounced impacts on traditional crops cultivated there especially if the increased water salinity is accompanied by elevation in temperature. The southern elevated lands in the Eastern Desert will have benefit of increased seasonal rainfall which would have positive impacts on rich natural flora.

Proposed adaptation measures: Use of nontraditional plants and halophytes appropriate for the variable conditions of stresses of heat, drought and salinity will have to be encouraged. Research efforts will be needed to harness the renewable energy available to permit desalination of water for nontraditional farming and for the ever-expanding touristic installatios. Capacity building and awareness campaigns are of high significance to enable use of scientific achievements and innovated techniques to be adopted.

2.4. Western Desert

The Western Desert represents the largest agro-ecological zone with the least population. The area has huge groundwater aquifer (the Nubian Sandstone Aquifer) at varied depths with most of the locations producing good quality water. Whether these water resources are renewable is debatable (El-Bagouri 2004).

Physiographic and climatic features: The Western Desert extends from the boarder with Sudan in a gradual slope to the coastal areas in the North. It extends from the Nile Valley to the east till the Libyan boarder to the west. This vast expanse is distinguished by several depressions forming the well known oases in addition to the 'Sea of Sand' in the middle section. To the North there is a large depression (Cattara depression with the lowest location of 130m bsl.) in addition to small scattered depressions (ASRT 1989). Climate is dominantly hyper-arid with scarce rainfall events in a narrow strip to the south of the Northern Coastal areas (50mm of seasonal rainfall or les). Average annual temperature gradually increases in the southern direction. Winds are active in the winter while solar radiation is at maximum throughout the year.

Soil and water resources: Soil resources are used in the scattered oasis through irrigation by groundwater from the Nubian Sandstone Aquifer to grow field crops and fruit trees. Over-extraction of groundwater resources has led to the progressive lowering of the static water level in the dug wells. Although the water quality is high yet the prevailing desert soil resources suffer from original salinity and inferior desert soil properties. There are two large projects to reclaimg hundreds of thousands of feddans in the Southern region of the Western Desert: one to the East (Tushka) of half a million feddan to be irrigated with Nile Water taken from the excess water of Lake Nasser, and the other at East Owynate solely dependent on groundwater with a target of 96,000 feddans.

Anticipated climate change impacts: Most anticipated impacts would be of the temperature rise, which in this hyper-arid zone would mean enhanced amounts of water requirements of field crops and fruit trees grown in the oasis and the areas developed in the major desert land reclamation projects in the south. This increase in water demands would have particular adverse impact under the conditions where the crop production was of dependent on irrigation with non-renewable groundwater resources.

Proposed adaptation measures: The proposed measures include adoption of water conservation measures, as well as, alterations in the cropping patterns to reduce water demands.
Appropriate techniques to treat and reuse waste water would be imperative to conserve resources and ensure environmental safety.

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1.3. Ten years continuous exposure to elevated CO_2 increases litter production and carbon sequestration in an undisturbed Mojave Desert ecosystem

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Abstract

Desert ecosystems are predicted to have large relative increases in net primary productivity (net CO_2 uptake) due to increased water use efficiency via stomatal regulation of water loss as atmospheric CO_2 continues to increase at a rate of 1-2 ppm per year. Consequently, within the context of current rates of fossil fuel consumption and global deforestation, atmospheric CO_2 is predicted to reach 550 µL/L within the next 50 to 75 years. However, increased CO_2 fixation by desert ecosystems coupled with little or no increase in litter decomposition rates could result in sequestration of significant amounts of carbon and subsequently dampen future rates of increase in atmospheric CO_2. We tested the hypothesis that under continuous fumigation with elevated CO_2 (550 µL/L) plant litter production by an undisturbed Mojave Desert plant community would be significantly greater than under ambient CO_2 (~367 µL/L). Fumigation of three 25 m diameter plots with elevated CO_2 (550 µL/L) began on 28 April 1997 at the Nevada Desert FACE Facility (NDFF). Studies of native plant responses to elevated CO_2 have shown that changes in growth or biomass production are species-specific and vary from less than 0% to greater than 80% with C_3 pathway species being more responsive to elevated CO_2 than C_4 species. We began measuring litter accumulation beneath the four dominant C_3 shrub species, (*Ambrosia dumosa*, *Larrea tridentata*, *Lycium andersonii*, and *L. pallidum*) at NDFF in April 1998. These four shrubs species contributed 74%, 80% and 81% to total shrub density, cover and aboveground biomass, respectively. Litter layer biomass beneath shrubs was exponentially related to shrub canopy volume and the relationship was species independent. Total litter biomass accumulation during this 10-year study was positively correlated with rainfall and for all species combined was significantly greater under elevated than ambient CO_2 by 17% for alpha = 0.17 Total litter accumulation beneath *Larrea* was significantly greater by 50% under elevated compared to ambient CO_2 (1321 and 881 g m^{-2} canopy area, respectively). Litter accumulation under elevated CO_2 by *L. pallidum* and *L. andersonii* was non-significantly greater than under ambient CO_2 by 7 and 25 percent respectively, while litter accumulation under *Ambrosia* decreased non-significantly by 6 % under elevated CO_2. Though total annual litter production was significantly correlated with total annual precipitation for all species; all species also experienced a lag in the predicted response to precipitation following two years of below average precipitation. Significantly greater relative turnover of total aboveground shrub biomass occurred under elevated compared to ambient CO_2 for *Larrea* (9.2% vs 5.3 %, respectively), while there was no CO_2 affect on *Ambrosia* (9.2% vs

9.5%), *L. andersonii* (4.0% vs 2.4%) or *L. pallidum* (3.5% vs 3.8%) canopy turnover. Apparent annual turnover of litter layers varied dramatically among species from 97 to 112 percent non-significantly for *Ambrosia* to 10 to 16 percent for *Larrea*, which was significantly greater under elevated CO_2. Atmospheric CO_2 levels will probably exceed the 550 µL/L CO_2 level used in our study well before the end of the 21 century and our results suggest that arid and semi-arid shrub communities (mean annual precipitation less than 300 mm) will respond to rising atmospheric CO_2 with increased rates of litter accumulation. Furthermore, global carbon sequestration by arid ecosystems should also increase, based on concomitant studies at our site showed no impact of elevated CO_2 on either litter quality (carbon:nitrogen ratio) or rates of litter decomposition.

Introduction

The burning of fossil fuels and deforestation over the past 150 years has resulted in about a 35% increase in atmospheric CO_2 from 270 to 367 µL/L (Houghton et al. 1995). At the current rate of increase (1-2 µL/L CO_2 year^{-1}), atmospheric CO_2 is expected to reach a concentration between 465 and 565 µL/L by the end of this century. Elevated atmospheric CO_2 has been shown to directly affect many plant species and functions, ranging from increases in leaf level photosynthetic rates to increases in primary productivity at the plant community level (Saxe *et al*. 1998). However, continued increases in atmospheric CO_2 will depend not only on the rate of release of CO_2 from fossil fuels consumption and deforestation, but also the potential for plant communities to act as sinks for atmospheric CO_2 (Gucinski et al. 1995). Arid ecosystems have been predicted to have the largest relative increases in net primary productivity due to rising atmospheric CO_2 (Bazzaz 1990) and many short-term positive growth responses by desert plants have been documented (Smith et al. 2000, Namberg 2002). To test hypotheses concerning the potential for elevated CO_2 to influence both the structure and function of an arid ecosystem, Free-Air CO_2 Enrichment (FACE) technology (Hendrey and Kimball 1994) was used to continuously expose an undisturbed Mojave Desert plant community to 550 µL/L CO_2, (Jordan *et al*. 1999). Therefore based on predicted and observed responses by perennial plant species from arid ecosystems to elevated CO_2, we hypothesized that (1) overall litter accumulation would be greater beneath shrubs exposed to elevated CO_2; (2) relative and absolute differences in litter accumulation would be species and rainfall dependent; and (3) relative contributions of leaf, wood and reproductive tissues to total litter accumulation would differ by species and CO_2 treatment. In order to relate short-term (10 years) litter accumulations rates to long-term expectations concerning carbon sequestration, we also determined species-specific allometric relationships of shrub size to aboveground biomass and litter layer biomass.

Materials and methods

Site description

Continuous CO_2 fumigation of an undisturbed Mojave Desert plant community at the Nevada Desert FACE Facility (36°49'N, 115°55'W) began with a stepwise increase from ambient (367 µL/L) to elevated (550 µL/L) atmospheric CO_2 on 28, April 1997 using Free-Air CO_2 Enrichment (FACE) technology. Advantages of using FACE technology compared to other fumigation strategies include minimizing affects on microclimate and the potential to study relatively large areas of natural vegetation (Fig. 1). Disadvantages of FACE technology are the high cost of CO_2 and low replication. Our experimental design consisted of nine circular 25 m diameter

Figure 1. Ariel view of a FACE plot.

plots; three plots were fumigated with 550 μL/L CO_2, three control plots were fumigated with ambient CO_2 and three additional control plots had no fumigation apparatus. The perennial plant community consisted of shrub and shrub clusters embedded in a matrix of perennial and annual forbs and grasses. The dominant C_3 shrubs, contributing more than 80% to total shrub cover, were; 1) Asteraceae drought deciduous *Ambrosia dumosa* (A. Gray) Payne, 2) Solanaceae drought deciduous *Lycium andersonii* (A. Gray), 3) Solanaceae drought deciduous *L. pallidum* (Miers var. *oligospermum* C. Hitchc.) and 4) Zygophyllaceae evergreen *Larrea tridentata* (DC.) Cov. (Table 1). Taxonomy is according to the Jepson Manual (Hickman 1993). The dominant perennial grasses were C_4 *Pleuraphis rigida* Thurber and *Erioneuron pulchellum* (Kunth) Tateoka and C_3 *Achnatherum hymenoides* (Roemer and Schultes) Barkworth. Shrub canopy heights varied from 0.10 to 1.50 m and total perennial plant cover averaged 77 m^2 plot $^{-1}$ or 16% of total plot area. The site had never been grazed by domestic ungulates and a well-developed cryptobiotic crust occurred in canopy interspaces on sandy calcareous Aridisols (Romney et al. 1973).

Litter sample collection and analysis

To minimize disturbance within the plots, estimates of litter layer biomass beneath shrubs in the plots were calculated by determining the best-fit relationship between litter layer biomass and shrub canopy volumes with data from off-plot litter layer collections. Off-plot shrubs were selected to include a range of shrub canopy volumes similar to those occurring in the experimental plots. Shapes for all shrub species were best approximated as half-spheres (Babcock et al. 2001), consequently canopy volumes and areas were calculated using the following equations:

Shrub Canopy Volume (m^3) = $(4/3)*\pi*r_1*r_2*r_3)/2$

Shrub Canopy Area (m^2) = $(\pi*r_1*r_2)/2$

The values for the parameters in the equations were obtained from field measurements, with the radius of maximum shrub canopy width = r_1, the radius of the width perpendicular to the maximum = r_2 and average canopy height = r_3. Two litter layer samples from northeast and southwest aspects within the dripline of each shrub were collected from beneath 8-12 shrubs per species. Intercanopy litter layers were also collected. Collection areas were 20 x 20 cm for large shrubs and intercanopy spaces and 10 x 10 cm for small shrubs. Within the plots, paired litter trays (25 x 25 cm) were placed beneath shrub canopies with northeast and southwest aspects and in intercanopy spaces on 28 April 1998 (Fig. 2). Criteria for selecting the three *Larrea* and two each of *Ambrosia*, *L. andersonii* and *L. pallidum* shrubs in each of the nine plots were based on choosing shrubs with minimal

Figure 2. Location of litter trays in an elevated CO_2 plot.

numbers of dead branches, minimum canopy overlap with other shrubs and total canopy volumes close to the plot means for each species (Table 1).

The four intercanopy trays per plot were placed in locations at least one meter or more from the nearest shrub. Litter accumulated in trays was collected 3 to 6 times per year, oven-dried at 60°C, and weighed. Samples collected from February 2000 to February 2002 were separated into leaf, wood and reproduction fractions of the overstory species. Litter accumulation expressed as grams m^{-2} shrub canopy area was calculated as the mean of litter biomass per tray shrub area of 0.0625 m^2.

Percent canopy turnover of total above-ground shrub biomass was determined by dividing total litter accumulation per year by species-specific canopy biomass (Table 1).

Allometric canopy biomass equations were determined by off-plot harvests of 10 to 18 shrubs per species including a range of size classes comparable to those in the plots. General linear models were used to analyze the effects of elevated CO_2 on total litter accumulation and litter fractions with n=3 for elevated plots and n=6 for ambient plots (SAS 2008).

Statistical significance was determined and error bars are presented as one standard error of the mean.

Table 1. Mean (± 1 std. error) density, cover and biomass by species for 9 circular (12.5 m radius) plots located in undisturbed Mojave Desert communities on the Nevada Test Site

*GROWTH-FORM	Density			Cover		Biomass*	
Species	plants/plot	plants/ha	%total	m^2/ha	%total	kg/ha	%total
EVERGREEN C_3							
Ephedra nevadensis	8±2	159±34	3.4	79.2±24.3	5.9	90.6±25.4	6.3
Larrea tridentata	25±2	523±45	11.0	444.1±42.0	33.3	401.5±48.6	27.9
DECIDUOUS C_3							
Acamptopappus shockleyi	12±2	263±46	5.5	21.3±5.0	1.6	15.1±4.0	1.0
Ambrosia dumosa	89±15	1883±318	39.6	187.4±41.3	14.1	127.9±31.6	8.9
Grayia spinosa	0.8±1	16±8	0.3	2.7±1.1	0.2	3.7±1.6	0.3
Hymenochlea salsola	0.5±0.3	9±7	0.2	1.7±1.7	0.1	2.2±2.2	0.2
Krameria erecta	25±10	532±212	11.2	117.6±44.0	8.8	118.3±44.6	8.2
Krascheninnikovia lanata	5±1	115±29	2.4	13.9±4.4	1.0	22.8±8.0	1.58
Lycium andersonii	37±4	776±87	16.3	265.7±28.2	19.9	396.7±52.3	27.5
Lycium pallidum	17±4	359±86	7.5	176.0±37.1	13.2	239.1±48.4	16.6
Psorothamnus fremonti	6±2	122±44	2.6	23.3±9.5	1.7	22.4±9.8	1.6
TOTAL LIVE	225±22	4757±474	100	1333.0±90.6	100	1440.2±103.0	100
FOUR DOMINANTS	168±16	3540±329	74.4	1073.2±85.1	80.5	1165.3±112.2	80.9

Biomass estimates based on species-specific allometric equations where Kg $shrub^{-1}$ = a (shrub volume m^3) and a=3.6286 for *Ambrosia*, a=1.3751 for *Larrea*, a=5.7943 for *L. andersonii*, and a=3.4403 for *L. pallidum* (Babcock et al. 2001).

Results

The best-fit relationship (r^2 =0.627) for estimating litter layer biomass, shown in Figure 3, was exponentially related to shrub cano) py volume:
Grams litter m^{-2} =
$1291*(1-e^{(-1.138*\text{canopy volume})})$

Based on this relationship and using mean canopy volumes by species for each of the nine plots, mean litter layer biomass estimates for *Ambrosia, Larrea, L. andersonii* and *L. pallidum* were 28, 586, 124 and 250 g m^{-2}, respectively (Fig. 3). All shrub species litter layer estimates were significantly different, and the interspace litter layer biomass estimate (7.89 g m^{-2}) was significantly less than mean litter layer biomass of all shrub species.

Litter accumulation beneath *Ambrosia* was not significantly affected by elevated CO_2. *Larrea* accumulated significantly more litter under elevated CO_2 for five of the nine years of the study. The response of *L. andersonii* and *L. pallidum* to elevated CO_2 was not significant, but the trend was for more litter production under elevated CO_2 in most years, comparable to the trend when all shrubs were combined (Fig. 4). Litter fall in intercanopy spaces was only significantly greater under elevated CO_2 during the above average precipitation year of 1998 (Fig. 5). After ten years of fumigation with 550 μL/L CO_2 only *Larrea* had a significantly greater amount of litter fall among the four shrub species studied (Fig. 6). All species litter production rates were significantly and positively correlated with annual precipitation, but after 10 years only *Larrea* produced more cumulative litter under elevated CO_2 than under ambient CO_2. The phenology of litter fall for *L. pallidum* was most often significantly affected by elevated CO_2, with decreases in reproductive and woody fractions and increases in foliar fractions occurring under elevated CO_2 during spring and summer months. *Ambrosia* was the most dynamic shrub species in relation to aboveground biomass and litter layer turnover rates but the least responsive relative to the impact of elevated CO_2 on plant functions (Table 2). Meanwhile, *Larrea* is the functional driver for the impact of elevated CO_2 on carbon cycling.

Discussion

Our data indicate that the predicted continuous rise in atmospheric CO_2 over the next century will result in increased rates of biomass and carbon accumulation in litter layers beneath desert shrubs. Consequently, there will be an increase in carbon sequestration in arid ecosystems if litter decomposition rates do not concomitantly increase. Litter quality and decomposition studies from our site (Billings *et al*. 2002 and Weatherly 2003) and other ecosystems (Kemp *et al*. 1994, Henning *et al*. 1996, Franck *et al*. 1997, Hirschel *et al*. 1997, Norby and Cortrufo, 1998, Gorissen and Cotrufo 2000, Norby *et al*. 2001) have shown little or no CO_2 effect on litter quality and decomposition. However, our ten-year study is still relatively short-term compared to the life-span of the shrubs in our study. Therefore, it will be essential to continue documenting litter dynamics in arid ecosystems in order to ensure that our observed responses are consistent long-term responses and not due to the stepwise increase in CO_2 at the start of our experiment. Besides significant impacts on carbon dynamics, potentially more than 20 kg per hectare year sequestered, the shift in significantly less reproductive biomass for *L. pallidum* under elevated CO_2 suggests elevated CO_2 may also implement changes in species composition and community structure in arid ecosystems.

Table 2. Comparison of shrub aboveground and litter layer biomass, annual litter biomass inputs and turnover rates within ambient and elevated CO_2 plots.

Species	Fumiga-tion	Standing biomass ($g\ m^{-2}$)	Litter layer ($g\ m^{-2}$)	Mean annual litter fall ($g\ m^{-2}$)	Annual percent canopy turnover	Annual percent litter turnover	Litter* ($kg\ yr^{-1}\ ha^{-1}$)
Ambrosia	Ambient	1681	137.8	155.4	9.8	112	29.12
Ambrosia	Elevated	1588	174.1	147.0	9.2	97	27.54
F, pr > F				0.03, 0.87	0.04, 0.84	1.19, 0.29	
Larrea	Ambient	1868	1048.0	97.8	5.3	10	47.45
Larrea	Elevated	1572	946.7	146.7	9.2	16	67.16
F, pr > F				7.04, 0.01	22.1, 0.001	8.11, 0.009	
L. andersonii	Ambient	3275	443.0	75.4	2.4	23	20.03
L. andersonii	Elevated	2691	289.0	94.1	4.0	48	21.99
F, pr > F				1.46, 0.24	3.41, 0.08	2.87, 0.11	
L. pallidum	Ambient	2655	613.0	98.2	3.8	21	17.28
L. pallidum	Elevated	2982	776.0	103.1	3.5	15	18.15
F, pr > F				0.17, 0.68	0.30, 0.59	1.00, 0.33	
All species	Ambient						113.9
All species	Elevated						134.8

Litter kg/yr ha = ((Litter fall g/m^2 canopy area)(m^2 canopy area/ha)/1000).

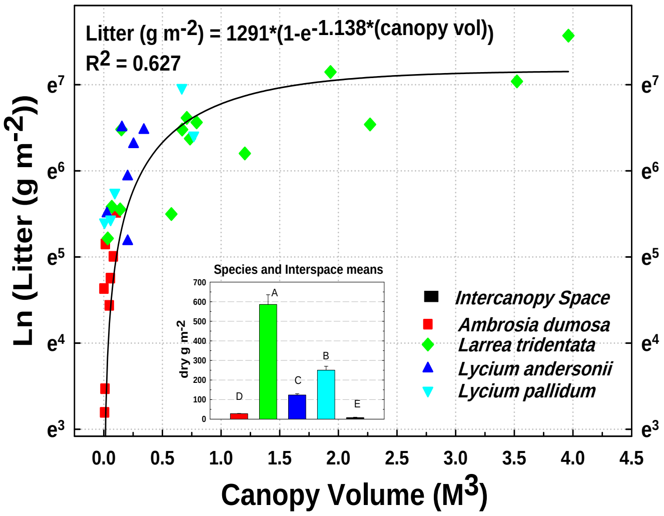

Figure 3. Litter layer biomass (g m-2 canopy area) beneath Mojave Desert shrubs as a function of whole shrub canopy volume.

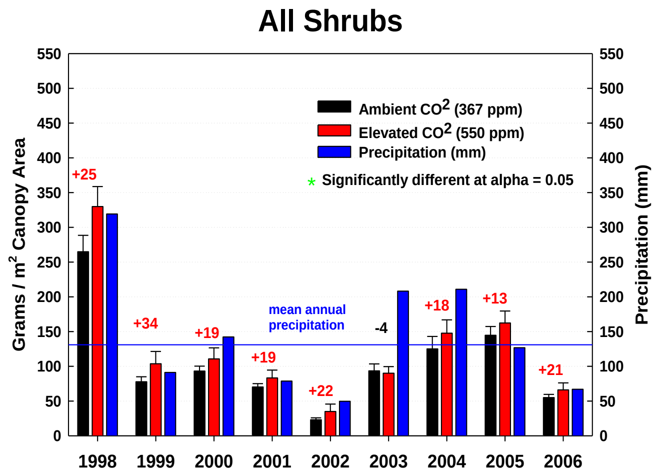

Figure 4. Influence of elevated CO_2 (550 µL/L) and rainfall on mean annual litter accumulation (g m^{-2}) beneath shrubs in an undisturbed Mojave Desert Ecosystem (mean ± 1 standard error).

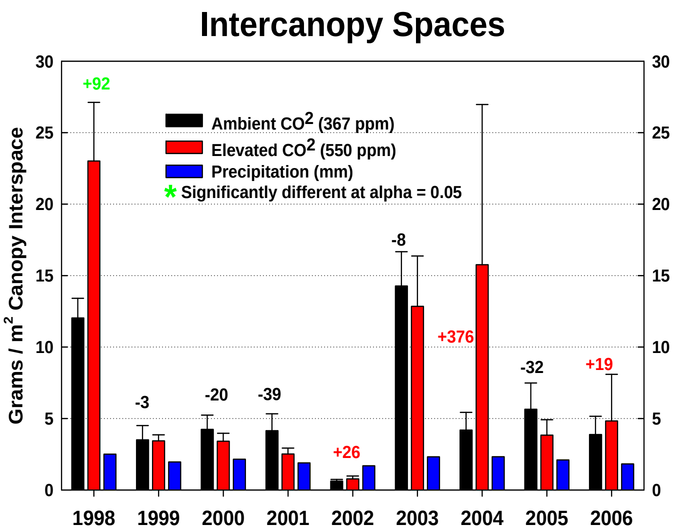

Figure 5. Influence of elevated CO_2 (550 µL/L) and rainfall on mean annual litter accumulation (g m^{-2}) in the intercanopy spaces.

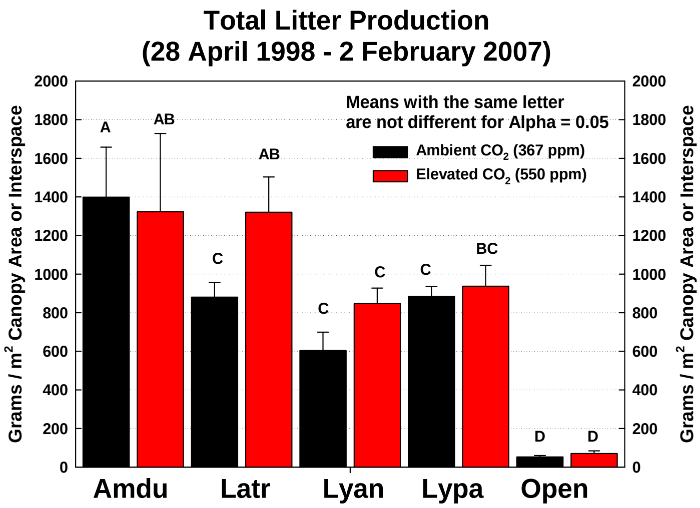

Figure 6. Cumulative impact of elevated CO_2 (550 µL/L) on litter accumulation (g m^{-2}) beneath four dominant shrubs in an undisturbed Mojave Desert.

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1.4. Multi-criteria analysis of some adaptation measures of on-farm irrigation system in Egypt

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Abstract

Agricultural community in Egypt is always seeking to find acceptable and efficient strategy to improver irrigation management at farm level, with the objective of maximizing crop yields per unit of water applied. Projected future rise in temperature under the climate change conditions is likely to reduce the productivity of major crops and increase their water requirement thereby decreasing the water use efficiency. Because of general rise in the potential evapo-transpiration, there will be increase in demand for irrigation water. The aim of this investigation was to evaluate some adaptation measures to overcome the projected impacts of climate change on the on-farm irrigation systems in Egypt. Improving irrigation system efficiency, changing irrigation systems and using deficit irrigation were the three adaptation measures evaluated by using multi-criteria approach for wheat, maize, tomato, and potato crops grown on old lands. Adaptation measures were studied under current climatic conditions and the climate change projections of IPCCC SRES for years 2025, 2050, and 2100 for their effects on the crop-water demand, crop yield, water use efficiency, irrigation-energy requirements and the abetment costs. Spatial analysis was considered in order to study the local variability of applying the evaluated adaptation measures. The study found that the vulnerability of the Egyptian agricultural regions and adaptation measures acceptable would vary depending on local conditions. Hence, the local variability will have to be factored in planning a national adaptation strategy.

Introduction

The overall objective of effective on–farm irrigation management is to maximize crop yield per unit of applied water (Buman et al. 1983). Projected future temperature rises under climate change conditions are likely to reduce the productivity of the major crops, and increase their water requirement thereby directly decreasing crop water use efficiency (Bazzaz and Sombroek 1996). On the other hand, there will be a general increase of potential evapotranspiration (Et_o), which will lead to increased irrigation demands. The Egyptian on-farm irrigation system is complex both on the supply side (water resources, irrigation systems) and demand side (crop pattern, cultivated area, ET_o). Abou Zeid (2002) stated that agriculture water-demand is one of the serious pressures to water sector. This is mainly due to the fact that (i) 85% of total available water is consumed in agriculture, (ii) 95% of the cultivated area is under fixed irrigation system, and (iii) most of the on-farm irrigation systems are low in efficiency coupled with poor irrigation management. Furthermore, the projected global warming and climate change is expected to add more pressures over the Egyptian on-farm irrigation system (Attaher et al. 2006). The high vulnerability of on-farm irrigation system in Egypt is attributed to low irrigation system efficacy and irrigation management patterns (Attaher et al. 2007). Under this situation, identifying adaptation strategies for on-farm irrigation system becomes a national priority. The term adaptation has been identified by IPCC (2001) as any adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. It involves adjustments to reduce the vulnerability of communities, regions, or activities to climatic change and variability.

The vulnerability of the on-farm irrigation in different agricultural regions and the acceptable adaptation measures vary according to the local conditions of each region (Attaher et al. 2007). Ornat and Morales (2002) stated that selection of adequate irrigation system is considered as a critical issue in agriculture water-use, and based on available water sources size and type, crop type, the society available technology and knowledge level, the existing infrastructure, and the devoted agricultural investment. Moreover, they asserted that using high-efficiency irrigation systems is one of the important adaptation options to reduce water used by agriculture, and switching from conventional irrigation systems to modern irrigation systems I's advisable strategies of the Mediterranean countries to improve water management.

The aim of this investigation was to evaluate some proposed adaptation measures to overcome the projected impacts of climate change on the on-farm irrigation system in Egypt.

Materials and methods

The study is focused on the agricultural system in the Nile valley and Delta region, which is characterized by heavy soil, traditional agriculture, surface irrigation system, poor management efficiency, small land holdings, low resource availability for investments, and several environmental pressures. The adaptation measure selected were those that most affected the vulnerability of on-farm irrigation system. Improvement in irrigation system efficiency, change in irrigation systems, and deficit irrigation were the adaptation measures evaluated by using a multi-criteria approach. The improvement of surface irrigation system efficiency from 50% to 75% was based on the affecting improvement in surface irrigation design, improving land leveling, and using control valves and gated pipes instead of traditional surface irrigation systems.

Current and future ET_o data sets of the Egyptian governorates were used to determine crop water demands from Attaher et al. (2006). Table 1 presents the average increase in Et_o based on air temperature changes implication of IPCC SRES scenarios using HadCM3 GCM climate model. The 'CropWat' program for Windows (Ver. 4.3) of FAO was used to calculate water requirements based on FAO modified Penman-Monteith methods (Smith 1992). The change in crop yield due to climate change was determined through crop model simulations by DSSAT (Decision Support System for Agrotechnology Transfer) Ver. 4.0. Table 2 presents the simulation models used. Historical data (average of 10 years) from 25 stations (EMA-CLAC-CAAE), and downscaled temperature data of A1 and B1 scenarios for 2025s, 2050s and 2100s (Attaher et al. 2006) were applied as weather inputs of DSSAT modeling. The other inputs of DSSAT were soil data for old land, calculated water requirements, and management operations (planting date , harvesting date, irrigation, fertilization, and residue management). The implications of IPCC's A1 and B1 scenarios for CO_2 concentrations were used to estimate the

Table 1. The average increase in Et_o under A1 and B1 IPCC SRES scenarios for 2025s, 2050s and 2100s under Attaher et al. (2006) study conditions

Years	The percent of ET_o Change (%) from the current	
	A1	B1
2025s	3.4	3.2
2050s	6.6	5.2
2100s	13.2	6.0

Table 2. Crop models used for the studied crops experiments of DSSAT

Crop	Model
Wheat	CERES-Wheat
Maize	CERES-Maize
Tomato	CROPGRO
Potato	SUBSTOR-Potato

Table 3. CO_2 concentration in ppm under current and future scenarios (A1 and B1) for 2025s, 2050s and 2100s

	Current	2025s	2050s	2100s
A1	370	433	542	732
B1	370	426	489	532

Table 4. Change in of extra labor cost dueto the change in irrigation system

Change in system	Extra-labor cost [per cent from total labor cost]
Traditional Surface to improved surface	75%
Traditional surface to sprinkler	200%
raditional surface to drip	100%

concentrations in the years 2025s, 2050s and 2100s (Table 3). Adaptation measures were studied under current conditions and climate change worst and best case scenarios for the years 2025s, 2050s and 2100s, and evaluated for the change in crop-water demands, crop-yield, field-WUE, energy requirements, energy applied efficiency (EAE) and cost. Energy requirements and EAE were determined according to Abdel-Aal (2000). Partial cost analysis was conducted according to Worth and Xin (1983).

'Abatement cost', which is the additional cost to the total normal production costs in order to reduce vulnerability of specific production system, was one of the criteria used in the economical evaluation of the studied adaptation options. Extra extension costs, labor costs and annual fixed costs were the components of the abatement costs. The base estimated value of each of these items referred to the current expenses of extension service, labor requirement for irrigation system, and prices of the initial items used for each irrigation system. The extra extension cost was 3% of total production cost. The change in labor cost due to the change in irrigation systems is given in Table 4.

Extra annual fixed cost was calculated as the difference between the fixed annual cost of current irrigation system and the new system that will replace the current one.The total annual cost for each scenario was the summation of the ordinary costs and the abatement costs.

The study focused on maize as a strategic field crop sensitive to irrigation application, and tomato and potato as the most important vegetable crops cultivated in both summer and winter seasons. The results of the adaptation analysis represent the overall average of the studied crops for each evaluation parameter. On-farm Irrigation Adaptation Index (OFIDI) was developed in order to present an integrated evaluation for the studied adaption measures based on multi-criteria interactions between water saving, crop yield, energy requirements and cost parameters. OFIDI was constructed, based on UNDP methodology of calculating Human Development Index (HDI) (UNDP 2007), as an aggregated dimensionless index from 0 to 1. Figure 1

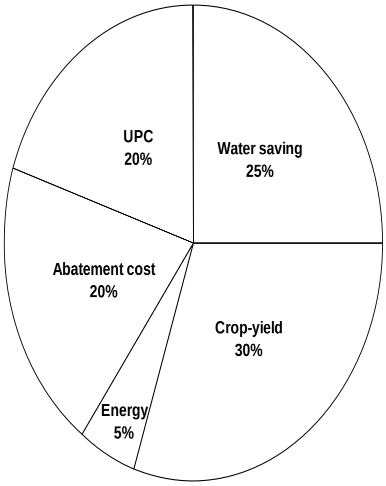

Figure 1. On-farm irrigation adaptation index [OFIDI] construction and weighting

Results and discussion

illustrates the OFIDI variables and the weights. Table 5 presents the simulated values of the overall average of evaluation parameters for the studied crops under the 'business as usual' situation of traditional surface irrigation system with 50% efficiency in old lands. The values of the evaluation parameters of total applied water, crop yield, field-WUE, total irrigation-energy, EAE, total irrigation cost, and irrigation-unit production cost, were used as the base for comparison with the other studied adaptation measures. The general trends of total applied water, irrigation energy requirements, irrigation cost and irrigation-unit production cost increased by temperature increase indicated under climate change scenarios. The observed increases in these parameters were coupled with general decrease in crop yield, field WUE and EAE.

The contribution of the adaptation measures in improving the current traditional system inside the time step

Table 6 summarizes the overall average of percents of change in the evaluation parameters between the traditional surface irrigation system ('business as usual') and the adaptation measures under current climate conditions. Under current climate conditions, switching to drip irrigation system had the best impact on improving crop yield, and it could be strongly recommended as an excellent adaptation measure, under the conditions of power and resource availability. Improving the surface irrigation efficiency from 50% to 75% had the second highest effect in improving crop yield, and the highest effect on field-WUE, irrigation-energy requirements and EAE. This measure requires abatement costs almost equal to those required for drip irrigation. On the other hand, switching from traditional surface irrigation system by sprinkler irrigation under traditional agriculture system in old land had the worst effect in all evaluated parameters, especially for energy economics. El Hessy and El Kady (1996) indicated that the sprinkler irrigation of light soils is somewhat more efficient than of heavy soils. Deficit irrigation measures were the best adaptation measures from the economical point of view. Moreover, these measures had a very good impact in saving water and energy with acceptable reduction incrop yield (Pereira 2000).

As illustrated in Figure 2, the effects of applying the *studied* adaptation measures in the old land under the different projections of climate change scenarios, were similar to that under current climate conditions, only the magnitude of the impact was changed according to the adaptation measure. Generally, the magnitude of impact under A1 scenario was higher than under B1 scenario for all the daptation measures.

The contribution of the adaptation measures in mitigating the impact of CC on on-farm irrigation system

Figure 3 shows the overall average impact of climate change under A1 and B1 scenarios, on crop-yield, field-WUE, irrigation energy, EAE and irrigation-unit production cost (UPC) under current traditional irrigation system ('business as usual') and the studied adaptation measures.

Table 5. The overall average of evaluation parameters for the maize, winter tomato, winter potato, summer tomatofdr and summer potato cultivated under business as usual situation of traditional surface irrigation system with 50% efficiency in old lands, for current and future climate conditions of climate change scenarios A1 and B1 of 2025s, 2050s and 2100s.

Evaluation parameter	Current	A1			B1		
		2025s	2050s	2100s	2025s	2050s	2100s
Total applied water [m^3/fed]	4454	4577	4713	5001	4567	4651	4696
Total crop-yield [kg/fed]	7322	6948	6117	5322	6991	6455	6291
Field-WUE [kg/m3]	2.0	1.9	1.6	1.4	1.9	1.7	1.7
Irrigation energy [kW·h/fed]	367	377	388	411	376	383	386
Energy Applied Efficiency (EAE) [kg/kW·h]	24.7	22.6	19.5	16.3	22.8	20.9	20.3
Total irrigation cost [LE/Fed]	789	876	965	1144	876	960	1119
Irrigation-unit production cost [LE/kg]	0.33	0.36	0.41	0.53	0.36	0.40	0.48

Table 6. The percent of change in evaluation parameters between the current system and the adaptation measures.

The percent of change [%]							
Adaptation measures	Applied water	Crop-yield	WUE	Energy	EAE	Abatement cost	UPC
I- Improve irrigation systems efficiencies							
Surface irrigation [50 to 75%]	-25	+4	+30	-50	+97	38	+161
II- changing irrigation systems							
Surface to Sprinkler	-13	-12	-4	142	-66	42	+755
Surface to Drip	-23	+8	+27	10	-11	39	447
III- Deficient irrigation.							
80 % from Etc	-20	-3	+21	-20	+21	3	-3
60 % from Etc	-40	-8	+20	-40	+52	3	-8

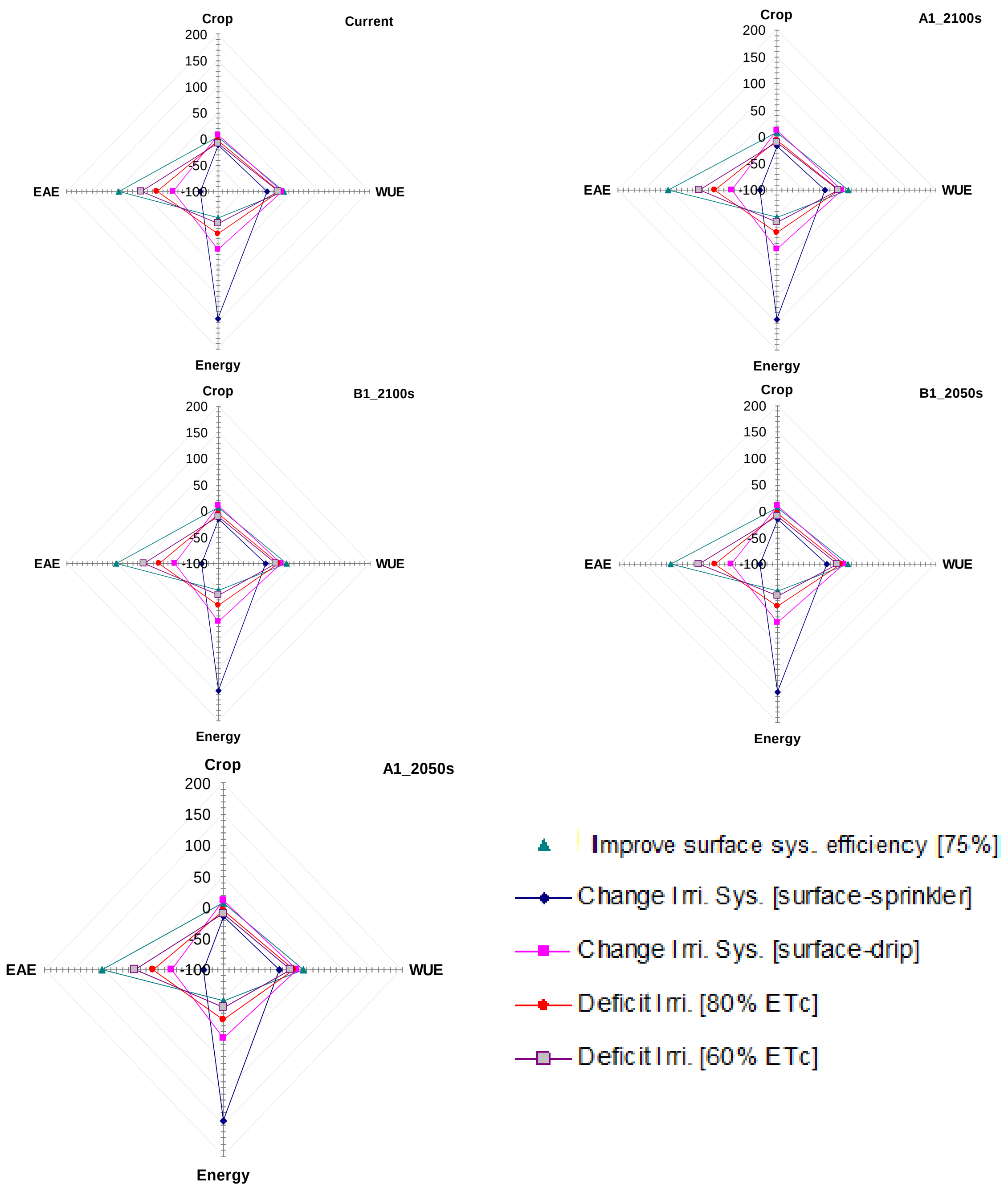

Figure 2. The difference [%] between the adaptation measures application and traditional surface systems application at current and future projected climate conditions in old lands (overall average of the studied crops).

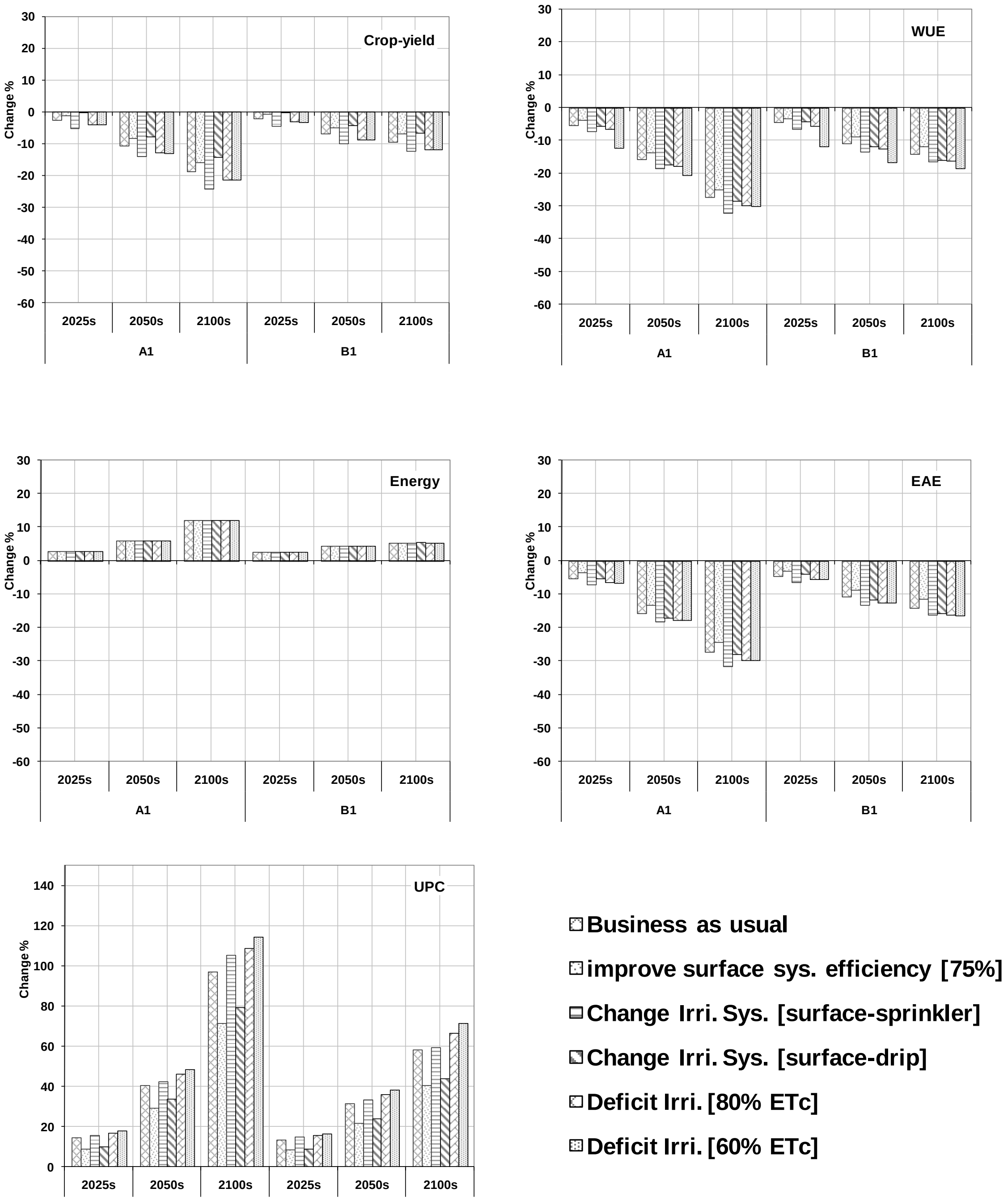

Figure 3. The impact of climate change under A1 and B1 scenarios, on crop-yield, water use efficiency (WUE), irrigation energy, energy application efficiency (EAE) and unit production cost (UPC) under current traditional irrigation system (Business as usual) and the studied adaptation measures (the overall average of the studied crops) .

There were no differences between the adaptation measures in irrigation energy requirements. The general trend revealed a remarkable positive effect of improving surface irrigation system efficiency from 50% to 75% on reducing the impact of climate change on all the parameters, except the change in crop yield. Switching to drip irrigation system had the highest positive effect in overcoming the harmful impact of climate change, and had the second positive effect for the rest of the evaluation parameters. Switching from the traditional surface irrigation to sprinkler irrigation system presented the highest contribution in intensifying the impact of climate change over the evaluation parameters for the studied crops. This unfavorable effect was also observed with applying deficit irrigation measures, but with lower intensity than sprinkler irrigation values. Under water sacristy conditions, in terms of Egyptian water resources fluctuation between +33% to -70% under projected climate change (Conway 2005), deficit irrigation will be a key answer for the agriculture sector. For all the adaptation measures applied, the difference between the values of the evaluation parameters under current and future conditions was higher under A1 scenario than under B1 scenario.

Evaluating the adaptation measures by OFIDI

OFIDI was developed in order to present an integrated evaluation for the studied adaption measures based on multi-criteria interactions between water saving, crop yield, energy requirements and cost parameters. From OFIDI values (Figure 4), deficit irrigation had the highest potential as the adaptation measure for traditional surface irrigation in old land. Whereas, switching to sprinkler irrigation system had the lowest potential. Improving surface irrigation efficiency and switching to drip irrigation resulted in the intermediate values between deficit irrigation measures and sprinkler irrigation measure.

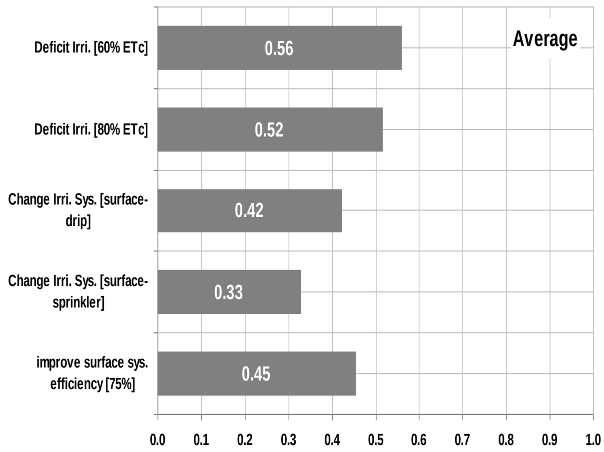

Figure 4. OFIDI values for the overall average of the studied crops

Conclusion

Table 7 summarizes the potential benefit of the studied adaptation measures for traditional surface irrigation system in old land in order to overcome climate change conditions. The salient points are:

- Improving surface irrigation efficiency had a higher potential to overcome the negative impacts of climate change on on-farm irrigation system in old land. However, this measure could be applicable when power and economical resources are available.
- Although the deficit irrigation measures had negative effects on overcoming the impacts of climate change on crop yield, these measures could be acceptable for the conditions where water saving is more important than crop yield reduction.
- Applying improved surface irrigation and deficit irrigation measures requires limited structural modifications in the engineering design of the system; it is therefore less costly.
- Power is going to be a critical issue under the projected changes in climate, even for agriculture sector; therefore low-power requirement irrigation systems would be better in the future.
- Using combination of different levels of improved surface irrigation system efficiencies and applying deficit irrigation could improve the capacity of

Table 7. The potentiality of the studied adaptation measures for traditional surface irrigation system in old land in order to overcome climate change conditions, regarding to water saving, productivity increase, power resources and economical resources factors.

Adaptation measure	Water shortage	Increase crop productivity	Enough power resources	Limited power resources	Enough economical resources	Limited economical resources
Improve surface irrigation system efficiency [50 to 75%]	++	+	+	++	+	++
Switching from Surface to Sprinkler	+	- -	+++	--	+++	--
Switching from Surface to Drip	++	++	++	-	++	-
Deficient irrigation	+++	-	+	+++	+	+++

surface irrigation system in old land to overcome the negative impacts of climate change.

- The current adaptation analysis did not consider the long term reliability of the adaptation measures, the socioeconomic capacity for accepting the adaption measures, political considerations, and limitations associated with other systems and sectors.

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1.5. Impact of climate and world market changes on wheat production in the Nile Valley and Sub-Saharan Africa region: the Egypt case study

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Abstract

Climate and world market changes regardless of their cause matter to people, businesses, communities and a country as a whole. Climate changes are likely to bring many changes to many nations in the Nile Valley and Sub-Saharan Africa region. Market changes have already added a substantial pressure on the majority of nations' economy in Africa. Africa as a whole is in need to work cooperatively and collaboratively to adapt to many of these changes, particularly to climate changes, but adaptation is often time and resource- consuming, not always possible or successful in a short term, and during the process of adaptation individuals, communities, and nation may have difficulties to bear. To minimize the negative impact, nations need to take a close look at how climate and market changes will affect each region from within or in relation to other agroecologically-connected basins. Thus this paper will attempt to answer two main questions: 1) How will Egyptian agriculture experience deal with the urgent need to increase its quality wheat production in light of projected climate changes? 2) How can Egypt respond to new world market changes?

Introduction

Climate and world market changes regardless of their cause matter to people, businesses, communities and a country as a whole. Climate changes are likely to bring many changes to many nations in the Nile Valley and Sub-Saharan Africa region. Market changes have already added a substantial pressure on the majority of nations' economy in Africa. Africa as a whole is in need to work cooperatively and collaboratively to adapt to many of these changes, particularly to climate changes, but adaptation is often time and resources consuming, not always possible or successful in a short term, and during the process of adaptation; individuals, communities, and nation may have difficulties to bear.

To minimize the negative impact, nations need to take a close look at how climate and market changes will affect each region from within or in relation to other agroecologically-connected basins. Thus this paper attempts to answer two main questions: How will Egypt agriculture experience deal with the urgent need to increase its quality wheat production in light of projected climate changes and how can Egypt respond to new world market changes?

For five thousand years, Egypt was a world leader in agriculture, with sophisticated irrigation systems and a diverse farming economy producing wheat, rice, cotton, fruits and other crops. Today it struggles to feed its population of about 80 million. This is because agriculture requires fertile land and adequate water supply, and Egypt has a limited quantity of both. Only 6% of the country's one million square kilometers is suitable for agriculture. The rest is mostly desert. Per capita water availability has currently reached to 700 cubic meters per year, one-fifth the global average which is already under the water scarcity threshold level. With rapid population growth it is predicted to go down the threshold value of 500 cubic meters per year per capita in the coming two decades or so.

Ensuring food security for the country will require additional improvement to agriculture productivity, a dramatic improvement in resource-use efficiency, more effective technology dissemination and stronger policy support. ICARDA and the Agricultural Research Center (ARC) of Egypt are working with policy makers and development agencies to address each of these issues, one of which is the wheat productivity and production.

The Agricultural Reform Program of Egypt initiated in 1987 was designed to help the government realize its main policy objectives in the agricultural sector. The reform included many important policy options, such as providing an adequate supply of food to all income groups; promoting greater self-sufficiency in crop production; and increasing farm income. In the first phase of the program the prices, quotas, and marketing controls were partially liberalized for 10 crops. Import subsidies were also reduced, and markets were opened to private investment.
Wheat is considered a strategic commodity in the country. It provides more than one-third of the daily caloric intake of Egyptian consumers and 45 percent of their total daily protein consumption Wheat is mainly consumed in the form of bread. It is also the major staple crop produced in Egypt, occupying about 32.6 percent of the total winter crop area. The new wheat varieties and improved agronomic practices coupled with market-driven reforms established in 1987 helped boost wheat cultivation, production, and marketing by the private industry. The wheat self-sufficiency ratio was increased from 21 percent in 1986 to 47 percent in 1996, to about 59 percent over the 2001-03 periods, to 60% in 2007. However, the country still imports 6-7 million tons of wheat per year or about 20 percent below the policy goal to reach 75 percent self-sufficiency in wheat.

To enable Egypt's wheat production reach the 75 percent goal, the government through the decision makers invited ICARDA in February 2008 to conduct an assessment study in relation to current production systems and to identify technical, social and economic constraints to increasing wheat production and suggest remedial measures including an outreach in agricultural research, extension, and market information, all of which contribute to higher productivity and production. An assessment study was therefore conducted by ICARDA in May 2008. The assessment (Rajaram 2008) identified the following potential five main climate change related drivers that impact agriculture in general, including wheat: temperature, precipitation, sea level rise (salinity of coastal areas), atmospheric carbon dioxide content and incidence of extreme events. These may affect wheat production in the following ways:

- Potential reduction in crop yields due to an increase in the temperature.
- Potential increase in pest attacks due to an increase in temperature and humidity would require new preventive measures.
- Limit the availability of water necessitating the development of water use efficient cultivars

- An increase in temperature is predicted to cause recurrent droughts in most of the regions and cause change in planting and harvesting calendars.
- An increase in temperature is likely to speed up soil moisture depletion rate, reduce temporal moisture storage capacity and the quality of the soil, which are vital for crops production.

Thus, Egypt's vulnerability to climate change requires enhancement in its ability to adapt to these changes to ensure sustainability of the agricultural production which is the main source of livelihood to about 70 percent of the population. Better understanding of the potential impact of the current and projected climate changes on Egypt agriculture and to identify ways and means to adapt and mitigate its detrimental impact is exceedingly vital to the country. In this regard, two questions are important: (a) How will Egypt agriculture experience deals with the urgent need to increase its quality wheat production in the context of the projected climate changes impacts? (b) How can Egypt respond to new world market changes?

The table below shows the planted area, productivity and production of wheat in Egypt from 1981 to 2007. It is clear that both area and productivity have shown a trend for increase, resulting in continuous rise in total production. While in 2007 Egypt produced about 7.4 million ton of wheat, its consumption reached about 14 million ton, making Egypt the second largest importer of wheat in the world.

The following are some of the obstacles for the country in reaching the production goal of the 75 percent self-sufficiency:

- Difficulty to increase the cultivated area of wheat in the Nile Valley and newly reclaimed areas from desert.
- Limitation of water recourses.
- Higher per capita wheat consumption (180 – 200 kg per year) compared to the world average (100 kg).
- Losses during production and post-harvesting processes reaching up to 30 percent.
- Climate change related drivers causing reduction in production (i.e. wheat diseases)

Table 1. Area, productivity and production of wheat in Egypt in last two decades

Year	Area (1000 ha)	Productivity (ton/ha)	Production (million ton)
1981	588	3.30	1.94
1986	507	3.81	1.93
1991	931	4.82	4.48
1996	1017	5.64	5.74
2001	984	6.35	6.26
2007	1134	6.5	7.40

The wheat assessment report covered the following eight main areas:

I. Institutional organization of national wheat
II. Wheat breeding
III. Crop protection
IV. Biotechnology
V. Wheat production system
VI. Maintenance and production of high quality seed
VII. Wheat research technology transfer Human resources development and infrastructure improvement

The study concluded that an increase in wheat productivity by 30 percent is achievable through:

a. wider dissemination of newly released cultivars with high yield potential and resistance to rust diseases;
b. minimizing the gap between potential yield and farmers' average by improved crop management;
c. developing improved resistance to biotic and abiotic stresses;

d. encourage farmers to use certified seeds of new wheat cultivars;
e. improve extension services; and
f. deploy new and appropriate available technology and enhance its adoption.

Conclusion

Egypt is still attempting to find technical, social, and policy options to address the need to increase its quality wheat production in the context of the projected climate changes impacts and global market changes. The recommendations in the assessment study have been seriously analyzed and debated to encourage feasible technical, financial, and policy changes to achieve the goal of providing an adequate supply of food to all income groups; promoting greater self-sufficiency in crop production; and increasing farm income, particularly of the the small-resource farmers.

Reference

Rajaram, S. 2008. Review of Egyptian National Wheat Program, April 22 - May 5, 2008. Available from the Nile Valley and Sub-Saharan Africa Program (NVSSAP), International Center for Agricultural Research in the Dry Areas (ICARDA) , 15 G Radwan Ibn El-Tabib Street , Giza, P. O. Box 2416, Cairo, Egypt.

Theme 2. Desertification processes and tools for assessment and their application

2.1. The ICARDA Agro-Climate Tool

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Abstract

A Visual Basic agro-climate application developed by climatologists at the International Center for Agricultural Research in the Dry Areas and the U.S. Department of Agriculture is described here. The database from which the application derives climate information consists of weather generator parameters derived from the station data of 649 meteorological stations. From those parameters the software calculates climate statistics calculated over arbitrarily defined periods within summer or winter growing seasons at user-selected latitude-longitude coordinates, The statistics reported include: crop evapotranspiration estimates derived from the FAO-56 single crop coefficient algorithm, probabilities of exceedance of both cumulative rainfall and growing degree days, the probability that minimum and maximum daily temperatures will exceed user-defined temperature thresholds, and the probability of heat stress, cold stress and dry periods of varying duration.

1. Introduction

The mandate area of the International Center for Agricultural Research in the Dry Areas (ICARDA) extends from northwest Africa to central Asia and is home to more than 755 million people (Fig. 1). The growing regions of those countries are climatically diverse (De Pauw 2000; Ryan et al. 2006; De Pauw 2007), but very little information about climate and abiotic plant stress is available to ICARDA plant breeders, agronomists, and hydrologists. The ICARDA Agro-Climate Tool, a Visual Basic application that can be run on Windows 98, 2000, XP, and Vista operating systems, was developed to address that need. A schematic screenshot of the application can be found in Figure 2.

This personal computer (PC) application's primary daily weather variables (daily minimum temperature, daily maximum temperature, precipitation) were generated by modified GEM6 (Hanson et al. 1994) weather generator code. Secondary variables (daily dew point temperature, short-wave surface radiation, net outgoing long-wave radiation and reference grass evapotranspiration) were derived from primary variables using algorithms drawn from the FAO's 'Guidelines for Computing Crop Water Requirements' (Allen et al. 1998), hereafter referred to as 'FAO-56'. Crop evapotranspiration (ET) values were then derived from the reference grass ET values using the FAO-56 single crop coefficient method.

2. Data

The application's climate statistics are derived from two data sets that provide daily records of minimum and maximum temperature and precipitation. The main data source is the Global Daily Summary Data (GLDS) set (National Climatic Data Center 1994), which provides data for ICARDA growing regions from 590 meteorological station locations. The period of record for the GLDS data set is October 1977 to December 1991. The secondary data source is the Global Daily Climatology Network data (GDCN; National Climatic Data Center 2002), which provides records of primary daily variables at 59 additional locations. Data from GDCN stations is of varying duration, but in some cases begins in the early 20th century. However, because the application's operation involves the averaging of weather generator parameters from different stations to derive parameters for locations between stations, it was decided that those parameters should be derived from data over a uniformly defined period. As a result, the decision was made to limit the calculation of statistics from GDCN data to the GLDS data period, i.e., from 1977 to 1991. Future versions of the application will attempt to expand data coverage to a longer data period.

3. Statistics calculation

3.1. Data sampling requirements and uncertainty

Although climate statistics are normally calculated over 30 year periods, over most ICARDA growing regions daily temperature and precipitation records of that length are not available. This lack of long-term daily station data, and the sparse nature of the data that was available over the ICARDA mandate region, was a primary limiting factor in the calculation of the application's climate statistics. Thus one of the leading development challenges involved deriving climatologically representative streams of stochastic weather variability from relatively short, and sometimes fragmentary, weather records. An additional challenge was to do this over a network of stations that was spatially representative of ICARDA growing regions. This challenge was met mainly through modifications to the original GEM6 code of Hanson et al. (1994) and by imposing minimum data sampling requirements. An additional strategy for addressing this problem requires the end-user to use the application in a way that acknowledges the possibility of the resulting sampling uncertainties.

Normally, the GEM6 code calculates weather statistics over 24 bi-weekly periods of the year. However, the limited daily data availability over many ICARDA agriculture areas, and the data sampling requirements imposed here, made bi-weekly averaging impractical. As a result, GEM6 weather generator parameters were derived from monthly statistics of precipitation, and minimum and maximum temperature. A complete daily data record during October 1977–December 1991 would result in approximately 14*30 = 420 daily weather measurements contributing to each month's precipitation and temperature statistics. But in ICARDA agricultural areas outside of the former Soviet Union gaps in daily weather records were frequent. To provide adequate station coverage over those areas while also calculating reasonably representative monthly statistics, a minimum sampling threshold of 60 days for monthly statistics was imposed. Thus for example, the mean daily maximum temperature for January at a station location might be based on as few as 60 daily temperature measurements. Deriving an average from such a relatively small number of measurements can lead to the following biases:

- ***Sampling error in the resulting statistic:*** The magnitude of sampling error is proportional to $N^{-1/2}$, where N is the

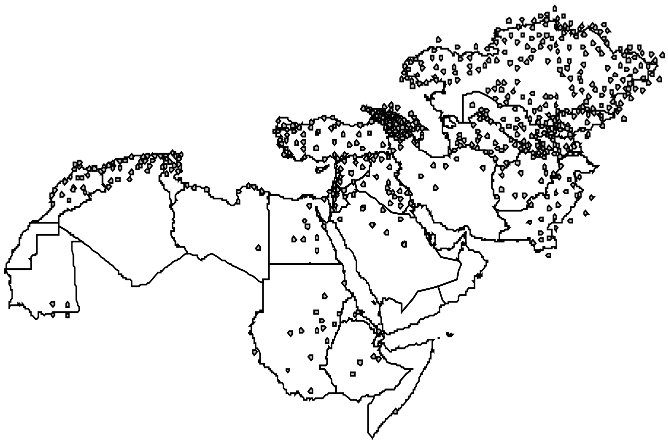


Figure 1. The ICARDA mandate region, with locations of the 649 meteorological stations used to provide data for the ICARDA Agro-Climate Tool.

number of measurements (Mendenhall et al. 1990). A sample mean calculated from N=60 measurements can lead to an error (i.e., the difference between the true, population mean and the mean calculated from a 60 day sample) as large as 0.26 * σ, where σ is the standard deviation of the population distribution. Errors for monthly rainfall transition probabilities (i.e., p00, p10 in Section 3.2), and daily temperature cross correlation values used in the GEM6 multivariate temperature generation scheme (i.e., Eq.s 12-15 in Hanson et al. 1994) may be of similar magnitude.

- ***Statistics representative of a limited subset of years during 1977-1991:*** Limiting the calculation of monthly statistics to 60 or more days makes it possible that those days may be, in the worst case, from two consecutive years, e.g. January 1979 and January 1980. Under those circumstances, the resulting statistics would not be representative of 1977-1991, and could differ considerably from nearby stations that reported more January data during the 1977-1991 period.

The method suggested here for identifying these possible errors is based on the assumption that they will most likely not be consistently evident at neighboring station locations. In operating the application the user selects a location by left-clicking that location on the large map in the applications's upper-left corner (Fig. 2a). The nearby stations whose Fourier parameters will be used to estimate the location's GEM6 parameter set will then flash in sequence. *In practice, the user should always compare the application's results for a location with the corresponding results for each of those nearby stations. The user should also compare each of the nearby station's results with one another*. For example, in the application's GUI display the annual cycles for the probability of heat and cold stress might be compared (Fig. 2f), as might the probability of exceedance curves for precipitation (Fig. 2t) and growing degree days (Fig. 2w). If these comparisons show one station's results to differ clearly from the remaining stations, that station's GEM6 parameters may have been derived from biased statistics. In that case the user should consider using results derived only from one of the remaining nearby stations.

3.2. Calculation of monthly statistics

The limitations of daily data over ICARDA agricultural regions also influenced the choice of statistics that were calculated from the data. The original GEM6 code calculates two sets of temperature statistics: the mean and standard deviation of maximum and minimum temperature during dry days, and the mean and standard deviation of maximum and minimum temperature during days with rain. However, dividing the temperature data by rainfall condition would have caused many stations to fail the minimum monthly sampling requirement described above, producing a sparse meteorological network. As a result, temperature statistics here were calculated over all days, both wet and dry. For each station, temperature variation throughout the year was described through. statistics that describe the mean and

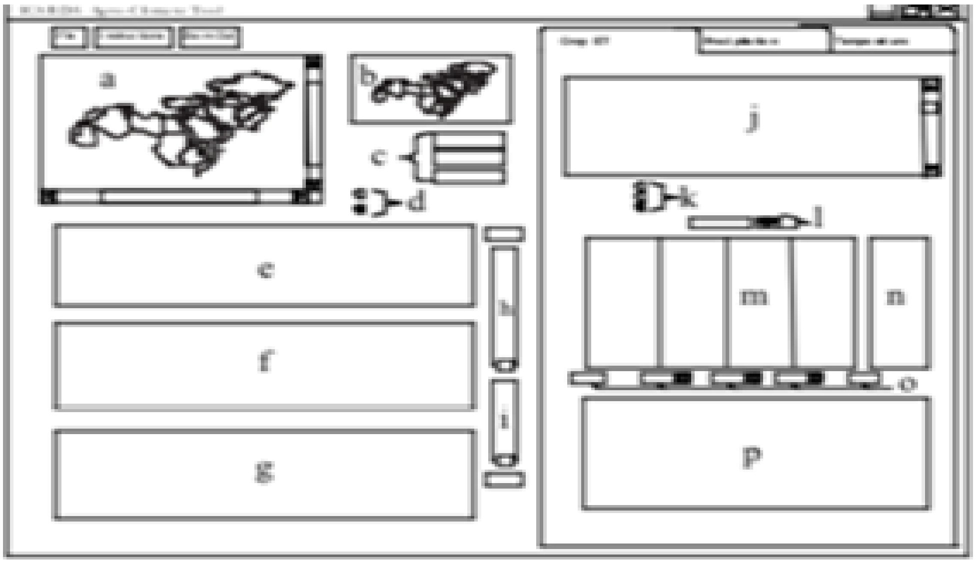
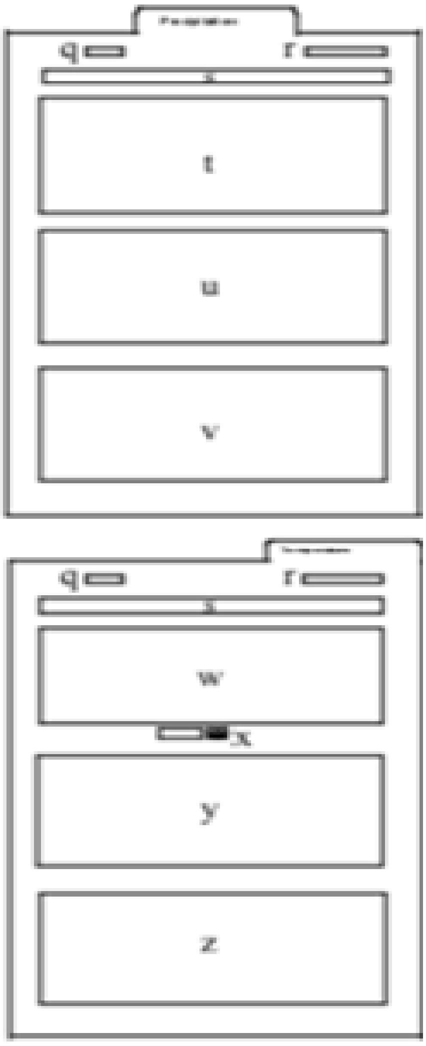


Figure 2 a) Location selection map. b) Pan view map. c) Longitude, latitude, elevation of selected location. d) Growing season display selector. e) Annual cycle of min. and max. temperature (T) for selected location. f) Probability of min. and max. T exceeding user defined heat stress and cold stress thresholds, and probability of rainfall. g) Annual cycle of mean rainfall on rainy days. h) Heat stress threshold (HST) slider control and display. i) Cold stress threshold (CST) slider control and display. j) Crop selection scroll list. k) Soil type selector. l) 2 metre wind speed spinner selector and display. m) Crop ET, precipitation, and irrigation demand distributions for four crop growth periods. n) Crop ET, precipitation, and irrigation demand distributions for entire growing season. o) Crop growth period date displays and spinner selectors. p) Probability of exceedance curve for Crop ET, precipitation, or irrigation distribution selected in (n) or (o). q) Day of Year cursor indicator for the (s) period selector control. r) Period selected by the (s) period selector control. s) Period selector control for precipitation or temperature tab. t) Probability of exceedance curve for cumulative precipitation for period indicated in (r) on precipitation tab. u) Probability that daily rainfall amounts will fall in one of five categories (< 5mm, 5-10 mm, 11-15 mm, 16-20 mm, 21-25 mm, > 25 mm). v) Probability of dry periods of varying lengths (< 3 days, 3-5 days, 6-8 days, 9-11 days, 12-14 days, > 14 days). w) Probability of exceedance curve for growing degree days (GDD) for period indicated in (r) on temperature tab. x) GDD temperature threshold spinner selector and display. y) Probability of heat stress periods of varying duration (< 3 days, 3-5 days, 6-8 days, 9-11 days, 12-14 days, > 14 days), for heat stress threshold defined by (h). z) Probability of cold stress periods of varying duration (< 3 days, 3-5 days, 6-8 days, 9-11 days, 12-14 days, > 14 days), for cold stress threshold defined by (i).



four sets of standard deviation of daily minimum and maximum temperature for each month of the year

The GEM6 weather generator uses multivariate regressive and autoregressive relationships to derive daily anomalies of maximum and minimum temperature (t_{max}, t_{min}) and short-wave surface radiation (s_{rad}) based on the current and previous day's anomaly values (Eqs. 12-15 Hanson et al. (1994)). The 3 X 3 'A' and 'B' matrices defining these regressive relationships are derived from cross correlation values calculated between t_{min}, t_{max}, and s_{rad} at 0 and 1 days lag. But because daily s_{rad} values are not available over the ICARDA mandate region, temperature generation here is based on 2 X 2 matrices that are derived from cross correlation values calculated only between daily t_{min} and t_{max} values. Daily shortwave surface radiation values were estimated via Hargreaves relationship (FAO 56 Eq. 50). Although GEM6 calculates 'A' and 'B' matrices for each month, the limited availability of daily data at many station locations made the calculation of daily correlation and cross-correlations on a monthly basis impractical. As a result, the application calculates only one 'A' and 'B' matrix per station, which are in turn derived from annual averages of t_{min} and t_{max} correlation and cross correlation values.

The probability that a day will be rainy in the GEM6 generation scheme depends on two sets of monthly statistics that describe the probability that a dry day will be followed by a dry day (p00) during each month, and the probability that a wet day will be followed by a dry day (p10) during each month. GEM6 code normally assigns the amount of rain that falls on a wet day using a mixed exponential distribution. However, here it was found that the three-parameter mixed exponential distribution did not perform noticeably better than a simple one-parameter exponential distribution. As the parameter for an exponential distribution is the expectation of the distribution's variable (Mendenhall (1990), the exponential parameter used here is the average of the daily rainfall totals, calculated for each month of the year.

4. GEM6 generation of primary synthetic variables

A flow chart tracing the generation of synthetic daily records of t_{min} ,t_{max} and precipitation can be found in Figure 3.

4.1. GEM6 Fourier parameter calculation and storage

The annual cycles of monthly temperature and precipitation statistics described in Section 3 are interpolated to daily variability in the application by solving for the first three annual Fourier harmonics of the monthly statistics, and then using those harmonics to reconstruct a smoothed version of the annual cycle through an inverse transform. The results of the Fourier transform are stored here in an Access™ database, which provides the primary inputs for the application's daily weather generation scheme. In addition the database stores information about each station's longitude, latitude, and elevation, and the elements of the 'A' and 'B' correlation and cross-correlation matrices.

4.2. Spatial interpolation of GEM6 parameters between stations

When the user selects a location by left-clicking on a pale yellow area of the large locator map (Fig. 2a), a number of nearby meteorological stations will flash in sequence. The VB6 code then calculates that location's GEM6 parameters as an inverse-distance weighted average of the Fourier parameter sets and the 'A' and 'B' matrix elements of those neighboring stations. Sets of nearest neighbor stations for ICARDA agricultural areas - the yellow shaded areas in the large locator map - are defined by a second Access database. That database table divides the yellow area into

792 1° longitude by 1° latitude grid areas. The neighboring stations for a 1° by 1° grid area are the stations that lie within a 3° longitude by 3° latitude grid that surrounds that central 1° by 1° grid.

Once the VB6 code determines which 1° by 1° grid contains the selected location, the Fourier parameter sets for the grid's neighboring stations are then retrieved from the application's primary GEM6 parameter database. The distances between the selected location and those stations are then calculated, and the stations are then sorted according to their distance from the selected location. If the nearest station is within 20 kilometers, then that station's parameters are assigned to the location. Otherwise, the location's parameters are calculated as a distance weighted average of the nearest neighboring stations using an expanding radius search algorithm. In some areas where station coverage is sparse (e.g., Sudan and Ethiopia) this algorithm could cause a location's parameters to, in the worst case, be averaged from the parameters of stations ~ 200 km away.

4.3. Maximum and minimum daily temperature generation

To account for the effects of elevation on a selected location's interpolated temperature variation, the Fourier parameters for the mean temperature of the selected neighboring stations are adjusted to sea-level before inverse-distance averaging. This adjustment assumes a mean wet adiabatic atmospheric lapse rate of – 6.5° ˚C/Km. The adjusted mean temperature parameters, and all the remaining amplitude and phase angle Fourier parameters for all the selected surrounding stations are then averaged using an inverse distance^2 averaging scheme. After all of the selected location's Fourier parameters have been estimated in this way, the location's mean maximum and minimum temperature parameters at sea level are then adjusted – in most cases decreased, as most stations are above sea-level – to the location's elevation as defined by the GTOPO30 digital elevation model.

After the entire Fourier parameter set for the selected location has been spatially interpolated, the location's annual cycles of the mean and standard deviations of daily maximum temperature and of the mean and standard deviations of daily minimum temperature are then constructed through an inverse Fourier transform. The annual cycles of mean daily maximum and minimum temperature are used to depict the location's annual temperature variation in the top graph of the Three-Pane display on the application's left side (Fig. 2e). The four annual mean and standard deviation annual cycles, and the location's spatially interpolated 'A' and 'B' matrices, are then used to generate stochastic streams of daily maximum and minimum temperature. These streams are stored as 100 years of synthetic temperature variation in two 100 X 365 arrays.

4.4. Daily precipitation generation

A selected location's precipitation Fourier parameters are estimated using the same inverse distance weighting method used to interpolate temperature parameters. The resulting parameters for the location are then inverse transformed into three annual cycles: the annual cycle of p00, the annual cycle of p10, and the annual cycle of the exponential rainfall distribution parameter (XMU). The annual cycle of the probability that rain falls on a given day of the year is derived from the p00 and p10 probabilities via Eq. 4 of Hanson et al. (1994).

$$P(day\ n\ is\ wet) = \frac{1 - p00(n)}{1 + p10(n) - p00(n)}, \quad \text{n=1,365} \qquad (4)$$

These probabilities for each day of the year are used to graph the location's annual cycle for daily rainfall probability in the middle graph of the Three-Pane display on the application's left side (Fig. 2f). Because the exponential rainfall distribution parameter is

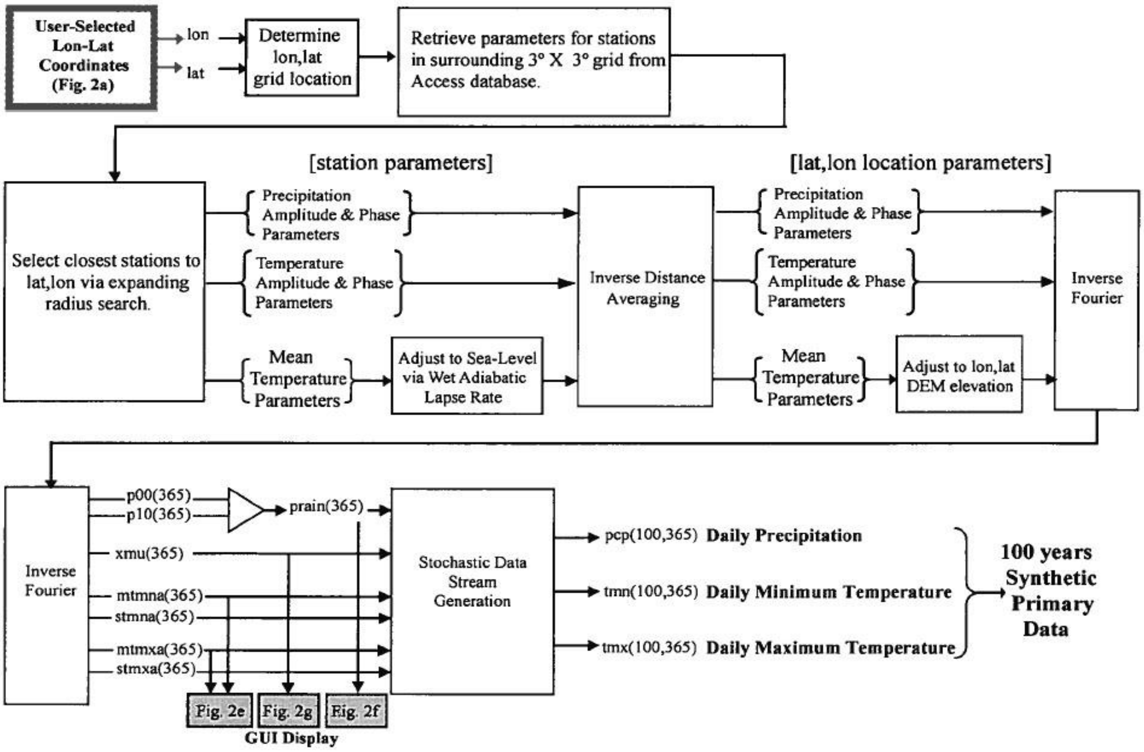


Figure 3. Flow chart of the generation of synthetic records of daily minimum and maximum temperature and rainfall at a user-selected latitude and longitude. Grey outlined elements indicate a user control, and grey shaded elements indicate a display marked in Figure 2.

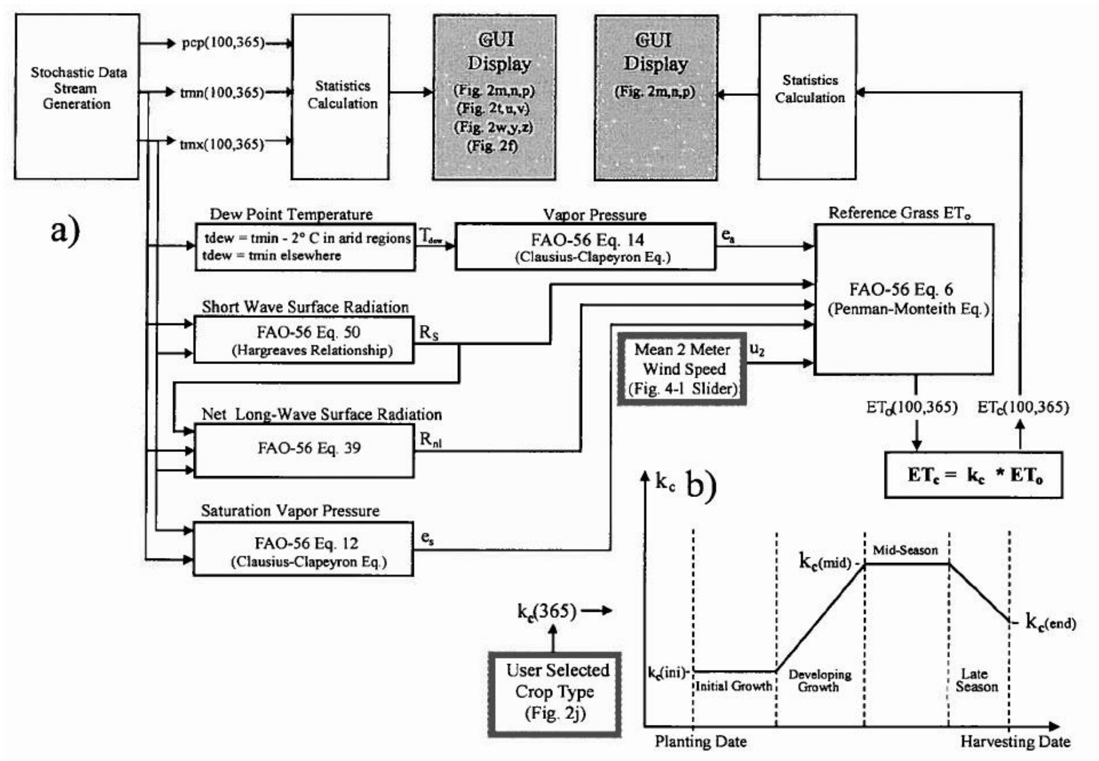


Figure 4. a) Flow chart of the generation of daily secondary weather and crop evapotranspiration variables. Grey outlined elements indicate a user control, and grey shaded elements indicate a display marked in Figure 2. b) Growing season coefficient profile for the FAO-56 single coefficient crop evapotranspiration method.

equal to the average rainfall amount on wet days, the XMU annual cycle is used to graph the average rainfall amount on wet days in the bottom graph of the Three-Pane display (Fig. 2g). The annual cycles of XMU and daily rainfall probability are both used to generate 100 years of synthetic precipitation data which is stored in a 100 X 365 array.

5. Generation of secondary weather variables

Secondary daily meteorological variables were derived here using parameterization relationships drawn from FAO-56 (Allen et al. 1998). For reference to the generation of those variables, see the Fig. 4a flow chart.

5.1. Dew point temperature

Daily dew point temperatures were estimated from daily minimum temperatures using the following parameterization scheme (FAO-56 Eq. 6-6):

$T_{dew} = T_{min} - 2°C$ for locations in arid areas,
$T_{dew} = T_{min}$ elsewhere (5)

Arid locations were defined here as stations with a mean annual temperature of 18 °C or greater, and a mean annual number of wet days of 55 or less.

5.2. Shortwave radiation at the surface

Daily integrated shortwave surface radiation (R_S) was estimated using the Hargreaves radiation formula (FAO-56 Eq. 50):

$$R_S = k_{Rs} \sqrt{T_{max} - T_{min}}\ R_a \quad (6)$$

where,

- k_{Rs} is an adjustment coefficient, assigned here as 0.175 $°C^{-0.5}$,
- T_{min} is daily minimum temperature (˚C),
- T_{max} is daily maximum temperature (˚C), and,
- R_a is the daily integrated shortwave radiation at the top of the atmosphere in units of Joules * 10^6 / (met.^{2} * day) (FAO-56 Eq. 21).

5.3. Vapor pressure and saturation vapor pressure

Given daily minimum, maximum, and dew point temperatures, the vapor pressure and saturation vapor pressure are solved for using the Clausius-Clapeyron equation

($e^o(T)$: FAO-56 Eq. 11).

Actual vapor pressure = $e_a = e^o(T_{dew})$, (7)

Saturation vapor pressure = $e_s = 0.5 * (e^o(T_{max}) + e^o(T_{min}))$ (8)

5.4. Net upwelling outgoing long-wave radiation (OLR) at the surface

Net upwelling surface OLR was estimated using FAO-56 Eq. 39:

$$R_{nl} = \sigma\left[\frac{T_{max}^4 + T_{min}^4}{2}\right]\left(0.34 - 0.14\sqrt{e_a}\right)\left(1.35\frac{R_S}{R_{SO}} - 0.35\right) \quad (9)$$

where,

- σ is the Stefan-Boltzmann constant,
- Tmin is daily minimum temperature in Kelvin,
- Tmax is daily maximum temperature in Kelvin,
- RS is the estimated daily shortwave radiation at the surface (Eq. 6)
- RSO is the estimated clear sky daily shortwave radiation at the surface (FAO-56 Eq. 37), and,
- ea is the actual vapor pressure (Eq. 7).

5.5. Reference grass evapotranspiration

The FAO-56 method for deriving evapotranspiration rates for various crops is based on the estimation of reference evapotranspiration rates over a hypothetical grass surface (FAO-56 Chapter 4). Daily reference grass ET rates are calculated using the FAO-56 Penman-Monteith equation (FAO-56 Eq. 6).

$$ET_O = \frac{0.408\Delta\left((1-\alpha)R_S - R_{nl} - G\right) + \gamma\frac{900}{T}u_2(e_S - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (10)$$

where,

- Δ is the slope of the saturation vapor pressure at the mean daily temperature (FAO-56 Eq. 3-3),
- α is the albedo of the hypothetical grass surface (=.23),

- RS is the shortwave solar radiation at the Earth's surface (Eq. 6),
- Rnl is the net upwelling outgoing long-wave radiation (OLR) at the surface (Eq. 9),
- G is the soil heat flux density (FAO-56 Eq. 5-2, with an assumed Leaf Area Index of 2.8),
- γ is the Psychometric constant (FAO-56 Eq. 8),
- T is the daily mean (i.e., 0.5(Tmax +Tmin))temperature in Kelvin,
- u2 is the mean wind speed at 2 meters, set in the application via a slider control on the Crop ET tab (Fig. 2l),
- ea is the actual vapor pressure (Eq.7) , and,
- es is the saturation vapor pressure (Eq. 8).

5.6. Crop evapotranspiration

The application derives crop evapotranspiration rates over arbitrarily defined periods for a number of crops listed in the selection box at the top of the 'Crop ET' Tab (Fig. 2j). These crop ET rates (ET_c) are derived from a location's derived reference grass ET rates (ET_o) using the FAO-56 single crop coefficient method (FAO-56 Eq. 58).

$$ET_C = k_C \ ET_O \qquad (11)$$

Over the growing season crop ET is derived from the reference grass rates using k_c values drawn from a growing season coefficient profile (Fig. 4b). That coefficient profile is in turn derived from three k_c values defined during an initial crop growth period, a mid-season period, and an end of season value.

6. Downloading, operating requirements and instructions

The ICARDA Agro-Climate Tool can be downloaded at: (http://www.lbk.ars.usda.gov/WEWC/icarda.aspx).

The application should be installed on a Windows PC with a Pentium III or better microprocessor and at least 230 Mbytes of available hard disk space. Monitor screen resolution should be at least 1024 X 768 pixels but no more than 1920 X 1440 pixels. The bright yellow text on the graphical user interface provides basic operating instructions. To access help for a specific control or graph, left mouse click on that object and hit 'F1'. More detailed instructions for the application's use can be found by left single-clicking on 'Instructions' on the application's upper left corner.

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2.2. Agroecological zoning of the CWANA region

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Abstract

The CWANA region constitutes the largest contiguous area of drylands in the world. Often overlooked is the fact that, within its overall dryland context, this region, the current focal area of ICARDA's research, also has a very high diversity in agro-ecologies and agricultural systems. This diversity has made it very difficult for many farmers to adopt the new techniques and crops that have been developed for drylands 'in general'. Already in the early days of ICARDA it was realized that in order to make headway with the 'outscaling' challenge at the level of the CWANA region, there was a need for an integrated approach using an 'agroecological zones' (AEZ) spatial framework. At the level of the CWANA region, the main use of an AEZ framework is as a tool for rapid identification of different biophysical environments and characterization of resources and constraints to assist agricultural research planning and policy development. For this a map was created of the agroecological zones of the CWANA region at 1-km resolution using a 6-step procedure and a total of 677 AEZ have been identified. The AEZ framework and 6-step procedure can be applied, using appropriate datasets, at a wide range of scales, from the global to the watershed. The four essential themes for the definition of the AEZ are climate, land use/land cover, terrain and soils. The CWANA AEZ methodology has, at national level, been taken up in Turkey, and in Iran at sub-national level in the Karkhe, Aras and Daryacheh-Uromieh River Basins.

Introduction

The International Center for Agricultural Research in the Dry Areas (ICARDA) deals with germplasm enhancement and natural resource management issues, including land degradation in drylands. Its current mandate region includes North Africa, West Asia, Central and South Asia, and the Horn of Africa (Fig.1, area in grey). For convenience this area is abbreviated as CWANA (= Central Asia + West Asia + North Africa).

The CWANA region, covering a total land area of 22.4 million km^2, constitutes the largest contiguous area of drylands in the world. Often overlooked is the fact that, within its overall dryland context, this region also has a very high diversity in agro-ecologies and agricultural systems. Climate is the first determinant of agro-ecological diversity. Using the UNESCO classification system for Arid Zones (UNESCO 1979), by the simple combination of major aridity and temperature regimes, 65 different agro-climatic zones can be differentiated in CWANA (see section on methodology). Further subdivision is possible, based on the distribution of precipitation in relation to the inter-annual temperature pattern. Within this highly heterogeneous climatic setting, more diversity in biophysical environments is created by differences in landscapes, soils, geological substrata, and surface water and groundwater resources.

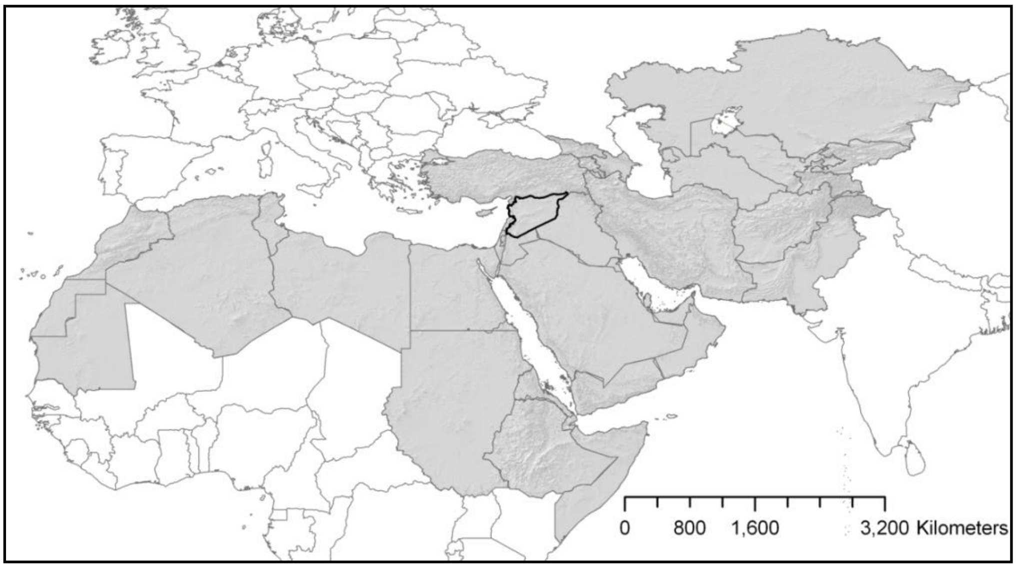

Figure 1. CWANA region (grey with hillshading); Syria in thick black line.

Irrigation development is the single most important factor in creating artificial agro-ecological niches, areas where natural conditions and production systems show abrupt differences with their surroundings. Ignoring the complex nature of such diverse agricultural environments has been one of the main reasons why it has been remarkably difficult to transfer research results or lessons-learnt, whether they concern biodiversity management, crop production intensification or diversification, land use optimization or combating land degradation, from one dryland area to another.

Already in the early days of ICARDA it was realized that in order to make headway with the 'outscaling' challenge at the level of the CWANA region, there was a need for an integrated approach using an agroecological zones (AEZ) framework. There is nothing new about the AEZ concept. Agro-ecological zones have been used in different regions or countries, and at different scales, for a variety of agricultural purposes, including the identification of agricultural production zones, fertilizer use recommendations, rationalizing the location of research stations, targeting of new technologies and crop cultivars, and regional comparative advantage and crop subsidy planning. On the other hand, the term 'agroecological zones' has no uniform meaning in the literature and covers, depending on the source, a different content. For example, the Food and Agriculture Organization of the United Nations (FAO), followed later by the International Institute for Applied Systems Analysis (IIASA), has a 25-year legacy of studies based on a concept of 'agroecological zones' as spatial entities that delineate areas with different production potential (or 'suitability') for specific crops (e.g. FAO 1978; Fischer et al. 2000).

In this paper the term 'agroecological zones' is used in a broader meaning of *integrated* and more or less homogeneous spatial units in which different conditions of available water resources, climate, terrain, and soils create *unique* environments, that are likely to be associated with distinct farming systems and land-use and settlement patterns. This concept of agroecological zones is probably more closely aligned with the needs of agricultural planners for clear information on the SWOTs (strengths, weaknesses, opportunities and threats) of geographically well defined areas.

The use of the spatial concept of 'agroecological zone' is advocated as a support tool for agricultural planning. By integrating the key components of the agricultural environments, an agroecological zones map (AEZ map) offers a bird-eye view of internal diversity, agricultural potential and constraints that decision-makers find easier to understand than a stack of single-theme maps.

Whereas in the past the manual integration of spatial data from different disciplines was problematic, GIS technology makes this operation now perfectly practicable. Collaborative research between ICARDA and different national agricultural research systems, particularly in Iran, Morocco, Syria and Turkey, has confirmed the feasibility of rapidly defining agroecological zones by the combination of climatic, land use/land cover, terrain, soil and other data using GIS procedures.

In this paper the case study of the CWANA region is presented to illustrate the general methodology. In addition, the value of this spatial information for agricultural planning is discussed. At the level of the CWANA region, the main use of an AEZ framework is as a tool for rapid identification of different biophysical environments and characterization of resources and constraints to assist agricultural research planning and policy development. For this purpose a map was created of the agroecological zones of the CWANA region at 1-km resolution, using a 6-step procedure as outlined in the following section.

Methodology

Overview:The AEZ map for the CWANA region was made by overlaying of single raster themes related to climate, land use, terrain and soils. Four specific layers were considered adequate in order to generate the AEZ map: (i) agroclimatic zones, (ii) land use/land cover, (iii) landforms, and (iv) soil management domains. The themes used for overlaying are *simplifications* of more complex thematic classifications. Simplification was necessary in order to avoid replication of the single-theme maps and unnecessary complexity for the purpose of the AEZ map.

The agroecological zones were generated by the following 6-step procedure:

- Converting point climatic data into basic climatic 'surfaces' through spatial interpolation;
- Generating a spatial framework of agroclimatic zones (ACZ) by combining the basic climatic surfaces into more integrated variables that provide a synthesis of climate conditions;
- Generating a spatial framework of land systems, which are land-based mapping units, created by the combinations of major land use/land cover, landscape and soil categories;
- Integrating the frameworks for agroclimatic zones and land systems by overlaying in GIS;
- Removing redundancies, inconsistencies, and spurious mapping units generated by the overlaying process;
- Characterizing the AEZ in terms of other relevant themes.

Converting point climatic data into basic climatic 'surfaces': A climatic database containing monthly precipitation and temperature averages for more than 1900 stations in the CWANA region was compiled. The main sources of climatic data were the FAOCLIM database (FAO 2001), and national meteorological datasets from the Central Asian and Caucasus countries and Iran. Potential evapotranspiration (PET) estimates according to the Penman-Monteith method (Allen et al. 1998) were obtained through a two-step disaggregated regression with temperature. This consisted of calculating first the PET (PET-H) according to the temperature-based Hargreaves method (Choisnel et al. 1992), followed by conversion of the PET-H values into Penman-Monteith PET (PET-PM) estimates, using regressions between PET-H and known PET-PM values for different climatic zones in accordance with the Köppen classification (Köppen and Geiger 1928).

This point database was then converted into raster layers with 30 arc-second spatial resolution (corresponding with roughly 1 km pixel size), by spatial interpolation using the ‘thin-plate smoothing spline’ method of Hutchinson (1995), as implemented in the ANUSPLIN software (Hutchinson 2000), and elevation data obtained from the GTOPO30 global digital elevation model (Gesch et al. 1996) as a co-variable. The Hutchinson method is a smoothing interpolation technique in which the degree of smoothness of the fitted function is determined automatically from the data by minimizing a measure of the predictive error of the fitted surface, as given by the generalized cross-validation (GCV).

Generating a spatial framework of agroclimatic zones: The monthly ‘climate surfaces’ of precipitation, temperature and PET were integrated into classes of the UNESCO classification for Arid Zones (using the criteria aridity index, summer temperature and winter temperature) and the class limits of this climatic classification. The classes are shown in Tables 1 to 3.

In this classification system the moisture regime is determined by the ratio of annual

Table 1. Classes for the moisture regime

Moisture regime	Hyper-arid (HA)	Arid (A)	Semi-arid (SA)	Sub-humid (SH)	Humid (H)	Per-humid (PH)
Aridity index	<0.03	0.03-0.2	0.2-0.5	0.5-0.75	0.75-1	>1

Table 2. Classes for the winter type

Winter type	Warm (W)	Mild (M)	Cool (C)	Cold (K)
Mean temp. coldest month	> 20°C	> 10°C	> 0°C	≤ 0°C

Table 3. Classes for the summer type

Summer type	Very warm (VW)	Warm (W)	Mild (M)	Cool (C)
Mean temp. warmest month	> 30°C	> 20°C	> 10°C	≤ 10°C

Table 4. New agroclimatic groups after simplifying the UNESCO climate classes

New zones	UNESCO zones	Description
1	HA-W-VW, HA-W-W, HA-M-VW, HA-M-W, HA-C-VW, HA-C-W, HA-K-W, HA-K-M	Hyper-arid climates with mostly warm or very warm summers and warm or mild winters; the overwhelming constraint is lack of moisture
2	A-W-VW, A-W-W, A-M-VW, A-M-W, A-M-M	Arid climates with mild or warm winters and warm or very warm summers; winter coldness is not an ecological constraint
3	A-C-VW, A-C-W, A-C-M, A-K-VW, A-K-W, A-K-M, A-K-C	Arid climates with cool or cold winters and warm or very warm summers; winter coldness is an ecological constraint
4	SA-W-VW, SA-W-W, SA-M-VW, SA-M-W, SA-M-M	Semi-arid climates with mild or warm winters and warm or very warm summers; winter coldness is not an ecological constraint
5	SA-C-VW, SA-C-W, SA-K-W	Semi-arid climates with cool or cold winters and mostly warm summers; winter coldness is an ecological constraint
6	SA-C-M, SA-K-M, SA-K-C, SH-K-C	Mostly semi-arid climates with mostly cold winters and mild summers; winter coldness is an ecological constraint as well as short thermal growing periods
7	SH-W-VW, SH-W-W, SH-M-VW, SH-M-W, SH-M-M	Sub-humid climates with mild or warm winters and mostly warm or very warm summers; winter coldness is not an ecological constraint
8	SH-C-VW, SH-C-W, SH-C-M, SH-K-W, SH-K-M	Sub-humid climates with cool or cold winters and mild or warm summers; winter coldness is an ecological constraint
9	H-W-W, H-M-VW, H-M-W, H-M-M	Humid climates with mild or warm winters and mild or warm summers; winter coldness is not an ecological constraint
10	H-C-VW, H-C-W, H-C-M, H-K-W, H-K-M	Humid climates with cool or cold winters and mild or warm summers; winter coldness is an ecological constraint
11	H-K-C, PH-K-C	Humid or per-humid climates with cold winters and cool summers; winter coldness is an ecological constraint as well as short thermal growing periods
12	PH-W-W, PH-M-W, PH-M-M	Per-humid climates with mild or warm winters and summers
13	PH-C-VW, PH-C-W, PH-C-M, PH-C-C, PH-K-W, PH-K-M	Per-humid climates with cool or cold winters and mostly mild or warm summers
14	SA-K-K, SH-K-K, H-K-K, PH-K-K	Glacial climates (mean temperature of the warmest month ≤ 0°C)

Table 5. Old and new land use/land cover classes

Old class (Celis et al. 2007)	New land use class
High-density/high yield dry-season irrigated field crops	Irrigated crops
Other dry-season irrigated field crops	
High density/high yield rainfed/wet season supplementary irrigated field crops; dry-season uncultivated	Rainfed crops
Other rainfed field crops or wet- season supplementary irrigated field crops; dry-season uncultivated	
Open shrublands/grasslands	Non-agricultural land use
High density/evergreen forests/ tree crops/ closed shrublands	
Other forests/ tree crops/ closed shrublands	
High density/evergreen woodland savannah	
Other woodland savannah	
Inland water	
Barren/sparsely vegetated	
Urban/built-up areas	

Table 6. Relief intensity and landform

Relief intensity	New landform
0-50 m	Plains and plateaux
50-300 m	Hills
>300 m	Mountains

rainfall over annual potential evapotranspiration (also referred to as *aridity index*), calculated according to the Penman method. It is therefore particular to this system that in the definition of the moisture regime not only the water supply (precipitation) is considered, but also the water demand (evapotranspiration). Different classes may thus result from different values of the two terms (Table 1). The moisture regime *Per-humid* (aridity index >1) has not been defined in the original system, but has been added here in order to provide a better differentiation within the more humid zones. The *winter type* is determined by the mean temperature of the coldest month (Table 2). The *summer type* is determined by the mean temperature of the warmest month (Table 3).

The UNESCO system thus allows a rapid characterization of a particular climate by the three attributes, moisture regime, winter type and summer type. For example, the climate *SA-C-VW* is characterized by a semi-arid moisture regime, a cool winter type and very warm summer type. Despite its apparent simplicity and its wide class limits, the system has a surprising differentiating power, resulting globally into 78 possible climates (after adding the *per-humid* class), of which 65 occur in CWANA. For the purpose of the agroecological zoning, these UNESCO climatic classes were simplified into 14 climate groups, as shown in Table

Generating a spatial framework of land systems:

To generate a framework of land systems, based on the integration of land use/land cover, terrain and soil patterns, required a more complex approach than for the agroclimatic zones. First of all there was a need for a regional or global land use/land cover classification at the same spatial resolution as the agroclimatic zones framework. In view of its good accuracy, the CWANA land cover/land use map for the year 1993 (Celis et al. 2007) was selected for this purpose. The twelve-class system of the map was reclassified into three categories, (i) irrigated crops, (ii) rainfed crops, and (iii) non-agricultural land use (Table 5).

The second step in generating the land systems framework was to create a simple classification of landforms, based on the reclassification of the global digital elevation model GTOPO30 into three terrain classes based on the maximum difference in elevation between neighbouring pixels: (i) plains and plateaus, (ii) hills, and (iii) mountains. Table 6 indicates the relationship between the new landform categories and the elevation differences (or relief intensity) between neighbouring pixels.

Soil patterns can vary significantly over small distances and were, unsurprisingly, the most difficult to integrate into a land systems framework at regional scale. Using the FAO Soil Map of the World (FAO 1995) as data source, it was found that within CWANA 1047 soil associations occur, as determined by varying combinations of 112 FAO soil types. Reducing this vast variability by regrouping was necessary in order to establish ecosystems that were not over-fragmented. This simplification was done in two steps: 1) regrouping the FAO soil types into *broader classes that are relevant to their* general management properties ('soil management groups'), and 2) mapping the major combinations of these soil management groups ('soil management domains'). The 26 FAO soil units were reduced to 9 soil management groups as indicated in Table 7.

Table 7. Conversion of FAO soil types into new soil management groups

FAO soil association	SMD no.	Soil Management Group % 1	% 2	% 3	% 4	% 5	% 6	% 7	% 8	% 9
Af14-3c	90	20	0	0	0	20	0	0	0	60
Bk16-2b	10	70	0	0	0	0	0	0	30	0
I-Rd	58	0	0	0	0	50	0	0	50	0
Jc14-2a	20	40	60	0	0	0	0	0	0	0
Lo40-ab	10	100	0	0	0	0	0	0	0	0
Qc21-1a	38	10	10	50	10	0	0	0	20	0
Vc13-3a	10	100	0	0	0	0	0	0	0	0
Xh43-2/3a	67	0	0	0	10	0	50	40	0	0
Yh15-1a	70	0	0	0	0	0	0	80	20	0
Zt1	40	0	0	0	100	0	0	0	0	0

Table 8. Examples of reclassification of FAO soil associations into soil management domains

AEZ code	0-1 day	1-30 days	30-60 days	60-90 days	90-120 days	120-150 days	150-180 days	180-210 days
13100	58	42	0	0	0	0	0	0
13170	45	55	0	0	0	0	0	0
33100	0	18	10	16	21	22	13	0
23170	57	43	0	0	0	0	0	0
23100	67	33	0	0	0	0	0	0
33170	0	48	12	10	6	10	13	0
53110	0	4	3	0	0	1	33	57
53100	0	4	4	2	6	17	43	23
13150	60	40	0	0	0	0	0	0
33140	0	20	16	8	10	18	27	0

Table 9. Percentages of frost day classes within the 10 most common AEZs

AEZ code	0-1 day	1-30 days	30-60 days	60-90 days	90-120 days	120-150 days	150-180 days	180-210 days
13100	58	42	0	0	0	0	0	0
13170	45	55	0	0	0	0	0	0
33100	0	18	10	16	21	22	13	0
23170	57	43	0	0	0	0	0	0
23100	67	33	0	0	0	0	0	0
33170	0	48	12	10	6	10	13	0
53110	0	4	3	0	0	1	33	57
53100	0	4	4	2	6	17	43	23
13150	60	40	0	0	0	0	0	0
33140	0	20	16	8	10	18	27	0

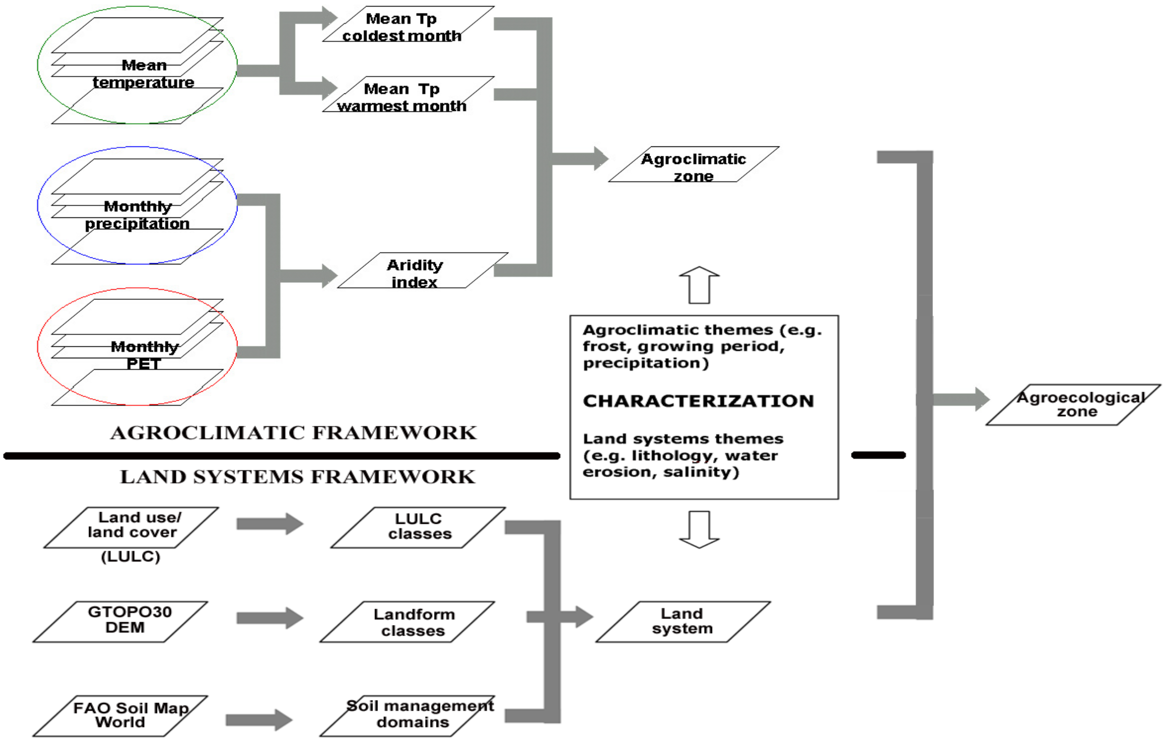

Figure 2. Flowchart for compilation of the CWANA Agroecological Zones Map.

Using these new soil groupings the units of the Soil Map of the World were converted by reclassifying the 1047 FAO soil associations into 60 Soil Management Domains (SMD). The SMDs are thus regroupings of the FAO soil associations on the basis of the main management properties of the soils, through combinations of the main soil management groups. Examples of soil management domains are shown in Table 8. The numbers in the table indicate the percentage occupied by each soil management group, as defined in Table 7 in the SMD.

Overlaying in GIS:

The agroclimatic framework generated 1 GIS layer with 14 classes, the land systems framework generated 3 layers (land use with 3 classes, landforms with 3 classes, and soil management domains with 60 classes). The four layers were overlaid in a GIS system, and the units resulting from the intersections of the four layers received a unique AEZ code. The entire process is outlined in Figure 2.

Removing redundancies, inconsistencies, and spurious mapping units:

The creation of new mapping units by overlaying multiple datasets, especially if they have different levels of precision, propagates errors that were already present in the component datasets and result in so-called ‘spurious mapping units’, artifacts from the overlaying process. Simplification of these datasets, as explained in earlier sections, was one way to reduce such errors. Inconsistencies were resolved by decision rules that favoured the most reliable or higher-resolution datasets. For example, for the pixels in which land use was either irrigated or rainfed, the soil management domain was not considered, as the FAO Soil Map of the World was deemed less reliable than the land use/land cover map, and these land uses suggest soils without serious constraints. Using ‘cleanup’ functions, available in standard GIS software, small dispersed clusters of pixels were absorbed into their nearest neighbors.

Characterizing the AEZ in terms of other relevant themes:
The AEZs, defined on the basis of the 4 critical overlays (climate, land use, terrain and soils) can be characterized more deeply in terms of other themes relevant to planning. This could be biophysical themes, such as frost occurrence, growing periods, soil management groups, but also socio-economic themes, such as farming systems. The characterization is in the form of overlays of additional themes, which are brought in relationship to specific AEZs through a composition table. An example is given in Table 9 for the theme 'Number of frost days'.

The composition table shows the proportion each class of the overlaying theme occupies in each AEZ. It can be interpreted as a 'probability', based on a frequency count, that a particular class will be encountered in a given AEZ.

Results

Using the methodology described in the previous section 677 agroecological zones were identified in the CWANA region. The features of the 10 largest AEZ are summarized in Table 10. A fragment of the map showing Iran, the Caucasus, and parts of Central Asia and Turkey is shown in Figure 3. In addition, database attribute tables were prepared that summarize for each AEZ the relative importance of classified ranges of precipitation, growing-degree days, frost days, length-of-growing period, and soil management groups.

Discussion

The ten largest AEZ cover only about one third (37%) of the CWANA region. Twenty three AEZ are needed to describe half of CWANA and 91 AEZ cover 80% of the region. The remainder 586 AEZ, with areas below 0.2% of CWANA, can be considered 'niche'agricultural environments. The relationship between number of AEZ, from the largest to the smallest, and area covered is illustrated in Figure 4.

As procedures were already included in the methodology to simplify the four overlay themes and to remove spurious units created by the overlaying, and considering the wide classes within the climate, land use, terrain and soil themes, the very large number of AEZ bears testimony to the great diversity in agricultural environments in the CWANA region. This finding offers some explanation for the relative lack of success in outscaling research results from one dryland area to another, and why there is such a diversity of farming and production systems.

As indicated in the introductory section, the term AEZ is not used in a uniform way in different countries or regions. However, virtually all systems for defining AEZs in different countries are 'ad-hoc' and 'stand-alone', based on different classification methods. This situation is testimony to a perceived need to respond to particular agricultural planning objectives with an approach that is both 'holistic' and classifies land into distinct, non-overlapping management zones.

The basic premises in our approach to mapping AEZ are the following:

- For various kinds of agricultural planning it is important to distinguish a limited number of mapping units that represent different agricultural environments;
- To define these biophysical environments it is necessary and sufficient to combine themes related to climate, land use/land cover, terrain and soils.
- These relatively homogeneous environments can be further characterized using theme-specific attribute tables that relate the AEZs to themes relevant to particular planning objectives

- GIS technology makes this complex overlaying process feasible at a wide range of scales.

The advantage to planners of our approach is that, by making use of the database capabilities of a GIS system, the same spatial framework (AEZs) can be retained, irrespective of the particular theme. The limited number of spatial entities makes it a less cumbersome operation to check on a particular piece of information. While the thematic information is *summarized* in a composition table, it is not lost since the more detailed spatial information for each theme is retained in the spatial database of thematic maps, which can still be consulted if and when needed.

Secondly, new layers of spatial information can be added, if relevant for particular planning purposes, and in a flexible manner. For example, the AEZ framework could be used for mapping different kinds of land degradation. A possible, but not exclusive, format for a land degradation attribute table is the one presented in Table 11.

The method for defining AEZs outlined in the previous section can be used at different scales, ranging from the global to the sub-national, subject to the use of appropriate and well-matching datasets, adapted to the particular planning needs.

Although it may be considered desirable to define AEZs once and for all, this may not be practical given the differences in quality of essential datasets. AEZs defined at a global or regional scale will make use of global or regional datasets, national or sub-national AEZs will have to use (more accurate) national or sub-national datasets. On the other hand, irrespective of scale, the principles for applying this method remain the same. In addition to the CWANA case study at regional level, the same approach has been or is being applied for the mapping and characterization of AEZ in Turkey, Syria and Egypt, using datasets at national level, and in Iran, using data at sub-national level.

While beyond the scope of this paper, the agroecological zones framework is sufficiently robust to incorporate spatialized socio-economic information in the form of production system zones. The latter could be derived from remote sensing in combination with farming systems information obtained from community-level sampling sites. By integrating the spatial agroecological and socioeconomic data, 'socio-ecological zones' (a term coined by Dr. Dutilly-Diane) could be established, which have unique characteristics in terms of climate, soil and water resources, population characteristics and livelihood systems.

Conclusions

In order to decipher and rationalize the great complexity of agricultural environments in drylands, this paper provides an approach for a regional assessment of agroecological zones using GIS procedures and the CWANA region as a test case. It is based on the integration of climatic, land use/land cover, terrain, soil and other data through overlaying in GIS and characterization of the resulting mapping units in terms of attribute layers relevant to the planning application.

The CWANA assessment can be extended to the global drylands without major modifications in the methodology. The AEZ framework, the 6-step methodology and GIS procedures can be applied, using appropriate datasets, at a wide range of scales, from the global to the watershed. The four essential themes for the definition of the AEZ are climate, land use/land cover, terrain and soils. These themes need to be differentiated at a level of detail commensurate with the scale and objectives of the particular study and in relation to the spatial variability within the study area.

Table 10. Predominant AEZs in CWANA

AEZ code	% CWANA	Climatic zone	Land use	Landform	Soil management domain
13100	7.76	Hyper-arid climates with mostly warm or very warm summers and warm or mild winters; the overwhelming constraint is lack of moisture	Non-agricultural land use	Plains and plateaux	Undifferentiated soils
13170	7.70	Hyper-arid climates with mostly warm or very warm summers and warm or mild winters; the overwhelming constraint is lack of moisture	Non-agricultural land use	Plains and plateaux	Predominantly desert soils
33100	4.37	Arid climates with cool or cold winters and warm or very warm summers; winter coldness is an ecological constraint	Non-agricultural land use	Plains and plateaux	Undifferentiated soils
23170	3.60	Arid climates with mild or warm winters and warm or very warm summers; winter coldness is not an ecological constraint	Non-agricultural land use	Plains and plateaux	Predominantly desert soils
23100	3.40	Arid climates with mild or warm winters and warm or very warm summers; winter coldness is not an ecological constraint	Non-agricultural land use	Plains and plateaux	Undifferentiated soils
33170	2.84	Arid climates with cool or cold winters and warm or very warm summers; winter coldness is an ecological constraint	Non-agricultural land use	Plains and plateaux	Predominantly desert soils
53110	2.77	Semi-arid climates with cool or cold winters and mostly warm summers; winter coldness is an ecological constraint	Non-agricultural land use	Plains and plateaux	Predominantly agricultural soils
53100	1.66	Semi-arid climates with cool or cold winters and mostly warm summers; winter coldness is an ecological constraint	Non-agricultural land use	Plains and plateaux	Undifferentiated soils
13150	1.50	Hyper-arid climates with mostly warm or very warm summers and warm or mild winters; the overwhelming constraint is lack of moisture	Non-agricultural land use	Plains and plateaux	Predominantly rocky outcrops and shallow soils
33140	1.39	Arid climates with cool or cold winters and warm or very warm summers; winter coldness is an ecological constraint	Non-agricultural land use	Plains and plateaux	Predominantly sodic and saline soils

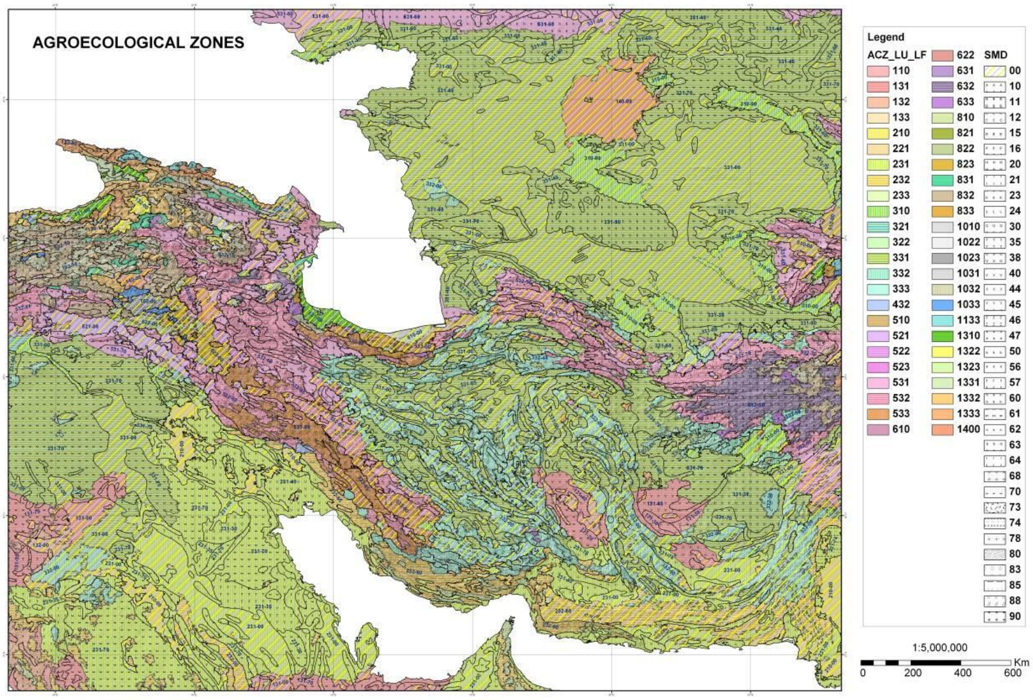

Figure 3. Agroecological zones of Iran and parts of West and Central Asia, Caucasus and Egypt.

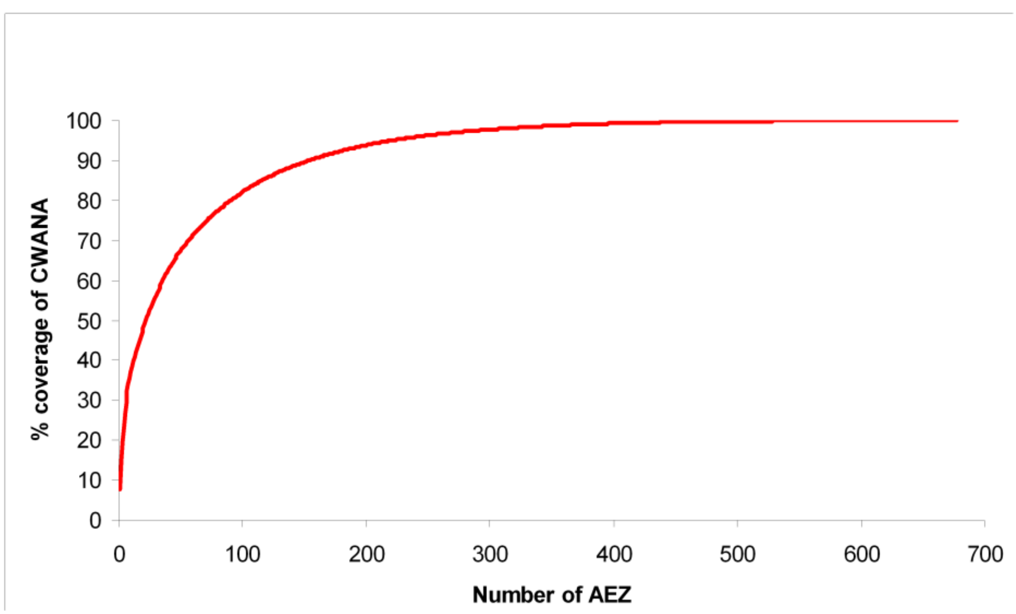

Figure 4. Area of CWANA covered by different AEZ.

Table 11. A theoretical example of an attribute table related to land degradation for some of the AEZ of the Karkhe River Basin, Iran

	Severity of land degradation							
AEZ	**WAT**	**WIN**	**SAL**	**LOG**	**GWT**	**FOR**	**RAN**	**SOI**
220	2	1	1	1	3	1	1	3
246	2	1	1	1	1	3	2	2
320	3	2	1	1	3	1	1	3
356	3	3	1	1	1	1	4	2
Badlands	4	3	2	2	1	1	3	3

The relatively homogeneous agricultural environments contained in each AEZ can then be further characterized using attribute tables that relate the AEZ to themes relevant to particular planning objectives, such as land degradation or land suitability assessments.

As climate change picks up pace, the distribution of the AEZ will change in due course. Given the importance of climate in defining the AEZ and the large number of climatic zones in CWANA, the zones are particularly responsive to changes in their climatic features. The latter can be derived from the International Panel of Climate Change (IPCC) projections of precipitation and temperature changes under different emission scenarios, which are issued periodically. These changes in climatic conditions will also have a feedback onto the land use systems, changes of which will be far more difficult to predict. Hence envisioning the future distribution of the dryland agroecological zones will require sophisticated modeling of the possible interactions of the IPCC climate projections with the many land use change options.

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2.3. Ecological modeling of Walker Lake to evaluate the influence of local and global environmental change

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Abstract

Walker Lake waters originate as snow in the Sierra Nevada mountain range of California and flow into Nevada through the Walker River. The closed lake system terminates at Walker Lake - one of only three desert, closed lakes with a freshwater fishery in the world. Due to excessive water withdrawals, Walker Lake levels have dropped 44 meters since 1882. Conversely, total dissolved solids (TDS) have risen from 2,500 ppm to approximately 15,000 ppm over that same period of time. Currently, the TDS concentration in Walker Lake is nearing a critical level that affects survival of the Lahontan cutthroat trout, classified as a threatened species. Walker Lake's Tui chub minnow population has also decreased drastically in recent years. The Tui chub serves as prey for the Lahontan cutthroat trout and several migratory birds. Here we report on the application of an ecological model developed to investigate how environmental change within and beyond the watershed are likely to influence Walker Lake. We have investigated potential future management scenarious to determine how changes in inflow and climatic conditions are likely to influence the limnology of the lake. The study results revealed potential changes in lake water surface elevations, TDS, dissolved oxygen and temperature profiles under high- and low-flow conditions.

Introduction

Walker Lake lies within a closed basin in Nevada, USA and is the terminus of the Walker River (Fig.1). The Walker River Basin has an area of approximately 10,500 km^2 with headwaters at a maximum altitude of 3,740 m above mean sea elevation at Matterhorn Peak in the Sierra Nevada Range. Approximately one quarter of the watershed is in the State of California with the remaining portion in Nevada. Most of the basin's precipitation falls in the form of precipitation in the Sierra Nevada mountain range. Snowmelt from the Sierra Nevada and other mountain ranges flows through the east and west Forks of the Walker River before merging in the Mason Valley and then ultimately to Walker Lake. The lowest point of elevation in the basin is at the bottom of Walker Lake at 1,173 m. Walker River is the main source of water to Walker Lake, but small tributaries from adjacent mountains, subsurface flow from groundwater, and direct precipitation all contribute to the lake as well. Water only exits the lake through evapotranspiration.

Diversions from the Walker River to support agriculture in the basin began in the 1880s. The largest agricultural region in the Walker Basin is the Mason Valley, followed by SmithValley, and Antelope Valley, for a total of 360 km^2 of irrigated land. The primary crop is alfalfa with smaller portions of onion, garlic, corn, and winter wheat. Early reports showed a drop in Walker River flows from 11.3 m^3/s in 1981 to near zero in 1982 Russell (1885) as irrigation was initiated in the Mason Valley.

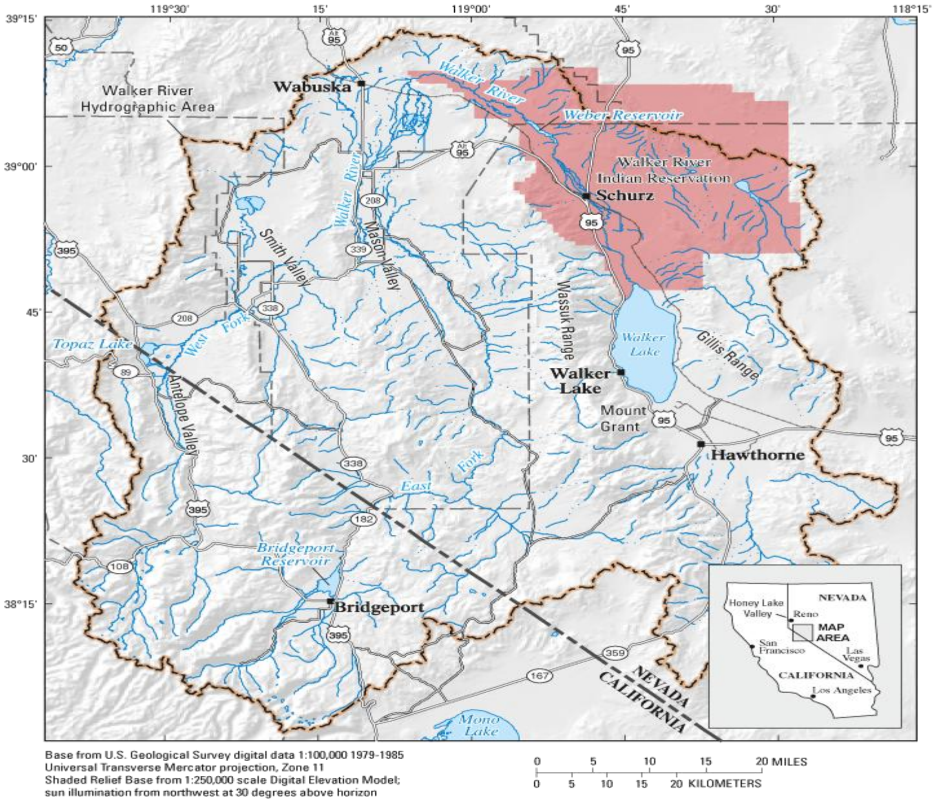

Figure 1. Walker River basin, Walker Lake, and major basin features (Source: Lopes and Smith 2007).

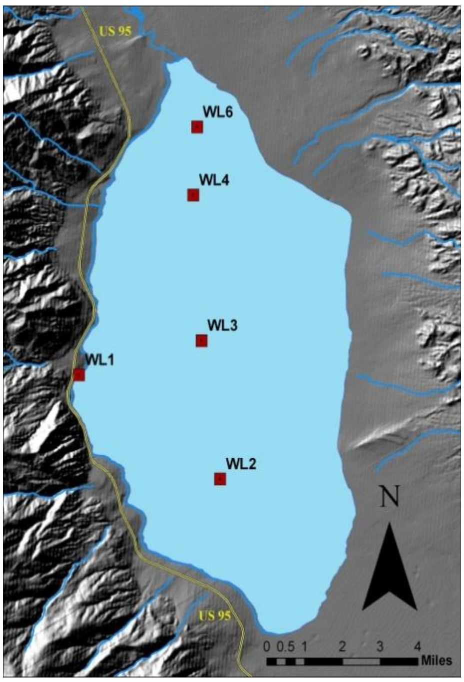

Figure 2. Walker Lake monitoring stations.

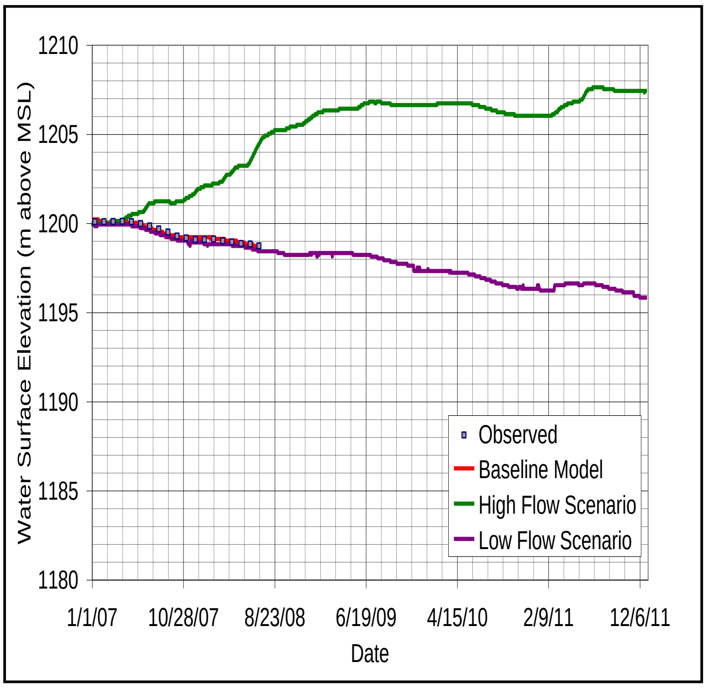

Figure 3. Walker Lake water surface elevations under high- and low-flow scenarios. Highflow scenario-top line, lowflow scenario lower line.

Since that period, the surface of the lake had dropped 44 m and TDS values have increased from 2,500 to 16,000 mg/L. The increase in TDS levels is a severe threat to the survival of the endangered Lahontan cutthroat trout and one of its important food sources, the Tui chub.

In 2007 the Walker Basin Project was initiated in part to halt the volumetric decline of Walker Lake. Water rights acquisitions along the Walker River are intended to increase average annual flows into Walker Lake for the purpose of providing a sustainable restoration of the lake's ecological health. As inflow volumes increase, however, many important water quality characteristics are likely to change over time. Whereas, a great deal is known concerning the physical structure and biogeochemical function of temperate lakes, Walker Lake is unusual in several ways and thus additional knowledge is required to predict the recovery responses of this lake. Most notably, Walker Lake is one of only a few freshwater terminal lakes in the world, and is therefore more vulnerable to increases in solutes than the more common flow-through type of lake. Even prior to anthropogenic desiccation that has taken place over the past century, Walker Lake was near the upper limit of salinity and pH for freshwater fish such as trout and chubs.

A lake water quality sampling program was implemented to help evaluate the current conditions and to establish a baseline for water quality parameters that may change as inflow volumes increase. Data from these studies and from previous monitoring and assessment work at Walker Lake were compiled into a searchable database that was used to calibrate and test an ecological model of the lake. The ecological model is capable of forecasting ecological conditions under a range of future conditions. The ecological model is the focus of this paper.

Methods

An intensive monitoring program was conducted in Walker Lake from the spring of 2007 through the spring of 2008. Monitoring was conducted at five stations within the lake every 4 to 6 weeks (Fig. 2). At each station, a multi-probe was used to collect complete vertical profiles of water temperature, photosynthetically active radiation, dissolved oxygen, pH, and specific conductivity. Water samples were also collected at 3 m intervals in order to evaluate water chemistry. Samples were transferred to the Desert Research Institute (DRI) laboratory where they were analyzed for major ions, nutrients, and trace elements, chlorophyll-*a*, organic substances, and microorganisms.

The information collected through the monitoring efforts was integrated into an ecological model to inform the monitoring plan and to support future decisions with regards to water management. The model consists of coupled hydrodynamic and ecological components based on the Computational Aquatic Ecosystem Dynamics Model (CAEDYM), developed at the University of Western Australia. CAEDYM consists of a series of mathematical equations representing the major biogeochemical processes influencing water quality. It contains process descriptions for primary production, secondary production, nutrient and metal cycling, and oxygen dynamics and the movement of sediment. In this study, CAEDYM was coupled to the one-dimensional Dynamic Reservoir Simulation Model (DYRESM) to allow investigation of seasonal and annual variations in Walker Lake. The one-dimensional approach assumes that the lake can be represented by a series of homogeneous horizontal plans. This assumption is necessary when available data and computational resources are limited and when long-term simulations are desired.

The ecological model requires several types of input data to properly simulate the processes within Walker Lake. Boundary conditions describe the forces acting on the lake and include meteorological and streamflow data. In this study, the daily inflow to Walker Lake from the Walker

River was estimated from USGS Gage 10302002 (Walker River at Lateral 2A). Groundwater discharge to the lake was estimated to be 13,568,300 m^3 (Thomas 1995). No long-term meteorological observations exist on or adjacent to Walker Lake. Thus, observations from the National Weather Service Cooperative Observer Program station at Hawthorne, the U.S. Forest Service Remote Automated Weather Stations at Brawley Peaks and Benton, and wind tower data collected by the Western Regional Climate Center at Luning were compiled to estimate local meteorological conditions. Initial conditions must also be provided to the model to describe the distribution of temperature, dissolved oxygen, nutrients, and biological organisms at the outset of the model. This data was provided through the monitoring efforts described in this chapter.Calibration of CAEDYM was required in order to ensure that the model was adequately representing existing conditions before it could be used to assess future scenarios. This was accomplished by comparing modeled and observed water surface elevations and vertical profiles of water temperature, dissolved oxygen, and chlorophyll-a. By making minor adjustments to the various process coefficients, good agreement was found for all parameters for most of the 2007 sampling dates. The exception was the October 3, 2007 sampling event where the model predicted lake mixing (breakdown of stratification), approximately one week after it was observed.

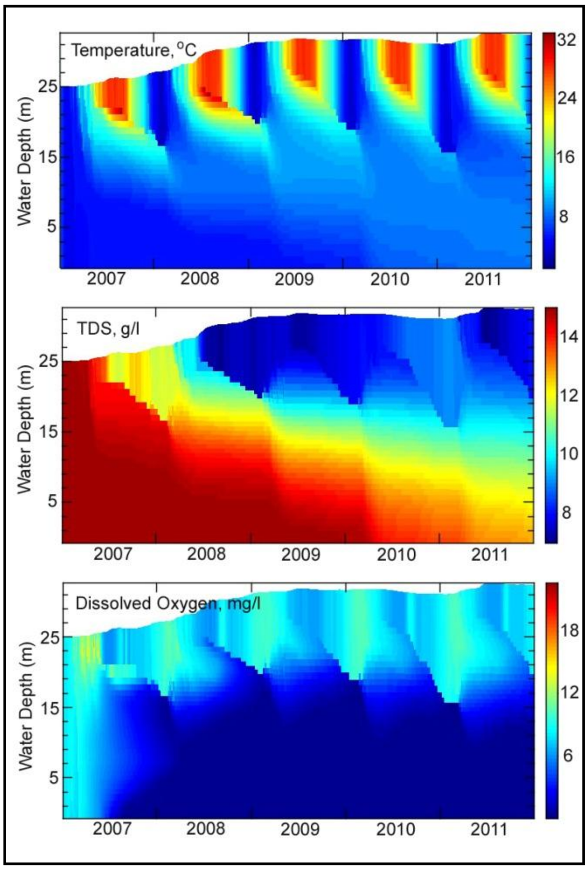

Figure 4. Temperature, TDS, and DO vertical profiles under the high-flow scenario.

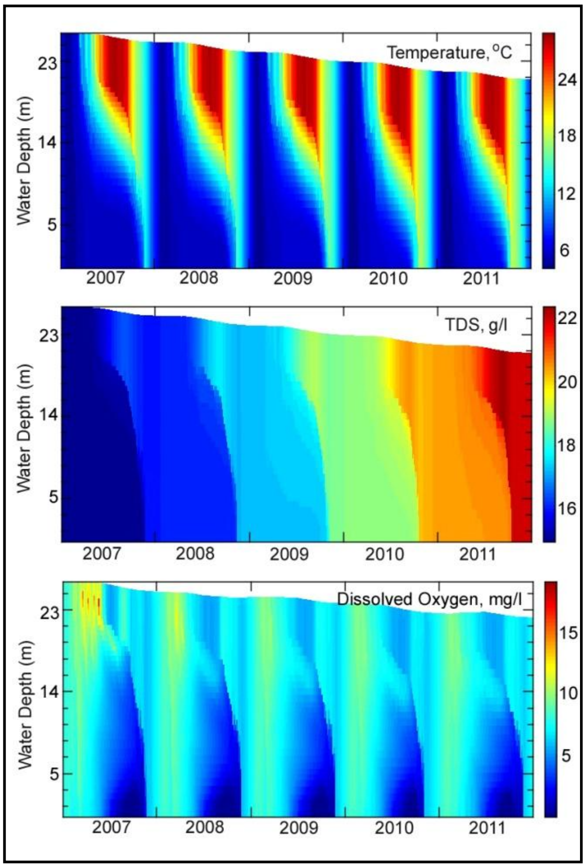

Figure 5. Temperature, TDS, and DO vertical profiles under the low-flow scenario.

In addition to the calibration simulation which was conducted over the period of January 1, 2007 to June 30, 2008, hypothetical 5-year high-flow and low-flow scenarios were also simulated. In the future, impact assessments will be based on streamflow scenarios currently being developed under a separate work unit. In order to demonstrate the forecasting technique here, historical streamflow from the periods of 1982-1986 (average Walker River discharge=425 cfs) and 1989-1993 (average Walker River discharge=30 cfs) were used to demonstrate the impacts of extended high and low flows, respectively.

Results and discussion

Water-quality conditions and trends in the lake were evaluated relative to historic Walker River inflow volumes, which provided a basis for scenario runs with the Walker Lake ecological model. The forecasts developed from this model indicate likely ecological conditions that would result under the high- and low-streamflow scenarios in the Walker River, as described above.

The ecological model produced forecasted vertical distributions in a number of water quality parameters including temperature, TDS, DO, chlorophyll-a, nutrients and carbon, along with water surface elevations. Figure 3 shows simulated and observed water surface elevations for the calibration period (1/1/2007 to 6/30/2008) as well as for the high- and low-streamflow scenarios. This figure illustrates the high degree of agreement between observed and simulated data for the baseline condition. Under high-flow conditions (based on 1982–1986 streamflow data) the water surface elevation was forecasted to increase by approximately 7 m. Under low-flow conditions (based on 1989–1993 data) the water surface elevation was forecasted to drop by 4 m.

Figure 4 contains a summary of forecasted vertical distributions for water temperature, TDS, and DO under the high-flow condition over a 5-year simulation period. It is important to note that these scales are different between scenarios, which is necessary to display the full range of variation. Under the high-flow scenario, the hypolimnion is forecasted to extend higher into the water column each summer as a result of increasing water surface elevation. According to the model predictions under these extremely high streamflows, a slight gradient in TDS could occur; with lower-density, low-TDS water not mixing completely with the higher-density, high-TDS water at the bottom of the lake. DO profiles under the high-flow scenarios are affectd by reduced mixing, with elevated DO near the lake surface and depressed DO at the lake bottom. The increased density stratification (TDS) forecasted here is likely a result of extremely high flows used in the high-flow scenario and a consequence of the assumptions inherent to a one-dimensional hydrodynamic model.

Forecasted results for the low-flow scenario are shown in Figure 5. In this case, the extent of the hypolimnion is predicted to be reduced within the water column as the lake grows shallower from year-to-year. Thus, the cooler water required by Walker Lake fish would become available over an increasingly smaller vertical portion of the lake. Both the temperature and TDS profiles indicate complete mixing of the lake every fall. As a result, DO concentrations are forecasted to be more evenly distributed throughout the vertical profile. However, DO concentrations are shown to drop to anoxic levels near the lakebed during stratification. Under this scenario of extremely low flows over an extended period of time, the TDS levels in the lake are predicted to rise above 20,000 mg/L.

Conclusions

An ecological model was calibrated, validated and then applied to Walker Lake to investigate the impacts on lake limnology from anticipated changes in river flows. These results provided a basis for assessing the potential changes in lake water quality as new water acquisitions are introduced. Data analysis, modeling results and professional judgment have contributed to recommendations for a monitoring plan that will track environmental conditions in the lake over time, including specific indicators important to diagnostic models or other decision tools used for Walker Lake assessment and management. Ultimately, the Walker Lake ecological model will help to optimize future water deliveries in terms of lake benefits, which is critical for developing sound management strategies.

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2.4. Modeling climate impact on carbon budget in drylands of Kazakhstan using remote sensing data and field measurements

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Abstract

This study investigated impact of climate on carbon balance of steppe, semi-desert and desert ecosystems in a large semi-arid region of Central Kazakhstan. Carbon budget during three consequent years with the low, normal and high amount of precipitation was estimated using an approach that integrates remote sensing, field measurements of standing carbon stocks occurring in plants and soil at 14 test sites along a 240-km transect, and meteorological data. Changes of carbon budget during the analysed years were computed as a product of total carbon stocks residing in vegetation and soils and carbon sequestration rates. 10-day carbon sequestration rates for each 1-km pixel in the study area were computed as a sum of Gross Primary Production (GPP), autotrophic respiration of plants (R_a), and respiration of soil (R_s). We utilized the Light Use Efficiency (LUE) algorithm to estimate GPP from the combination of incoming solar radiation, fraction of the photosynthetically active radiation (fPAR) computed from the Normalized Difference Vegetation Index (NDVI) resulting from the data of SPOT-VGT satellite, and a biological conversion factor (ε_p) which describes the potential ability of plants to convert light energy into biomass. R_a and R_s were quantified using common equations given in recent literature. The study established quantitative relationships between carbon sequestration rates and climatic factors both at inter-annual and intra-annual scales. The results demonstrated that during the year with normal precipitation amount, the carbon budget of the most area of the study region was close to none. In the wet year, there was an increase of the carbon absorption by plants and increasing accumulation of carbon in soils, while in the dry year, the respiration of ecosystem was greater than the carbon absorption. The model presented in the study delivers detailed information on an area-wide carbon budget to be estimated using remote sensing and ground truth data and is proposed to be used for preparation of annual reports for the Kyoto Protocol signed by the Government of the Republic of Kazakhstan in 2003.

Introduction

Drylands cover more than 30% of the earth area and comprise a variety of ecosystems, such as shrublands and grasslands, which are large reservoirs of carbon as well as potential carbon sinks and sources to the atmosphere (Heimann 2001). In Central Asia, where drylands cover about 85% of the total territory, shrubland and grassland carbon sinks represent the major pool for carbon absorption and are believed to offset significant proportion of carbon emissions associated with fossil fuel combustion (Lal 2004). Thus, the ability to monitor carbon sequestration in drylands is of great interest in relation to understanding the current status of the global carbon cycle and to meeting requirements of the Kyoto Protocol.

Physical-based models of carbon sequestration, where the key factors for plant development are extracted from remote sensing data, have been widely used in the last two decades to calculate the production of plant biomass (Potter et al. 1993; Field et al. 1995; Gower et al. 1999; Running et al. 2000; Heinsch et al. 2003). These models are based on the approach first described by Monteith (1977) to calculate biomass by linking the incoming radiation to vegetation production through an empirical biophysical conversion factor. The current methodology for estimating gross primary production (GPP) and net primary production (NPP) from satellites is to estimate the amount of photosynthetically active radiation absorbed by the canopy (APAR) from remotely sensed vegetation indices and incident radiation (Seaquest et al. 2003; Hill et al. 2004; Olofsson et al. 2007). The Normalized Difference Vegetation Index (NDVI) computed from red and infra-red satellite channels is commonly used to estimate the fraction of photosynthetically active radiation absorbed by vegetation (fPAR) (Goward et al. 1994; Goward and Huemmrich 1992). The amount of the solar radiation reaching the canopy is usually derived from remotely sensed data or computed using common mathematical algorithms (Frouin and Pinker 1995; Seaquest and Olsson 1999).

From recent published studies it is clear that the photosynthetic activity of vegetation on the surface of the Earth is rapidly changing. Change is occurring to the phenology, to distribution of vegetation on the Earth surface and to the annual dynamics of photosynthetic activity by vegetation. For example, recent studies have demonstrated linear increase in plant growth over the last two decades especially in the northern high latitudes of Eurasia and North America between 40° N and 70° N (Muneni et al. 1997; 1998; Tucker et al. 2001). Climate is the most important factor affecting vegetation condition and its development over the time. Much of the changes in photosynthetic activity by vegetation is being driven by climate change, especially global warming. According to the Intergovernmental Panel on Climate Change (IPCC 2001), the Earth’s climate has warmed by 0.6°C over the past 100 years. Certainly, global warming controls vegetation dynamic and its inter-annual change (Chen et al. 2004). Thus, increases in spring temperatures following by an earlier start of vegetation growing season are reported to be the main driving force for increase in vegetation growth in the northern high latitudes of Eurasia and North America (Tucker et al. 2001). In other cases, increase in vegetation growth over the last two decades is controlled by rainfall increase (Tucker and Nicholson 1999).

The main objective of this study is to investigate the relationship between climate and vegetation productivity in a semi-arid region in Central Kazakhstan at inter-annual and intra-annual temporal scales. We used a physical-based model to calculate the vegetation net primary production at 1-km spatial resolution and 10-day temporal resolution over a 250*250-km large region situated in the semi-arid climatic zone. This model is based on the algorithm of Monteith and incorporates remote sensing data from SPOT-Vegetation satellite, local climate records and ground data on biomass. Using retrievals from this model we examined dynamics in vegetation activity seasonally and annually and determined effects of air temperature and precipitation on these dynamics.

Study area

The study area is located in the middle part of Kazakhstan between 48°20` and 49°30` northern latitude and 72° and 74°10` eastern longitude and encompasses the southern margin of the Kazakh Hills. It comprises the northern area of the Shetsky *raion* (district) in Karaganda *oblast* (province). The climate is semi-arid to arid with average annual precipitation of 250-300 mm and potential evaporation of 1000-1200 mm. The most part of precipitation falls during warm period from March to October with two peaks at the end of May-June and the end of July. The temperature amplitude is relatively high: average January temperature is below -12°C while average July temperature is above 26°C. According to the land cover map Figure 1 semi-desert short grassland covers 74.22% of the whole territory, while grassland covers 25.77%. The short grassland has a complex combination of grasses such as *Convolvulus arvensis*, *Agropyron cristatum*, *Lactuca altaica* and semi-shrubs such as *Artemisia pauciflora*, *Artemisia incana*, *Artemisia lessingiana*. The grassland is dominated by grass species such as *Festuca sulcata*, *Stipa capillata*, *Stipa lessingiana* and *Filipendula ulmaria*.

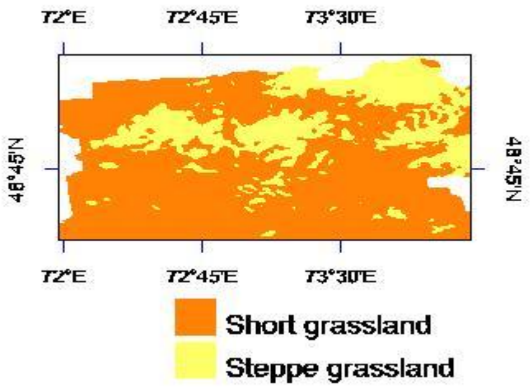

Figure 1. Distributions of land cover classes in the study region based on the MODIS land-cover map.

Data

Satellite data: The Normalized Difference Vegetation Index (NDVI) has been the most common vegetation index used throughout the history of satellite data applications. NDVI represents the absorption of photosynthetic active radiation and hence is a measurement of the photosynthetic capacity of the canopy. NDVI is calculated from reflectance in the red (R) and near-infrared (NIR) bands using the following equation:

$$NDVI = \frac{(NIR - R)}{(NIR + R)} \qquad (1)$$

NDVI has been established to be highly correlated to green-leaf density, absorbed fraction of photosynthetically active radiation and above-ground biomass and can be viewed as a surrogate for photosynthetic capacity (Tucker and Sellers 1986; Asrar et al. 1984).

The 10-day 1-km NDVI data set for growing season (April-October) of three consequtive years 2001-2003 was obtained from SPOT-Vegetation satellite data. The data set had been generated using a maximum value composite procedure, which selects the maximum NDVI value within a 10-day period for every pixel. This way, non-vegetated noise originally presented in the row data was significantly reduced. Nonetheless, some noised pixels remained in the NDVI data set and were removed by employing a spatial filter, which calculated a new value for each noised pixel from values of neighbouring non-noised pixels.

Climate data:The data on 10-day mean temperature, precipitation amount, air humidity and the cloud cover of the sky at 9 climate stations located in the study area were obtained from the National Hydro-Meteorological Centre of Kazakhstan. Gridded maps of 10-day values for each variable were constructed using the interpolation method kriging with external drift (KED) where a digital elevation model, scaled in meters, was used as an external drift. In order to assess the accuracy of the data preparation, we randomly reserved 3 weather stations from the interpolation for one of the 10-day from the recorded values of mean temperature.

Average error was less than 6%. It means that the KED approach worked very effectively.

Methods

NPP represents the net new carbon stored as biomass in stems, leaves or roots of plants and defines a balance between gross photosynthesis (GPP, Gross Primary Production) and autotrophic respiration (Field et al. 1995; Gower et al. 1999) and is calculated by:

$$GPP \text{ (g C/m}^2\text{/yr)} = NPP \text{ (g C/m}^2\text{/yr)} + R_a \text{ (g C/m}^2\text{/yr)} \quad (2)$$

where NPP is net primary production, GPP is gross primary production, and R_a is autotrophic respiration of biomass. This equation includes both above-ground and below-ground compartments of biomass. In the equation above, GPP can be estimated by the simple LUE approach using remotely sensed data. The remote sensing based LUE model is defined as follows (Running et al. 2000):

$$GPP = \sum_{i=1}^{365} LUE * fPAR * PAR * SI \quad (3)$$

where LUE is the optimum of biological efficiency of energy conversion into dry matter that refers to the potential ability of plants to convert the incoming energy from the photosynthetically active wavelengths into green biomass (Goetz and Prince, 1999; Gower et al. 1999; Turner et al. 2003); fPAR is the fraction of photosynthetically active radiation absorbed by vegetation that can be estimated from remotely sensed vegetation indices such as NDVI (Asrar et al. 1983); PAR is photosynthetically active radiation which is defined as the domain of incoming solar radiation exploited by green vegetation for photosynthesis (400 – 700 nm) and derived from a budget modelling approach, with the potential solar radiation calculated from the geographical location (Monteinth and Unsworth 1990); and SI is stress index (White et al. 2000; Thornton 2000). Net ecosystem production, NEP, is the difference between GPP and total ecosystem respiration (R_e), which determines the amount of carbon lost or gained by the ecosystem without disturbances, such as harvests and fire (Running et al. 2000).

$$NEP = GPP - R_e \quad (4)$$

where R_e is the sum of all autotrophic respiration and heterotrophic respiration over some time period from instantaneous fluxes to annual total. The respiration was calculated using modelling equations given by Running et al. (2000), Ryan (1991) and Raich et al. (2002).

Results

The model is used to calculate GPP, NPP and NEP at a spatial resolution of 1 km² and a temporal resolution of ten days. The basis for this modelling is a time series of the described SPOT-Vegetation data set. From 10-day values we also calculated the growing season product of GPP, NPP and NEP for 2004. The results of these calculations are presented in Figure. 2.

The maps of the growing season GPP and NPP show that there is a clear spatial pattern in distribution of these variables over the study area (Fig. 2 a, b). The growing season GPP and NPP was significantly higher in the areas covered by the steppe grassland. This difference was primarily a reflection of differences in the productive potential of the vegetation in the two land cover types. As the steppe grassland occupies territories with significantly higher precipitation amount, the conditions for vegetation growth are much better. It is well known that precipitation being the major limiting factor for vegetation growth in drylands, it controls strongly the spatial patterns in

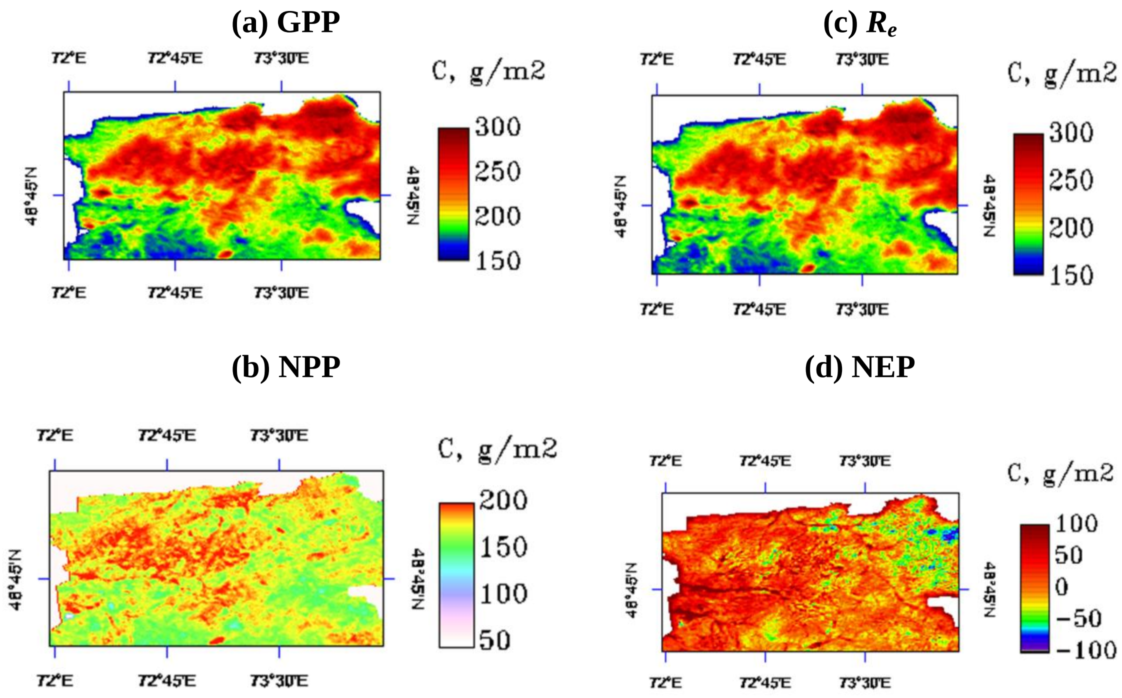

Figure 2. Spatial distribution of the modelling results for the year with normal precipitation amount: (a) Gross primary production, GPP, (b) Net primary production, NPP, (c) Total ecosystem respiration, R_e, and (d) Net ecosystem production, NEP.

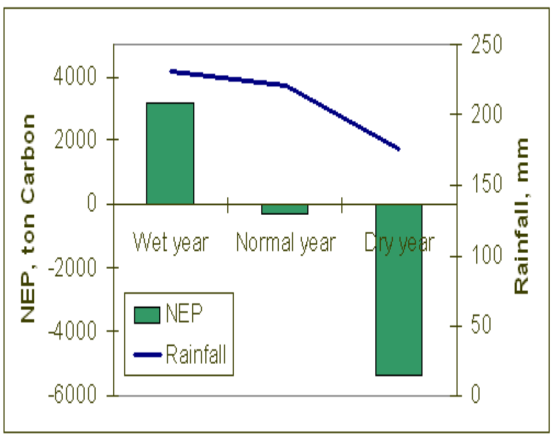

Fig. 3 a

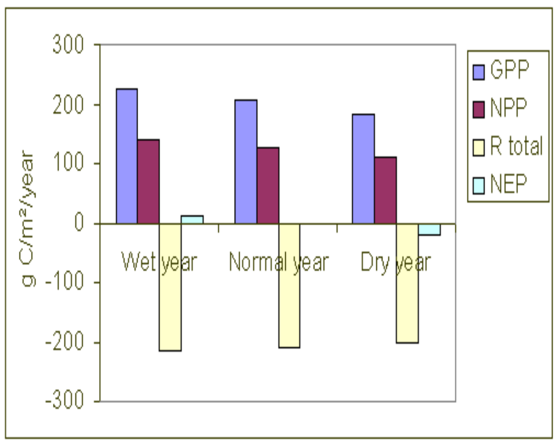

Fig. 3 b

Figure 3. (a) Total carbon sequestration (NEP, tons) in the study area as calculated by the model versus precipitation amount. (b) Values of GPP, NPP, R_e and NEP averaged over the study area for wet, normal and dry years .

vegetation (Richard and Poccard 1998; Wang et al. 2003). Within the short grassland, there is a distinct gradient in the distribution of GPP and NPP from south (S) to north (N). The southern areas show low biomass production with values of 12-150 g C/m² for GPP and 100-120 g C/m² for NPP, while the northern areas of the short grassland demonstrate much higher values of GPP and NPP: 200-250 g C/m² and 130-160 g C/m², respectively. This pattern was driven primarily by the S-N precipitation gradient clearly presented in the flatland areas, which are occupied mainly by short grassland.

The values of the modelled NEP ranged from about –100 to 100 g C/m²/year (Fig. 2, d). Spatial pattern in the NEP is different from those of GPP and NPP. The spatial distribution of the net ecosystem production, NEP, was imposed mainly by the patterns in the ecosystem respiration, R_e (Fig. 2, c, d). There is a strong gradient in the distribution of NEP from SE to NW. Most of the areas with positive values of NEP are located in the western and southern parts of the study area, while the northeastern part is dominated by low or negative values of NEP. The association of NEP distribution with the land cover categories was not so strong as that of GPP and NPP.

For the year with high amount of precipitation, the mean GPP was 243.7 g C/m²/year for the steppe grassland and 211.03 g C/m²/year for the short grassland. The mean NPP was 145.6 g C/m²/year for the steppe grassland compared to 131.31 g C/m²/year for the short grassland. The NEP values totalled by the cover type showed that the steppe grassland as a whole was characterized by a slight escape of carbon into the atmosphere (-625.9 tons), while the short grassland assimilated a total of 2637 tons carbon (about 1.37 tons C/km²/year). A positive balance of carbon characterizes the whole study region in the wet year, whereas for the dry year, the carbon balance is negative (Fig. 3). For the year with normal precipitation amount, the carbon balance was close to none. The results demonstrate that precipitation amount has a substantial control over the compartments of the carbon balance. Thus, both GPP and NPP increase with increasing precipitation amount. However, the ecosystem respiration R_e depends directly on precipitation, too: generally, it increases, if precipitation increases. Nonetheless, the increase of GPP during wet years is greater than that of respiration. Therefore, the total carbon balance is positive. The results of this study support the suggestion made by Shaefer et al. (2002) that climate, particularly precipitation amount, should be the major driving force for dynamics of carbon flux. Schaefer et al. (2002) concluded that globally about 44% of interannual variability in NEP resulted from precipitation, about 16% from temperature and about 12% from soil carbon.

Conclusions

Based on SPOT-VGT, *in situ* measurements of carbon residing in the aboveground and underground vegetation and climate data, the values of gross primary production (GPP), net primary production (NPP), total respiration of ecosystem (R_e) and net ecosystem production (NEP) were calculated for a large region in Central Kazakhstan. Such a regional approach allows a better representation of the area-wide real situation at the ground. The presented study used the well-known Monteinth’s approach, but the most important advantage of the model presented is the exclusive use of the variables obtained from the field survey data for model’s calibration and validation. The model is fixed in its regional scale of 1*1km and its temporal resolution of 10 days.

Our analysis showed that for the investigated wet year, the study area was a net carbon sink, while for the dry year, the study area was a net carbon float. The average accumulation of carbon in the wet year was 11.9 g C/m²; this resulted in 2637 tons over the whole area of the study. In the dry year, the ecosystems in the study area were losing carbon with a low rate of –19.8 g C/m²/year. One of the reasons for the carbon loses was a higher relative rate of respiration and lower NPP modelled in the dry year. Other reasons were not investigated in this study and are objective of an ongoing research.

The findings of the study help in providing a better understanding of carbon cycle in dry lands of the interior Eurasia and should play an important role in the finding an appropriate model for calculation of carbon assimilation in grasslands of Kazakhstan for annual reports for the Kyoto Protocol.

Acknowledgments

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2.5. Drought memory concept and its application to an early warning

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Abstract

Drought has been identified as the world's most hazardous natural disaster. Since the late 1970s, there has been a shift in El Niño-Southern Oscillation toward more warm events, closely related to a worldwide trend for intensified drought. Pastoral livestock husbandry, a major industry in Mongolia, has repeatedly suffered from drought and dzud (anomalous climatic and/or land-surface conditions leading to significant livestock mortality in winter-spring) due to its dry, cold climate. In the present study, drought memory is defined as a series of water deficits that result from below-normal precipitation and lead to below-normal conditions in soil moisture and plant water levels. Based on this concept, we proposed a methodology towards developing an early warning system of the meteorological disasters that is suitable for the Mongolian environment and socio-economy.

1. Introduction

Among natural disasters, drought has affected the most people worldwide during the past few decades (Obasi 1994). Since the late 1970s, there has been a shift in El Niño-Southern Oscillation toward more warm events, closely related to a worldwide trend for intensified drought (Dai et al. 1998). In particular, this trend was manifested as widespread droughts during 1999-2002 in the Northern Hemisphere (Lotsch et al. 2005), including Asia, and notably in Mongolia (Shinoda et al. 2007). Mongolia's territory is landlocked in the eastern part of the Eurasian continent and lies at relatively high altitudes with an average of 1580 m in the middle latitudes. This geographical location causes a continental, dry climate with a cold winter. In Mongolia, about 40% of people are engaged in livestock-farming. The livestock are exposed to outside environments all the year round and thus they are vulnerable to year-to-year climate variations.

In dry, cold regions, such as Mongolia, people living in rural areas are subjected not only to drought in the summer but also to another natural disaster in the winter. Harsh winter conditions can prevent livestock from accessing pastures and can result in a large number of livestock deaths. Even when winter conditions are comparatively moderate, if the pasture conditions are inadequate due to poor conditions (e.g., drought) in the previous growing season, livestock may not survive the winter. In Mongolia, this type of disaster—a mass livestock loss directly induced by a harsh winter climate but often influenced by drought in the previous summer—is called a dzud (Fig. 1). Dzud is experienced throughout central Asia.

In Mongolia, pastoral livestock husbandry has repeatedly suffered from drought and dzud (anomalous climatic and/or land-surface conditions leading to significant livestock mortality in winter-spring).

Droughts and dzuds between 1999 and 2002 killed 8.2 million livestock, about 30% of the total number of livestock in

Figure 1. Recent dzud disaster

Mongolia, and 3.0 million female livestock miscarried.

As for the countermeasures of such disasters, major responses have previously been made in the post-disaster phase (Fig. 2). However, frequent external assistance as a post-disaster response tends to increase external dependency and vulnerability of society. Thus, future disaster management should be focused on pre-disaster activities including an early warning. With this background in mind, an attempt is made to develop a combined drought-dzud early warning system (EWS) that will potentially be operationalized nationwide in Mongolia. This approach incorporates newly introduced remote sensing data of land-surface conditions for summer and winter in the context of drought memory as explained below.

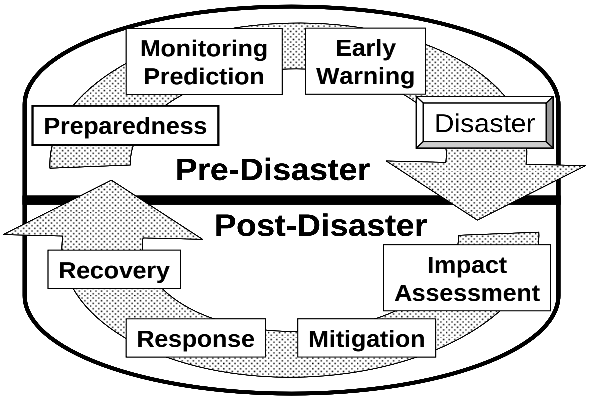

Figure 2. Cycle of disaster management (Shinoda and Morinaga 2005; modified from Wilhite 2000)

Advanced drought EWSs on the national or regional scale have been developed in Australia (e.g., Carter et al. 2000), United States (Drought Monitor by the National Drought Mitigation Center, http: //www.drought.unl.edu/dm/monitor.html), and several regions of Africa. In addition to these drought-related technologies, future Mongolian EWS should also be targeted at the dzud that is rarely seen in the other regions of the world.

2. Drought memory and EWS

Climate memory is the function in which seasonal/interannual anomalies of atmosphere (temperature, moisture, and precipitation) are carried over and maintained as earth-surface system's anomalies. Drought memory is the climate memory that results from below-normal precipitation. In this study, drought is defined, comprehensively, as water deficits in a series of the climate memory mechanisms including atmospheric moisture, precipitation, soil moisture, and plant water (Shinoda et al. 2004).

As seen in Fig. 3, drought is a creeping phenomenon having a time-lagged carryover of anomalies in rainfall→soil moisture→pasture→livestock and eventually leading to a dzud (Shinoda and Morinaga 2005). Preparedness for dzud is ensured with the time lag that a drought in summer leads to a dzud in winter-spring. Monitoring and forecast of soil moisture and pasture is an essential need for the drought-dzud EWS.

3. Development of the EWS

Begzsuren et al. (2004) found that livestock mortality is a result of drought combined with dzud (18.8%), dzud (13.3%), drought (11%), and neither drought nor dzud (8.8%). That is, a disastrous situation for the livestock sector in Mongolia is likely to occur when a summer drought and severe winter conditions come together within one year.

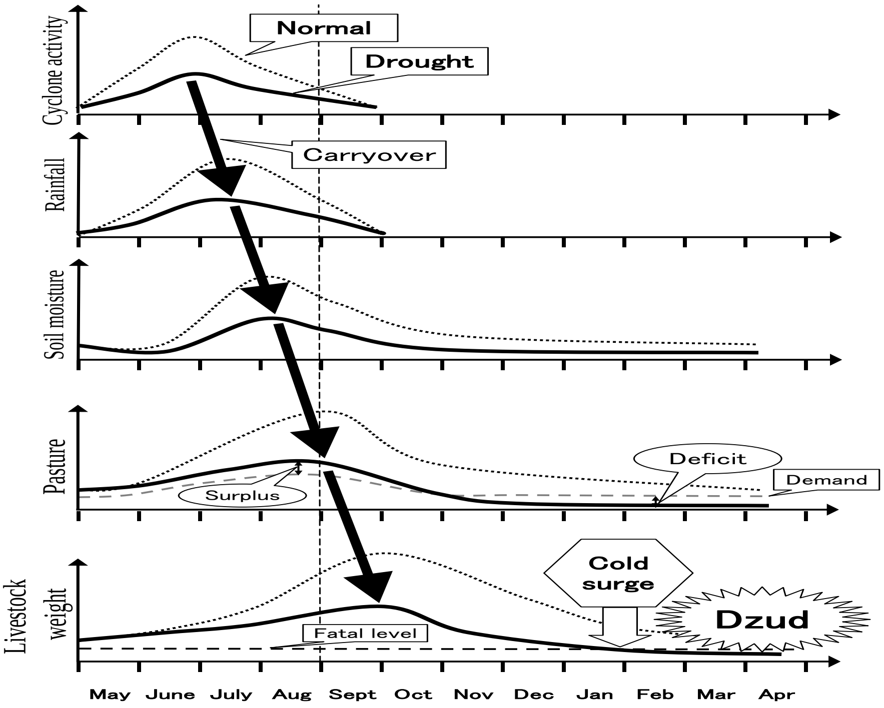

Figure 3. Processes by which drought influences livestock (Shinoda and Morinaga 2005)

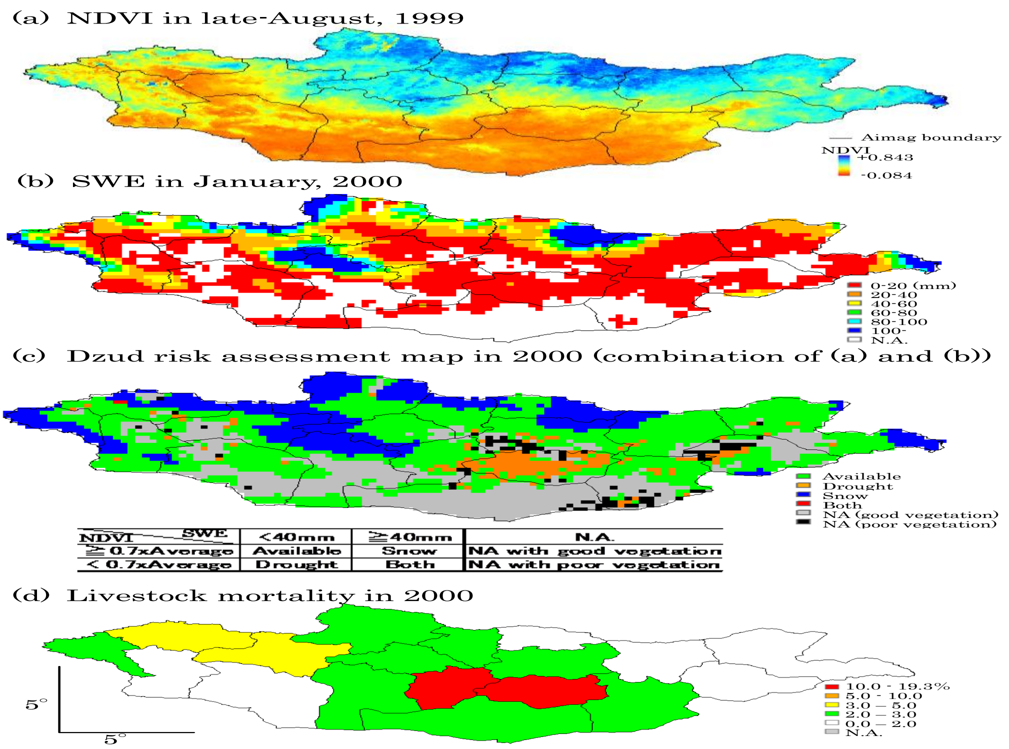

Figure 4. Example of the dzud risk assessment using vegetation and snow conditions.

In this study, dzud risk assessment combining the summer and winter climatic anomalies was carried out using remotely sensed vegetation and snow condition data. For the vegetation cover data, we used the Global Inventory Modeling and Mapping Studies dataset (GIMMS, http://glcf.umiacs.umd.edu/data/gimms/) provided by the Global Land Cover Facility, University of Maryland. The Global Mosaic of GIMMS provides semi-monthly Normalized Difference Vegetation Index (NDVI) data derived from NOAA/AVHRR data covering 1981-2003. The original cell size of this data is 0.073 degrees by 0.073 degrees. For snow condition, we used the Global Monthly EASE-Grid Snow Water Equivalent (SWE) Climatology provided by the National Snow and Ice Data Center (NSIDC) of United States (http://nsidc.org/). This dataset presents global, monthly SWE data from November 1978 through June 2003.

Combining these two data for the previous summer's vegetation (Fig. 4a) and this winter's snow (Fig. 4b), the dzud risk was assessed as in Fig. 4c. The annual climatic condition was classified using exemplified thresholds as: (1) sufficient vegetation and appropriate snowfall (denoted as available in Fig. 4c), (2) insufficient vegetation and appropriate snowfall (drought), (3) sufficient vegetation and too much snowfall (snow), and (4) insufficient vegetation and too much snowfall (both), and the resultant map (Fig. 4c) is considerably consistent with the livestock mortality map (Fig. 4d). These maps illustrate the drought-driven and snow-driven dzud areas in 2000. Since January snow depth averaged over Mongolia is only 34 mm (Morinaga et al. 2003), the snow threshold of 40 mm in SWE is much larger than the average.

As a more sophisticated statistical method, a regression tree model was developed in order to forewarn dzud; the predictor variables included NDVI and SWE as well as the previous year's livestock numbers and mortality (Tachiiri et al. in press). The details of the model are presented in the paper (Fig. 5) illustrates four major dzud-producing factors that were identified in the model. The background factors include livestock conditions in the previous year; that is, weakened livestock inferred from large livestock loss or small capacity due to many livestock. The environmental factors are related to the poor pasture conditions in summer and deep snow in winter that both weaken livestock. If some of the factors are combined, dzud is most likely to occur. The regression tree model also conforms that, the most serious livestock mortality in winter-spring was associated with low NDVI values in the previous year's summer, high SWE values in winter, and a high previous year's mortality.

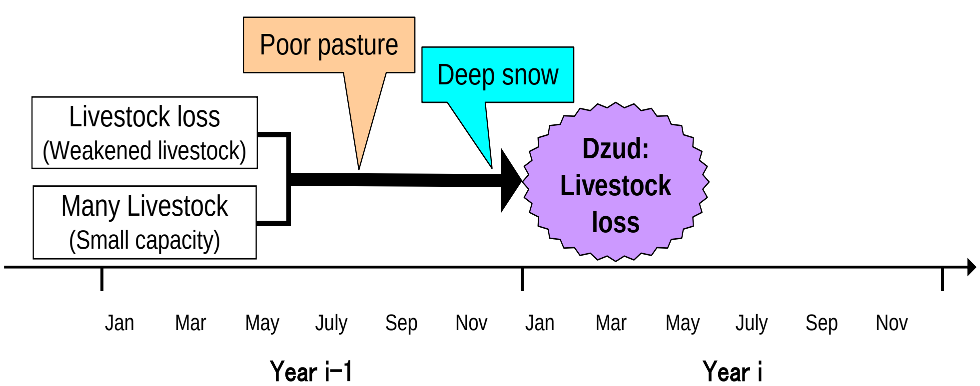

Figure 5. Four major dzud-producing factors that were detected by the tree-based model

4. Conclusions

Although the state-of-the-art long-range weather forecasting has not yet produced reliable quantitative information, timely accurate monitoring of the drought memory of land-surface anomaly conditions (such as soil moisture and pasture) in Mongolia that resulted, with a time lag, from summer deficit rainfall will enable us to deliver early warnings of possible drought and dzud and finally to mitigate their effects on livestock husbandry.

We proposed a regression tree model as a tool of the combined drought-dzud EWS that will potentially be operationalized nationwide in Mongolia (Tachiiri et al. in press). For more precious monitoring and forecast, further study should incorporate ground-based operational measurements of soil moisture, pasture, and livestock conducted in Mongolia as well as the satellite data used here.

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2.6. Agroecological characterization studies: a case study in the Aras and Daryacheh Oromieh basins, Iran

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Abstract

The need for growing more food, on a sustainable basis, to support the ever-increasing population demands a systematic appraisal of our natural resources. Since agriculture is highly location-specific, grouping the available land area in the country into different agro-ecological regions based on certain identifiable characteristics becomes all the more important. In this study, a relatively small pilot area was selected, consisting of 4 sub-basins located in the Aras and the Daryacheh-Oromieh basins of eastern Azarbaijan and Ardebil Provinces, North West Iran, covering about 32,000 km^2. This area has been selected due to its tremendous ecological diversity, making it representative for large areas in Iran, and allowing widespread application of the methods detailed in this report. The report includes descriptions of the characteristics and mapping of the patterns of precipitation, temperature, frost, potential evapotranspiration, aridity index, climatic productivity indicators, growing periods, land use/land cover, landforms, soils and agroecological zones. There are 242 agroecological zones, ranging in size from a maximum of 1,852 km^2 to a minimum of 0.5 km^2. The 10 largest AEZ occupy less than 39% of the study area, 48 AEZ cover 80% of the area, and 69 AEZ 90% of the area.

Introduction

The dryland areas of Iran are characterized by considerable weather variability, as well as major abiotic stresses, in particular drought and cold. They are also very diverse in landscape and soil patterns. The combination of these interacting factors leads to different agroecological conditions, which can be suitable for some crops, but marginal or unsuitable for others. The intensification of crop production in these areas needs to take into consideration the agroecological diversity, and adapt cropping and land use patterns to the opportunities and constraints of each agroecological niche.

In this paper we present the case study of the 4 sub-basins located in the Aras and the Daryacheh-Oromieh basins of Eastern Azarbaijan and Ardebil Provinces, North West Iran, to illustrate the general methodology of agroecological charaterization. In addition, we discuss the value of this spatial information for agricultural planning and link the Aras and the Daryacheh-Oromieh basins case study to others in order to point out challenges in generating useful planning information.

The study area

The study area is located in Eastern Azarbaijan Province in the northwest corner of Iran, between 37º 23' and 39º 44' northern latitude and 45º 65' to 48 º 37' eastern longitudes and the total area is 32,055 km^2. The study area has been delimited on the basis of hydrological basins and sub-basins. It includes 2 sub-basins of the Aras Basin and 2 sub-basins of Daryacheh-Oromieh Basin (Fig.1).

Within the study area the elevation varies tremendously, from a minimum of 30 meter in Bileh Savar to 4811 meter at the top of Sabalan Mountain. Hence it is not surprising that the area contains a very diverse range of climatic conditions, soil types, landforms and land use/land cover patterns. This makes the study area very representative of the diversity of physical environments that can be expected in the rainfed areas of Iran and is one of the reasons why it has been selected as a ‘pilot area’.

Methodologies

Data used

Only a few datasets were used in this study, yet they are the basis for the large range of maps generated by this study. The basic data, from which all other datasets are derived, are climatic data (precipitation and temperature), a land use/land cover map, a digital elevation model and a soil map.

A database was established of point climatic data covering monthly averages of precipitation and temperature for the main stations in Iran, covering the period 1973-1998. These quality-controlled data were obtained from the Organization of Meteorology, based in Tehran. The database also included some precipitation and temperature data from neighboring countries, obtained from the FAOCLIM2 database (FAO 2001). From this database, covering all of Iran, the climatic conditions in the study area were derived.

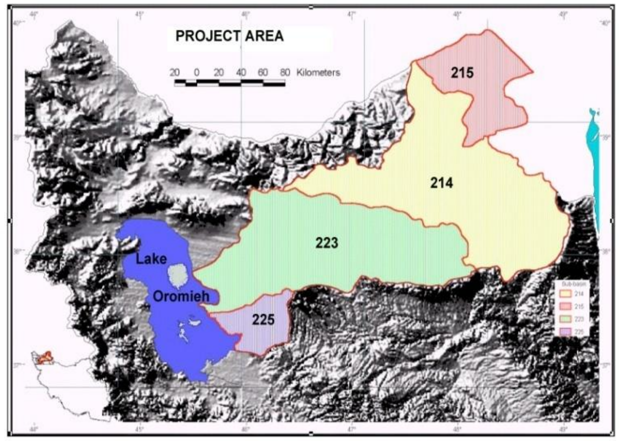

Figure 1. Location of the study area and four sub-basins in NW Iran

The source of the land use/land cover map is the Agricultural Planning and Economic Research Institute (APERI) in Tehran, which produced a vector map for the whole of Iran. The Land Use/Land Cover Map of study area was created by clipping from the country map and conversion to raster using a cell size of 0.000833 decimal degrees, equal to the resolution of the high-resolution SRTM (Shuttle Radar Topographic Mission) digital elevation model.

Soil information for the study area was extracted from the Soil Map of Iran at scale 1:1,000,000. This map was available in digital form with map units in the form of soil associations, using the Soil Taxonomy classification system, and with associated attribute tables. It is based on the interpretation of a 10x10 km grid of soil profiles, which have been described and sampled for chemical and physical analysis.

Spatialization and transformation of climatic data

The ‘thin-plate smoothing spline’ method of Hutchinson (1995), as implemented in the ANUSPLIN software (Hutchinson 2000), was used to convert the station-based climatic database into ‘climate surfaces’. These are raster-based files that are geographically referenced, contain continuous climatic values, and can be imported into a GIS system. The Hutchinson method is a smoothing interpolation technique in which the degree of smoothness of the fitted function is determined automatically from the data by minimizing a measure of the predictive error of the fitted surface, as given by the generalized cross-validation (GCV). De Pauw et al. (2004) provide more details on this method.

Using above procedure, surfaces of mean monthly precipitation, minimum, maximum and mean temperature were generated with 3 arc-second resolution.

By applying various transformations on the basic climate surfaces, involving different formulas or iterative calculation procedures, new GIS layers were generated for a more focused agroclimatic characterization of the study area. Depending on the specific climatic theme, the operations used to generate new layers were either elementary raster calculations on the existing basic climatic layers, or calculations involving a pre-programmed model.

Results

Annual precipitation: Across the study area, annual precipitation is generally low, with 400 mm or less in more than 75% of the area, and less than 500 mm in 98% of the area. Only on highest mountain peaks it is more, during most of the year in the form of snow.

Temperature: As a result of the major elevation differences in the pilot area, there is a very large variation in temperature. The mean temperature of the coldest month, with minima of -18 to -15 °C on the highest mountain tops to 3-6 °C in the Moghan plain, shows that within the pilot area the climate in winter can be very diverse, from extremely cold to relatively mild winters.
Annual growing degree days: Temperature patterns can also be represented as the distribution of available atmospheric energy, which can be used, for example, to evaporate water or make plants grow faster. This representation of temperature as a source of energy for plant growth and biomass production can be done through the concept of *growing degree days* (GDD, also accumulated heat units), which sum the daily temperatures above a threshold (e.g., 0 °C) for a specified period (e.g., one year). Annual growing degree days show, unsurprisingly, the same pattern as the maps of mean temperature, only the units (°C days) are different.

Annual chilling degree days: Some crops require a cold period for optimal growth and yield formation. The intensity of the required cold period can be expressed through the concept of ‘chilling requirement’ and quantified by the *chilling degree days* (CDD, also *accumulated cold units*), a summation on annual basis of the daily temperatures below the same threshold as GDD, in this case 0°C, and the same units (°C days). Annual chilling degree days show that in about 60% of the pilot area at least 100 CDD can be expected.

Potential evapotranspiration: The average annual PET for the pilot area is about 1000 mm, whereas for 90% of the pilot area the annual PET is in the range 800-1200 mm. The highest values (1100-1300 mm) are in the Moghan, Tabriz, Bonab and the lowest parts of the Meshkin Shahr plains, whereas low values (600 to 900 mm) prevail on the mountain slopes of Sahand and Sabalan.

Aridity index: The vast majority (87%) of the pilot area is semi-arid. There is a small pocket of aridity in the valley that runs in north-south direction through Moshiran. Towards the higher elevations the climate becomes sub-humid or even humid (12% of the pilot area).

Agroclimatic zones: The map of agroclimatic zones confirms the essential features of the pilot area: semi-arid and relatively cold conditions. Nearly 70% of the pilot area has a semi-arid climate with cold winter, either with warm summer (38%) or with mild summer (31%). A significant part of the pilot area is still semi-arid, but with mild winter (18%), whereas about 11% is more humid but with cold winters and mild summers.

Duration of the growing periods: Nearly 70% of the area has a moisture-limited growing period of 150-240 days, 20% has a higher growing period. Also the temperature-limited growing period is reasonably high, with 95% of the study area in the range 180-300 days, and 70% in the range 210-270 days. In 95% of the study area the period without moisture or temperature limitations is limited to 30-120 days.

Land use/land cover: Three land use categories dominate the study area: rangelands occupying 61%, rainfed crops with 24%, and irrigated crops with 13% of the study area. Saline areas occupy the edge of Lake Oromieh in the west, and there are wetlands (1%) in the Tabriz plain. Forests occupy a negligible area. Also land use shows a spatial pattern strongly influenced by the elevation. The crops are located in the warmer plains, with the irrigated crops in the deepest parts and the rainfed crops on higher, often more sloping land. The rangelands are mostly located on the higher, colder elevations with more strongly sloping land.

Topography: There is a very wide range of elevations in the study area, with a elevation difference of nearly 4800 m between the lowest point, Bileh Savar in the Moghan plain, and the top of Sabalan Mountain. Elevation is the main factor that determines climate, and by association, is a key determinant of the potential for crops and land use systems in the area. In total, more than 80% of the area is above 1000 m elevation. About 58% of the study area is located between 1200 and 2000 m elevation, and an additional 15% is in the range 2000-2600 m.

With about 65% of the area having slopes below 8%, and 35% with slopes above, the study area is best described as an alternation of flat plains and sloping land. The aspect map indicates that within the sloping land there is a slight dominance of the south-facing slopes (31%).

On the basis of elevation zones, slope and aspect classes a basic map of landforms was prepared. The study area contains 32 combinations of 4 elevation classes (<800 m, 800-1200 m, 1200-1600 m, and >1600 m), 4 slope classes (0-2%, 2-12%, 12-30%, >30%), and 3 aspect classes (north, south and undifferentiated). Of these the following landform classes occupy 55% of the study area:

- Landform 310 (14%): high elevation (>1200-1600 m), flat to almost flat (0-2% slope)
- Landform 320 (13%): high elevation (>1200-1600 m), gently undulating to undulating (2-12% slope)
- Landform 420 (28%): very high elevation (>1600 m), gently undulating to undulating (2-12% slope)

Soils: The map of soil management domains indicate that nearly 60% of the study area is occupied by only 2 soil management domains: SMD1 (27%) and SMD6 (33%).

Agroecological zones: Fig. 2 shows the distribution of the agroecological zones in the study area. There are 242 agroecological zones, ranging in size from a maximum of 1,852 km^2 to a minimum of 0.5 km^2. The ten largest AEZ occupy less than 39% of the study area, 48 AEZ cover 80% of the area, and 69 AEZ 90% of the area. There are 99 ‘niche’ AEZ with a total area of 10 km^2 or less.

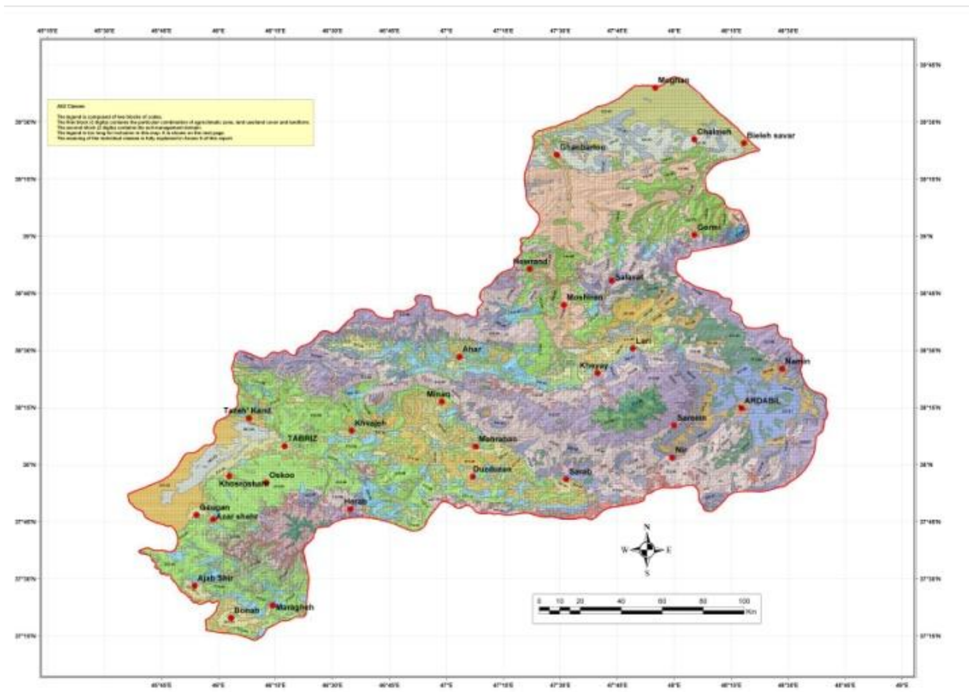

Figure 2. Agroecological zones of the study area

Discussion

The basic premises in our approach are the following:

- For various kinds of agricultural planning it is important to keep the number of spatial units manageable.
- For the definition of these spatially homogeneous agricultural environments it is necessary and sufficient to combine themes related to climate, land use/land cover, terrain and soils.
- These homogeneous environments can be further characterized using theme-specific attribute tables that relate the AEZs to themes relevant to particular planning objectives
- GIS technology makes this feasible at a wide range of scales.

There is nothing new about the AEZ concept. AEZs have been used or are intended to be used in different regions or countries for a variety of agricultural purposes. These may include identification of agricultural production zones (e.g. Horn of Africa, Sri Lanka, Kenya), fertilizer use recommendations (e.g. Tanzania), positioning of research stations (e.g. Iran), targeting of new technologies and crop cultivars (e.g. Central Africa, Bangladesh), regional comparative advantage and crop subsidy planning (e.g.Turkey).

Virtually all systems for defining AEZs in different countries are 'ad-hoc' and 'stand-alone', based on different classification methods. This situation is testimony to a perceived need to respond to particular agricultural planning objectives with an approach that is both 'holistic' and classifies land into distinct, non-overlapping management zones.

Conclusions

In order to reduce the great complexity of agricultural environments, this paper provides a generalized approach for defining agroecological zones using GIS procedures. It is based on the combination of terrain (DEM), climatic, land use/land cover, soil and other data. The GIS procedures can be applied to a wide range of scales, subject to data availability at the required level of detail for the integration to be meaningful. The datasets are combined in an overlaying procedure of different biophysical frameworks, each one characterized separately through its own specific attributes. This approach is useful to define areas that can be considered relatively homogeneous in their biophysical characteristics and can thus serve as a first basis for area-specific agricultural (research) planning.

Characterization of the identified AEZ in terms of themes relevant for specific planning purposes is an essential step.

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2.7. Vegetative roughness controls on wind erosion: A shear stress partitioning approach

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Abstract

The effect that vegetative roughness elements have on entrainment of sediment by wind using a shear stress partitioning approach based on a model developed by Raupach et al. (1993) is evaluated. This model predicts the shear stress partitioning ratio (R), i.e., the percent reduction in shear stress on the intervening surface between the roughness elements as compared to the surface in the absence of those elements, based on knowledge of the geometric properties of the roughness elements, the characteristic drag coefficients of the elements and the surface, and the assumed effect these elements have on the spatial distribution of the mean and maximum shear stresses. When the roughness elements are vegetation, sparsely distributed across an erodible surface, the partitioning of shear stress between the roughness and the bare intervening surface is non-linear. This is due to the dependency of the element drag coefficient, because of the flexible nature of plants and their components, on flow Reynolds numbers (Re_h) for the expected range of wind speeds in arid land environments. The relationship between drag coefficient and plant geometric properties (e.g., frontal area) and Re_h is dependent on the plant type. Using drag curves and frontal area versus Re_h relationships for three typical forms of vegetation we examine the effectiveness of vegetation type (grass, shrub, and bush) over a range of roughness densities to control aeolian sediment transport of sand-sized particles.

Introduction

Dryland ecosystems are vulnerable to the impacts of drought and poor land management practices, which can lead to desertification and progressive and sometimes irreversible changes in vegetation structure and community composition that severely reduce ecosystem productivity (Schlesinger et al. 1990). At critical but poorly defined levels of vegetation cover, the system is vulnerable to wind erosion processes. Increased aeolian activity, including sand drifting and dust emissions, results in a further degradation of the ecosystem and vegetation community. Drifting sand increases the harshness of the environment affecting seedling establishment and subsequent growth (Armbrust 1972; 1984), as well as contributing to self-perpetuating ‘islands’ of soil fertility centered around desert shrubs. Loss of fine soil particles through dust emissions decreases the fertility of bare areas between the shrubs. The fine fraction of particles, which includes mineral grains, clay platelets, and organic material contain a disproportionate share of soil nutrients (Zobeck and Fryrear 1986a; 1986b; Zobeck et al. 1989).

Although several authors (e.g., Schlesinger et al. 1990; Gibbens et al. 1983) have acknowledged that wind erosion contributes significantly to the progressive degradation of arid and semi-arid lands, the mechanisms involved and the critical thresholds of vegetation cover and type have not been systematically studied. Vegetation reduces sediment loss by wind in three main ways (Wolfe and Nickling 1993), by: 1) providing direct coverage of the surface, which shelters it from the wind; 2) extracting momentum from the boundary layer winds, thereby reducing wind shear stress at the surface; and 3) trapping fine sediment that is already in transport and that may be ejected or have the ability to abrade or eject other particles. Of these three mechanisms momentum extraction is the most effective.

The shear stress generated by the wind flowing over the surface becomes partitioned in a sparsely vegetated community between the plants that protrude into the boundary-layer and the open ground between them. Schlichting (1936) first described the partitioning of shear stress between roughness elements and a smoother intervening surface. This approach is inherently applicable to understanding the aerodynamics of a sparse vegetative canopy and its affect on wind erosion and dust emissions. Shear stress partitioning has been used to evaluate the role roughness elements exert on the threshold of entrainment of particles in the presence of solid element roughness (e.g., Gillette and Stockton 1989; Musick et al. 1996; Nickling and McKenna Neuman 1995; Gillies et al. 2008, submitted) and its effects on sediment transport rates (e.g., Orndorff 1998; Gillies et al. 2006) as well as the evaluation of how vegetation decreases wind erosion in agricultural fields (Marshall 1971) and rangelands (Stockton and Gillette 1990; Wolfe and Nickling 1996).

In this paper the results of Gillies et al. (2002), which provide drag curves and data to define morphological relationships (e.g., frontal area) and flow conditions (e.g., flow Reynolds and regional shear stress) for three different types of vegetation (clumps of grass [*Pennisetum setaceum*, Fountain Grass], a bush with finely toothed leaves arranged on opposite sides of the stems [*Euonymous alatus*, Burning Bush], and a stiff shrub with needle-like leaves [*Picea pungens glauca*, Colorado Blue Spuce]), are used in a shear stress partitioning model (Raupach et al. 1993) to evaluate how vegetation aerodynamic properties affect the partitioning of shear stress. The model results are compared with shear stress partitioning data collected by Gillies et al. (2007) for solid elements at similar roughness densities and of similar height and basal area. In addition, the affect the partitioning has on the threshold of entrainment of 125 μm diameter particles positioned among vegetative roughness elements of varying roughness density and type is evaluated. The particle size of 125 μm is arbitrary and represents, according to Bagnold (1941), an easily entrainable particle size by wind. Finally, the efficacy of these three types of vegetation to control wind erosion are discussed in the context of numbers of plants required and with respect to seasonal changes in their morphologies that can affect design criteria to control wind erosion.

Background

The Raupach et al. (1993) model evaluates the partitioning of wind shear stress between non-erodible roughness elements and the bare intervening surface. This relationship is expressed in terms of the *threshold wind shear velocity ratio* (R_t), which defines the ratio between the threshold wind shear velocity over a smooth surface and a similar surface covered with non-erodible roughness elements. The wind shear velocity (u_*, m s^{-1}) describes the magnitude of the shear stress imparted by the wind on the surface and is defined by the "law of the wall", which describes the logarithmic wind profile observed near the Earth's surface and is represented by the equation:

$$\frac{u_z}{u_*} = \frac{1}{\kappa} \ln\left(\frac{z}{z_0}\right) \qquad (1)$$

where u_z (m s^{-1}) is mean wind speed at height z (m), κ is the von Kármán constant (0.4), and z_o is the aerodynamic roughness length (m). Shear velocity is proportional to the surface shear stress (τ_o [N m^{-2}] = $\rho_a u_*^2$, where ρ_a is atmospheric density [kg m^{-3}]).

The Raupach et al. (1993) model has been successfully applied to a wide range of empirical data representing various scales of measurements, from marbles in a wind tunnel to large solid roughness and shrubs in field settings (e.g., Marshall 1971; Lyles, et al. 1974; Gillette and Stockton 1989; Musick and Gillette 1990; Wolfe and Nickling 1996; Musick et al. 1996; Gillies et al. 2006, 2007). King et al. (2005) demonstrated that the Raupach et al. (1993) shear stress partitioning model performed better than that of Marticorena and Bergametti (1995), due to scale dependencies inherent in their model.

The Raupach et al. (1993) model is defined as:

$$R_t = = \frac{u_{*t}}{u_{*s}} = \frac{1}{(1-m\sigma\lambda)^{0.5}(1+m\beta\lambda)^{0.5}} \qquad (2)$$

where: R_t = threshold shear velocity ratio

u_{*t} = threshold shear velocity of bare surface (m s^{-1})

u_{*s} = threshold wind shear velocity with roughness elements (m s^{-1})

σ = roughness element basal area to frontal area ratio

λ = roughness density

β = ratio of element to surface drag coefficients

m = an empirical constant ranging from 0 to 1 that accounts for the spatial heterogeneity of surface shear stress

The roughness density (λ) is defined as:

$$\lambda = n\, b\, h / S \qquad (3)$$

where: n = the number of roughness elements occupying the ground area (of the plant community)

b= element breadth (m)

h = element height (m)

S = ground area (m^2)

From a methodological perspective it may be impractical to monitor a surface for the onset of erosion as the threshold shear velocity is unlikely to remain constant with time because of changes in the plant configuration. Consequently, it may be necessary to consider the shear velocity ratio for a range of wind speeds and shear velocities, rather than for a single set of threshold conditions. Wolfe and Nickling (1996) proposed an alternative to the threshold shear velocity ratio (R_t), the shear velocity ratio (R) that simply characterizes the ratio for simultaneous shear velocities (or shear stresses) of the bare soil and the vegetated surface, irrespective of threshold conditions. This generalizes Eq. 2 and in effect allows for the consideration of shear stress partitioning between roughness and the intervening ground surface for all total stresses. Testing of the model in either form is hindered due to several factors including the need for drag coefficients for vegetative roughness elements and the uncertainty in the m parameter (Brown et al. 2008).

The Raupach et al. (1993) model requires knowledge of the drag coefficients of both the surface and the roughness elements positioned on the surface. The dimensionless drag coefficient (Cd_s) of a surface can be described by (Priestly 1959):

$$Cd_s(z) = \frac{\tau_0}{\rho u_z^2} = \frac{u_*^2}{u_z^2} \qquad (4)$$

and represents the degree to which the total force of the wind is reduced by drag on the surface as a result of momentum extraction from the wind flow.

The drag coefficient of a surface-mounted roughness element can be defined as (Raupach 1992):

$$Cd_e = F/(\rho_a A_f u_z^2) \quad (5)$$

where F is the force (N) exerted on the element by the fluid flow and A_f is element cross sectional or frontal area (m^2). For winds in terrestrial environments, Cd_e for solid elements becomes independent of flow Reynolds number (Re_h) at relatively low wind velocities. Reynolds number here is defined as:

$$Re_h = \frac{\rho_a u_z h}{\mu} \quad (6)$$

Where h is element height, and μ is atmospheric (dynamic) viscosity (kg m s^1).

To apply the Raupach et al. (1993) model requires knowledge of the aerodynamic properties of the surface and the roughness elements. Unlike solid elements very little information is available on the behavior and aerodynamic properties of different plant types. Recent work has demonstrated that the drag coefficients of porous elements are greater than solid element forms with the same physical dimensions (e.g., Wyatt and Nickling 1997; Grant and Nickling 1998). As a result, the use of a single solid element drag coefficients for vegetative roughness elements would lead therefore to underestimation of their effectiveness to partition shear stress using the Raupach et al. (1993) model. However, in addition to their drag coefficient properties as observed by Wyatt and Nickling (1997) and Grant and Nickling (1998), Gillies et al. (2000, 2002) demonstrated that different plant forms can have very different drag curves from solid elements as well as among different plant form types. Using drag balances to measure the force of the wind on plants in a wind tunnel, Gillies et al. (2002) presented drag curves (Fig. 1) for three plant types that show, unlike solid elements, dependency on flow Reynolds numbers over the range of wind speeds for which wind erosion and dust emissions can be expected to occur. This creates non-linearity in the shear stress partitioning ratio when vegetation is the roughness that is sparsely distributed across a surface.

Modeling shear stress partitioning for three vegetation types

The Raupach et al. (1993) model can be used to evaluate how different vegetation types can affect the partition of shear stress between the surface, if data on the drag and morphometry of the pants are available. For this study we draw on several published studies for developing model inputs for three types of plants (i.e., Fountain Grass, FG; Burning Bush, BB; and Colorado Blue Spruce, CS). For the purpose of this paper we assume that: 1) the roughness elements are arranged in a staggered array configuration, 2) the height of the roughness elements (0.36 m) and their basal areas (0.101 m^2) are constants (the same as the solid element roughness used by Gillies et al. 2006, 2007), 3) the Cd_e and frontal area relationships as a function of flow Re_h are the same as those defined by Gillies et al. (2002) for FG, BB, and CS and for a similarly sized solid element by Gillies et al. (2007), 4) the surface on which the roughness is positioned is a bare soil surface with an aerodynamic roughness length of 0.003 m and a Cd_s of 0.0033 (both from Gillies et al., 2007 for a bare surface in the Chihuahuan Desert, USA), 5) the m parameter in Eq. (1) is 0.5, and 6) the aerodynamic roughness height (z_o), which is needed to estimate regional shear stresses, is estimated using the relationship presented by Gillies et al. (2007) relating λ to z_o/h (see Gillies et al. 2007, Figure 10). For discussion purposes we first assume the still-air value for λ is 0.095.

With respect to assumption three above the following information is provided for clarification. The aerodynamic properties of the plants as described in Gillies et al. (2002) consist of Cd_e versus Re_h relationships (Fig. 1) for each of the plant types for five different porosity (or trim conditions) conditions. For the present work a fourth order polynomial was best fit using least-squares regression to both the BB and CS data of Gillies et al. (2002). For the FG Cd_e versus Re_h data, a power function was fit using least squares regression. The Cd_e versus Re_h relationships for each trim condition of each plant type were also generated from Gillies et al. (2002) data, but are not shown here. These polynomial and power relationships for Cd_e versus Re_h were subsequently used to provide estimates of Cd_e for specific flow conditions to serve as input into the Raupach et al. (1993) model.

In addition to the Cd_e data, the frontal area of the roughness is required to calculate the λ and σ terms in the model (Eq. 2). Based on the data presented in Gillies et al. (2002), the relationships between normalized frontal area (NFA) and Re_h were calculated for each plant type. The NFA is the frontal area when wind is blowing divided by its still-air frontal area. An example of this relationship for each plant type in their untrimmed condition is shown in (Fig. 2). The relationships for the other trim conditions are not shown. Similar to the Cd_e versus Re_h relationships, fourth order polynomial equations were best fit with least-squares regression for the BB and CS plants. For the FG an exponential equation was found to provide a best fit to the NFA versus Re_h data.

The plant type and its aerodynamic properties affect the shear stress partitioning through several mechanisms. Most important are the changes in Cd_e and frontal area as a function of Re_h. The former affects the β parameter and the later affects both σ and λ. All these effects occur simultaneously within the model as wind speed (and Re_h) is modulated. In this modeling exercise u_* is limited to a maximum of 1.0 m s^{-1}, which is near the limit for terrestrial winds flowing over sparse roughness.

The effect on λ (for $\lambda = 0.095$) for the three plant types as u_* increases from 0 to ≈1.0 m s^{-1} is shown in (Fig. 3). The change in λ as a function of Re_h for CS is slight (a delta change of <1%) as the NFA changes very little from its still air value. The other two plants show a much greater change in λ with increasing u_*. At $u_* \approx 0.35$ m s^{-1} the BB has entered that part of the FA versus Re_h relationship that shows an increase in NFA with increasing Re_h, following an initial decline in NFA (Fig. 2). An increase in NFA as u_* increases to ≈1.0 m s^{-1} causes λ to increase as well to nearly the still air value, being just 4% less. The opposite occurs for the FG, which exhibits a continual decline in λ with increasing u_* due to the fact that NFA decreases continually as u_* (and Re_h) increase. At the imposed model limit of $u_* \approx 1.0$ m s^{-1}, λ has decreased by 21% of its still air value for the FG.

The effect of the plants altering their frontal areas (bending of branches or re-alignment of leaves) in response to increasing u_* causes changes in both λ and σ, which combine to affect the shear stress partitioning ratio (R). Based on the relationships shown in Fig. 3, at first appearance it would suggest that the lower λ for the BB over the range of u_* indicates that the effectiveness of BB to partition the shear stress would be less than that provided by the CS. However, plotting the relationship between λ and R (Fig. 4) shows that they have similar R values for similar u_* values, varying less than 2%-5%. The reason for this is that the σ value for CS varies between 40% to 46% less than the σ value for the BB, due to its lower frontal area for a similar sized (height and basal area) plant at similar values of Re_h. In addition, the Cd_e values for CS are lower.

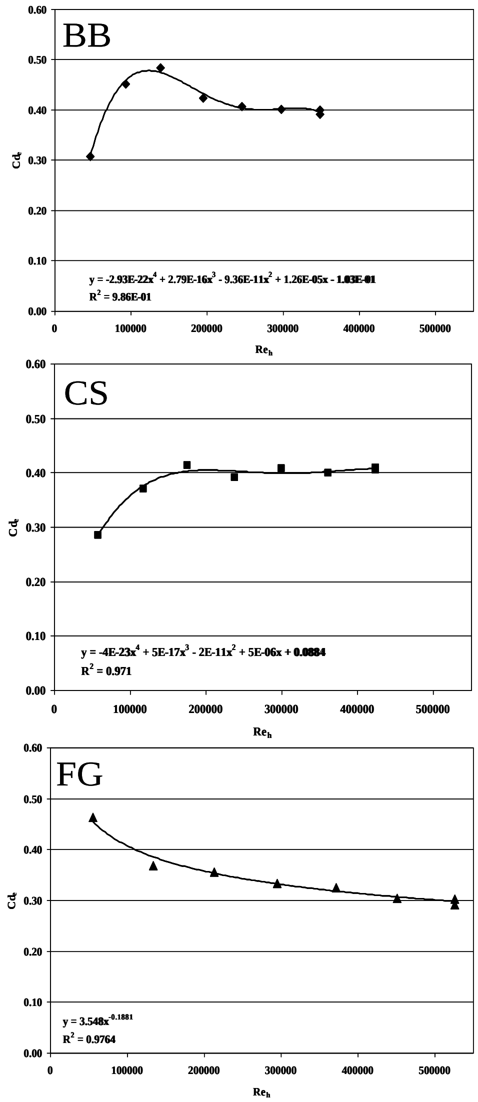

Figure 1. **Drag curves relating Cd_e with Re_h for BB, CS, and FG in their untrimmed condition (after Gillies et al. 2002).**

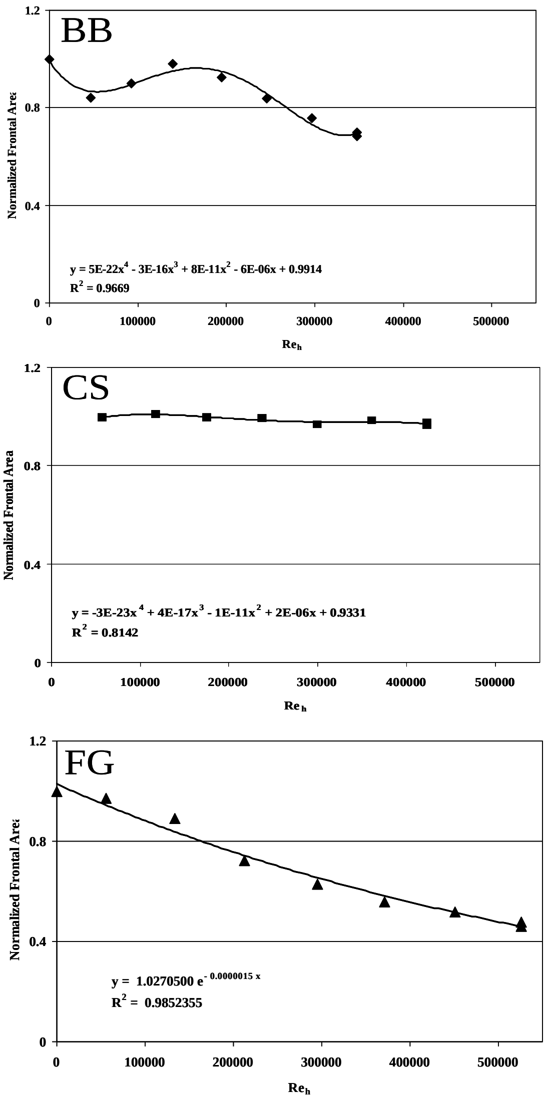

Figure 2. **The relationship between normalized frontal area and Re_h for BB, CS, and FG in their untrimmed condition (after Gillies et al. 2002).**

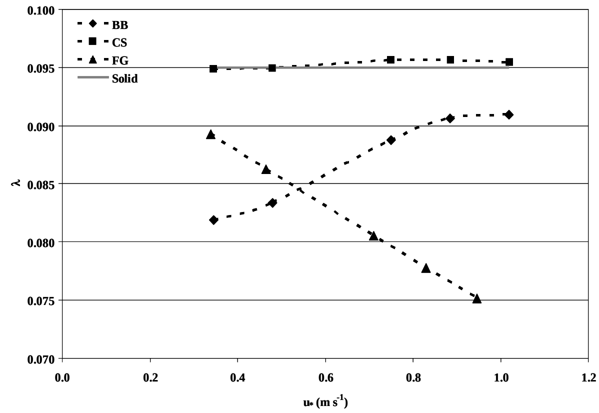

Figure 3. **The relationship between λ and u_* for the three plant types as u_* increases from 0 to ≈1.0 m s^{-1} (Re_h range is 0 to >50,0000) for the untrimmed condition.**

than those for the BB, reducing the value of the β term between 7% and 37% less than the β term for BB for equivalent Re_h values.

The FG absorbs the greatest momentum and therefore has the lowest R value of all the element types up to a regional u_* of ≈0.47 m s^{-1}, even as its efficiency to absorb momentum is declining. At u_*>0.47 m s^{-1} for the BB and >0.59 m s^{-1} for the CS, both these plants have lower R values than FG indicating that for higher winds BB and CS are more efficient at absorbing momentum and protecting the surface than the FG for equivalent still-air values of λ. For all three vegetation types and for the entire range of shear velocity, vegetation is more effective than equivalent sized solid elements in absorbing momentum and reducing the shear stress on the intervening surface among the elements. At the limit of u_* = 1.0 m s^{-1}, the R values for FG (R=0.45) and BB (R=0.39) and CS (R=0.39) are 20% and 30% lower, respectively than the solid element roughness value (R=0.56).

Modeling threshold as a function of roughness density and plant for a 125 μm diameter particle

To evaluate how the entrainment of an 125 μm diameter mineral sand grain is affected by the vegetative roughness that surrounds it, we assume that the threshold shear stress in the absence of large roughness (i.e., a smooth surface) is 0.06 N m^{-2} (u_{*t}≈0.23 m s^{-1}) calculated using the threshold equation of Bagnold (1942):

$$u_{*t} = A\left(\frac{\rho_a}{\rho_p}\, g\, d_p\right)^{0.5} \qquad (7)$$

where a = a constant (0.1)
ρ_p = particle density
g = acceleration due to gravity
d_p = particle diameter

As described above, as regional u_* increases there are distinct changes in the plant form of each type that results in corresponding changes in λ and R. Due to these changes, the regional u_* required to cause u_{*s} to be achieved on the intervening surface among the roughness (i.e, threshold shear velocity for the 125 μm particle) differs for each plant type and roughness density. As (Fig. 5) shows, over the range of λ considered (0.02 – 0.095) the FG always requires higher regional shear velocities to entrain a 125 μm diameter particle, followed by the BB and CS roughness types. Note the threshold condition is described in Fig. 5 by the ratio of the regional u_* required to cause entrainment on the rough surface in the presence of the plants and that needed to cause entrainment on the surface with solid elements roughness present. For the FG, regional shear velocities required for entrainment are 10% to 20% higher than needed for the equivalent solid element roughness configurations for the minimum and maximum roughness densities, respectively. For the BB this same comparison shows the need for 8% to 14% higher regional shear velocities and 6% to 11% for the CS vegetation type.

The advantage of FG to create conditions that require higher winds to cause entrainment from the surface is balanced against the fact that once regional shear velocities exceed about 0.47 m s^{-1} the BB and CS will become more efficient in reducing momentum transfer to the bare surface as described earlier. This will result in potentially greater mobilization of surface sediments on a FG roughened surface as compared to the other types (except solid elements).

Efficiency of plants to affect wind erosion potential

In evaluating configurations of roughness composed of plants it is also critical to consider how their effectiveness to control wind erosion may be affected by changes in their form. For example, seasonal changes in leaf number will affect the frontal area,

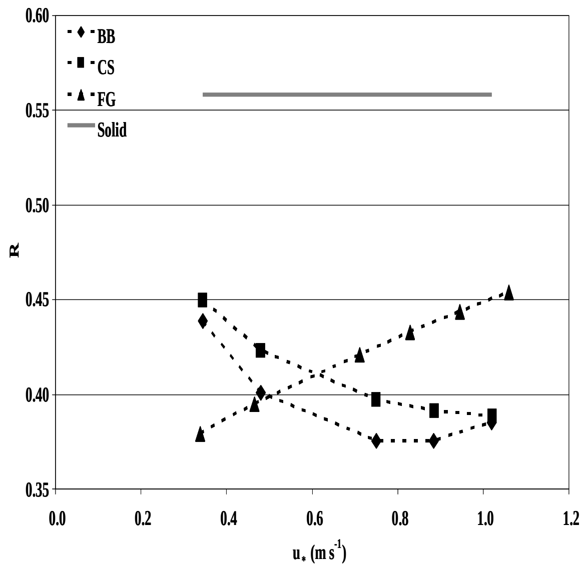

Figure 4. The relationship between R and u* (Re_h range is 0 to >50,0000) for the untrimmed condition.

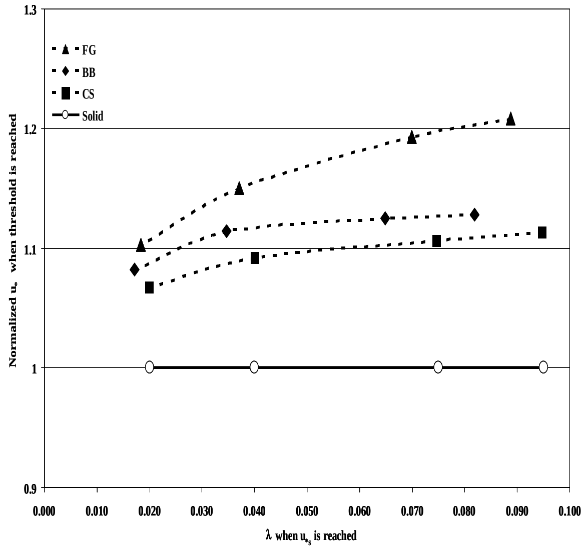

Figure 5. The relationship between u* at threshold in the presence of (vegetative) roughness:u* at threshold in the presence of solid element roughness and λ when threshold is reached for each plant type (and for solid element roughness).

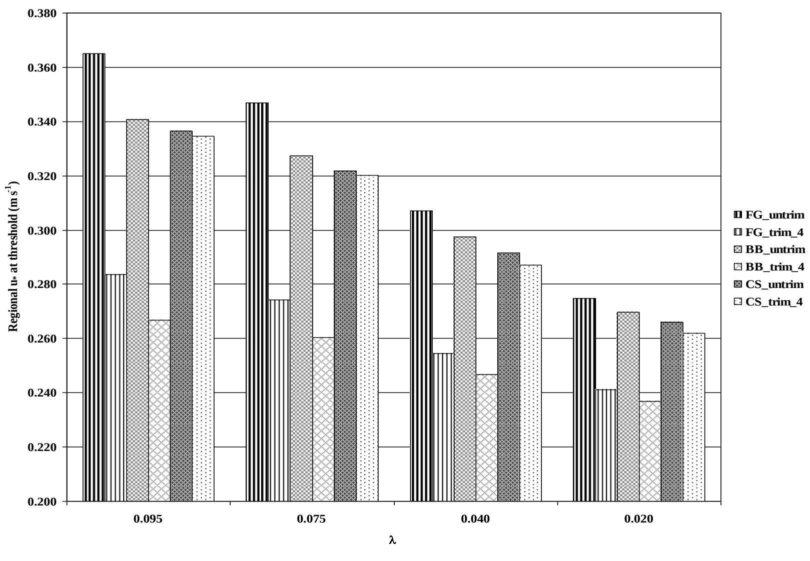

Figure 6. The regional u* required for entrainment of a 125 µm diameter particle for the untrimmed and trim 4 condition for each plant type as referenced to the still-air value for λ (untrimmed condition).

λ, drag coefficients, and hence R. To illustrate this effect we can substitute the aerodynamic characteristics of the plants with those of the same three plants but with the aerodynamic properties altered as a result of selectively removing branches and leaves while maintaining the same frontal area as described by Gillies et al. (2002) for the condition termed 'trim 4' (see Gillies et al. 2002, Figs. 2, 3, and 4). In the present modeling scenario we maintain the same number of plants that were used in the original calculation of λ to achieve a value of 0.095, for all three plant types but with differing aerodynamic properties (porosity) as a result of trimming. In this state the FG, BB, and CS represent a condition where the plants have essentially lost different amounts of foliage due to, for example, senescence. The effect on the efficiency of momentum partitioning can be dramatic depending on the plant type.

With this simulated loss of foliage the change in the still-air λ values for BB is the most dramatic. The average decrease in λ due to the loss of leaves is 73% for each of the four original λ values (i.e., 0.02, 0.04, 0.075, and 0.095) for BB. For FG and CS, the average decrease in λ due to the imposed foliage loss in the trim 4 condition is 60% and 27%, respectively. In the dynamic condition, i.e., when the threshold of entrainment for a 125 μm diameter particle is reached for any value of λ, the average reduction in λ for BB is 69%, and for FG and CS, is 57% and 27%, respectively. This reduction in λ is due mainly to the decrease in frontal area for the plants, as compared to their untrimmed condition. The effect of the decreased λ values plus the associated effects in β and σ due to the different Cd_e and FA versus Re_h relationships for the 'trim 4' plant conditions (not shown) creates higher R values, over the same range of regional shear velocities, resulting in more momentum reaching and a greater percentage of shear stress acting on the intervening surface among the roughness elements. The effect of the loss of leaves or stalks on the regional u_* required to cause entrainment of a 125 μm diameter particle is shown in (Fig. 6.) In the case of the BB altered from λ (static) = 0.095 to λ (static) = 0.025, the decrease in regional u_* required for entrainment is from 0.341 m s^{-1} to 0.267 m s^{-1}, which is a decrease of 22%. On average, regardless of the static λ value, the change from untrimmed to the trim 4 condition reduces the regional shear stress required for entrainment by 18% for the BB. For the FG and CS, the required regional u_* for entrainment for the trim 4 conditions is 18% and 1% lower than required for the untrimmed conditions, respectively. This demonstrates that if one has knowledge of how plant development affects the aerodynamic and frontal area for plants, this information could be used to evaluate how the protection afforded by the plants will change as the plants themselves change.

Another useful aspect of a shear stress partitioning approach to evaluate the effectiveness of plants to control wind erosion is to evaluate how trading off factors such as cost and logistics of site development for different plant types affects the ability to effectively and efficiently meet control objectives. For example, it may be important to consider the water needs of the plants and the numbers of plants required. To achieve the same λ values for the three plant types requires very different numbers of plants. To attain a λ of 0.095 for similar sized areas requires 61% less 'bunches' of FG (0.101 m^2 and 0.36 m high) compared to using BB, and 37% less than required to achieve this value using CS plants. Although the FG looses effectiveness to partition momentum between plant and surface at a greater rate than the BB and CS, it may be a better choice in designing a control strategy because of the lower numbers of plants required to meet a control objective. To improve the control effectiveness of FG at higher winds would require more plants be used initially, which may still be less than the number required for protection using a plant type that is similar to the BB or CS plant type. Considering the use of a deciduous plant form like the BB to control erosion requires that, following leaf-loss, approximately four times as many plants would need to be used to meet a λ value, which may be the design specification if the plants were fully-leaved.

Conclusions

As demonstrated in this paper the aerodynamic properties of plants arrayed sparsely on a surface susceptible to wind erosion can have a profound affect on their ability to affect the partitioning of momentum, and hence the effectiveness to control wind erosion and dust emissions. Unlike solid elements, plants create conditions where this momentum partitioning is non-linear. This is due to the fact that plant drag coefficients and form characteristics show dependencies on Reynolds number for the range of wind speed expected on Earth. The Raupach et al. (1993) model can be a powerful tool to evaluate the protective role of vegetation and aid in design control strategies to mitigate wind erosion using roughness elements. However, to be effective, when the roughness elements to be used are plants, requires knowledge of the aerodynamic properties of the plants that are potentially to be used for control purposes. To date there are limited data available that describe these properties, and to expand the use of this approach requires a concerted effort to increase the amount of information on the aerodynamic behavior of plant species that may be used to control wind erosion.

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2.8. Impact of hydrological constraints on natural vegetation cover in a representative watershed south of the Mediterranean Sea: an integrated approach

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Abstract

The watersheds south of the Mediterranean Sea have generally typical landforms and are composed of table land, piedmont plain, vegetated wadis and coastal plain units. The main source of water is the rainfall which varies, depending on area, from 25 to 310 mm/year and decreases southward to become half the value of the coastal zone at 15 km distance from the coast. The groundwater aquifers (Quaternary, Pliocene and Miocene), having water quality ranging from fresh to saline, are used for supplementary irrigation. The coastal plain, especially in the downthrown of wadis, is affected by intensive reclamation, while the inland areas are used as range lands. This work is an integrated approach between the hydrogeological constrains (climate, geomorphology, structure, soil, surface and groundwater) and natural vegetation to study the inter-relationships and build a new modeling framework that can be used for identification of the occurrence and distribution of the natural vegetation elsewhere south of the Mediterranean Sea. A representative watershed was selected for detail studies. The most common vegetation pattern was spotted or stippled and banded. Spot is restricted mostly in the piedmont plain and the downstream of the wadi and is characterized by low relief areas, irregular in shape and surrounded by bare soil. It has mostly very shallow, sandy loam, slightly saline soils that are fed by surface runoff and/or shallow groundwater. On the other hand, banded vegetation is located in the banks of the upstream of the main wadi and tributaries. It is usually aligned along contour lines and commonly acts as closed hydrological systems, with little net outflow and sediment coming out of the system. It is located as stripes or arcs and is characterized by mild to moderate topography, shallow sediments, sandy loam, slightly saline soils, fed by surface runoff.

Introduction

Arid and semi-arid areas constitute over 30% of the world's land surface. These areas function as tightly coupled ecological-hydrological systems with strong feedbacks and interactions occurring across fine to coarse scales (Noy-Meir 1973; Wilcox et al. 2003; Ludwig et al. 2005). Generally, the vegetation of these regions consists of a mosaic composed of patches with high biomass cover interspersed within a low-cover or bare soil component. A key condition for the development of these patterns is the emergence of a spatially variable infiltration field with low infiltration rates in the bare areas and high infiltration rates in the vegetated areas. This spatially variable infiltration has been observed in many field studies of the world and is responsible for the development of a runoff-runon system. Several field studies have reported much higher infiltration rates (up to 10 times) under perennial vegetation patches than in interpatch areas (Bhark and Small 2003; Dunkerley 2002; Ludwig et al. 2005). The amount of water received and infiltrated into the vegetation patches, which includes runon from bare areas, can be up to 200% of the actual precipitation (Valentin et al. 1999; Wilcox et al 2003; Dunkerley 2002). The runoff-runon mechanism triggers a positive feedback, that is, increases soil moisture in vegetated patches reinforcing the pattern (Puigdef'abregas et al. 1999; Valentin et al. 1999; Wilcox et al. 2003). The redistribution of water from bare patches (source areas) to vegetation patches (sink areas) is a fundamental process within dry lands that may be disrupted if the vegetation patch structure is disturbed. This efficient redistribution of water is accompanied by sediments and nutrients and allows for higher net primary productivity.

Vegetation patterns play an important role in determining the location of runoff, sediment source and sink areas (Cammeraat and Imeson 1999; Wilcox 2003; Imeson and Prinsen 2004). These patterns are thus functionally related to hydrologic processes through their effect on determining soil moisture patterns, runoff redistribution and evapotranspiration; and to geomorphologic processes through their role on determining the spatial distribution of erosion-deposition areas. In these systems the spatial redistribution of flows and material is regulated by both topography and vegetation (Tongway and Ludwig 2001). That is, the downslope routing of water, sediments, nutrients, seeds, litter, etc, is strongly influenced by the interaction between vegetated and bare patches, which is determined by their spatial connectivity (Imeson and Prinsen 2004).

Northwestern (NW) coast of Egypt is an ideal case for application of the above mentioned constrains and others which are called hydrogeological constrains, on the occurrence and distribution of natural vegetation. The hydrogeological constrains are mostly climate, geomorphology, geology, structure, soil, surface water, groundwater and water quality. A lot of disconnected natural vegetation and hydrogeological studies were done in NW coast without any relations in-between (Said 1962; El Shazly 1964; El Senossi 1968; Tächholm 1974; Cherif et al. 1975; Zahran and Willis 1992; Boulos 1995; Boulos 1999 and 2000). Building a good relation can be useful for identifying each other and decreases the effort and cost for prospecting.

The main objective of this study is to identify the state of the hydrogeological constraints to understand the relation between them and the natural vegetation cover in a representative watershed in the NW coastal region of Egypt and consequentially south of the Mediterranean Sea. Also aimed was building of a new framework model which can be replicated elsewhere. The study outputs could support sustainable land and water management and participatory agricultural development processes in rain fed areas in arid and semi-arid regions

Description of the area

Wadi Naghamesh in the NW coast of Egypt was selected as a representative watershed south of the Mediterranean Sea due to the available data sets and it is an ideal case for analyzing the correlation between natural vegetation patterns and hydrogeological constrains which can be replicated in other wadis. The area has a fragile natural resource base and offers limited alternatives for sustainable increases in agricultural productivity under purely rain fed conditions. The wadi is located 270 km west of Alexandria, about 10 km east of

Marsa Matruh and extends 22 km south from the coast. It is bounded by longitudes 27° 14\ – 27° 27\ and latitudes 31° 10\ – 31° 16. The area is dissected by different paved roads such as Alexandria – Matruh and East Matruh - Siwa Roads. Topographically, wadi Naghamesh is highly undulating, ranging from more than 144 m above sea level in the south to less than 0 m in the north.

The area contains three distinct agricultural zones (Abdel-Kader et al. 2004). Zone I extends up to 5km from the coast and the production systems are predominately trees (figs and olives) with some cereals, small ruminant and limited rain fed vegetable production. Zone 2 extends from 5 km to 15 km inland and the production systems have fewer trees and more cereals and livestock. Zone 3 extends from 15 km inland and the production systems in the zone are dominated by livestock (small ruminants and to a lesser extent camels) with some cereal production.

Approach and methodology

Initially, in order to understand the climatic variability with time in the selected watershed as constrain, long term records of Mersa Matrouh Airport Meteorological Stations from 1921 to 2004 were obtained. To recognize the general geomorphological and surface geological features, information from satellite images, topographic maps, five geologic cross sections and geologic maps (Said 1962,1990; El Shazly 1964) were collected, processed, and field verified. For the pedological studies, soil profiles were studied and some of them (13 samples) were selected for physical and chemical analysis in the Desert Research Center Laboratory according to Piper (1950), Jakson (1958 and 1967), Pettijohn (1975), Amaral and Pryor (1977) and Galehouse (1971).

The lithological description of the continuous coring from 2 wells and the available composite logs data of the drilled groundwater wells, which were collected from private companies and Bedouin, were used to study the subsurface geological and hydrogeological conditions. To identify the general variation in the groundwater chemistry, eleven water samples were collected using Magellan Global Position System (GPS). Four samples represented Miocene aquifer and the others 7 represented the Quaternary aquifer. Two samples were collected (after pumping for 10 min. to remove groundwater stored in the well) at each location for cation and anion analysis. *In situ* measurements included EC, pH and bicarbonate using a portable field kit. The chemical analysis was carried out as per the standard procedure given in ASTM (2002).

To recognize the natural vegetation cover, regular visits were done in the study area over the period of two years (2006-2007). Floristic categories of species were made. The plant life forms of species were identified according to Raunkiaer's system (1934) into chamaephytes, phanerophytes, non phanerophytes and therophytes. Twelve stands were selected on the basis of geomorphologic units and visual difference using GPS. At each stand (10-50) quadrates (10 X 10 m^2) were randomly made except the salt marshes where the quadrates were (2 X 2 m^2). The list of species in each stand was identified according to Tächholm (1974) with update of Boulos (1995, 1999 and 2000). Within each quadrate, cover, relative cover, density, relative density, frequency and related frequency were calculated according Braun Blanquet (1964). Species richness is considered as the count of species per unit area. Two-Way Indicator Species Analysis (TWINSPAN) was applied to classify 12 stands in the watershed. TWINSPAN is a divisive hierarchical program that uses indicator species *i.e.*, species with clear ecological preferences, to characterize and separate the classes (Hill 1979). The one-way analysis of variance test was used to compare the means of all environmental factors and diversity indices for the identified groups. All statistical treatments followed Zar (1984) using student SYSTAT 7.0.

Result and discussion

Climatic constraint

The climatic factors control not only the plant growth but also the development, distribution and density as well as plant life on the earth (Zahran and Willis 1992). Wadi Naghamesh lies within the semi-arid belt of Egypt. The long term records of Mersa Matrouh Airport meteorological station show that the rainfall is low and extremely variable and the precipitation occurs in the form of storms of varying intensity between November and February months (Fig. 1). The extreme annual fluctuations range from 25 mm to 310 mm with a mean annual rain fall of 140 mm/year for the period. The amount and variability of precipitation indicate that the region is clearly subject to non-equilibrial ecosystem dynamics (Ellis 1994). The mean maximum temperature ranges from 26.7 °C in August to 12.6 °C in February and the relative humidity varies from 61% in

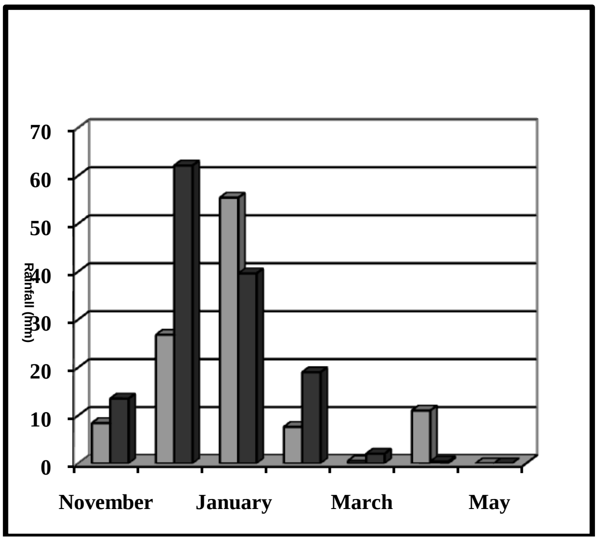

Figure 1. The rain fall data of Mersa Matrouh in the rainy period from 1921-2004.

October to 73.3% in June. There are three climatic zones according to the amount of rain fall. The first zone which has higher rain fall extends up to 5 km from the coast. Zone 2 extends from 5 to 15 km inland, and zone 3 extends more than 15 km where the precipitation is less than half of the first zone.

Geomorphological constraint

The area is divided into four main geomorphologic units namely table land, piedmont plain, vegetated wadis and coastal plain (Fig. 2) from south to north. The table land unit occupies most of the study area that extends to south to join gradually El Diffa Plateau. It is characterized by undulating topography that rises gradually southward to about +145 m above sea level. It is dissected by the main wadi and their tributaries that debouch their water into the sea. It is composed mainly of massive cavernous limestone rocks that belong to the Milazzian to the Sicilian (Middle Miocene) (Philip 1955) and is covered partially by Quaternary sand sheets.
The piedmont plain unit is located to the north of the table land and has ground elevation ranging from over +50 m in the southern part to +25 m northward with relatively low gradient. Their width varies from about 700 m to over 4000 m.
Vegetated wadis unit occupy the main channel of the wadi and their tributaries. The main channel of the wadi and their tributaries are covered mostly by natural vegetation in the upstream and are cultivated in mid-stream and downstream. The cultivated areas are irrigated from the surface water during rainy season utilizing different types of rock dams. Occasionally, groundwater is used as supplementary irrigation.

The coastal plain is only a small part in the study area and is characterized by the occurrence of sand sheets, spiels, playa, coastal ridges, sandy shore and tourism villages. Sand sheets occupy most of the coastal plain and are composed mostly of medium sand in the southern part and of fine sand northward. Playa deposits are along the main course of the wadi and built mostly of fine sand and silt that are covered by natural vegetation. The spiels are located in about 10 km east of Mersa Matruh in four cycles taking concave shape. They are formed mainly due to the accumulation of the eroded sediments from the western head land (Ras Alam El Rum) by long shore current. They are composed mainly of calcareous fine sand and silt which are partially cultivated depending on rain fall and groundwater as supplementary irrigation. There are no ridges in the coastal plain except some remnants of the coastal ridge in the outlet of the wadi. The ground elevation ranges from +2 m to +3 m. Some of the tourism villages were built on this ridge.

Sandy shore is located parallel to the shoreline of the Mediterranean Sea. It is narrow with the width of a few meters to a few hundred meters. It has ground elevation ranging from + 2 m to about +0.5 m. It is composed mainly of sand with shells and shell fragments.

Geological constraint

The surface geology of the study area is represented by Miocene and Quaternary deposits (Fig. 3). Miocene rocks dominate and are represented by Marmarica Formation (Middle Miocene). It is composed mainly of four claystone beds alternating with three limestone beds (El Shazly 1964). The Quaternary deposits are located mostly in the northern part and are represented by Pleistocene (cardium limestone and oolitic limestone) and Holocene sediments (alluvial, sabkha, sand sheet and beach). Cardium limestone series is recognized in the escarpment terminating to the north of the table land. The detrital oolitic limestone sediments are exposed as a ridge and built mainly of whitish layers of oosparite with detrital texture. On the other hand, the Holocene alluvial sediments are deposited mainly in main channels and their distributaries as well as the coastal plain. They are composed mostly of calcareous coarse sand in the southern part and fine sand and silt in the northern part. Sabkha deposits are recorded in the low lying areas and are composed mainly of evaporties (gypsum with halite), while beach deposits are located parallel to the present shoreline and are built mainly of calcareous white loose fine sands with shells.

Structural constraint

The study area is a part of Mersa Matruh homocline (El Shazly 1964). Lineation map (Fig. 4) is prepared using geological map and satellite images followed by intensive field works to determine the aerial extent of faults of each set. The lineament map shows the following aspects:

- NE system is the major trend that has controlled the main course of the wadi and some tributaries.
- NW system is the next main trend that has managed some tributaries in the northern part.
- E-W set is the oldest one which has affected some tributaries in the eastern part.
- The N-S set is occupied by some segments of the wadi and some tributaries.
- Due to the activity of different segments of various transverse faults terminal fans were formed on the downthrown blocks. Thus, role of extensional tectonics in an overall compressional regime is significant.

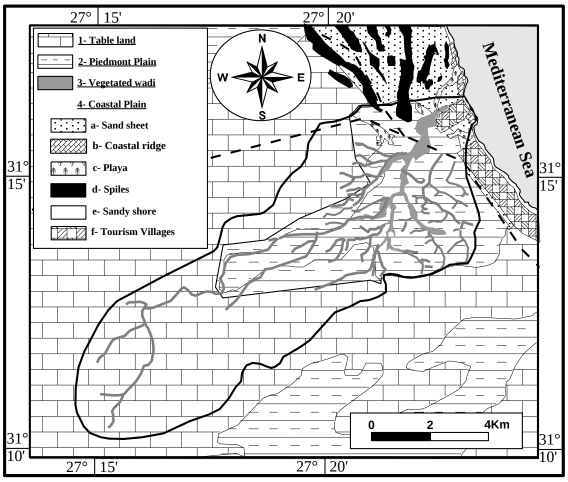

Figure 2. Geomorphical map of the study area.

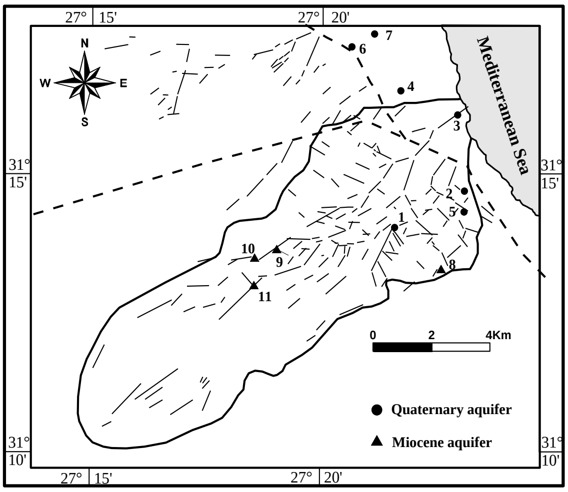

Figure 4. Lineament map with selected water samples of the study area.

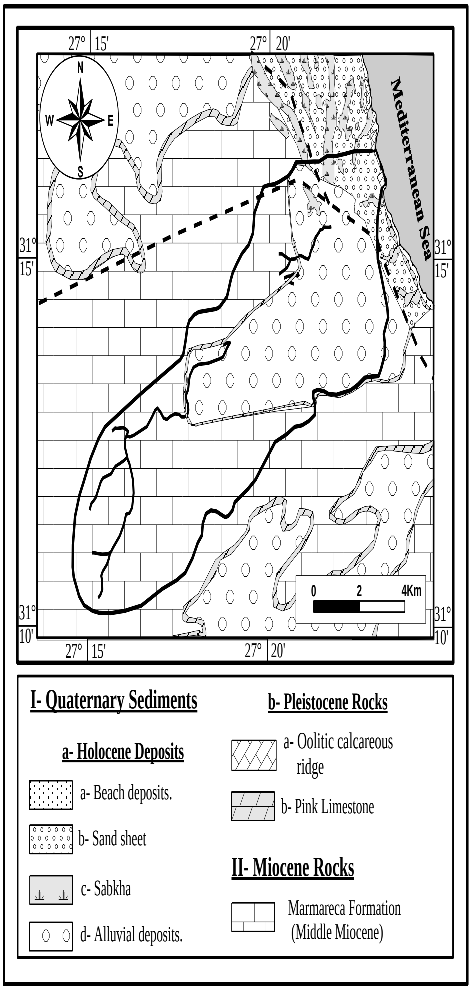

Figure 3. Geologic map of Wadi Naghamesh

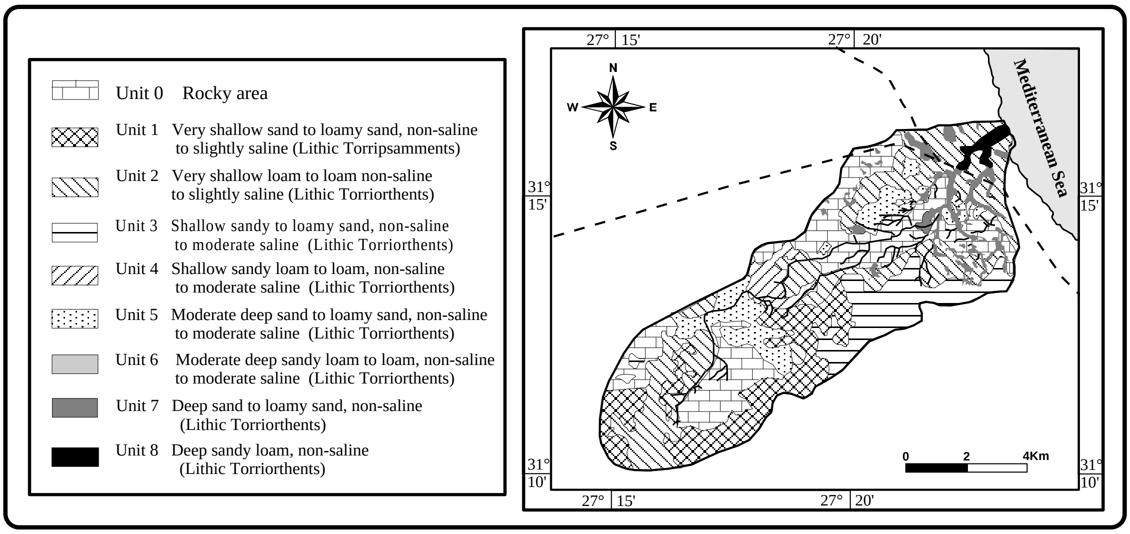

Figure 5. Soil map (modified after Abdel Kader et al. 2004)

Table 1. Physical analysis of some soil samples.

No.	Profile (Site)	Depth (cm)	E.C. µMhos/cm	TDS ppm	pH	Cations (ppm) Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Anions (ppm) HCO_3^{-}	SO_4^{--}	Cl^{-}
1	1	0-12	4.19	2477.7	8.54	100	76.0	530.0	294.64	122.0	46.1	1370.0
2		12-17	2.14	1225.1	8.79	35	33.4	340.0	73.46	134.2	21.1	665.6
3		17-	2.04	1178.9	8.75	45	21.3	335.0	66.39	146.4	23.0	615.0
4	2	0-20	5.10	2856.2	8.48	135	109.4	760.0	65.21	61.0	36.0	1720.0
5		20-27	5.55	3154.4	8.35	85	100.3	955.0	49.50	73.2	48.0	1880.0
6		27-	6.64	3737.6	8.30	145	118.6	1050.0	90.35	73.2	247.0	2050.0
7	4	0-30	0.49	275.3	8.49	35	6.1	52.0	15.00	85.4	9.5	115.0
8	6	0-20	50.08	27230.3	7.85	1500	5000.0	300.0	61.00	399.8	17000.0	61.0
9		20-33	65.50	37348.0	8.13	768	538.7	13000.0	108.80	85.4	389.8	22500.0
10		33-40	87.90	47526.3	7.85	2000	3000.0	12000.0	50.00	73.2	439.7	30000.00
11		40-	24.80	13655.5	7.91	1200	650.6	3000.0	52.64	85.4	309.6	8400.0
12	7	0-15	21.40	11528.2	9.01	950	620.2	2500.0	64.03	48.8	369.6	7000.0
13		15-25	21.20	11734.4	8.52	890	571.5	2700.0	70.32	85.4	459.8	7000.0

Table 2. Chemical analysis of some soil samples.

No.	Profile (Site)	Depth (cm)	E.C. µMhos/cm	TDS ppm	pH	Cations (ppm) Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Anions (ppm) HCO_3^{-}	SO_4^{--}	Cl^{-}
1	1	0-12	4.19	2477.7	8.54	100	76.0	530.0	294.64	122.0	46.1	1370.0
2		12-17	2.14	1225.1	8.79	35	33.4	340.0	73.46	134.2	21.1	665.6
3		17-	2.04	1178.9	8.75	45	21.3	335.0	66.39	146.4	23.0	615.0
4	2	0-20	5.10	2856.2	8.48	135	109.4	760.0	65.21	61.0	36.0	1720.0
5		20-27	5.55	3154.4	8.35	85	100.3	955.0	49.50	73.2	48.0	1880.0
6		27-	6.64	3737.6	8.30	145	118.6	1050.0	90.35	73.2	247.0	2050.0
7	4	0-30	0.49	275.3	8.49	35	6.1	52.0	15.00	85.4	9.5	115.0
8	6	0-20	50.08	27230.3	7.85	1500	5000.0	300.0	61.00	399.8	17000.0	61.0
9		20-33	65.50	37348.0	8.13	768	538.7	13000.0	108.80	85.4	389.8	22500.0
10		33-40	87.90	47526.3	7.85	2000	3000.0	12000.0	50.00	73.2	439.7	30000.00
11		40-	24.80	13655.5	7.91	1200	650.6	3000.0	52.64	85.4	309.6	8400.0
12	7	0-15	21.40	11528.2	9.01	950	620.2	2500.0	64.03	48.8	369.6	7000.0
13		15-25	21.20	11734.4	8.52	890	571.5	2700.0	70.32	85.4	459.8	7000.0

Table 3. Chemical analysis of the groundwater samples in Wadi Naghamesh; TDS and ions in ppm.

No.	Aquifer			Elevation (m)	Water level (m)	pH	TDS	K+	Na+	Mg++	Ca++	HCO3-	CL-	SO4--
1	Quaternary	Wadi Fill	Mid-stream	27	18.0	8.46	4160	2.16	47.04	54.52	18.57	32.23	31.87	13.61
3			Down-stream	8	2.0	8.05	4800	2.94	41.97	38.59	18.86	36.22	28.91	32.50
2				7	1.0	8.03	4941	2.73	41.04	30.13	19.74	36.49	26.36	43.29
4			Near sea	11	4.0	8.18	4045	2.85	42.03	33.61	17.69	37.43	35.41	30.99
5		Playa		12	1.0	8.09	6598	2.82	36.69	30.58	25.74	34.75	24.03	45.39
6		Sabkhas		12	-0.6	8.06	7921	2.68	29.86	22.83	28.59	38.87	18.77	58.40
7				14	-1.8	7.62	8288	2.79	30.85	24.67	28.76	37.60	19.24	56.09
8	Miocene	Mar-marica		38	21.0	8.08	4384	2.78	42.15	38.95	18.20	36.88	30.05	31.0
9		Moghra	Springs	67		8.15	5376	3.22	40.94	29.43	19.67	36.17	29.19	41.38
10				70		8.02	6016	2.99	40.85	33.10	19.47	36.69	25.52	41.38
11				69		7.88	6285	1.17	45.34	29.51	17.10	36.39	25.35	40.63

Table 4 Mean importance values of plant species in the different groups in Wadi Naghamesh

Species	**I**	**II**	**III**	**IV**
Arthrocneumum glaucum	—	—	4.61	32.56
Atriplex halimus	42.13	13.08	60.42	13.53
Cynodon dactylon	3.94	6.67	29.03	—
Deverra tortusus	20.42	16.40	7.46	15.11
Halocnemum strobilaceum	—	—	2.97	23.32
Haloxylon salicornica	29.97	43.53	8.48	—
Haloxylon scoparium	31.39	24.75	4.10	—
Juncus rigidus	—	—	44.55	—
Peganum harmala	12.83	33.49	1.42	—
Salsola tetrandra	28.89	27.02	23.89	9.94
Thymalea hirsute	26.13	24.43	15.62	6.87
Zygophyllum album	—	—	—	27.92
Zygophyllum coccineum	9.32	12.63	2.65	20.75

Soil constraint

The representative wadi has been intensively studied from pedological point of view (Abdel Kader et al. 2004). For verification, samples from 12 profiles were collected and subjected to physical and chemical analysis (Tables 1 and 2). An enhancementof soil map was done and eight soil units were identified (Fig. 5). Rocky area occupied about 22% of the total area and is located mostly in the table land. The very shallow, sand to loamy sand and loam, non-saline to slightly saline soils occupy 42%, restricted generally in the table land and piedmont plain. The shallow, sandy loam to loam, non-saline to moderate saline soils are recorded in the piedmont and coastal plains with about 17% of the watershed. The moderate deep, sandy loam to loam, non-saline to moderate saline soils occupy about 11% area, especially in the piedmont plain, while the others (8%) deep, sandy loam, non-saline soils are restricted mostly in the downstream of the wadi.

Surface water constraint

A total of 582 stony dams were recorded in the selected watershed utilizing advanced satellite image of 2006 and detailed field survey. They are located mostly in the mid-stream and down stream of the main wadi and their tributaries. The spatial analysis of the digital elevation model (DEM) flow accumulation indicated an additional 300 potential sites for stony dams (cisterns) in the upstream of the main wadi and their tributaries. Different infiltration tests have been carried in the adjacent watersheds by Zaki (2000), who concluded that they have low infiltration rate. The average rates are 0.29, 0.88 and 0.34 m/day of table land, piedmont and coastal plain, respectively. The relatively high infiltration for the piedmont may be because of their coarser texture. Abdel Kader et al. (2004) estimated the volume of surface runoff in the watershed for two annual rainfall scenarios, 75 mm and 150 mm. The values were 459 000 m^3 (0.0048 m^3/m^2, equivalent to 4.8 mm rain fall) for 75 mm and 1584 000 m^3 (0.0167 m^3/m^2, equivalent to 16.7 mm rain fall) for 150 mm. The above condition is favorable for the occurrence and growth of natural shrubs than trees.

Groundwater constraint

The groundwater aquifers of the study area are classified based on the available data of springs and drilled wells, chemical analysis of the collected water samples (Fig. 4 and Table 3), hydrogeologic cross sections (Fig. 6) as well as literature reviewed on the Quaternary and Miocene aquifers.

Quaternary aquifer is represented by wadi fill water bearing formation that tapped by seven wells. It occupies the bottom of the main channel and its distributaries and is composed mostly of calcareous sandy gravels in upstream, calcareous coarse sand in the mid-stream, and calcareous fine sand in the downstream. Their thickness increases from few meters in the southern part to more than 30 m near the sea. The absolute water level varies between +18.0 m in the southern part and –1.8 m in the northern part with the hydraulic gradient northward. It has variable salinity level northward, where it changes from 4160 ppm in mid-stream to 4941 ppm in the downstream and about 8290 ppm in the coastal sabkhas. It is recharged mainly from rainfall and Miocene aquifer through fracture system.

Miocene aquifers can be differentiated according to the type of aquifer sediments into Marmarica and Moghra aquifers. Marmarica aquifer is outcropped in the southern part and is tapped by one drill well with absolute water level +21 m and groundwater salinity 4384 ppm. Moghra aquifer is recorded only in the upstream of the wadi and represented by three structural springs. These aquifers are formed perhaps due to the effect of NW fault system that

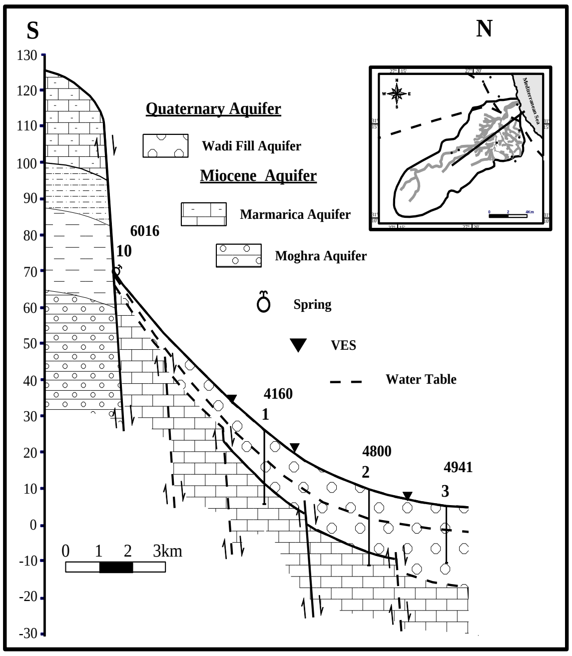

Figure 6. Hydrogeologic cross section in wadi Naghamesh.

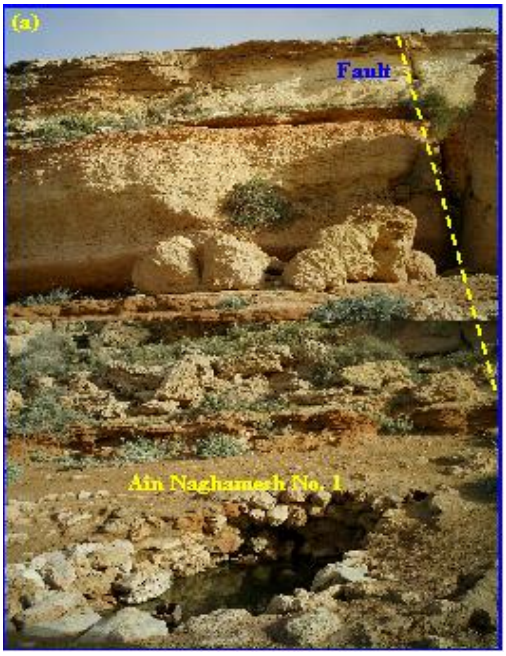

Photo 1. Structural spring (see fault).

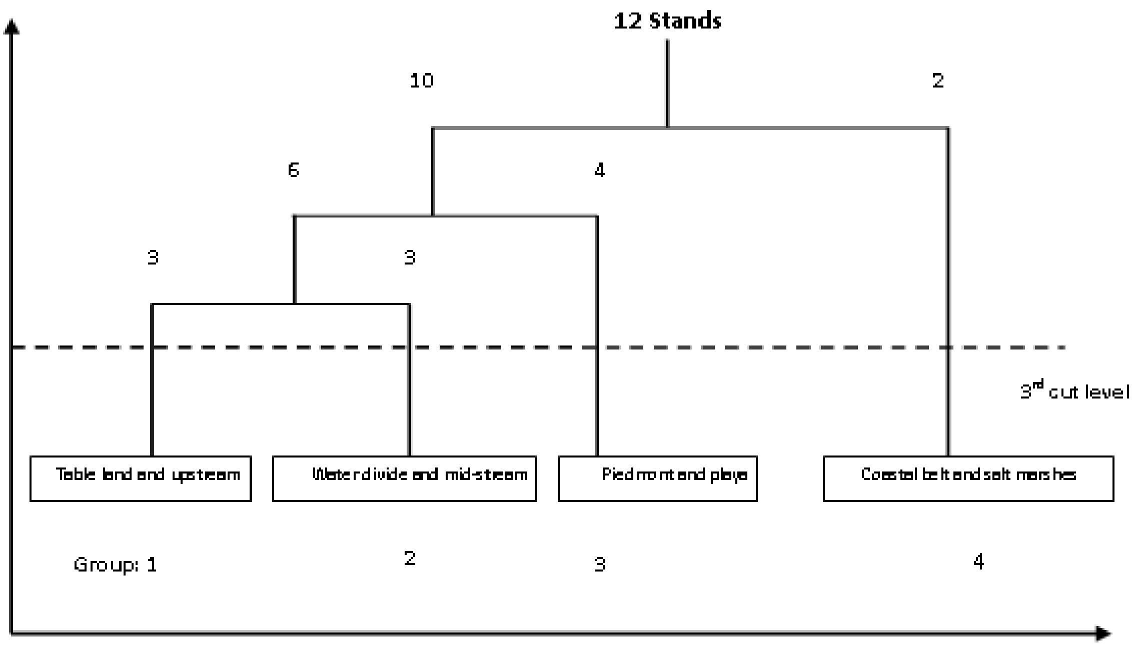

Figure 7. TWINSPAN dendogram of 12 stands based on the importance values in the watershed.

allows the upward leakage from the aquifer to the surface (Photo 1a). It is composed mostly of coarse to medium sandstone with shale layers deposited under marine condition (Hilmy et al. 1978). It is overlain by thick layer of sandy shale (i.e. confined aquifer). There is a good relationship between the springs discharge and rate of rainfall, the discharge being very low in summer season and relatively high in rainy winter season. The groundwater salinity ranges from 5376 ppm in the southern part to 6285 ppm northward because of the marine nature.

Water quality constraint

The chemical analysis of the collected water samples (Table 3) and the hypothetical salt percentages of the groundwater aquifers in the study area show the impact of structure setting especially the density of NE fault systems (Fig. 4) and the type of aquifer sediments that much control groundwater quality.

Quaternary aquifer is characterized by the following:

i. The pH varies mainly from 7.62 to 8.46 due to the variation in aquifer sediments.
ii. The TDS value is 4160 ppm (brackish water) in the southern part and it increases northward to 4941 ppm because of the leaching processes, while the in the coastal sabkhas salinity reaches to 8288 ppm because of the evaporation.
iii. The water is Mg $(HCO_3)_2$ and Ca $(HCO_3)_2$ type in the mid-stream and changes northward to $MgSO_4$ and $CaSO_4$ type because of the leaching process.
iv. There are wide variations of the dominant cations and anions sequences along the main channel of the wadi. They change from $Na^+ > Ca^{++} > Mg^{++}$ – $HCO_3^- > Cl^- > SO_4^{--}$ in the mid-stream to $Na^+ > Ca^{++} > Mg^{++}$ –$SO_4^{--} > HCO3^- > Cl^-$ in the down stream due to the effect of leaching and change further to become $Na^+ > Ca^{++} > Mg^{++}$ – $Cl^- > HCO_3^- > SO_4^{--}$ near the sea, while the sequence in the coastal sabkhas are $Ca^{++} > Na^+ > Mg^{++}$ - $SO_4^{--} > HCO_3^- > Cl^-$ because of the effect of evaporates that are rich in sulphates.

Miocene aquiferis characterized by the following:

i. The pH varies mainly from 7.88 to 8.15 due to the variation in aquifer sediments.
ii. The TDS of Marmerica aquifer is 4384 ppm (brackish water), while that of Moghara aquifer ranges from 5376 ppm to 6285 ppm because of the marine nature of aquifer sediments.
iii. The water type of Marmarica aquifer samples is $MgSO_4$, while in Moghra aquifer it is $MgSO_4$ and $CaSO_4$ type because of the marine effect.
iv. The dominant cations and anions sequences of Marmarica aquifer are $Na^+ > Ca^{++} > Mg^{++}$ – $HCO3^- > SO4^{--} > Cl^-$, while of Moghra are $Na^+ > Ca^{++} > Mg^{++}$ –$SO4^{--} > HCO3^- > Cl^-$. The variation is due to the direct rainfall recharge to outcropped Marmarican.

Natural vegetation cover

The TWINSPAN analysis of the recorded 50 perennial and 14 annual plant species in the watershed (Fig. 7) resulted in four vegetation groups (1 – 4) and the mean importance values (IV) of the plant species are tabulated in Table 4. Group 1 is dominated by *Atriplex halimus* (IV =42.1) associated with *Haloxylon scoparium* (IV =31.4), *Haloxylon salicornica* (IV =28.9) and *Thymalea hirsuta* (IV =26.1). It is located mostly in table land and the upstreams of the wadi and their tributaries. The area is characterized by very shallow soils, coarser texture, slightly saline soils, low soil moisture content and low to moderate precipitation. Group 2 is dominated by *Haloxylon scoparium* (IV =43.5) associated with *Peganum harmala* (IV =33.5), *Salsola tetrandra* (IV =27.0), *Haloxylon salicornica* (IV =24.8) and *Thymalea hirsuta* (IV =24.4). It is mostly in the water divids and the mid-streams of the wadi and their tributaries that are characterized by shallow soils, medium to coarser texture, non to slightly saline soils, moderate moisture content and moderate precipitation. Group 3 is dominated by *Atriplex halimus* (IV =60.4) associated with *Juncus rigidus* (IV =44.6), *Cynodon dactylon* (IV =29.0), *Salsola tetrandra* (IV =23.9) and *Thymalea hirsuta* (IV =15.6). It is located generally in the piedmont plain and playa which are characterized by moderately deep soils of medium to fine texture, slightly saline, high to moderate moisture content, moderate to high precipitation and shallow slightly saline groundwater. Group 4 is dominated by *Arthrocneumum glaucum* (IV =32.6) associated with *Zygophyllum album* (IV =27.9), *Halocnemum strobilaceum* (IV =23.3) and *Zygophyllum coccineum* (IV =20.8). It is located mostly in the coastal plain with salt marshes that are characterized by deep to moderate soils of fine texture and saline, high soil moisture content, high precipitation and shallow saline groundwater.

From Table 4 the following remarks can be made:

a) The presence of *Atriplex halimus, Deverra tortusus, Salsola tetrandra, Thymalea hirsute, Zygophyllum coccineum* and *Gymncarpos decandran* species in the four groups may be related to their wide ecological adaptation.
b) The occurrence of *Atriplex halimus* in table land and upstreams as well as piedmont plain may due to the presence of shallow and slightly saline soils.
c) The restriction of *Juncus rigidus* in piedmont plain and playa may be due to the moderately deep finer textured soil, high moisture content, , moderate precipitation and runoff.
d) The dominance of *Arthrocneumum glaucum* and *Halocnemum strobilaceum* species in the coastal plain and salt marshes may be due to their tolerance to high salinitys.

Hydrogeological constrain and natural vegetation interactions

The most common vegetation pattern in arid and semi-arid ecosystems is usually referred to as spotted or stippled and consists of dense vegetation clusters that are irregular in shape and surrounded by bare soil (Lavee et al. 1998; Aguiar and Sala 1999; Ludwig et al. 1999). Another common pattern is banded vegetation, also known as 'tiger bush' in Africa and 'mogotes' in Mexico, in which the dense biomass patches form bands, stripes or arcs (Aguiar and Sala 1999; Ludwig et al. 1999; Valentin et al. 1999). Banded patterns commonly act as closed hydrological systems (Valentin and d'Herbes 1999; d'Herbes et al. 2001), with little net outflow and sediment coming out of the system, while the redistribution of runoff and erosion occurs at the inter-patch scale due to effect of spotted vegetation.

In the study watershed, spotted and banded vegetation patterns were recorded. Spots were located mostly in the table land and piedmont plain. They were characterized by low relief areas, irregular in shape and surrounded by bare soil. The area mostly has very shallow to shallow, sandy loam, slightly saline soils that fed by surface runoff and/or shallow groundwater and have low moisture content. The appearance of the spotted or strippled microtopography may be linked to differences in soil erosion rates (Tongway and Lundwig 1990; Dunkerly 2002), the variation of rock units and distribution (deposition) of soil in runon (sink) areas.

Most of the vegetated bands (groves) were located in the regions of high slope and not on the flatter areas as could have been expected from differences in erodability between bare and vegetated areas (Dunkerley and Brown 2002). They were located generally in the banks of the main wadi and their tributaries , which are structurally controlled and characterized by higher slope, and variation of rock types and erodibility, shallow sediments, sandy loam and slightly saline soils (Photo 2a). The same type was recorded by Dunkerley and Brown (1995, 1999 and 2002) in Australia but in the hill slopes. The appearance of bands is due to the effect of anisotropic seed dispersal resulting from preferential redistribution of seed by surface flow down slope.

A coupled dynamic vegetation-landform evolution model (Photo 2b) for water limited ecosystem has been developed. It was used to explore the interactions between patterned vegetation, geomorphic changes and erosion by explicitly accounting for the effect of dynamic water distribution. The bands grow laterally because there is no competition for water with other lateral plants. Each concave functions as a source – sink unit. In the intergrove areas increasing amount of sediments (and nutrients) are removed by runoff that increases with distance from the upper grove boundary. At the boundary of the grove where runoff is highest, the depth of flow is also highest inducing high infiltration rates. Therefore, these areas become important sinks of water (runon) and sediments, and the simulated depositional rate are highest.

Vegetation plays a key role in the interactions between groundwater and surface water system, because of its direct and indirect influence on recharge and because of the dependence of vegetation

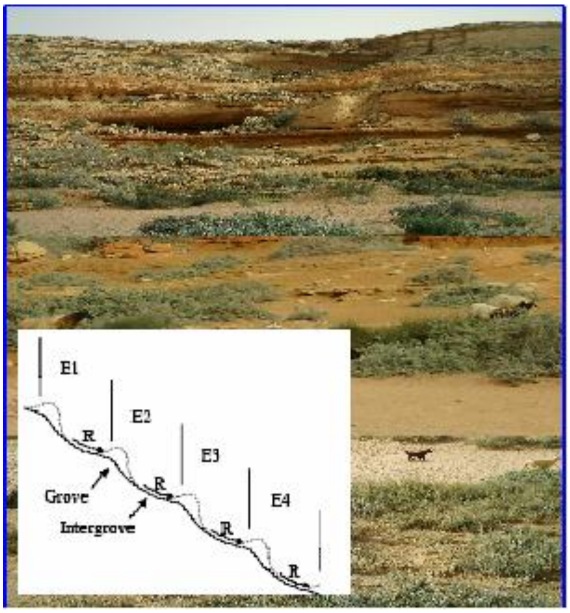

Photo 2. Banded vegetation in wadi Naghamesh (a) and schematic diagram (b) of the microtopographic profile (continuous line), vegetation (dashed line) and surface water distribution (curved arrows) that arises (self-organizing) from our model.

communities on groundwater. Where, the domination of *Zygophyllum*, *Arthrocneumum glaucum* and *Halocnemum strobilaceum* species, which are susceptible to changes in the depth to groundwater, both annual and seasonal surface water, salts in the marshes (wetlands), are a good indication of the interactions between saline groundwater and surface water system. distribution (curved arrows) that arises (self- organizing) from our model.

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2.9. Dryland wheat yield prediction by precipitation and edaphic data: Regression and artificial neural network models

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Abstract

Dryland wheat is highly dependent on climatic factors and therefore yields show high fluctuations. Since wheat plays an important role in food security, wheat yield prediction can help government decision-making. The objectives of this study were to 1) investigate if artificial neural network (ANN) models can effectively predict Khorasan dryland wheat yield in typical climate conditions and 2) compare the effectiveness of multiple linear regression models to ANN models. Models were developed using historical yield data at multiple locations throughout Khorasan. Field-specific rainfall data including total rainfall through the year (beginning from 1st Oct), total rainfall throughout the growing season (total rainfall from 1st Nov to 30th Jun) and monthly rainfall in the growing season and also edaphic data such as soil texture, moisture content at field capacity (FC) and permanent wilting point (PWP) and also available water (AW) were used for each location. The results showed that monthly rainfall, soil clay percentage, moisture content at FC and PWP are necessary for effective dryland wheat predictions. Adjusting ANN parameters such as learning rate and number of hidden nodes affected the accuracy of yield predictions. Optimal learning rates fell between 0.7 to 0.9 and smaller data sets required fewer hidden nodes and lower learning rates in model optimizations. ANN models consistently produced more accurate yield predictions than regression model. One ANN dryland wheat yield model resulted in r^2 value of 0.8 and RMSEs value of 7% as against 0.66 and 29% for linear regression model. Although more time consuming to develop than linear regression model, ANN modeing proved to be a superior methodology for accurately predicting dryland wheat yield under typical Khorasan climate conditions.

Introduction

Crop growth and yield models are based on a combination of soil, crop, and climatic variables. Water availability is frequently one of the most critical factors for estimating yield in rain-fed agriculture. Sadras and Calvino (2001) determined that 90% of soybean and 76% of corn yield variations were linked to water deficits. Rainfall was deemed to be primarily responsible for yield variability within a region. Crasta and Cox (1996) determined that temperature did not influence yields in the northeastern US during years with adequate rainfall as compared to years with moderate to severe water stress. According to Bandel and Heger (1994), differences of growing season had little influence on yield, but soil water holding capacity and land capability class were important factors in the

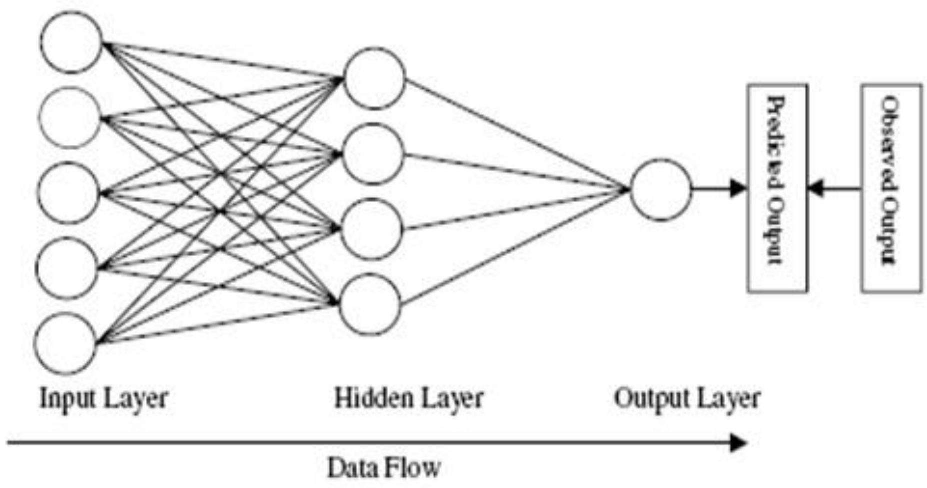

Figure 1. Layers and connections of a feed-forward propagating artificial neural network

MASCAP yield predictions. Environmental factors, such as climatic information, in addition to multiple soil properties related to crop rooting depth and water availability, are significant factors for crop yield models (Gbadegesin 1987; Liang et al. 1986; Whisler et al. 1986; and Huddleston 1984). Agronomic models are based on mechanistic or empirical approaches (Poluektov and Topaj 2001). Mechanistic models use mathematical functions to represent physical, biological, and chemical processes (Whisler et al. 1986). Although these models are suitable for areas outside the data range used for development, they tend to be complex and require many input parameters (Basso et al. 2001; Bolte 1997; Wang et al. 2002). Empirical models are based on correlative factors between variables, are relatively simple, and require less data although such models cannot be used in areas outside the data range for which they were created. Artificial neural network (ANN) models are a powerful empirical modeling approach and yet relatively simple compared to mechanistic models. The ANN models offer a more versatile empirical modeling approach in comparison to the linear regression methods used in developing crop yield predictions.

Artificial neural networks can be used to develop empirically based agronomic models. The ANN structure is based on the human brain's biological neural processes. Interrelationships of correlated variables that symbolically represent the interconnected processing neurons or nodes of the human brain are used to develop models. ANNs find relationships by observing a large number of input and output examples to develop a formula that can be used for predictions (Pachepsky et al. 1996). Non-linear relationships overlooked by other methods can be determined with little *a priori* knowledge of the functional relationship (Elizondo et al. 1994).

A minimum of three layers is required in an ANN: the input, hidden, and output layers (Fig. 1). The input and output layers contain nodes that correspond to input and output variables, respectively. Data move between layers across weighted connections. A node accepts data from the previous layer and calculates a weighted sum of all its inputs, t:

$$t_i = \sum_{j=1}^{n} w_{ij} x_j, \quad (1)$$

where n is the number of inputs, w is the weight of the connection between node i and j, and x is the input from node j. A transfer function is then applied to the weighted value, t, to calculate the node output, o_i.

$$o_i = f(t_i). \quad (2)$$

The most commonly used transfer function is a sigmoidal function for the hidden and output layers and a linear transfer function is commonly used for the input layer.
The number of hidden nodes determines the number of connections between inputs and outputs and may vary depending on the specific problem under study. If too many nodes are used, then the ANN may become over-trained causing it to memorize the training data resulting in poor predictions (Lawrence 1994). The learning rate determines the amount of weight change during a series of iterations to bring the predicted value within an acceptable range of the observed value. The training tolerance refers to the maximum error rate at which the network must converge during training. Once the network converges, an approximate function is developed and utilized for future predictions (Schmueli 1998). The trained network is then tested with a separate data set with its output information omitted.

Agronomic ANN applications include crop development modeling (Kaul et al 2005; Uno et al. 2005; Elizondo et al. 1994), pesticide and nutrient loss assessments (Yang et al. 1997), soil–water retention estimations (Schaap and Bouten 1996), and disease prediction (Batchelor et al. 1997). Pachepsky et al. (1996) reported ANNs estimated soil water content based on soil physical properties better than regression techniques. Starrett et al. (1997) reported that an ANN performed better (r^2 = 0.984) than a regression model (r^2 = 0.780) when predicting applied-nitrogen leaking below the root zone of turf grass. According to Batchelor et al. (1997), ANNs produced better results than traditional statistical methods when predicting soybean rust.

The goal of this study was to develop simple crop yield prediction models with readily available data that could be easily applied by an end user and also by government to help their decision-making process. The specific objectives were to: investigate if an ANN could effectively predict Khorasan dryland wheat yield for typical climatic conditions using field-specific rainfall, soil factors, and historic yield data and compare the effectiveness of multiple linear regression model with ANN model for predicting Khorasan dryland wheat yield.

2. Materials and methods

2.1. Data

Historical (1982-2003) Khorasan dryland wheat yield data from the Jahad-e-Agriculture organization of Khorasan state were accessed. The yield data came from 8 locations. Mean yield of all varieties at a test location was used to reduce the inherent variability associated with individual varities when approximating expected yields for Khorasan.

Precipitation data were obtained from weather station records from each location. Monthly rainfall means from November through June (dryland wheat growing season), total precipitation during growing season and total precipitation during fall (total precipitation during October, November and December), winter (total precipitation during January, February and March) and spring (total precipitation during May, April and June) were used.

For estimating the edaphic variable including soil texture, soil moisture content at field capacity (FC) and permanent wilting point (PWP); and also soil available water

(AW), 59 samples were taken from the area. After determining the soil texture, soil moisture content at FC and PWP (cm^3cm^{-3}) were estimated by transfer functions introduced by De Ridder and van Kuelen (1995):

$$FC = \theta_{pF\ 2.5} = \{(0.37 - 0.0035\ Sa_p) *Bd\}/100 \quad (3)$$

$$PWP = \theta_{pF4.2} = \{(0.007 + 0.0039\ Cl_p) *Bd\}/100 \quad (4)$$

$$AW = \theta_{pF\ 2.5} - \theta_{pF4.2} \quad (5)$$

where Sa_p is soil sand percentage, Bd is soil bulk density and Cl_p is soil clay percentage. The available water (AW) is:

2.2. Artificial Neural Network models development

A feed-forward back-propagating ANN structure as illustrated in Fig. 1 was used to develop yield prediction model. A feed-forward network is a common ANN architecture that requires relatively little memory and is generally fast (Lawrence 1994). Data move through the layers in one direction, from the input through the hidden to the output layers, without loops as opposed to feedback networks. Feed-forward networks may be based on linear or non-linear transfer functions that affect the output from the input and hidden layers. Non-linear networks may be trained using supervised learning, learning by example with outputs, or unsupervised learning, self-organizing without outputs. Supervised learning uses known outputs to train the ANN and is more commonly used than unsupervised learning. Back propagation is a form of supervised learning where the error rate is sent back through the network to alter the weights to improve prediction and decrease error.

The general process to build a neural network model included creating data sets for training and testing, training multiple networks with varied parameters, analyzing network results, and testing the models (Broner and Comstock 1997). Training sets used to develop models included field-specific rainfall and edaphic values as inputs with associated yields as outputs (Table 1). Because the assignment of connection weights in an ANN is sensitive to differences in the magnitude of input variables, yield values were scaled to range from 0 to 1 so that the values were within a similar numerical range as other input values. Multiple combinations of rainfall and edaphic inputs were used during training to determine critical rainfall periods and the most affecting edaphic variable for model development. Both training and testing data sets contained data from all locations and were randomized before model development. Training data consisted of 77 dryland wheat yield observations of a total of 107 dryland wheat observations. The remaining data for the crop were used to test the models.

Adjustment of ANN parameters included the number of hidden nodes, the number of neuron in each layer, learning rate, and training tolerance. The number of hidden nodes selected per model was equal to one-half the total number of inputs plus outputs. The number of nodes were then increased and decreased by one to improve model performance.

2.3. Regression model development

Step forward linear regression models were developed and tested with the same data sets used for ANN development. Field-specific rainfall information and edaphic variables were independent variables and crop yield was the dependent variable (Table 1). Thus, independent and dependent variables correspond to ANN input and output variables, respectively.

The regression equations that were developed are referred to as trained models. These models were then validated with the same data sets used to test the ANN models, thus making the results comparable, and are

Table 1. Inputs used for development of dryland wheat yield prediction models

Input number	Description	Abbreviation
1	Total precipitation during dryland wheat growing season	S8
2	Sand percentage in soil	Sa_p
3	Silt percentage in soil	Si_p
4	Clay percentage in soil	Cl_p
5	Soil moisture content at FC	FC
6	Soil moisture content at PWP	PWP
7	Soil available water	AW
8	Total rainfall at Spring	RS
9	Total rainfall at Fall	RF
10	Total rainfall at Winter	RW
11	Monthly rainfall at November	R_{Nov}
12	Monthly rainfall at December	R_{Dec}
13	Monthly rainfall at January	R_{Jan}
14	Monthly rainfall at February	R_{Feb}
15	Monthly rainfall at March	R_{Mar}
16	Monthly rainfall at April	R_{Apr}
17	Monthly rainfall at May	R_{May}
18	Monthly rainfall at June	R_{Jun}

referred to as validated models. The validated models are indicative of the models capability to predict yield, since the testing data are independent of the data used for model development. Specific comparisons were based on RMSE and r^2 of the validated regression and the ANN model results. Variations of monthly rainfall inputs were considered for models. The grouping patterns of precipitation inputs used in regression analysis were identical to ANN model input groupings.

3. Results and discussion

3.1. Artificial neural network models

More than 25 ANN yield prediction models were developed and tested for dryland wheat yield. Discussion of ANN model results refers to the tested models. Models that used sand and silt percentage failed to converge during training, indicating that the ANN was unable to develop a yield prediction function. So these models were omitted from the list of models. Table 4 shows the models with reasonable results. The RMSE of the models that used mean monthly rainfall for December-April failed to improve during training, indicating that the use of monthly rainfall means for December-April did not adequately account for dryland wheat yield variability (Table 5). The model that included total precipitation during growing season, mean monthly rainfall for November, April and June, resulted in the best fit of predicted to measured yield.

The timing of rainfall inputs for all models is consistent with water utilization by the dryland wheat crop during the growing season. Peak water use by wheat crop occurs during April to June, while plants are in the reproductive stages of development (HongBo et al. 2005; Fredrick and Cambertato 1995). On the other hand, dryland wheat is cultivated during November, so monthly precipitation in November determines the plant density by affecting the germination. Arora and Prihar (1983) reported that rainfall at sowing time is one of the factors affecting the wheat yield in dryland condition. Since monthly rainfall means for December-April provided insufficient information to predict crop yield, it is evident that the models are sensitive to the timing of precipitation as an important factor for crop development.

Table 2. Description of different Regression models (abbreviations are described in Table 1)

Model	S8	Sa_p	Si_p	Cl_p	FC	PWP	AW	R_{Jan}	R_{Feb}	R_{Mar}	R_{Apr}	R_{May}	R_{Jun}	R_{Nov}	R_{Dec}
1	*				*	*									
2	*	*	*	*											
3	*	*	*	*	*	*									
4	*	*	*	*			*								
5								*	*	*	*	*	*	*	*
6					*	*		*	*	*	*	*	*	*	*
7		*	*	*				*	*	*	*	*	*	*	*
8							*	*	*	*	*	*	*	*	*
9		*	*	*	*	*		*	*	*	*	*	*	*	*
10		*	*	*			*	*	*	*	*	*	*	*	*

Table 3 Results of different regression models (models are described in Table 2)

Model	r^2_{adj}	r^2	β_0	β_{S8}	β_{Clp}	β_{FC}	β_{PWP}	β_{RJan}	β_{RApr}	β_{RJun}	β_{RNov}	RMSE (kg ha^{-1})	RMSE (%)
1	0.332	0.594	420.95	19.318	-	248.2	-6195.3	-	-	-	-	369	49
2	0.28	0.548	556.42	21.411	12.88	-	-	-	-	-	-	345	46
3	0.48	0.71	847.55	17.731	220.075	2460.7	-47826.1	-	-	-	-	232	34
4	0.28	0.548	556.42	21.411	12.88	-	-	-	-	-	-	345	46
5	0.40	0.65	277.35	-	-	-	-	-2.3	5.987	4.29	5.11	288	38
6	0.59	0.67	361	-	-	2411.308	-5360.6	-	5.05	3.09	4.43	253	33
7	0.40	0.65	277.35	-	-	-	-	-2.3	5.987	4.29	5.11	288	38
8	0.40	0.65	277.35	-	-	-	-	-2.3	5.987	4.29	5.11	288	38
9	0.594	0.78	766.9	-	225.03	2423.6	-47937	-	5.1	2.32	4.03	218	27
10	0.40	0.65	277.35	-	-	-	-	-2.3	5.987	4.29	5.11	288	38

β: constant /coefficient

Table 4. Description of different Artificial Neural Network models (abbreviations are described in Table 1)

Model	S8	FC	PWP	AW	RW	RF	RS	R_{Jan}	R_{Feb}	R_{Mar}	R_{Apr}	R_{May}	R_{Jun}	R_{Nov}	R_{Dec}
1	*	*	*												
2	*			*											
3	*										*		*	*	
4	*	*	*					*	*	*	*	*	*	*	*
5	*							*	*	*	*	*	*	*	*
6	*	*	*	*				*	*	*	*	*	*	*	*
7	*				*	*	*								
8	*				*	*	*	*	*	*	*	*	*	*	*
9					*	*	*								
10										*	*	*	*	*	
11								*	*	*	*	*		*	*
12					*	*	*	*	*	*	*	*	*	*	*
13		*	*					*	*	*	*	*	*	*	*
14				*				*	*	*	*	*	*	*	*
15				*	*	*	*	*	*	*	*	*	*	*	*
16				*							*			*	
17		*	*	*							*			*	
18											*			*	
19	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 5. Results of Artificial Neural Network models

Model	No of hidden layers	No of neurons in each layer	$RMSE_{train}$ (kg ha^{-1})	$RMSE_{train}$ (%)	$RMSE_{test}$ (kg ha^{-1})	$RMSE_{test}$ (%)	r^2
1	2	10	67	12	99	18	53.3
2	2	30	65	12	122	22	46.4
3	2	25	27	5	40	7	83.0
4	2	5	43	8	55	10	74.7
5	2	20	20	4	77	14	67.9
6	2	45	24	4	83	15	60.2
7	2	40	55	10	70	13	70.1
8	2	10	19	3	49	9	75.1
9	2	5	58	10	63	11	77.0
10	2	10	23	4	46	8	80.2
11	2	5	38	7	54	10	74.0
12	2	20	49	9	67	12	67.9
13	2	25	60	11	81	15	44.8
14	2	30	60	11	75	14	62.4
15	2	45	51	9	59	11	71.7
16	2	45	33	6	41	7	86.9
17	2	50	44	8	59	11	77.0
18	2	5	30	5	50	9	82.8
19	2	15	120	22	148	27	39.4

$RMSE_{train}$: RMSE for train data
$RMSE_{test}$: RMSE for test data

Amongst edaphic data, available water proved to be an important factor affecting wheat yield under dryland conditions, so that entering available water to the models improved the simulation. According to Richards et al. (2001), crop yield under dryland condition is a function of available water in soil. Soil moisture content at field capacity (FC) and permanent wilting point (PWP) were next determining factors for dryland wheat yield prediction.

The best ANN models were model 16 and 3 which used monthly rainfall data of April and November and soil available water (r^2= 86%, RMSE= 41 kg ha^{-1}, 7%) and monthly rainfall data of April, June and November and also soil available water (r^2= 83%, RMSE= 40 kg ha^{-1}, 7%), respectively. According to RMSE definition, the model simulation is considered excellent with RMSE<10%, good if 10-20%, fair if 20-30% and poor>30% (Rinaldi et al 2003). It seems that ANN models can forecast dryland wheat yield with excellent accuracy.

3.2. Regression models

The data used for ANN models were also used for regression models. The validation of the models was assessed based on normality and homocedasticity tests and also the significance of their r^2. The model was excluded if it failed in any of these test. Table 2 shows the models whose validation met the tests.

Table 3 indicates the results obtained from regression models, the r, r^2 and adjusted r square of the studied models described in Table 2.Based on the results, dryland wheat yield can be predicted using total rainfall during growing season, monthly rainfall of January, April, June and November, moisture content at FC and PWP and also soil clay percentage. Since the other variables are excluded by the step-forward regression without changing the r^2, it seems that they did not affect dryland wheat yield significantly.

According to regression coefficient of models, the best equations were those models which used 1) precipitation in April, June and November and soil moisture content at FC and PWP ($r^2 = 0.78$, RMSE= 218 kg ha^{-1}, 27%) and 2) total precipitation during growing season, soil clay percentage and soil moisture content at FC and PWP ($R^2 = 0.71$, RMSE=232 kg ha^{-1}, 31%). So, the best dryland wheat yield simulation by regression model was only fair.

4. Summary and conclusions

The management planning of drylands of Khorasan state necessitated a simple and accurate technique to estimate crop yields. Previous efforts to predict the dryland wheat yield using regression models were not successful. This paper describes the development of artificial neural network models as an alternate and more accurate technique for yield prediction in Khorasan. The regression models resulted in lower r^2 and higher RMSE than ANN models (Table 3&5). Validated multiple regression models did not predict wheat yield with the same level of accuracy as ANN models (Table 3&5). ANN yield prediction models produced consistently higher r^2 and lower RMSE values than multiple linear regression-based yield models. Note that validated r^2 values were lower than the r^2 of the non-validated regressions, indicating that testing regression equations with independent data is critical for the evaluation of regression-based crop yield prediction models. Rainfall inputs required for the ANN model correspond to crop developmental phases. Although rainfall during December-March tend to be necessary for crop growth and development, monthly rainfall means during these months were inadequate for effective crop yield prediction. Rainfall during April, June and November was critical to account for the variability associated with wheat yield.

The available water provided a concise and effective variable related to crop yield. The soil available water was a critical input variable for ANN model convergence. ANN models, like regression models, are applicable only to the conditions for which they were developed. The models reported here are appropriate for predicting wheat yields in Khorasan for average climatic conditions and for the specific soil types used to develop the models.

Since there is no set methodology for ANN development, the approach differs for specific problems and thus requires more time for development than regression models. The learning rate, number of hidden nodes, and the training tolerance had an effect on model development and the accuracy of ANN crop yield predictions. As the quantity of data being modeled decreased due to smaller spatial levels, fewer hidden nodes were required. As the number of hidden nodes decreased, the optimum learning rate decreased. As the number of nodes decreased, ANNs tended to train slower and required smaller increments of change in the assignments of weights which is reflected by the assigned learning rate. Improved ANN models were produced with training tolerances set high and gradually lowered as the networks trained (Fausett 2004).

These ANN models have the potential to be useful as a component of management planning within Khorasan given further development and validation. ANN modeling with additional locations will increase the variability of soil types and should broaden the usefulness, and possibly increase the predictive capabilities of ANN-based yield prediction. ANN models show promise as a more accurate technique that could be used by Khorasan management specialists to develop, revise, or update management plans.

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2.10. Impact of human activities on groundwater depletion and quality deterioration in the northwestern shelf of Nubian sandstone and fractured carbonate aquifer systems

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Abstract

Nubian Sandstone aquifer system is one of the largest aquifers in North Africa, overlying fractured carbonate aquifer system. These systems are affected by intense human activities, especially in the northern Nubian shelf where a lot of shallow and deep water wells are being dug in different development programs. The aim of this study was to examine various activities with time, and study their impact on the hydrogeological and hydrogeochemical situation as well as predict the future condition of the groundwater aquifer systems in the area. Groundwater depletion, the disappearances of most springs, and the deterioration of the groundwater quality with time was clearly evident. Prediction, based on the observed data, is that most of shallower natural lakes such as Jaghbub, Um El Ghezlan, Sheiata and Tameira will disappear before 2045 without drilling any more deep wells. On the other hand, the deeper lakes in Siwa Oasis would become dry before 2055, and the continuous drilling of deep wells will accelerate the process. The farmers have to deepen their shallow groundwater wells in fractured carbonate zones every five year at least, for keeping flow-irrigation working. The government must stop land reclamation based on shallow and deep water wells, and encourage cultivation of plants that resist high salinity in groundwater, and should drill a lot of observation wells for evaluating deep Nubian water body. The hydrogeologic and hydraulic setting of this area must be re-evaluated every ten years or after all intensive activities.

Introduction

Less than 1% of the Earth's water is available for human consumption and 70% of the world groundwater withdrawals are used for irrigation purposes (Datta 2005). Heavy use of groundwater leads to steady declines in water tables as recorded in many parts of the world (IWMI 2006). The magnitude of the problem is poorly documented, particularly in the developing countries. In spite of decreasing land area under irrigated agriculture, groundwater will continue to be used intensively. The physical depletion, low quality water, water logging and salinization will pose great challenge for the future development. The main factors for the occurrence of these phenomenons are the human activities and the low rate of groundwater recharge.

The region of northwest Egypt and northeast Libya (Fig. 1 A), which constitutes the northern shelf of Nubian mega aquifer system in northeast Africa and overlying fractured carbonate aquifer system, is an ideal case for studying these phenomena. The area has some connected aquifer systems, series of natural lakes, and a lot of developmental activities. From hydrogeological point of view, the area can be divided into seven local sub-basins using geophysical data (such as aero-magnetic, aero-gravity, seismic and well logging), geological information from drilled oil and water wells. These sub-basins are Al Salum, Matruh, Al Alamin, Kohla, Gibb Affia, Siwa and west Qattara Depression (Fig. 1 B).

Siwa sub-basin, which extends from west Qattara in Egypt to the west of Jaghbub in Libya, has been selected as a representative area for detecting these phenomena due to the available information about subsurface geology, water wells tapping most of the aquifer systems, the presence of some natural lakes, and the intensive human activities after 1990 for water development for agricultural and drinking purposes. Siwa sub-basin lies between latitudes 29° 00' and 29° 50' N, and longitudes 24° 30' and 26° 10' E (Fig. 1 C), approximately 210 km south of the Mediterranean coast. It occupies a series of depressions running mostly E-W such as Jaghbub, Um Gheizlan, Sheiata, Gerba and Siwa. The depressions are topographically bounded by an escarpment to the north which rises to about 20 - 100 m above the floor of the depressions and sand dune belt with elevations ranging from 20 to 50 m to the south. The average elevations of the floor of Siwa lakes range from -10 to -18 m below the sea level, while the others are of higher elevations. Most information about surface of the area comes from orbital remote sensing thematic mapper (TM) imageries which are uniquely suited for defining major morphological changes of surface water bodies in this broad and poorly studied region. This technology provides an overview of geomorphological setting and permits identification of important features that can be the focus of the field studies. Siwa sub-basin is divided into three main geomorphic units, namely high lands (El Diffa plateau, isolated hills, piedmont slope) in the northern part, table land (the elevated sandy plain and sand sea) in the southern part, and low lands (salt lakes, sabkhas and cultivated lands).

The private and public sector drilling of water wells started in the beginning of 1990 in the sub-basin. With the shortage of drinking water in Libya, Libyan government drilled a lot of wells in Jaghbub Oasis for providing water to the main towns. Many of the Siwa Bedouins came to Libya after 1990 and drilled a lot of shallow wells for agricultural and drinking purposes. Within the same time, the Egyptian government planned to drill deep wells for combating water logging in Siwa Oasis and for developmental activities. Due to the intensive groundwater excavation as well as bad management during the last two decades, most of the above phenomena become obvious in the sub-basin. The main objectives of this article are to record and analyze the impact of human activities on groundwater depletion, disappearance of most springs, and deterioration of groundwater quality, as well as, predicting the future condition of the groundwater aquifer systems in the area.

Geological background

According to Klitzsch et al. (1986) and Said (1990) the exposed rocks of Siwa sub-basin are extended from Middle Eocene to Quaternary. The Eocene rocks are restricted to the east of Siwa Oasis and are differentiated into Middle Eocene (chalky limestone with shale beds) at Minqar El Talh and Upper Eocene (shale with limestone interbeds) in west El Arag. Miocene deposits are widespread and represented by Lower and Middle Miocene. Lower Miocene (Moghra Formation) bounds mostly Siwa depressions and is composed of fluvio-marine gypsiferous shale, sandstone and marl beds. Middle Miocene rocks (Marmarica Formation) are

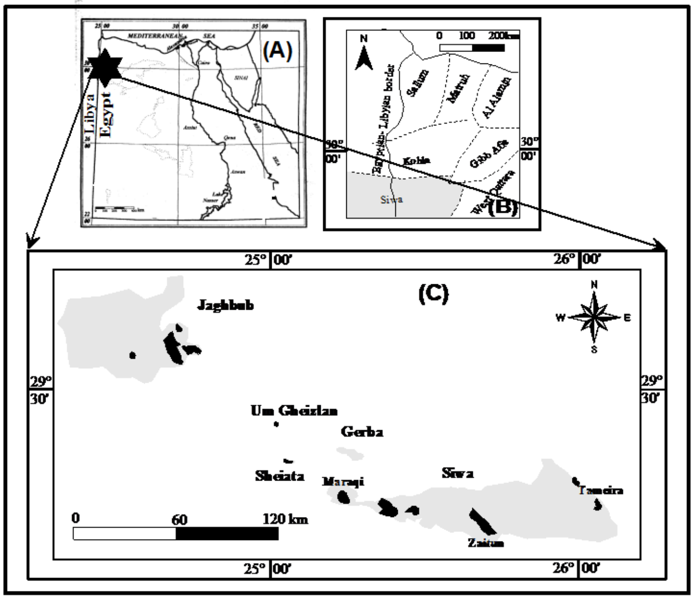
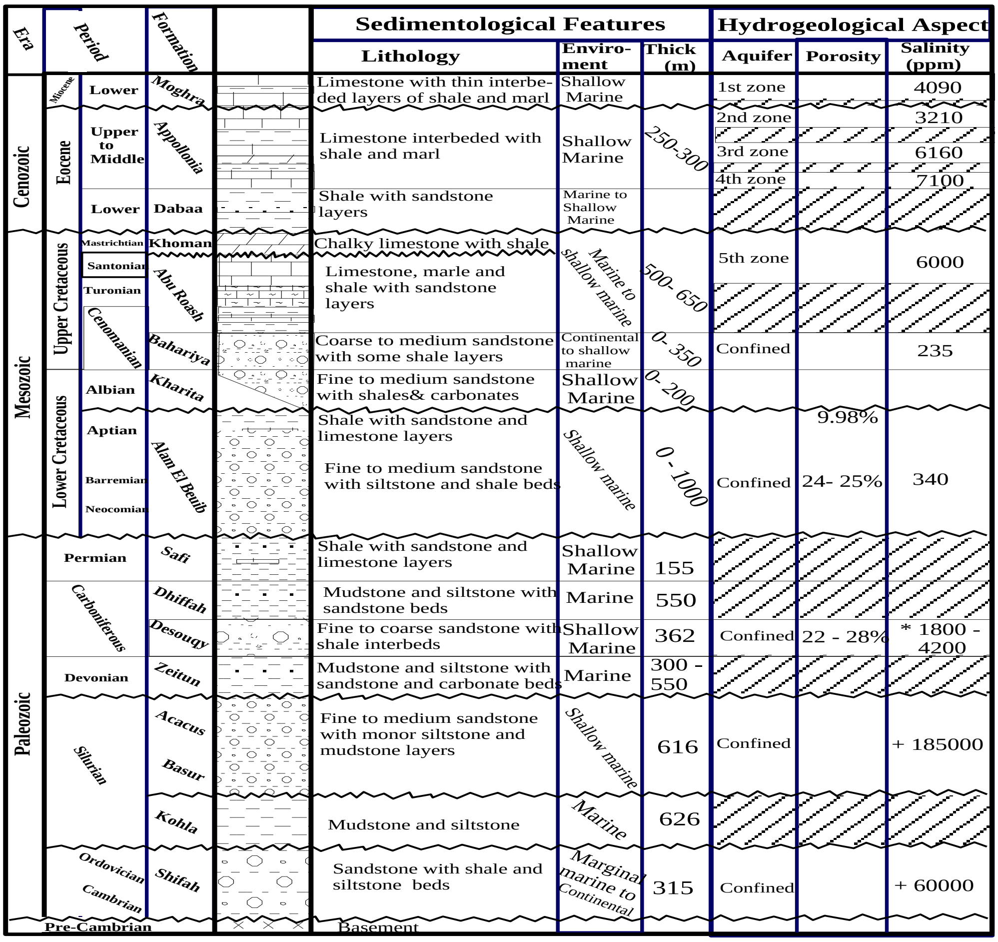


Figure 1. (A) The general location of the study area in Egypt and Libya. (B) The seven main sub-basins in northwest Egypt and Northeast Libya. (C) Siwa sub-basin showing the distribution of main lakes (black color) and the low laying area (grey color).



* Total salimity calculated from well logging + Drill strem test (GPC, 1991)

Figure 2. Compiled subsurface geological column and hydrogeological setting of northern shelf of Nubian aquifers (not to scale) showing the age, aquifer thickness, lithology, environment of deposition and the average salinity.

located in the northern scarp and are built up of limestone, dolomite and shale. The Quaternary deposits are recorded in the depressions and are represented by alluvium, aeolian and sabkha deposits. From the hydrogeology point of view, the compiled information on subsurface geologic column is shown in Figure 2.

Water resources

Surface water

Springs: The sub-basin of Siwa rests mostly on 450-600 m fractured limestone and highly piezometric head Nubian sandstone aquifer system (NSAS). Under the effect of Nubian pressure and the occurrence of high fractured carbonates, the groundwater is pushed upward in all of them to the surface as spring. Some 148 springs are recorded in Siwa Oasis only according to RIGW (1997). The springs can be differentiated into Lower Miocene, Lower Eocene and Upper Cretaceous springs according to the isotope values, physical properties and chemical analysis of water samples. The Lower Miocene springs have ^{2}H values around -78%, Lower Eocene samples from -66 to -68%, while the Upper Cretaceous springs less than -69% (Table 1).

Nine water samples were collected to represent all types of springs in Siwa Oasis (Fig. 3 and Table 2). Lower Miocene springs show three salinity zones, the lowest one (1500 – 2000 ppm) is recorded to the east of Siwa Oasis, the moderate (2000 – 3000 ppm) is located around Maraqi lake and relatively high (3000 – 3500 ppm) is restricted around Siwa lake. The variation in the level of salinity may be due to the effect of the variation in NSAS piezometric head (which is the main source of recharge), density of fault systems in carbonate rocks, and the rate of leaching processes.

The salinities of Lower Eocene and Upper Cretaceous springs (Qrusht and Abu Shrof) are higher,7597 and 5952 ppm, due to the enrichment of their rocks by shales and gypsum. The springs discharge decreases westward from some hundred cubic meters to a few cubic meters per day due to the decline of Nubian piezometric head. The higher rate of discharge and the occurrence of H_2O_2 near NW and WNW might be due to the activity of these faults.

Lakes: The major lakes of Siwa sub-basin are Jghboub, Sheiata, Um El Ghezlan, Maraqi, Siwa, Aghormy, Zaitun and Tameira, from west to east. Some small water ponds such as El Maaser series and the extension of Zaitun have been recorded. Maraqi, Siwa, Aghormy and Zaitun lakes are formed as a result the storage of pumped drain water from the surrounding cultivated area, a lot of deep springs in the lakes, and the seepage of groundwater from surrounding high lands. Jaghbub, Sheiata, Um El Ghezlan, Tameira and El Maaser lakes are formed mostly due to a lot of deep springs under their surface and the upward leakage from the NSAS through faults. Five water samples were collected with total salinities of 101952, 118592, 86400, 40512 and 30720 ppm of Maraqi, Siwa, Zaitun, Tameira and the extension of Zaitun, respectively (Fig. 3 and Table 2). Due to the effect of mobile sand dunes and political border between Egypt and Libya, the author was not able to collect any samples from Sheiata, Um El Ghezlan and Jaghbub lakes. The higher salinities of Maraqi and Siwa lakes, compared others, may be due to the effect of surrounding cultivated area and their high saline drain water as well as the low rate of upward leakage from NSAS. In contrast, the lower salinity of Tameira lake might be due to the fact that the main source of water is deep springs and the NSAS through faults.

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Table 1. Isotope values of some springs, fractured carbonate zones and Nubian aquifers (modified after El Hossary1999 and Abd El Samei et al. 2005

No.	Aquifer		Name	δO^{18} % ves SMOW	δD% ves SMOW	C^{-14} Y. BP.
1	Spring	Lower Miocene	Mashandat	-9.98	-78.65	
2		Lower Eocene	Quresht	-8.8	-68.03	
3			El Naqab	-8.71	-66.20	
4		U. Cretaceous	Abu Shrof	-8.5	-69.30	
5	Fractured carbonate aquifer system	1st zone	Mohmed Essa	-10.10	-79.30	
6			Ghaliet	-9.97	-80.10	
7			El Dakrur shallow	-10.03	-80.20	
8		3rd zone	Zedan	-9.46	-75.83	
9		5th zone	El Ghazalat shallow	-10.30	-80.01	19 967
10	Nubian Sandstone		Bahei El Dein	-10.90	-80.10	
11			Siwa-1	-10.62	-81.08	21 360
12			El Dakrur	-10.57	-80.19	
13			Military	-10.10	-80.70	
14			Quresht	-10.33	-79.54	
15			Abu Shrof	-10.31	-78.24	

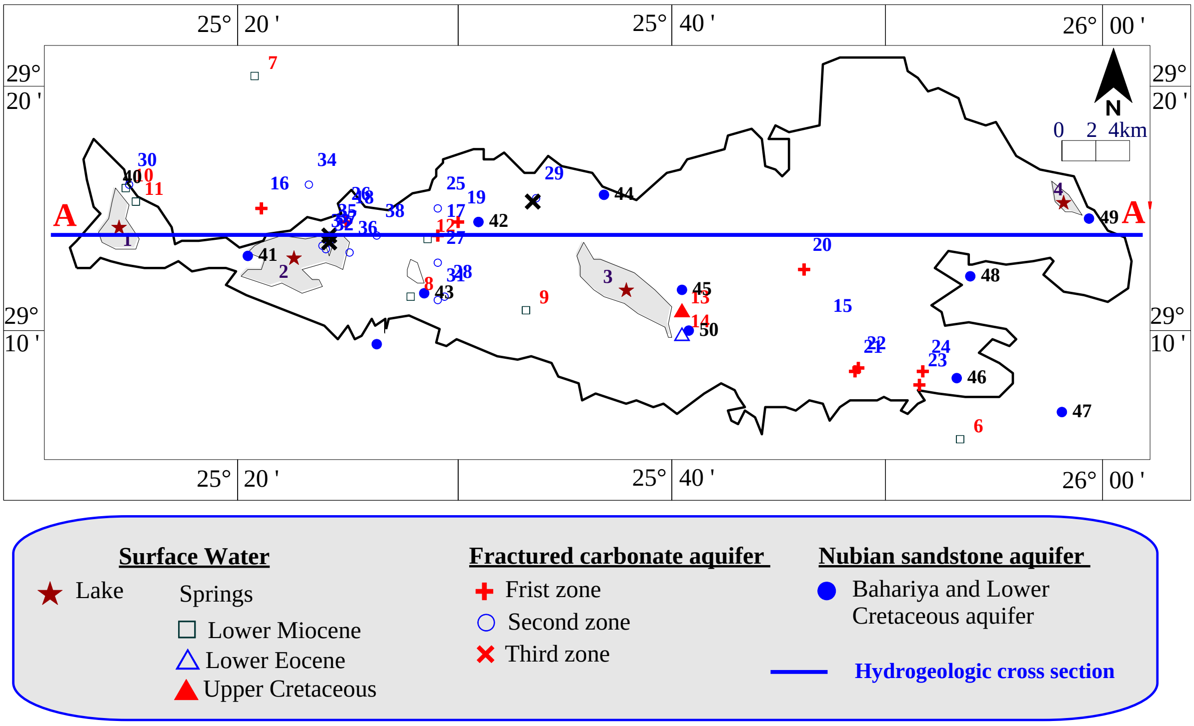

Figure 3. Location map of the selected water samples and the hydrogeologic cross section.

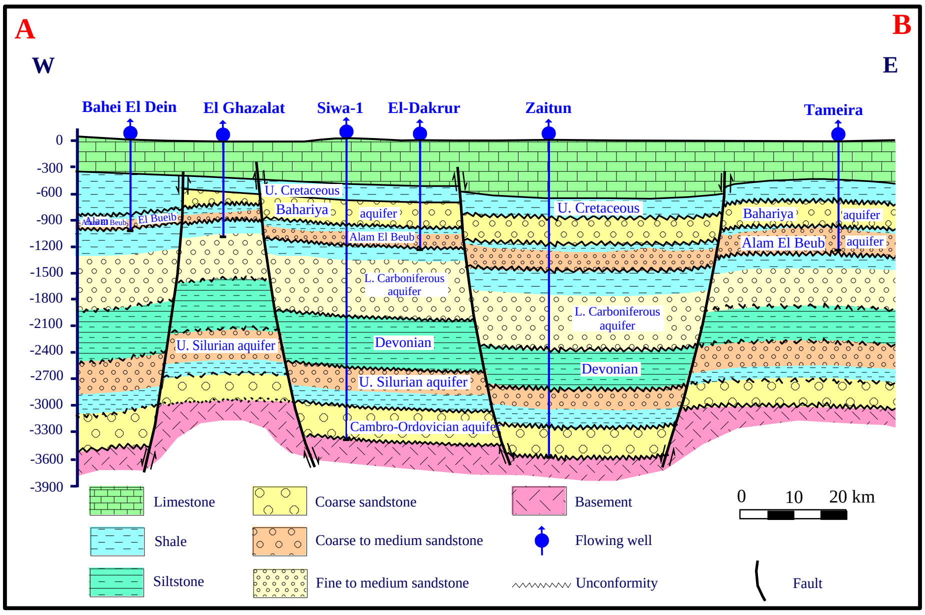

Figure 4. E-W hydrogeologic cross section showing the groundwater aquifers situation in Siwa sub-basin.

Groundwater aquifers

Based on geophysical data, the geological information gained from oil and water wells, hydrogeological cross section (Fig. 4), chemical analysis of the collected water samples (Table 2), field observations and measurements, the groundwater aquifers can be classified into fractured carbonate (FCAS) and Nubian sandstone aquifer systems (NSAS).

Fractured carbonate aquifer system (FCAS): Fractures introduce secondary porosity into the rocks and can serve as storage zones, collectors and transmitters of groundwater (Bisson and El-Baz 1991; El-Baz 1995; National Research Council 1996; Babiker and Gudmundsson 2004; Kusky et al. 2005; Sultan et al. 2008). For example, open tensional faults are ideal conduits for groundwater in hard rocks. Utilizing lithologic and well logging data, stratigraphic study of El Hossary (1999), and chemical analysis of the collected water samples, FCAS is classified into five zones (Tables 2 and 3).

The upper zone is encountered at a depth of 70 m from the floor of the oases, and is made up of hard limestone with thin layers of shale. The sediments of the zone (Moghra Formation) were deposited under marine condition during Lower Miocene. Water samples showed a wide range of salinity, from 3072 to 5280 ppm with an average of 4090 ppm, with the expectation of Zaitun and Khamisa areas that have values around 1500 and 2200 ppm, respectively. The variation of groundwater salinitiy may be due to the variation of lithology, density of fractured systems and the head pressure of NSAS, which is the main source of recharge from one area to another.

The second zone is the main productive zone, and is recorded at depth of 100 to 180 m from the ground surface. It consists mostly of highly fractured hard limestone belonging to Upper Eocene and deposited under shallow marine conditions. The groundwater salinity varied from 2598 to 4160 ppm with an average of 3210 ppm. Generally, the salinity of this zone decreases eastward because of the increase of NSAS piezometric head and the density of fault systems.

The third zone is at the depth of 210 to 250 m from the ground surface. It is made up of sandy limestone and dolomitic limestone, overlain and underlain with shale layers. It belongs to the Middle Eocene and its groundwater sample had a salinity of 6163 ppm. The higher salinity of this zone might be attributed to high shale content and low density of fracture systems.

The fourth zone is detected at the depth of 340 to 400 m and consists of cavernous limestone belonging to Lower Eocene. The salinity varies from 8100 to 6100 ppm with an average of 7100 ppm due to the presence of large cavities that may be filled by saline water.

The fifth zone is at the depths of 440 to 510 m from the ground surface and is made up of highly fractured hard sandy limestone with shale layers, belonging to Upper Cretaceous. The salinity of the zone ranged from 5000 to 7000 ppm with an average 6000 ppm. The lower salinity level may be due to the direct recharge from the Nubian aquifer, while the higher salinity than Nubian might be due to the effect of shale content.

Generally, the piezometric head, discharge and salinity as well as temperature increase with depth. This concept must be confirmed and verified by drilling more productive wells tapping different zones in the study area especially in the 3^{rd}, 4^{th} and 5^{th} zones. The groundwater moved upward through fault plains from NSAS to fractured carbonate zones that are hydraulically connected.

Nubian sandstone aquifer system (NSAS):
NSAS is one of the largest aquifers in northeast Africa, occupying an area of about two million km^2 spread in Egypt, Sudan, Chad and Libya with huge thickness (Ezzat 1974). The aquifer is composed of sandy Paleozoic and Mesozoic deposits which are older than the Pre-Upper Cenomanian (PUC). In the northwestern part of the aquifer at Siwa Oasis and Jaghbub area (Siwa sub-basin), the aquifer is close to the freshwater-saltwater interface and would probably augment the risk of deterioration of the water quality (CEDARE 2001). Utilizing the recent information gained from deep oil and water wells, NSAS can be divided into Lower Cenomanian (Bahariya), Lower Cretaceous (Alam El Bueib), Lower Carboniferous (Desouqy), Silurian (Acacua and Basur) and Cambro-Ordovician (Shifah) aquifers from the top downwards as follows:

- Bahariya aquifer is recorded in some recent deep water wells at depths of about 700 to 900 m, in the eastern part of Siwa sub-basin and completely eroded in the western part (Hantar 1990). It is composed mostly of fine to coarse sandstone with shale layers that are overlain by Upper Cretaceous shales and carbonates, and underlain by discontinuous compact shale beds of Alam El Bueib Formation. The sediments have porosity ranging from 20 to 30%. The contour map at the top of Bahariya aquifer (Fig. 5 a) shows horst around Siwa lake and two grabens to the east and west. The aquifer thickness increases from about 190 m in Ghazalat well in the western part of Siwa Oasis to about 390 m in El Khoshby well in the eastern part (Fig. 5 b). The groundwater salinity increases westward from about 190 ppm to about 280 ppm (Fig. 5 c); in contrast the piezomteric head increases in the opposite direction (Fig.5 d) which means that with the decreases of the aquifer pressure the salinity increases perhaps due to the relatively long time for leaching processes or rock-water interaction.
- Alam El Bueib formation is restricted in the central and eastern part of Siwa Oasis

with thickness varying from 50 m to 1000 m and is totally eroded in the western part of the sub-basin (Hantar 1990). It is totally penetrated by deep oil wells, and only partially by some deep water wells such as Bahei El Dein, El Ghazalat, El Awafy, Tameira and El Khoshby. The aquifer is composed mostly of fine to very fine sandstone with shale layers and is separated partially from the overlying Bahariya aquifer by relatively thick shale beds, and overlain Permian siltstone and/or Upper Carboniferous mudstone. The porosity varies from 24 to 25% and decreases upward to 9.98% owing to the increase of shale content. The salinity ranges from about 320 ppm in El Awafy well to 365 ppm in Bahei El Dein well. Bahariya and Alam El Beiub aquifers are hydraulically connected through faults and/or pores. Trial piezometric head, temperature and salinity maps of both (Fig. 6d, e and f) have been constructed. The pizeometric head and temperature decrease mostly westward and the lowest values were recorded around Siwa lake (horst), while the salinity increases westward.

- Lower Cretaceous aquifer is not encountered by deep water wells, while it is totally penetrated by the Siwa-1 and Zaitun oil wells at depths of -1259 and -1376 m below sea level (bsl) with thickness of 450 m and 362 m, respectively. The aquifer is overlain by Upper Carboniferous mudstone and underlain by Devonian siltstone. It consists of fine to coarse sandstone with shale layers that were deposited under marine conditions (El Sweify 1975) and have porosity range from 22.5 to 24% . The salinity of the aquifer varies from 1800 to 4200 ppm.
- Upper Silurian aquifer is totally penetrated by the Siwa-1 and Zaitun oil wells at depths -2662 and -2760 m bsl with an average thickness of 610 m. The aquifer is overlain by Devonian siltstone and underlain by Lower Silurian mudstone. The sediments of the aquifer are made up of fine to medium sandstone with minor siltstone layers deposited under marine conditions (El Sweify 1975). The salinity was estimated as 185000 ppm.
- Cambro-Ordovician aquifer is totally penetrated by the Siwa-1 and Zaitun oil wells at depths of -3080 and -3240 m bsl with an average thickness of 315 m. The aquifer is overlain by the lower Silurian mudstone, and underlain by fractured basement rocks. It is built up of coarse to medium sandstone with shale layers deposited under marginal marine to continental conditions (El Sweify 1975). The salinity was estimated as 60000 ppm.

Discussion and conclusions

With the continuous human activities in the Siwa Sub-basin especially for land reclamation, a lot of tube wells have been drilled from 1960 onwards. Most of the wells and springs are under poor management. With new land reclamation a lot of wells are being dug without planning. Consequently, the piezometric head and discharge of the springs and groundwater are declining. The present study sheds lights on groundwater depletion, decrease in groundwater discharge, and deterioration of water quality by salinity.

Groundwater depletion

Fractured carbonate aquifer system: Up to 1970, the static water level in the shallower part of 1st zone (25 m depth) was actually above the ground surface and hand dug wells were flowing (Misak et al. 1997). After the extensive exploration of this zone, the farmers had deepened their wells to 70 m for getting water, except in Khemeisa area where water is still flowing at 40 m due to the effect of southern sand dunes (El Hossary

Table 2. Chemical analysis of the collected water samples in Siwa sub-basin

No.			Well Name	Tempe-ature °C	EC at 25° C (mmohs /cm)	TDS ppm	pH	K^+ ppm	Na^+ ppm	Mg^{++} ppm	Ca^{++} ppm	CL^- ppm	$SO4^{--}$ ppm	HCO_3^- ppm	CO_3^- ppm
1	Lakes		Maraqi	18.4	159.30	101952	7.65	3900.00	29900.00	1764.00	500.00	49500.00	8000.00	137.00	20.00
2	Lakes		Siwa	17.4	185.30	118592	7.97	3810.00	36340.00	1614.00	510.00	58000.00	9500.00	12.20	19.00
3	Lakes		Zaitun	20.5	135.50	86400	7.65	1755.00	24771.00	2499.00	455.00	42000.00	7000.00	183.00	16.00
4	Lakes		Tameiara	22.2	63.300	40512	8.02	195.00	12903.00	438.00	580.00	17750.00	6000.00	61.00	0.00
5	Lakes		Ex- Zaitun	20.5	48.00	30720	7.71	293.00	8855.00	663.00	605.00	14800.00	2600.00	153.00	30.00
6	Springs	Lower Miocene	Safy	25.0	2.78	1779	7.93	28.00	440.00	59.00	60.00	750.00	120.00	244.00	0.00
7	Springs	Lower Miocene	El Mal Gerbah	22.7	4.70	3008	8.21	43.00	794.00	66.00	100.00	1290.00	350.00	132.00	6.00
8	Springs	Lower Miocene	Fetnas	28.6	5.21	3334	7.97	46.00	851.00	96.00	110.00	1420.00	450.00	125.00	0.00
9	Springs	Lower Miocene	El Molok	24.6	2.45	1568	8.05	27.00	274.00	78.00	90.00	605.00	210.00	122.00	0.00
10	Springs	Lower Miocene	Taghlesiah	26.2	4.45	2848	8.12	44.00	764.00	54.00	100.00	1200.00	380.00	92.00	15.00
11	Springs	Lower Miocene	El Sarar	24.6	4.25	2720	7.86	44.00	741.00	51.00	85.00	1150.00	330.00	92.00	15.00
12	Springs	Lower Miocene	Telwah	24.9	5.25	3360	8.10	45.50	840.00	110.00	105.00	1180.00	830.00	50.00	15.00
13	Springs	L. Eocene	Qurosht	25.9	11.87	7597	7.85	95.00	1930.00	170.00	165.00	2800.00	1300.00	70.00	30.00
14	Springs	U. Cretaceous	Abu Shrof	25.8	9.30	5952	8.10	73.00	1460.00	210.00	200.00	2300.00	1200.00	153.00	20.00
15	Fractured Carbonate Aquifer System	1St Zone (Lower Miocene)	286	25.0	3.45	2208	7.99	46.00	480.00	78.00	80.00	780.00	320.00	220.00	0.00
16	Fractured Carbonate Aquifer System	1St Zone (Lower Miocene)	El Slema	24.7	4.80	3072	8.00	46.00	810.00	84.00	70.00	1280.00	400.00	95.00	16.00
17	Fractured Carbonate Aquifer System	1St Zone (Lower Miocene)	Telwah	25.2	5.60	3584	8.07	46.00	930.00	111.00	90.00	1480.00	480.00	100.00	19.00
18	Fractured Carbonate Aquifer System	1St Zone (Lower Miocene)	Lotiah	26.5	7.3	4672	8.09	58.00	1230.00	141.00	115.00	1950.00	690.00	122.00	17.00
19	Fractured Carbonate Aquifer System	1St Zone (Lower Miocene)	Garf Allah	27.2	8.25	5280	8.07	47.00	1410.00	157.00	120.00	2300.00	700.00	92.00	16.00
20	Fractured Carbonate Aquifer System	1St Zone (Lower Miocene)	285	24.9	2.50	1600	8.08	26.00	375.00	48.00	70.00	650.00	190.00	122.00	0.00
21	Fractured Carbonate Aquifer System	1St Zone (Lower Miocene)	Ahaly 1	24.8	2.10	1344	8.10	22.00	249.00	75.00	65.00	530.00	170.00	99.00	16.00
22	Fractured Carbonate Aquifer System	1St Zone (Lower Miocene)	Ahaly 2	25.2	2.35	1504	7.99	27.00	274.00	81.00	65.00	540.00	181.00	200.00	0.00

23			Sheikh Ahmed	25.9	5.46	3494	8.21	46.00	823.00	150.00	100.00	1400.00	590.00	153.00	0.00
24			Abu El Wafa	25.0	6.95	4448	7.86	51.00	1087.00	150.00	150.00	1810.00	710.00	130.00	0.00
25		2nd zone (Upper Eocene)	21	25.9	5.50	3520	8.14	48.00	860.00	141.00	90.00	1500.00	430.00	120.00	17.00
26			Bakdeen	26.2	4.90	3136	8.16	41.00	800.00	96.00	95.00	1340.00	400.00	120.00	14.00
27			265	29.0	4.06	2598	8.03	39.00	557.00	105.00	105.00	1020.00	380.00	129.00	0.00
28			83	28.8	4.17	2669	8.24	38.00	672.00	72.00	100.00	1100.00	400.00	107.00	0.00
29			Moh. Mousa	26.1	4.36	2790	8.15	31.00	745.00	54.00	110.00	1186.00	310.00	183.00	0.00
30			74	26.9	4.45	2848	8.12	44.00	764.00	54.00	100.00	1200.00	380.00	90.00	17.00
31			132	28.1	4.33	2771	7.96	41.00	713.00	66.00	95.00	1130.00	390.00	122.00	0.00
32			64	24.8	4.50	2880	7.98	45.50	750.00	72.00	70.00	1190.00	360.00	99.00	16.00
33			Bahriat deep	24.1	4.40	2816	8.91	41.00	730.00	72.00	70.00	1140.00	350.00	122.00	17.00
34			To Gerbah	22.9	4.27	2733	8.13	43.00	734.00	60.00	90.00	1090.00	440.00	116.00	6.00
35			221	26.6	6.12	3917	7.90	48.00	1090.00	66.00	110.00	1600.00	600.00	120.00	14.00
36			66	25.7	6.45	4128	7.94	42.00	1150.00	78.00	110.00	1700.00	610.00	118.00	13.00
37			42	26.0	6.25	4000	8.27	51.00	1000.00	96.00	130.00	1542.00	650.00	132.00	0.00
38			65	26.4	6.50	4160	7.87	52.00	1058.00	114.00	140.00	1660.00	680.00	116.00	12.00
39		3rd	Bany Beir	27.4	9.63	6163	7.33	74.00	1690.00	147.00	160.00	2700.00	890.00	46.00	0.00
40	Nubian Sandstone	Bahariyat and Alam El Bueib	Bahie El Dein	35.6	0.57	365	8.18	30.03	52.44	10.00	26.00	82.00	36.00	104.00	12.00
41			El Ghazalat	32.9	0.43	275	8.30	20.67	42.00	9.00	24.00	62.00	26.00	91.00	15.00
42			Safy	30.6	0.35	224	8.11	19.50	36.00	6.50	21.00	54.00	21.00	88.00	0.00
43			El Dakrur	40.6	0.42	269	8.30	19.50	48.00	8.50	18.00	71.00	29.00	91.00	0.00
44			Mosalahah	31.8	0.45	288	7.92	25.74	41.00	8.50	24.00	76.00	28.00	91.00	0.00
45			Quresht	42.3	0.33	211	7.88	17.16	31.00	6.00	18.00	51.00	19.00	81.00	0.00
46			El Zohrah	44.8	0.30	192	8.02	8.00	34.00	11.00	7.20	50.00	17.00	71.00	0.00
47			El Khoshby	44.5	0.30	192	8.29	14.00	23.00	9.00	17.00	53.00	20.00	61.00	0.00
48			El Awafy	37.5	0.50	320	8.12	13.00	55.00	10.00	24.00	71.00	56.00	91.50	0.00
49			Tameira	46.8	0.32	205	8.33	11.70	37.00	6.00	15.00	58.00	13.00	74.00	0.00

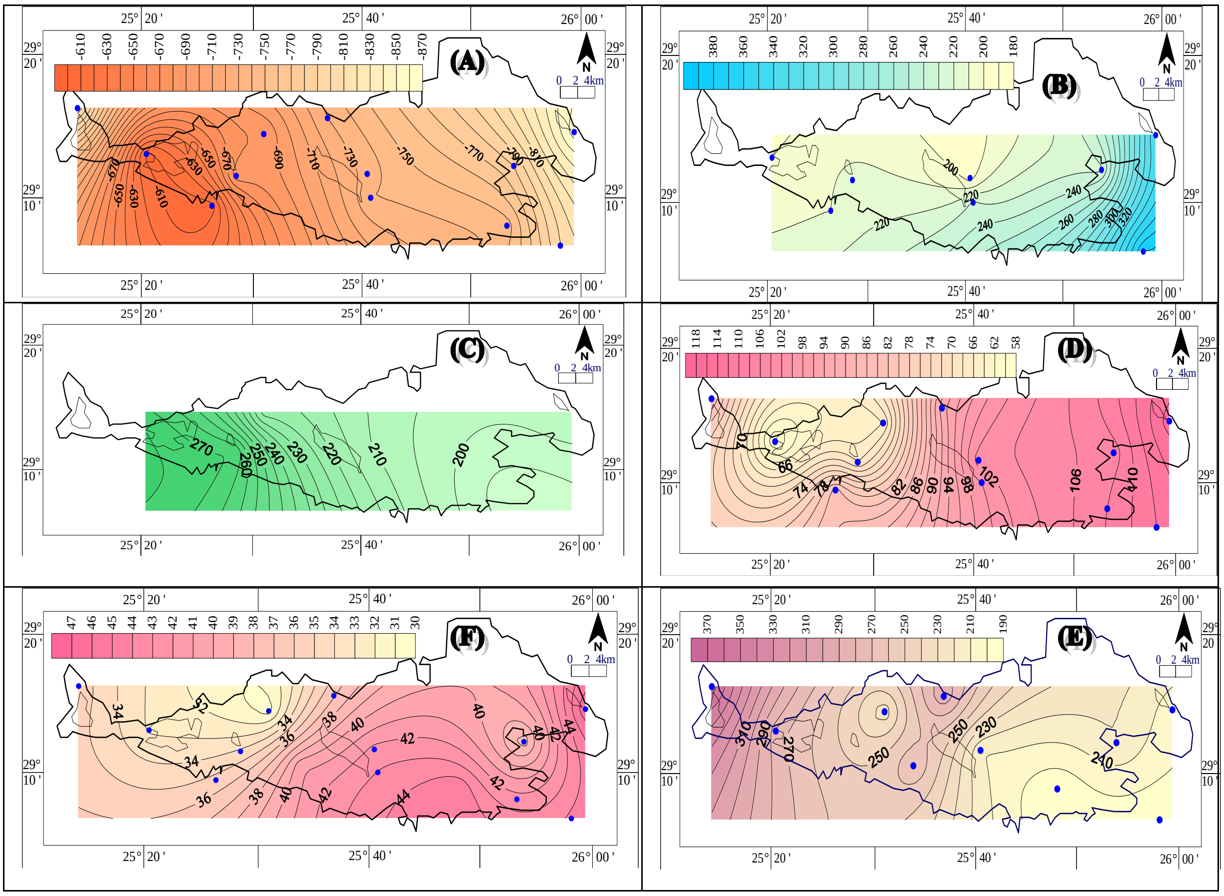

Figure 5. (A) The structure contour map at the top of Bahariya aquifer, (B) the isopach map of Bahariya aquifer, (C) the salinity map of Bahariya aquifer in 2008, (D) the piezometric head map of Bahariya and Alam El Bueib aquifers in 1999, (E) the Temperature map of Bahariya and El Bueib in 2008, and (F) the salinity map of Bahariya and Alam El Bueib aquifers in 2008.

Table 3. Classification of the fractured carbonate aquifer system in Siwa sub-basin

Zone	**Depth (m)**	**Discharge** (m^3/hour)	**Average salinity (ppm)**	**Zone**	**Depth (m)**	**Discharge** (m^3/hour)	**Average salinity (ppm)**
First	2-25 **	20	3000	Second	70-130 **	40	1600
	3-60 ***	5	3200		100-130 ***	75	1900
	3-70 *	2	4090		100-180 *	50	3210
Third	150-200 **		4000	Fourth	350-750 **		6500
	220-250 ***	30	5000		340-370 ***	90	6800
	210-250 *	25	6200		340-400 *	~ 70	7100
Fifth	450-480***		8000				
	440-510 *		6000				

* the author ** El Shazly and Abdel Mogheeth (1991) *** El Hossary (1999)

Table 4. Salt combinations and hydrogeochemical characteristics of the collected water samples

No.		Salt combinations %										Hydrogeochemical classification		
		KCL	NaCL	$MgCL_2$	$CaCL_2$	K_2SO_4	Na_2SO_4	$MgSO_4$	$CaSO_4$	$Mg(HCO_3)_2$	$Ca(HCO_3)_2$	Sulin Diagram	Ovitchinikov Graph	Piper Diagram
1	Lakes	6.37	82.79	0.00	0.00	0.00	0.01	9.24	1.41	0.00	0.19	Shallow marine deep meteoric	Meteoric lagoon water dissolved NaCl	$NaCl,Na_2SO_4$ water type,
2		5.32	83.83	0.00	0.00	0.00	2.23	7.23	1.34	0.00	0.05			
3		3.33	79.76	5.70	0.00	0.00	0.00	9.52	1.42	0.00	0.26			
4		0.79	79.08	0.00	0.00	0.00	9.82	5.71	4.44	0.00	0.16			
5		1.57	80.66	5.58	0.00	0.00	0.00	5.84	5.57	0.00	0.77	Shallow marine	Marine water of open seas and oceans	NaCl water type, i.e. it may be meteoric or marine during reduction
6	Springs	2.59	69.06	4.82	0.00	0.00	0.00	9.05	0.00	3.65	10.83			
7		2.39	74.96	1.65	0.00	0.00	0.00	10.14	5.72	0.00	5.14			
8		2.29	71.74	3.76	0.00	0.00	0.00	11.55	6.68	0.00	3.98			
9		2.94	50.65	19.18	0.00	0.00	0.00	8.09	10.59	0.00	8.54			
10		2.58	74.73	0.00	0.00	0.00	1.14	10.14	6.83	0.00	4.59		meteoric lagoon water dissolved NaCl	$NaCl,Na_2SO_4$ water type, i.e. it may be meteoric or marine during reduction process
11		2.70	75.78	0.00	0.00	0.00	1.31	10.04	5.30	0.00	4.80	deep meteoric water		
12		2.24	61.86	0.00	0.00	0.00	8.39	17.40	7.55	0.00	2.72			
13		2.24	70.72	0.00	0.00	0.00	6.57	12.88	5.61	0.00	3.35			
14		2.02	67.93	0.00	0.00	0.00	0.61	18.65	7.74	0.00	4.45			
15	Fractured Carbonate Aquifer System	3.63	64.05	0.00	0.00	0.00	0.24	19.76	0.54	0.00	11.11			
16		2.52	75.05	0.00	0.00	0.00	0.19	14.76	2.98	0.00	4.57			
17		2.14	73.19	1.93	0.00	0.00	0.00	14.60	3.93	0.00	4.21	Shallow marine	Marine water of open seas and oceans	NaCl water type, i.e. it may be meteoric or marine during reduction process
18		2.06	73.96	0.42	0.00	0.00	0.00	15.62	4.38	0.00	3.83			
19		1.48	75.29	2.81	0.00	0.00	0.00	13.05	4.86	0.00	2.84			
20		2.73	66.77	5.95	0.00	0.00	0.00	10.22	6.09	0.00	8.24			
21		2.71	52.03	17.64	0.00	0.00	0.00	12.00	5.17	0.00	9.11			
22		3.07	52.91	12.35	0.00	0.00	0.00	16.94	0.00	0.29	14.43			
23		2.17	65.90	4.64	0.00	0.00	0.00	18.08	4.58	0.00	4.62			
24		1.91	69.09	4.08	0.00	0.00	0.00	13.96	7.83	0.00	3.14			
25		2.25	68.34	8.03	0.00	0.00	0.00	13.16	3.51	0.00	4.71			
26		2.17	71.75	3.95	0.00	0.00	0.00	12.34	4.85	0.00	4.92			
27		2.56	61.93	8.99	0.00	0.00	0.00	13.09	7.15	0.00	5.41			
28		2.37	71.07	2.00	0.00	0.00	0.00	12.40	7.89	0.00	4.27			
29		1.84	75.11	0.99	0.00	0.00	0.00	9.31	5.75	0.00	7.00			$NaCl,Na_2SO_4$ water type, i.e. it may be meteoric or marine during reduction process
30		2.58	74.67	0.00	0.00	0.00	1.20	10.14	6.75	0.00	4.67		meteoric lagoon water dissolved NaCl	
31		2.49	73.38	0.00	0.00	0.00	0.03	12.85	6.48	0.00	4.77			
32		2.70	74.93	0.00	0.00	0.00	0.55	13.71	3.11	0.00	4.98	deep meteoric water		
33		2.49	74.02	0.00	0.00	0.00	1.17	14.03	2.18	0.00	6.06			
34		2.60	70.56	0.00	0.00	0.00	4.62	11.62	5.59	0.00	4.83			
35		2.07	73.62	0.00	0.00	0.00	5.96	9.11	5.91	0.00	4.37			
36		1.71	74.35	0.00	0.00	0.00	5.03	10.18	4.97	0.00	4.06			
37		2.21	71.23	0.00	0.00	0.00	2.23	13.34	7.32	0.00	3.66			
38		2.09	71.86	0.00	0.00	0.00	0.34	14.72	7.35	0.00	3.60			
39		1.99	76.97	0.81	0.00	0.00	0.00	11.86	7.59	0.00	0.79	shallow marine	Marine water	NaCl water type,
40	Nubian Sandstone	14.89	29.84	0.00	0.00	0.00	14.24	0.28	0.00	15.62	25.13		meteoric surface water leaching to clay, shale and carbonate rocks	$NaCl,Na_2SO_4$ water type, i.e. it may be meteoric or marine during reduction process
41		12.34	28.47	0.00	0.00	0.00	12.66	0.00	0.00	17.23	27.93	deep meteoric water		
42		13.70	31.02	0.00	0.00	0.00	11.86	1.00	0.00	13.65	28.77			
43		11.94	36.88	0.00	0.00	0.00	12.97	1.78	0.00	14.92	21.50			
44		15.20	34.11	0.00	0.00	0.00	6.95	6.49	0.00	9.61	27.64			
45		13.83	31.63	0.00	0.00	0.00	10.74	1.78	0.00	13.73	28.29			
46		6.96	41.17	0.00	0.00	0.00	8.98	3.13	0.00	27.56	12.21			
47		8.41	40.05	0.00	0.00	0.00	13.80	14.98	3.44	0.00	19.33			
48		7.02	35.11	0.00	0.00	0.00	15.27	9.31	0.00	8.01	25.28			
49		9.52	42.89	0.00	0.00	0.00	8.15	0.54	0.00	15.12	23.79			

1999). In 1999, the farmers had deepened their wells to the depth from 100 to 130 m (2^{nd} zone) and the piezometric head was around 2 m above the ground surface (El Hossary 1999). Nowadays, most of the groundwater wells of depths of 100 to 130 m are pumped and the farmers have deepened their wells to the depths of 150 to 180 m (deep 2^{nd} zone) for getting flowing water. The continuous decrease of fractured carbonate piezometric head may be due to the intensive consumption from both NSAS and fractured carbonate zones.

Shallow Nubian sandstone aquifer system: Heinl and Brinkmann (1989) simulation model of Nubian sandstone mega aquifer predicted that with the start of 2070, the maximum drawdown of the aquifer will become 130 m in Bahariya, Farafra, Siwa, Kharga and small parts of Libya. The same figure of drawdown was concluded by Abuflla (1984) who noted that the projects dependent on Nubian aquifer would change the natural groundwater flow system completely after 80 years and the groundwater level in Farafra and Bahariya will drop to the Qattara level. The average piezometric head of Siwa Oasis and surrounding areas was 83 m (~65 m above sea level) in 1997 (RIGW 1997) and declined to 80 m (~62 m above sea level) in 1999 (Gad 1999), but decreased sharply to 67 m (-49 m above sea level) in 2008. Over this period there was a linear decrease in piezometric head values with time, which could be described by the equation $Y = -1.359 X + 2796$, where Y is the estimated value and X is the input year.

By applying this equation for predicting the future pizometric head of NSAS in Siwa sub-basin, it can be concluded that the pizometric head will become zero in 2045. As NSAS is the main source of lakes and FCAS, most lakes of ground elevation above zero (such as Sheiata, Um El Ghezlan, Tameira, Al Masser and Jaghbub) will disappear in 2045 even without drilling any deep wells. The Maraqi, Siwa and Zaitun lakes of ground elevation of -10 m below sea level in Siwa Oasis will disappear in 2055 without drilling any deep wells.

Satellite images from 1989 to 2005 have been used for monitoring the decline of lake size and detecting the old shorelines. Sheiata and Tameira lakes have been selected for monitoring as the lakes are located in the two limbs of Siwa sub-basin and outside the direct effect of intensive activities. Twelve old shorelines have been detected in 2005 satellite image with different width in-between that decrease towards the lakes (Fig. 6 A and C) owing to the human activities in the last years. The same features of old shorelines are obvious in Jaghbub Oasis (Fig. 6 B). The hydrogeochemical characteristics of the groundwater aquifers in 2008 (Table 4) support the idea of the decline of NSAS piezometric head with time.

Decline of groundwater discharge

Springs: Based on the data in Table 5 of the discharge of some natural springs in Siwa Oasis with time, it is clear that the discharge decreased from about 43000 m^3/day in 1963 to about 37000 m^3/day in 1977, a decrease of 12.73 %, while the discharge declined abruptly to about 16 000 m^3/day in 1997, a decrease of 57.91 % (Fig. 7).

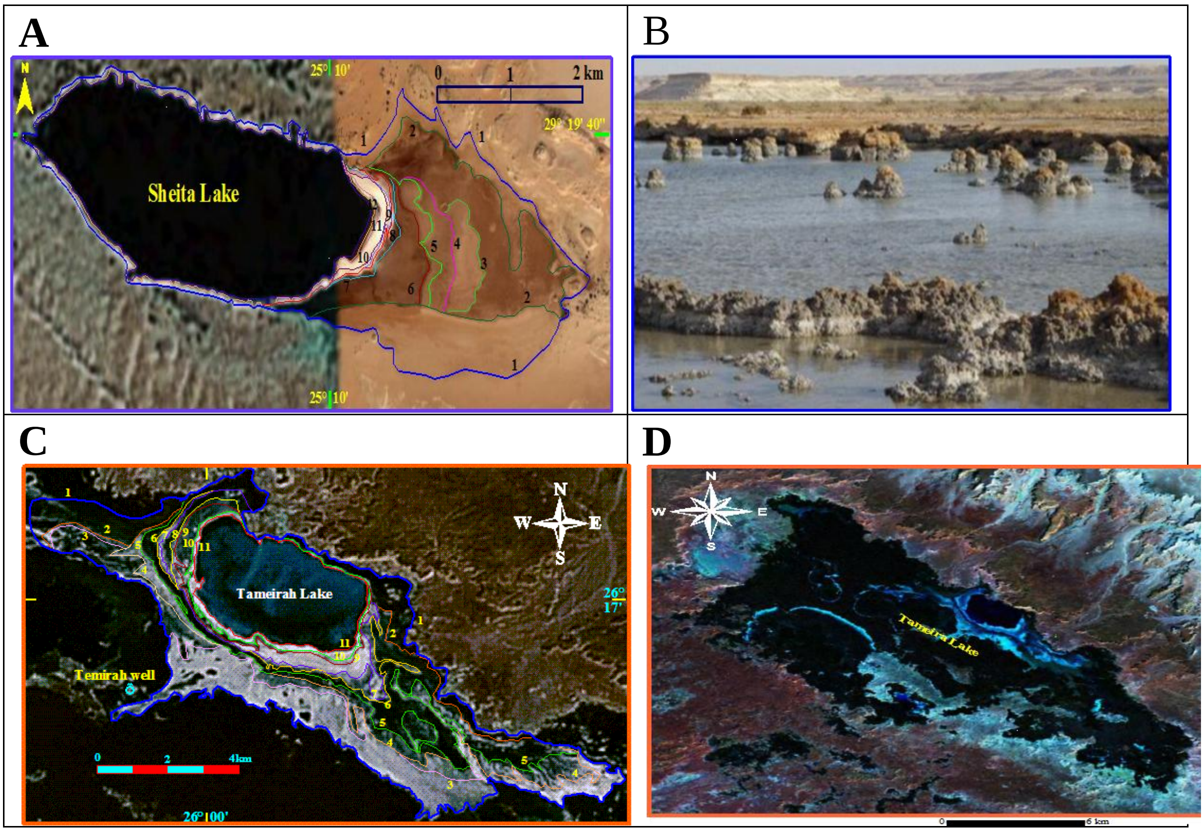

Figure 6. (A) Satellite image of Sheiata lake in 2005 with old shorelines related to groundwater depletion. (B) Photo image of Jaghbub lake showing the retreat of water level with time. (C) Tameira satellite image in 2005 with the old shorelines. (D) The satellite image of Tameira in 1989.

Table 5. Comparison between the discharges of some natural springs (m^3/day) at different periods

No.	Spring Name	Parson (1963)	AOAD (1977)	RIGW (1997)	No.	Spring Name	Parson (1963)	AOAD (1977)	RIGW (19970
1	El Guba	5200	4580	2784	15	Quta	1200	1140	48
2	Deheaba	4000	3420	1992	16	Umm Elsus	1300	1150	480
3	Tatrart	3500	3090	960	17	Mallul	1300	1150	720
4	El Gary	2500	2200	240	18	Zammur	1300	1160	480
5	Amelser	2500	2220	504	19	Gheit Khalil	700	620	48
6	Ghalith	2200	2200	960	20	Ghabit bahr	680	600	432
7	Taghaien	2000	1760	648	21	Bako	480	420	100
8	Hegaz	2000	1000	Pumped	22	Tamtokh	480	430	96
9	Dakror	1850	1630	960	23	Tammos	480	460	460
10	El lehrik	1600	1410	92	24	Maamel	480	480	360
11	Tallehra	1500	1320	960	25	Tamozei	430	380	120
12	Zidan	1500	1330	600	26	Hatabet	420	380	24
13	Tazetiy	1350	1190	816	27	Al Tobo	400	350	182
14	Fetnase	1300	1150	600	**Total**		42650	37220	15666

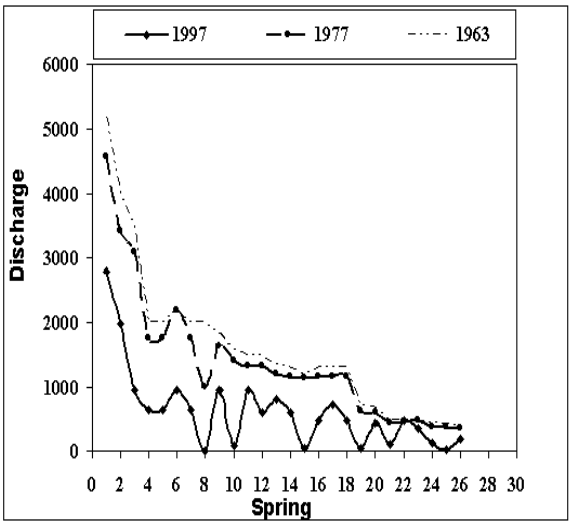

Figure 7. Decreasing of spring discharge in Siwa Oasis with time.

The decrease can be attributed to the intensive exploration (more than 1200 wells) after 1990 and the decline of NSAS piezometric head with time. Nowadays, with more extensive exploration, deepening of the wells by farmers as well as the more decrease of NSAS pressure, the discharge has become less than 7000 m^3/day, a decrease of 55%. The discharge data of Fetnase (west Siwa Town) and Mallul (east Siwa) springs were plotted against time. The relationship can be described by the following linear equations:

Fetnase Y = -21.062 X + 42698;
Mallul Y = -17.363 X + 35418;

where Y is the estimated value and X is the input year. Utilizing these equations for predicting the future discharge, Fetnase and El Mallul will have to be pumped in 2028 and 2040, respectively without drilling any new deep wells.

Fractured carbonate aquifer: The farmers have deepened their wells more than once from less than 25 m in 1970 to 70 m in 1990 and to 130 m in 1999 for getting flowing groundwater, and current depth is 150 and 180 m. These means that there has been decrease in the groundwater discharge naturally with time. This has been well demonstrated by RIWG (1997).

Changes in groundwater salinity

Springs: Long period data of salinity levels are available for Fetnase, Quresht and Abu Shrof only. The equations showing change in water quality with time are as follows:

Fetnase Y = -78.188 160320;
Quresht Y = -214.62 X +437815;
Abu Shrof Y = -245.97 X + 499308;

where Y is the estimated salinity value and X is the input year. Using these equations, the water quality of springs will be enhanced with time due to the decrease of Alam El Bueib pizometric head with time and the main source of recharge changing to become mostly from less saline Bahariya aquifer. These equations must be re-evaluated before 2030 without drilling new deep well.

Fractured carbonate aquifer: Utilizing the available data of fractured carbonate aquifer, equations have been obtained showing relationship of the groundwater salinity with time for the four zones as well as for the whole area as follows:

1^{st} zone Y = 64.839 X – 126204;
2^{nd} zone Y = 95.161 X – 188026;
3^{rd} zone Y = 129.49 X – 258833,
4^{th} zone Y = 29.263 X – 51739;
Total Y = 79.839 X – 155249

where Y is the estimated value and X is the input year. Based on these equations, the groundwater salinity of 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} zones will become 6700, 7100, 11600 and 8300 ppm, respectively in 2050.

The prediction cannot be made for the 5^{th} zone because of the lack of data. These equations must be re-evaluated every five years.

Nubian aquifer system: Using the available data of NSAS water quality from 1996 to 2008 for five water wells the following relationship has been obtained for salinity level with time:

Bahei El Dein	Y = -14.59 X + 2964;
El Ghazalat	Y = -12.467 X + 25322;
El Dakrur	Y = 2.3718 X - 4494.4;
Quresht	Y = 0.2436 X - 278.24;
Abu Shrof	Y = -0.0897 X + 373.09;
Total	Y = -2.5179 X + 5302.9;

where Y is the estimated salinity value and X is the input year. The differences between equations may be attributed to the variation in the penetration thickness, shale content and well design, as well as hydraulic parameters. Based on these equations it can be predicted that the quality of groundwater of most deep wells would decrease with time, except El Dakrur. The increase in the salinity in some the wells is because they are tapping mainly Alam El- Beuib aquifer which is characterized by shallow marine origin and relatively high content of shale layers.

Conclusion

Nubian Sandstone aquifer system (NSAS) and the overlaying fractured carbonate aquifer system (FCAS) are the main sources of water for development in northwest Egypt and east Libya. A lot of geophysical, geological and hydrogeological information has been gained from the available recent shallow and deep drilled wells for oil and groundwater. The groundwater deep wells are tapping mostly Bahariya shallow water bearing formation of NSAS and partially Alam El Bueib water bearing formation, while the shallower wells are tapping fractured carbonate aquifer system (Lower Miocene, Eocene and Upper Cretaceous). NSAS and FCAS are hydraulically connected through fault systems, and both are responsible for the occurrence of springs and natural lakes from Jaghbub in the west to Tameira in the east.

With the increase in human activities in the northern Nubian shelf, especially in Siwa sub-basin, through the last two decades, there has been groundwater depletion, disappearances of most springs, and deterioration of the groundwater quality with time. The regression models developed using the available data predict that the piezometric head of NSAS will decline to become zero in 2045. Most of the shallower natural lakes such as Jaghbub, Um El Ghezlan, Sheiata and Tameira will disappear before 2045. On the other hand, the deeper lakes in Siwa Oasis (Maraqi, Siwa, Aghormy and Zeitun) would become dry before 2055, and the continuous drilling of deep water wells will accelerate this phenomenon.

The farmers have to deepen their shallow groundwater wells in fractured carbonate zones every five year at least for getting flowing water. In the shallower zones, change to pumping of the groundwater would lead to quality deterioration with time. The government must stop land reclamation based on shallow and deep water wells, and encourage cultivation of plants that tolerate high salinity of groundwater. The government should also drill a lot of observation wells for evaluating deep zones of FCAS and deep Nubian water bearing formations (Lower Carboniferous, Upper Silurian and Cambro-Ordovician). The hydrogeologic and hydraulic setting of the study area must be re-evaluated every ten years or after a period of any major activity.

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2.11. Utilization of remote sensing and geographical information system for estimating degree-days units of the cotton leaf-worm *Spodoptera littoralis*

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Abstract

Cotton leaf-worm *Spodoptera littoralis* (Boisd.) is one of the most destructive agricultural lepidopterous pests in Egypt. Studies on the temperature requirements of *S. littoralis* were made under field conditions where insect was reared on cotton leaves in cages at fluctuating temperatures. The numerical weather results (daily maximum and minimum air and soil temperatures derived from satellite images) were obtained from the regional model which was developed at NARSS Modeling Simulation and Visualization Laboratory and the corporate data from NOAA satellite images using remote sensing and geographic information technologies and from thermograph at the time of experiment. Knowledge of the larval-age distribution in the field, by calculation of the average of thermal units in degree-days, is important for prediction purpose and timing of any insecticide application for pest management. Statistical analysis indicated that there was no significant difference between degree-days obtained from daily maximum and minimum air temperatures derived from satellite images and those from thermograph. Daily maximum and minimum air temperatures derived from satellite images appeared to be the best way for predicting and calculation of the average of thermal units required for completion of development of *S. littoralis* generation. The results are of value for quick prediction purposes, timing of control measures, and also as a valuable tool used in an integrated control program for managing *S. littoralis* in Egypt.

Introduction

The Egyptian economy has traditionally relied heavily on the agriculture sector as a source of growth and support for the non-agricultural sector. Cotton has traditionally been the most important fiber crop in Egypt as well as the leading agricultural export crop. One of the major obstacles facing the production of crops in Egypt is the damage caused by pests.

The cotton leafworm *S. littoralis* (Boisd.) is the most destructive lepidopterous cotton pest in Egypt; it causes a lot of yield losses (Amin and Gergis 2006). Knowledge of the larval-age distribution in the field is important for timing of sampling and insecticide applications for insect pest management (Doerr et al. 2004). Visual monitoring of larvae is labor-intensive and also has proven to be a difficult method for timing insecticide applications (Doerr et al. 2005).

Early prediction of insects is important to help the farmers to take the necessary actions to restrict dangerous infestations and avoid heavy sprays of pesticides. The prediction necessitates real time weather data covering the country because the development of insects is temperature dependent; each phase of development requiring certain heat units. Applications of developmental thresholds and rates in the form of phenological models are often used in agricultural integrated pest management (IPM) programs to predict and manipulate pest population dynamics in the field.

The countries often have networks of agro-meteorological ground stations to monitor the agricultural production and for weather forecasting. But, such networks are generally less dense for a correct representation of the high spatial climatic variability. Also the agro-meteorological data from various ground stations are not delivered in real time to a central collection point. So, conventional agro-meteorological techniques have severe limitations as source of data for the real time agricultural monitoring and yield forecasting.

The approach used in the present study was based on the integration of remotely sensed data and Geographic Information System (GIS) for the purpose of managing agricultural insects. This study is by far the first attempt to integrate remotely sensed data and GIS in relation to the agricultural insects in Egypt. National Oceanic and Atmospheric Administration (NOAA) satellite images supported by maps in specific dates and different scales checked by field observations were the primary sources of data for this study. This approach was used to monitor and assess the air and soil temperatures in some areas of Delta region. The objective was firstly to verify if there was any difference in the air temperatures derived from satellite images and thermograph; and hence to determine if the temperature data derived by Remote Sensing (RS) and Geographic Information System (GIS) could reliably be used for calculating the degree-day units for prediction purposes. The second objective was to find out how these findings could be used in an IPM program to control a major insect pest of cotton in Egypt namely cotton leafworm, *S. littoralis* (Boisd.).

Methodology

The study was conducted during 2006 in Ezbet Shalaqan, located in El-Kanatir El-Khairia, Al-Qalyubiya Governorate, Egypt (30˚ 12' 45" N, 031˚ 08' 02" E). Egg masses of the cotton leafworm, *S. littoralis*, were obtained from the cotton leaves in the fields in Ezbet Shalaqan. The eggs were transferred to 4 clean 500ml plastic-jars covered with muslin and secured with rubber bands. Each jar was kept on the ground level by the side of a cotton plant in cotton field, and both jar and plant were together covered with a wire cage (130 x 50cm). Newly hatched larvae were provided with fresh cotton leaves every day until the larvae showed signs of pupation. A thin layer of fine clay-dust was spread on the bottom of the plastic-jar to help successful pupation. Pupae were allowed to stay in the jars until moth emergence. Eight pairs of newly - emerged moths were confined into oviposition cages. The experiment was carried out under field conditions of temperature and relative humidity.

Temperature data and calculation of the thermal heat unit accumulations:
Temperature summations can provide an index for heat energy required to complete a given stage of development of insects or their entire life cycle. So, temperature data can be transformed into heat units for studying the population dynamics and predicting the appearance of an insect in the field.

Temperature data from the field:
Following the procedure of Doerr et al. (2002), temperature data were collected from the site of experiment by placing a maximum-minimum temperature recorder “Thermograph Model Sigma 2” inside the weather shelter. The weather shelter was placed under the canopy of a tree beside the cotton field. Degree-day accumulations were calculated from daily maximum and

minimum temperatures and a base threshold.

Data from remote sensing: The Latitude and Longitude of the study area were determined by Global Positioning System (30˚ 12' 45" N and 031˚ 08' 02" E). The numerical weather results (daily maximum and minimum air and soil temperatures derived from satellite images) were obtained from the regional model, which was developed at NARSS Modeling Simulation and Visualization Laboratory, and corporate data from NOAA satellite images (Sherif et al. 2005 a, b, c). The MM5 model (December, 2004) is a model designed to simulate or predict mesoscale atmospheric circulations (Dudhia 1993). The application run time takes about 36 hours to obtain air temperature from NOAA satellite images and about 36 hours to predict 3 days air temperature from NOAA satellite images.

Stages of *S. littoralis* expected and degree-days (dd's) were calculated by formulas of Davidson (1944) from the daily maximum and minimum air temperatures derived from satellite images and thermograph (°C) and daily maximum and minimum soil temperatures derived from satellite images with developmental threshold temperature (zero development) as 9.89 °C and the dd units (°C) for the generation as 524.27 (Yones et al. 2008).

Results and discussion

Field experiment indicated that in all the four replicates (cages) the egg stage of *S. littoralis* took 3 days, the larval stage lasted 16 days, the pupal stage 8 days and the pre-oviposition period 2 days under the prevailing field conditions of Ezbet Shalaqan.

According to the average of thermal units by daily maximum and minimum air temperatures derived from thermograph, the expected periods required for completion of respective stages of *S. littoralis* were 2, 15, 9 and 1 days and whole life cycle took 27 days as shown in Table 1 and Figure 1. According to the average of thermal units by daily maximum and minimum soil temperatures derived from satellite images the expected periods required for completion of *S. littoralis* stages were 2, 13, 7 and 1 days with total 23 days as shown in Table 2 and Figure 2. According to the average of thermal units by daily maximum and minimum air temperatures derived from satellite images the expected periods required for completion of *S. littoralis* stages were 2, 14, 8 and 1 days with total cycle requiring 25 day as shown in Table 3 and Figure 3; while the observed periods, as indicated before, were 3, 16, 8 and 2 days with total cycle requiring 29 days) for egg hatch, larval, pupal and pre-oviposition periods, respectively. So, there were 2, 6 and 4 days difference between expected and observed values for the egg hatch,larval and pupal periods.

The average of thermal units required for completion of generation were 544.9, 640.6 and 599.6 dd units (°C) as calculated from daily maximum and minimum air temperatures derived from thermograph and satellite images, and daily maximum and minimum soil temperatures derived from satellite images, respectively, considering 9.89°C as a developmental threshold. These were higher than the estimated value of dd units based on laboratory data (524.27 °C dd units) according to Yones et al. (2008).

Thus, comparing the average of thermal units in degree-days (dd's) required for the completion of the development of *S. littoralis* generation as calculated under laboratory constant temperature, with that under field conditions, it was found that under filed condition it took about 48 h more. These results indicated that, the rate of development was slower under field conditions than in the laboratory conditions.

This is in agreement with the observations of Woodson and Edelson (1988), who found a difference of about 84 h under field conditions for the carrot weevil, *Listronotus texanus*.

Table 1. Expected stages of *S. littoralis* by calculation of the degree days from daily maximum and minimum air temperatures derived from thermograph compared with observed stages in the field during the period of experiment.

Date /2006	Temperature (°C)		Degree days (dd's)				Stage	
	Max.	Min.	Per day	Accumulated	Corrected (0.96)	Expected corrected	Expected	Observed
July 17	34	23	18.61	18.61	17.87	Eggs	Eggs	Eggs
18	35	23	19.11	37.72	36.21	Eggs	Eggs	Eggs
19	32.5	22.5	17.61	55.33	53.12	Larvae	Larvae	Eggs
20	33	22	17.61	72.94	70.02	Larvae	Larvae	Larvae
21	33	22	17.61	90.55	86.93	Larvae	Larvae	Larvae
22	33	22.5	17.86	108.41	104.07	Larvae	Larvae	Larvae
23	35	23	19.11	127.52	122.42	Larvae	Larvae	Larvae
24	34	23	18.61	146.13	140.28	Larvae	Larvae	Larvae
25	34	22	18.11	164.24	157.67	Larvae	Larvae	Larvae
26	34	22	18.11	182.35	175.06	Larvae	Larvae	Larvae
27	34	22	18.11	200.46	192.44	Larvae	Larvae	Larvae
28	35	23	19.11	219.57	210.79	Larvae	Larvae	Larvae
29	35	25	20.11	239.68	230.09	Larvae	Larvae	Larvae
30	35	26	20.61	260.29	249.88	Larvae	Larvae	Larvae
31	37	26	23.49	283.78	272.43	Larvae	Larvae	Larvae
Aug.1	36.5	27.5	24.01	307.80	295.49	Larvae	Larvae	Larvae
2	34	28	21.11	328.91	315.75	Larvae	Larvae	Larvae
3	33.5	24	18.86	347.77	333.86	Pupae	Pupae	Larvae
4	34	23	18.61	366.38	351.72	Pupae	Pupae	Larvae
5	34	23.5	18.86	385.24	369.83	Pupae	Pupae	Pupae
6	33	23.5	18.86	404.10	387.94	Pupae	Pupae	Pupae
7	34	25	19.61	423.71	406.76	Pupae	Pupae	Pupae
8	33	24	18.61	442.32	424.63	Pupae	Pupae	Pupae
9	33	22	17.61	459.93	441.53	Pupae	Pupae	Pupae
10	34	22.5	18.36	478.29	459.16	Pupae	Pupae	Pupae
11	31	20	15.61	493.90	474.14	Pupae	Pupae	Pupae
12	33	20	16.61	510.51	490.09	Pupae	Adult	Pupae
13	33	20	16.61	527.12	506.04	Adults	Eggs2	Adults
14	32.5	23	17.86	544.9763	523.18	Adults		Adults
15	33	23	18.11	563.0863	540.56	Eggs2		Eggs2

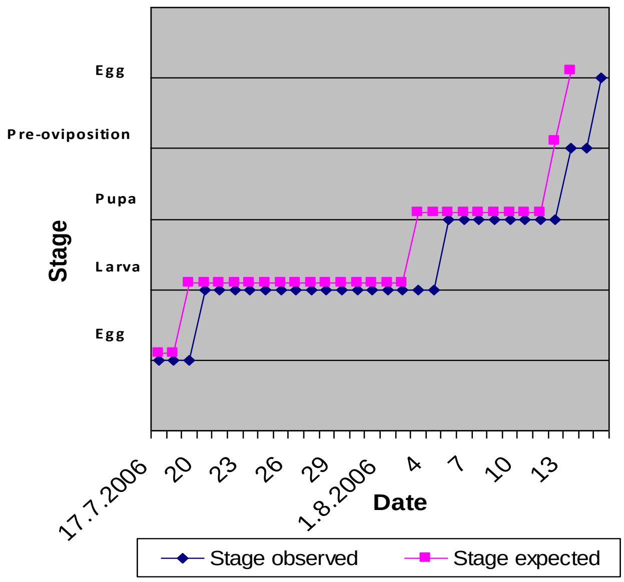

Figure 1. Expected stages of *S. littoralis* by calculation of the degree days from daily maximum and minimum air temperatures derived from thermograph.

Table 2. Expected stages of *S. littoralis* by calculation of the degree days from daily maximum and minimum satellite soil temperatures compared with observed stages in the field during the period of experiment

Date /2006	Temperature				Degree days (dd's)			Stage		
	Max.		Min.		Per day	Accumulated	Corrected (0.81)	Expected corrected	Expected	Observed
	°K	°C	°K	°C						
July 17	320.56	47.56	297.5	24.50	22.46	22.46	18.19	Eggs	Eggs	Eggs
18	319.72	46.72	297.92	24.92	22.55	45.00	36.45	Eggs	Eggs	Eggs
19	317.9	44.90	297.17	24.17	22.16	67.16	54.40	Larvae	Larvae	Eggs
20	318.35	45.35	295.43	22.43	21.56	88.72	71.86	Larvae	Larvae	Larvae
21	318.03	45.03	295.21	22.21	21.48	110.20	89.26	Larvae	Larvae	Larvae
22	319.16	46.16	295.25	22.25	21.51	131.71	106.69	Larvae	Larvae	Larvae
23	320.13	47.13	296.67	23.67	22.09	153.79	124.57	Larvae	Larvae	Larvae
24	319.38	46.38	297.98	24.98	22.55	176.34	142.84	Larvae	Larvae	Larvae
25	318.55	45.55	295.93	22.93	21.73	198.07	160.44	Larvae	Larvae	Larvae
26	319.13	46.13	296.18	23.18	21.846	219.92	178.14	Larvae	Larvae	Larvae
27	320.25	47.25	297.26	24.26	22.33	242.25	196.22	Larvae	Larvae	Larvae
28	318.18	45.18	296.06	23.06	21.77	264.02	213.86	Larvae	Larvae	Larvae
29	319.49	46.49	296.05	23.05	21.88	285.90	231.58	Larvae	Larvae	Larvae
30	320.67	47.67	296.84	23.84	22.20	308.09	249.55	Larvae	Larvae	Larvae
31	320.14	47.14	297.00	24.00	22.22	330.31	267.55	Larvae	Larvae	Larvae
Aug. 1	319.82	46.82	296.10	23.10	21.85	352.16	285.25	Larvae	Pupae	Larvae
2	320.21	47.21	298.44	25.44	22.8	374.96	303.72	Larvae	Pupae	Larvae
3	319.92	46.92	297.26	24.25	22.3	397.26	321.78	Larvae	Pupae	Larvae
4	320.56	47.56	296.99	23.99	22.25	419.51	339.80	Pupae	Pupae	Larvae
5	320.05	47.05	296.39	23.39	21.97	441.48	357.60	Pupae	Pupae	Pupae
6	319.47	46.47	296.38	23.38	21.94	463.42	375.37	Pupae	Pupae	Pupae
7	319.64	46.64	296.32	23.32	21.92	485.34	393.13	Pupae	Pupae	Pupae
8	318.09	45.09	298.02	25.02	22.48	507.82	411.33	Pupae	Adults	Pupae
9	318.47	45.47	296.35	23.35	21.88	529.70	429.06	Pupae	Eggs2	Pupae
10	318.31	45.31	295.06	22.06	21.43	551.12	446.41	Pupae		Pupae
11	321.78	48.78	296.12	23.12	22.00	573.12	464.23	Pupae		Pupae
12	320.14	47.14	300.00	27.00	23.48	596.61	483.25	Pupae		Pupae
13	318.16	45.16	297.01	24.01	22.11	618.71	501.16	Adults		Adults
14	318.26	45.26	296.48	23.48	21.92	640.63	518.91	Adults		Adults
15	320.17	47.17	296.69	23.69	22.1	662.73	536.81	Eggs2		Eggs2

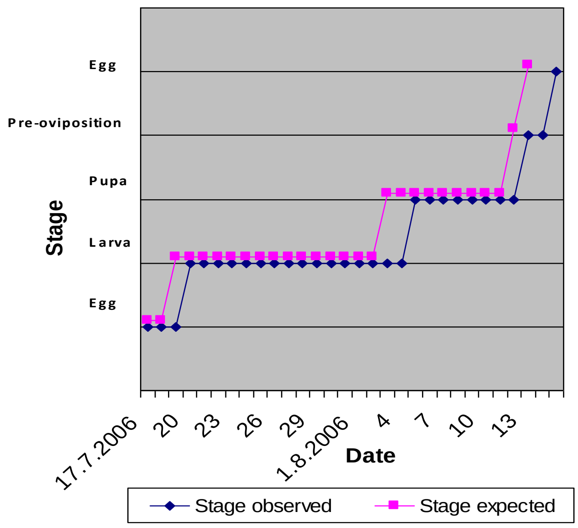

Figure 2. Expected stages of *S. littoralis* from calculation of the degree days from daily maximum and minimum soil temperature derived from satellite images.

Table 3. Expected stages of *S. littoralis* from calculation of the degree days from daily maximum and minimum satellite air temperatures compared with observed stages in the field during the period of experiment

Date /2006	Temperature				Degree days (dd's)			Stage		
	Max.		Min.		Per day	Accumulated	Corrected (0.87)	Expected corrected	Expected	Observed
	˚K	˚C	˚K	˚C						
July 17	308.64	35.64	295.67	22.67	19.26	19.26	17.14	Eggs	Eggs	Eggs
18	309.28	36.28	295.48	22.48	22.98	42.25	37.60	Eggs	Eggs	Eggs
19	308.16	35.16	296.51	23.51	19.44	61.70	54.91	Larvae	Larvae	Eggs
20	306.11	33.11	297.18	24.18	18.76	80.45	71.60	Larvae	Larvae	Larvae
21	306.32	33.32	293.08	20.08	16.81	97.26	86.56	Larvae	Larvae	Larvae
22	308.03	35.03	293.78	20.78	18.01	115.27	102.59	Larvae	Larvae	Larvae
23	309.41	36.41	295.46	22.46	22.92	138.19	122.99	Larvae	Larvae	Larvae
24	308.64	35.64	294.76	21.76	18.81	157.00	139.73	Larvae	Larvae	Larvae
25	307.24	34.24	294.25	21.25	17.85	174.85	155.62	Larvae	Larvae	Larvae
26	309.30	36.30	294.42	21.42	22.74	197.59	175.86	Larvae	Larvae	Larvae
27	310.72	37.72	295.28	22.28	22.41	220.00	195.80	Larvae	Larvae	Larvae
28	307.29	34.29	294.52	21.52	18.02	238.02	211.84	Larvae	Larvae	Larvae
29	308.25	35.25	294.24	21.24	18.35	256.37	228.17	Larvae	Larvae	Larvae
30	311.21	38.21	295.75	22.75	22.38	278.75	248.09	Larvae	Larvae	Larvae
31	309.21	36.21	295.36	22.36	22.99	301.74	268.55	Larvae	Larvae	Larvae
Aug. 1	309.78	36.78	295.06	22.06	22.69	324.42	288.73	Larvae	Larvae	Larvae
2	308.74	35.74	296.56	23.56	19.76	344.18	306.32	Larvae	Pupae	Larvae
3	308.57	35.57	296.06	23.06	19.43	363.61	323.61	Larvae	Pupae	Larvae
4	309.13	36.13	295.72	22.72	23.10	386.71	344.17	Pupae	Pupae	Larvae
5	309.09	36.09	295.38	22.38	23.05	409.75	364.68	Pupae	Pupae	Pupae
6	309.46	36.46	294.89	21.89	22.78	432.53	384.95	Pupae	Pupae	Pupae
7	310.32	37.32	294.76	21.76	22.42	454.95	404.91	Pupae	Pupae	Pupae
8	308.13	35.13	295.11	22.11	18.73	473.68	421.58	Pupae	Pupae	Pupae
9	309.75	36.75	293.80	20.80	22.42	496.10	441.53	Pupae	Pupae	Pupae
10	309.44	36.44	293.50	20.50	22.48	518.57	461.53	Pupae	Adults	Pupae
11	312.97	39.97	294.70	21.70	21.72	540.30	480.87	Pupae	Eggs2	Pupae
12	309.50	36.50	295.43	22.43	22.88	563.17	501.22	Adults		Pupae
13	307.28	34.28	295.15	22.15	18.32	581.50	517.54	Adults		Adults
14	321.96	34.24	294.88	21.88	18.17	599.66	533.70	Eggs2		Adults
15	323.25	37.05	294.84	21.84	22.54	622.20	553.76			Eggs2

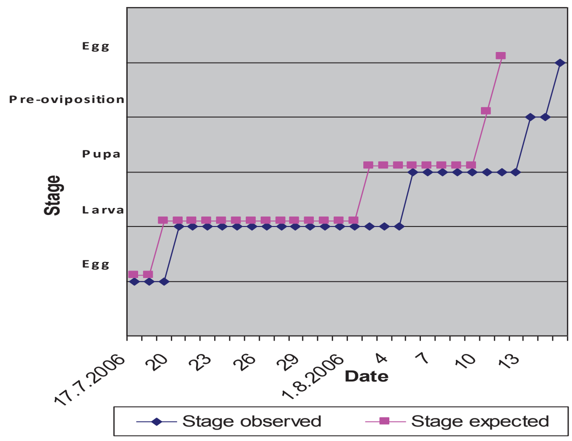

Table (4): Comparison between satellite and thermograph air temperatures and the deviation between degree days obtained from them.

Date /2006	Temperature (˚C)				DDU		Deviation (DDU)
	Max.		Min.		Thermograph	Satellite	
	Thermograph	Satellite	Thermograph	Satellite			
July 17	34	35.64	23	22.67	18.6	19.3	0.7
18	35	36.28	23	22.48	19.1	23.0	3.9
19	32.5	35.16	22.5	23.51	17.6	19.4	1.8
20	33	33.11	22	24.18	17.6	18.8	1.2
21	33	33.32	22	20.08	17.6	16.8	-0.8
22	33	35.03	22.5	20.78	17.9	18.0	0.1
23	35	36.41	23	22.46	19.1	22.9	3.8
24	34	35.64	23	21.76	18.6	18.8	0.2
25	34	34.24	22	21.25	18.1	17.9	-0.2
26	34	36.30	22	21.42	18.1	22.7	4.6
27	34	37.72	22	22.28	18.1	22.4	4.3
28	35	34.29	23	21.52	19.1	18.0	-1.1
29	35	35.25	25	21.24	20.1	18.4	-1.7
30	35	38.21	26	22.75	20.6	22.4	1.8
31	37	36.21	26	22.36	23.5	23.0	-0.5
Aug.1	36.5	36.78	27.5	22.06	24.0	22.7	-1.3
2	34	35.74	28	23.56	21.1	19.8	-1.3
3	33.5	35.57	24	23.06	18.9	19.4	0.5
4	34	36.13	23	22.72	18.6	23.1	4.5
5	34	36.09	23.5	22.38	18.9	23.1	4.2
6	33	36.46	23.5	21.89	18.9	22.8	3.9
7	34	37.32	25	21.76	19.6	22.4	2.8
8	33	35.13	24	22.11	18.6	18.7	0.1
9	33	36.75	22	20.80	17.6	22.4	4.8
10	34	36.44	22.5	20.50	18.4	22.5	4.1
11	31	39.97	20	21.70	15.6	21.7	6.1
12	33	36.50	20	22.43	16.6	22.9	6.3
13	33	34.28	20	22.15	16.6	18.3	1.7
14	32.5	34.24	23	21.88	17.9	18.2	0.3
15	33	37.05	23	21.84	18.1	22.5	4.4
Total	59.2						

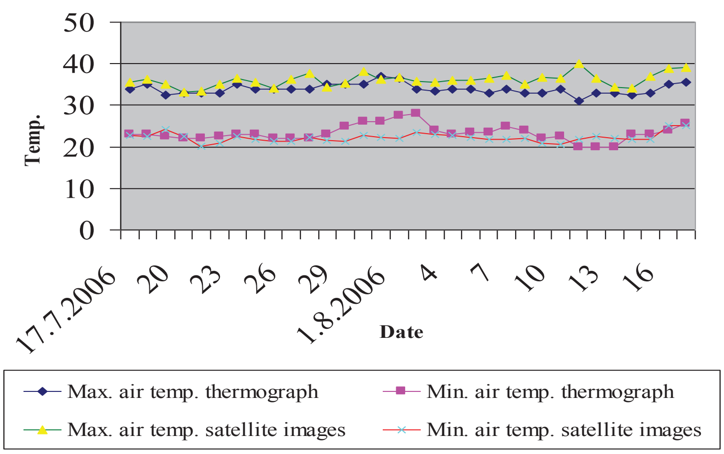

Figure 4. Comparison between air temperatures derived from satellite images and from thermograph.

There was a difference of 14.38 % or 75.39 dd's above the estimated value based on air temperatures derived from satellite images. In contrast, the field value based on soil temperatures derived from satellite images was 19.40 % or 116.36 dd's above the estimated value for the laboratory constant temperature. According to Higley et al. (1986), DD models with up to 15% error can be used to define control strategies.

There was a difference between degree days obtained from daily maximum and minimum air temperatures derived from satellite images and thermograph by 59.2 dd units (this value represents only about 2.85 days) Statistical analysis indicated that there was no significant difference between degree days obtained from daily maximum and minimum air temperatures derived from satellite images and thermograph as shown in Table 4 and Figure 4.

Daily maximum and minimum air temperature derived from satellite images appeared to be the best way for calculating and predicting the average of thermal units in degree-days (dd's) required for the completion of generation of *S. littoralis*. In contrast, most of the field models using soil temperature to determine the temperature requirements appeared adequate for making decisions for Integrated Pest Management (IPM), unlike the situation for models that, use air temperature. This difference may be related to the larger variation in air temperature compared with soil temperature, which remains more stable (Nava and Parra 2003**)**. However, Davis et al. (1996) found that both air and soil temperatures were adequate for predicting the occurrence of the corn root-worms, *Diabrotica virgifera* and *Diabrotica barberi* in field corn in the United States, with specific models for each region. Similar results were reported before by Elliott et al. (1990) for the same species.

As suggested by Cullen and Zalom (2000) while working on *Euschistus conspersus*, a degree days model for *S. littoralis* when used with a pheromone trap in the field should focus on field monitoring of the first to third instars larvae (the economically damaging generations in-field) which are more susceptible to insecticidal control than adults. Predicting timing of the more susceptible larval stages could make the use of 'softer' insecticides feasible for growers, thus providing an alternative to the toxic chemicals traditionally used for adult control.

The results obtained from the present study appear to be important for quick prediction purposes, control timing and also as valuable tools used in an integrated control program for managing *S. littoralis* in Egypt.

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Theme 3. Enhancing resilience of agriculture in dry areas through management of water and land resources and agronomic practices

3.1. Management of rain water harvesting lined ponds in dry areas of Rwanda: A case study of Ntarama lined ponds owners

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Abstract

Rainwater harvesting involves collection, storing and spreading various forms of runoff from different sources for domestic, agricultural, and other uses. To overcome poor distribution of rainfall in time, it is necessary to collect rainwater when it rains and store it for use; to meet the water needs in the subsequent dry period. In Rwanda, MINAGRI through RADA and ICRAF has introduced a pilot project of rainwater harvesting in Ntarama sector in Bugesera district. With 25 lined ponds, Ntarama sector is combating desertification by promoting tree cultivation and improved vegetative cover and thus improve standard of living and mitigate rural poverty. The study, supported by Young Professionals' Platform engaged in Agriculture Research and Development (YPARD), has identified useful effects of lined ponds to small scale farmers by conducting a case study of lined pond owners of Ntarama with the objective of understanding how the system is being promoted and managed at small scale farmers' level and the way forward to extend the system in sustainable way for all categories of people

1. Introduction

Rwanda, with rapid economic growth and industrialization, is becoming increasingly water stressed. Recognizing this imminent risk, the Government of Rwanda invited International Center for Research in Agroforestry (ICRAF) to help find solutions to avert the impending crisis. It was recommended to conduct a nationwide assessment of the country's water harvesting potential using satellite images that take into account rainfall, terrain and current land use. The detailed maps showed that different rain water harvesting (RWH) techniques can provide a total of 20 billion cubic meters of water, which can meet the needs of about 15 million people -- one and half times the current population of about 9 million. ICRAF is now helping the Government to plan how best to use this water. Less than 1 percent of the land is currently under irrigation and part of the solution to the impending water crisis lies in greater investments to better use available water for irrigation. Other safeguards include agroforestry and value addition to agricultural produce.

Nine scaling up sites were identified in the 3 districts of Bugesera, Ruhango and Nyanza, covering about 2,700 households. GIS data for the selected sites were compiled and regional GIS maps capturing the hydro-physical features were produced. A total of 108 runoff ponds, situated on 1000 m^2 farm plots, each with a storage capacity of 120,000 liters were constructed. An additional 15,000 pits and 180 conservation agriculture farms were established for agroforestry interventions. Following these interventions, 56 artisans and 13 frontline agricultural extension staff (agronomists) were trained in the design, construction and maintenance of RWH systems, and in conservation agriculture and water prospecting. These sites have attracted considerable interest from organizations such as the Japanese International Cooperation Agency (JICA), UNDP-GEF, The Nile Basin Initiative, World Food Program and the MDG project in Rwanda.

A quiet revolution is also emerging in some rural parts of this small landlocked nation. Smallholder farmers are turning to irrigation to diversify the range of crops on their farms, an important step towards achieving food security. Traditionally, the Rwandese diet consists of meat, sweet potatoes and beans, supplemented with bananas, maize, peas and millet. Fruits in season are often added. But with water harvesting and supplementary irrigation, many Rwandese farmers are now growing vegetables such as kale, spinach and tomatoes in a series of trial schemes implemented with technical support from ICRAF and RADA. Although the 'new' vegetables are yet to become a regular part of the daily meals of many families, farmers are earning extra money by selling these greens. They have formed cooperatives that collect and transport the vegetables to markets in the capital city of Kigali and satellite towns. Bugesera district has abundant water and is thus endowed with high potential for development, though prevailing farming practices remain at low level. The area has suffered from grave food shortage with a low food security, 52.8% in 2001, by far lower than the national average, owing to the degradation of arable land by soil erosion and frequent drought in the hills (e.g. Ntarama Sector). With a view to improve the situation, an action plan for agricultural and rural development that envisages poverty alleviation through the improvement of farming techniques on hillside was needed. With 25 lined ponds, Ntarama area is combating desertification by promoting tree cultivation and improved vegetative cover to improve standard of living of poor farmers. The usefulness of this initiative was studied. This paper presents the results of this study.

2. Study area

The study area encompasses Ntarama sector of Bugesera district (Fig.1), in the Eastern Province, with a population of about 14,961 where 3 cells and 22 villages are distributed. The rainfall is relatively low in Southern Bugesera (800-900 mm) and it is often exposed to drought. The district was affected by serious drought in 2000 and 2003 (Airport rainfall record). Rainfall pattern shows a tendency to reduce over time and to have high fluctuation from year year. According to the survey conducted by JIICA some people in Kidudu village in the Cyugaro Cell died from starvation because of drought while in other areas/years there was damage from high intensity of rain. These phenomena show examples of climate change.

The government has recognized the need to pilot and disseminate appropriate water harvesting techniques to supplement the

Figure 1. Admimisatrative map of Bugesera district.

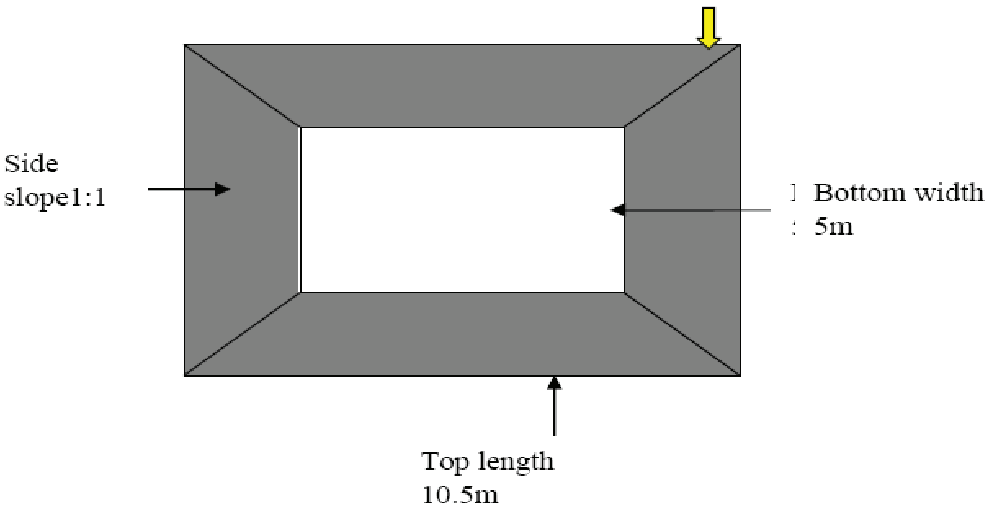

Figure 2. Design of lined ponds in Ntarama sector (120 m^3).

Picture 1. Harvesting water in Ntarama sector.

indigenous practice to protect crops from failure due to moisture stress. Ntarama sector was selected for piloting of water harvesting project. The sector has many lined ponds but this study is limited to 25 lined ponds (Fig. 2; Picture 1) funded by RADA in collaboration with ICRAF. The project was launched with the aim of improving the living conditions of local people by installing water harvest lined ponds for supplemental irrigation. On each pond, one community group is responsible for all the activities being done there, assuming the control of water and crops, and basic maintenance, while a youth cooperative trains the users. Each community group involved in Rainwater harvesting is composed of at least 5 persons with a steering committee. The mission of that youth cooperative is to develop these Picture 2. Harvesting water in Ntarama sector community groups and become the cooperatives in the future.

3. Methodology

The author used open discussion with stakeholders who responded to various questions, based on methods used elsewhere, using criteria that include: suitability of the technology, required maintenance and operational skills, environmental and health impacts, and cost.

4. Results

Adequacy of water: The beneficiaries indicated that they started using harvested water in 2007. Water was being used earlier by land owners but with bad management and misuse. The ponds were now open to community groups with assistance from a youth cooperative (trained).

Requirements for operation and maintenance: The beneficiaries indicated the need for the replacement of some materials in the ponds because they had clogged due to accumulation of waste material and bad management when they were being managed by land owners. When asked whether there were any problems faced by women, the aged or disabled, or any member of the community in having access to the use of these ponds, the beneficiaries indicated that there were none.

Permanence of structure and risk of failure: The beneficiaries were asked about the ease of work and durability of the ponds during construction and there after. In general,they felt that the system was well constructed . In terms of operational risks, the users were asked if they ever thought pumps and other materials (plastic sheets) could breakdown while collecting or receiving runoff water. Those that thought so felt that pressure of water could destroy the ponds the study found that they had no contingency plans when those problems could occur.

Environmental and health impacts: Beneficiaries were asked whether rainwater harvesting system had any impact on water conservation and management. They felt that the system (a) reduced runoff and soil erosion; (b) captured rainwater which could otherwise go to waste; and (c) when covered, could provide water that is less contaminated and safer. The beneficiaries used the water for washing, cleaning house, bathing, cooking, and irrigation.

Costs of construction and maintenance: When asked whether the rainwater harvesting system was worth the investment or effort, beneficiaries indicated that it was worthwhile. They indicated that their contribution of local materials and labour was far less compared to the total cost of the project. They were willing to pay or contribute to the maintenance cost of the systems, having seen the advantages of storing rainwater for averting water deprivation in dry months. They were ready to construct additional ponds. However, in view of poverty, they stated that the best way to finance this kind of project was to follow an approach which was used in the pilot project. When asked whether they would be willing to pay or invest in the system for their own use at their households, they were willing.

Requirements for scaling-out and scaling-up: The beneficiaries were not aware of any other individual or centre that had constructed its own rainwater harvesting system. However, they had received large number of visitors (professional farmers and CBOs) expressing interest in adopting the technology.

5. Conclusions

To overcome poor rainfall distribution in time, it is necessary to collect rainwater when it rains and store it for use; to meet the water needs in the dry period. The lined pond owners indicated that funded lined ponds were improving their life and helping in combating desertification. Improving the availability of water all year round would provide farmers with the opportunity to diversify production and increase income, for instance by growing vegetables during the dry season, when demand is highest, to increase earning potential and profitably.

3.2. Land and water use for irrigated agriculture in the lower Ili River Basin, Kazakhstan

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Abstract

The lower Ili River Basin is located in semi-arid area of Kazakhstan, where the annual rainfall is 240 mm. During the cropping period from May to August, the total amount of rainfall is only about 100 mm. Therefore, irrigation is necessary for agriculture. The Ili River originates from an offset of Tian Shan mountains in China and flows into the Lake Balkhash through the southeast part of Kazakhstan. A large-scale irrigated agriculture has developed in the lower part of the river since 1960's and the total irrigated area is about 32,000 ha. In the project area, a 'paddy rice - upland crop' rotation has been practiced. Due to domestic water use for hydropower and agriculture as well as water use among riparian countries, the deficit of water for agriculture in the lower part has been a matter of concern. In addition to that, inappropriate water management in the fields has a threat of salinity problem. Therefore, a field survey and water balance analysis of the Akdara irrigation project in the lower Ili River basin was conducted in order to assess the land and water uses. The results of survey and the current technical problems after privatization of the state farms in the project area are discussed.

1. Introduction

The lower Ili River Basin in Kazakhstan is located in the arid region and therefore large scale irrigated agriculture has been developed there since late 1960s. The Ili River, which is an indispensible water resource for agriculture, is a trans-boundary river. Due to domestic water use between hydropower and agriculture as well as water use among riparian countries, the deficit of water for agriculture in the lower part has become a matter of concern. Inappropriate water management in the fields has developed a threat of salinity, which is typical in irrigated agriculture in arid areas. Therefore, a survey was conducted to clarify the actual water use of the irrigated agriculture in the lower Ili River Basin.

2. Study area and methodology

The Ili River generates from the branch of Tian Shan Mountains in China and flows into the Lake Balkhash through southeast part of Kazakhstan. The annual discharge is about 19.6 cubic km and 80 % of the discharge comes from the Chinese territory. Figure 1 shows the Ili River Basin. The lower Ili River Basin is located in the continental arid zone and annual precipitation there is only 177 mm while the average temperature is 10.7°C. Figure 2

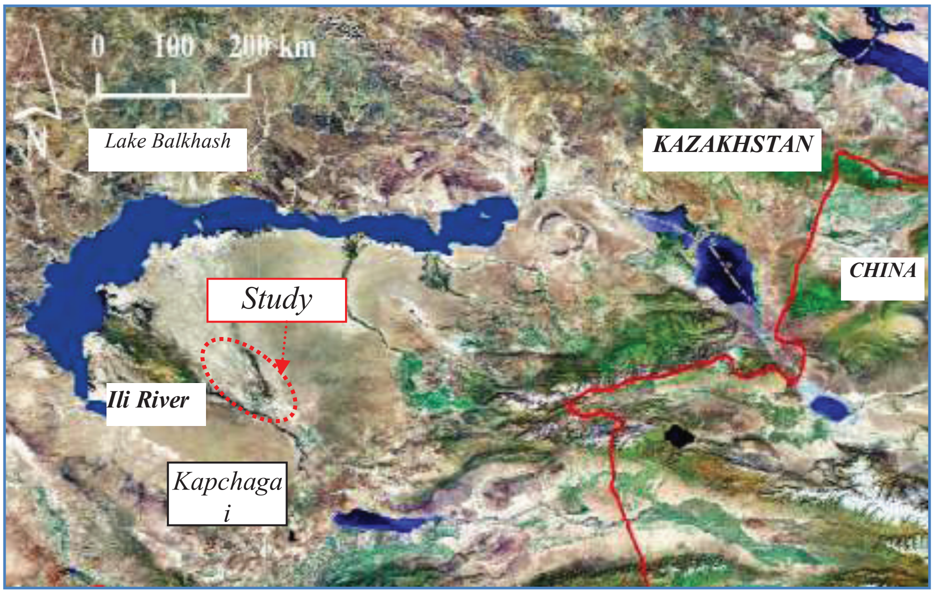

Figure 1. Ili river basin and study area.

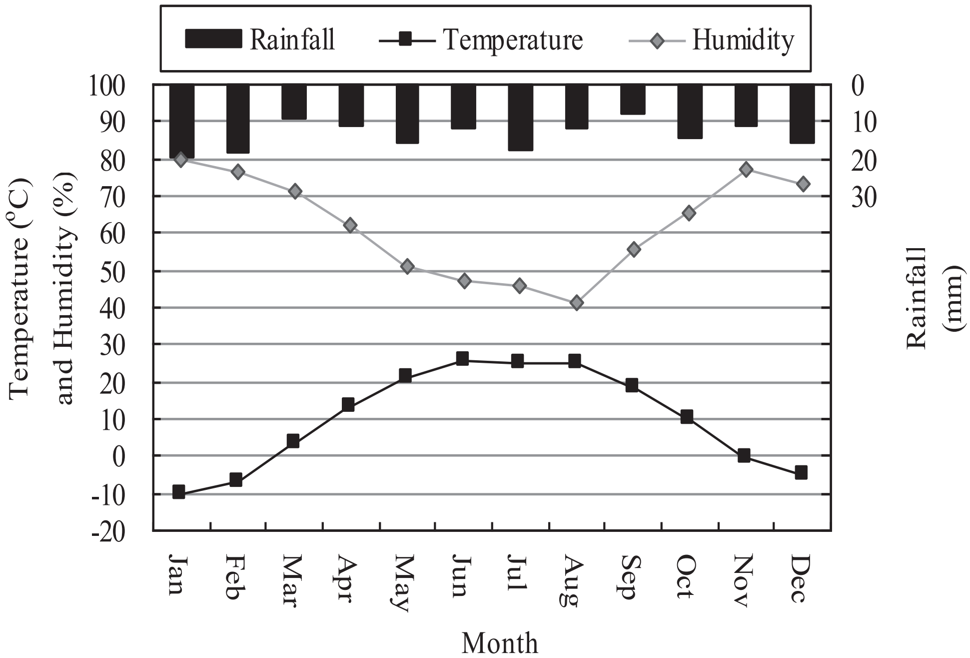

Figure 2. Monthly average, temperature, humidity and rainfall

shows the monthly average temperature and rainfall. Kapchagay reservoir is located in the middle part of the river, and there water is stored during summer season since water is used for hydropower generation during winter. Therefore, water shortage for agriculture occurs in summer.

The authors conducted field survey, in Aug., 2007 and 2008, at the former Bakbakthi State Farm (BBF), which is a part of the Akdara Irrigation Scheme (AIS) in the lower Ili River Basin. Information on land and water use of the farm was collected from Balkhash Water Management Office, Almaty Oblast (BWMO), the BBF and individual farms. Water discharge data and crop water requirement were collected from BWMO and information on transition of structure of agricultural production, cropping pattern and on-farm water management was collected from the BBF. Sampling of water was done at the irrigation and drainage canals, the Kapchagay Reservoir and the Lake Balkhash.

3. Transition of agricultural production system

The irrigable area of the AIS is 31,800 ha. The BBF has 9,500 ha of irrigated area. The farm was established in 1968 during the Soviet era and the Soviet Union placed great importance on the farm for rice production. During the period of the state farm, required materials and machinery were provided by the government. After independence of Kazakhstan, following the collapse of USSR, state farms were privatized and become cooperatives and private farms during 1994 and 1995. After privatization of the BBF, it had lost all supports from the government. Figure 3 shows the transition of agricultural production system before and after privatization (Shimizu et al. 2000, 2001). The BBF had 5 brigades, which were agricultural production units. These 5 brigades became 5 independent agricultural farms. After that, these farms were subdivided into small farms. At present, there are 41 individual farms in the AIS.

4. Land and water uses

4.1. Former and current crop rotations

Due to climate condition, cropping period is restricted between early May and late August, that is, the irrigation period is 120 days. Major crops are paddy rice, wheat and alfalfa. In the Soviet era, a 6 or 7- year crop rotation had been practiced and about 50 % of the cropped area was devoted to paddy rice cultivation. This paddy rice based crop rotation was employed in order to leach out the salts accumulated in the fields during cultivation of upland crops. Growing alfalfa provided not only fodder but also improved soil fertility by fixing atmospheric nitrogen. The area under one rotation block was about 100 ha and within the rotation block, same crop was cultivated.

After privatization of the BBF, privatized farms kept a crop rotation system. However, the proportion of paddy rice area was decreased to 40%. The farms have practiced 4 to 5-year crop rotation, in which for 1 or 2 years paddy rice cultivation is done followed by a 3-year period of upland crops (Fig. 4) shows the ratio of the paddy rice area to the cropped area in the AIS from 1995 to 2007. As shown in the figure, total cropped area in 1998 decreased to less than 50 % of original (1995) irrigated area due to the disorder of the farm organization during the transition period. However, the total cropped area recovered gradually and reached to the original of 1995. The paddy rice area also increased to become about 10,000 ha while the upland crops area did not change much. However, while the proportion of the alfalfa

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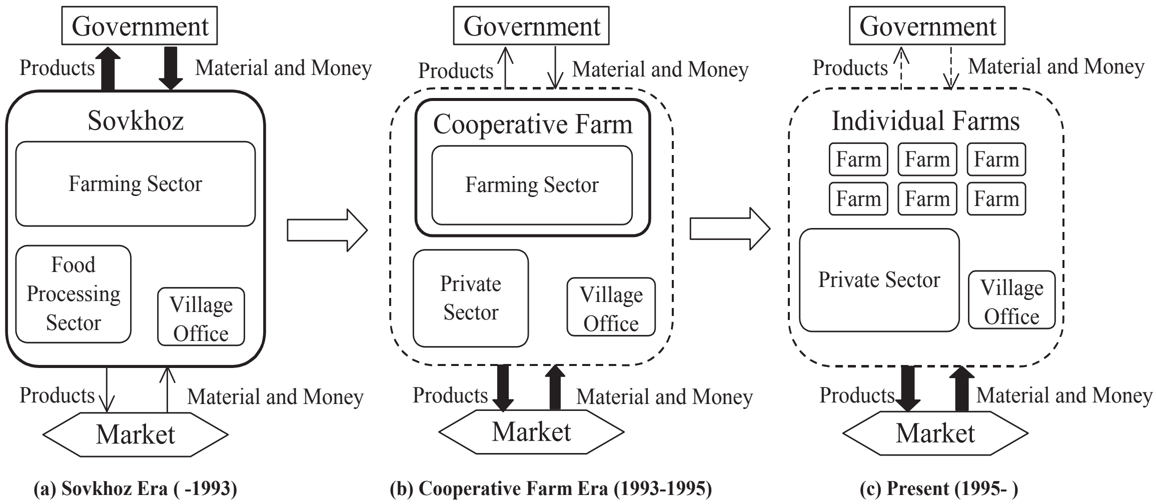

Figure 3. Transition of agricultural production system of Sovkhoz, arms and individual farms.

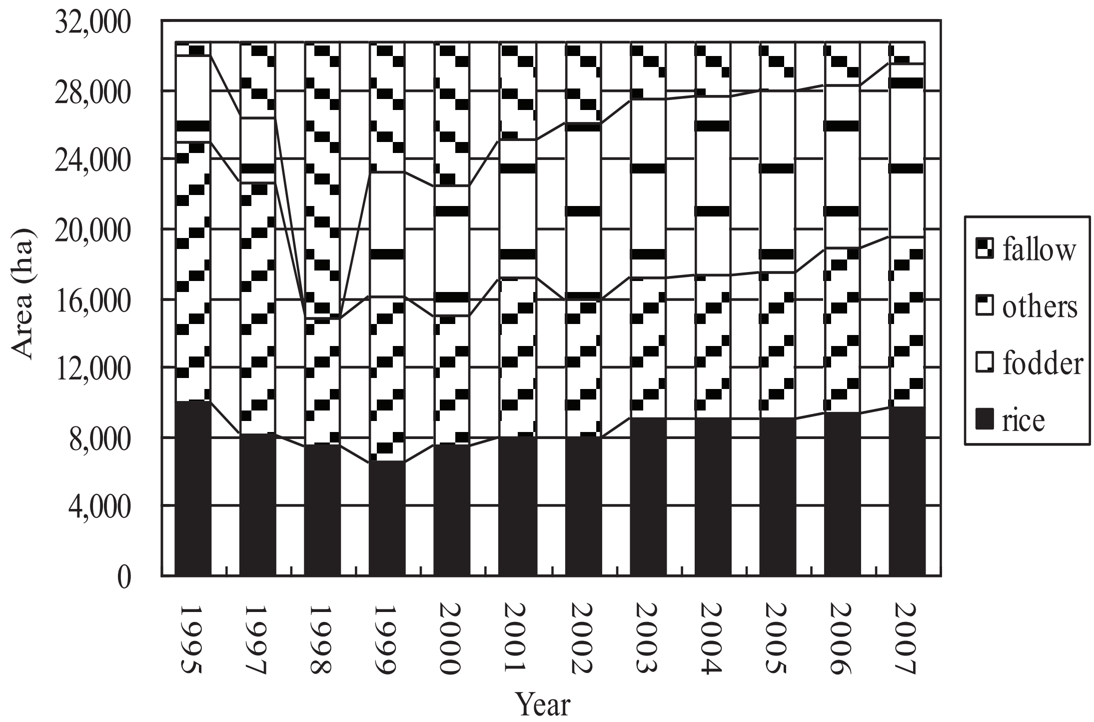

Figure 4. Cropped areas in the Akdara Irrigation Scheme.

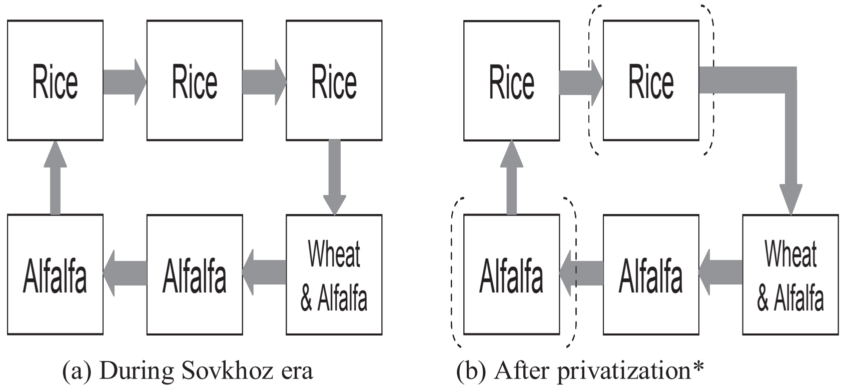

Figure 5. Change of crop rotation system. Crop phase in parentheses it means that the crop is often skipped due to low productivity in the previous year.

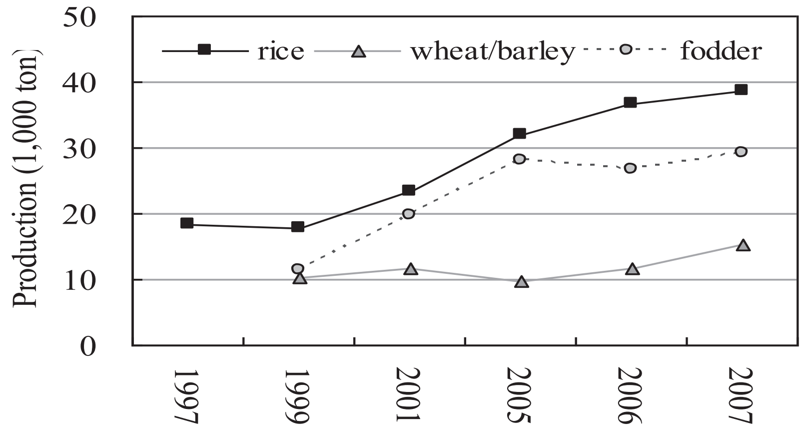

Figure 6. Production of major crops in the Akdara. Irrigation Scheme.

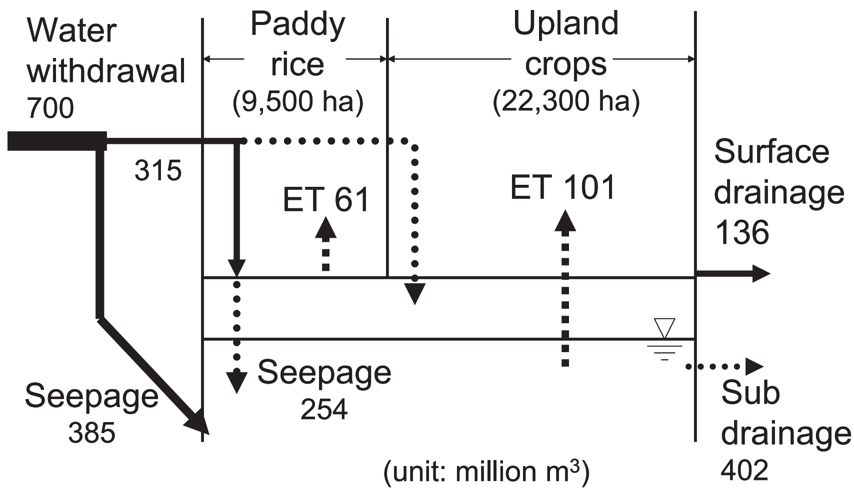

Figure 7. Water balance in the Akdara Irrigation Scheme in 2006.

area decreased, the area under other crops such as industrial crops increased. According to the interview with BWMO and farmers, paddy rice area occupied about 45 % of the original irrigated area in the mid 1980s. Compared with that, the rice cropped area decreased before and after privatization of the state farm.

There are two reasons for the change in crop rotation. The first is the high water fee for paddy rice and the second is the low rice yield. As mentioned above, after privatization, farms did not get any financial support from the government, therefore, the rate of application of fertilizers drastically decreased. Soil fertility depended on the fixation of nitrogen by alfalfa. If the yields from the second and third year of paddy rice were not enough, the farmers turned the paddy rice field to alfalfa. Figure 5 shows crop rotation systems before and after farm privatization. The size of the field is 1 to 2 ha (100m×100～200m) and the size of the rotational block is about 100 ha.

The average yield of paddy rice and wheat is 3.5 to 4.0 t/ha and 2.0 t/ha, respectively and they are relatively lower than the average yield of Kazakhstan, but the yield of the alfalfa is high at 10.0 t/ha, since it is harvested 3 times per year. Figure 6 shows production of major crops in the AIS.

4.2. On-farm water management

Main task of the BWMO is water withdrawal from the Ili River and its conveyance and distribution to 29 farms. The main canal is under control of BWMO and secondary and lateral canals are managed by each farm. According to the irrigation schedule prepared by BWMO, water demand based on the crop water requirement and cropped areas is calculated on 10-day basis, however, in actual situation, most of water is used to irrigate paddy fields and irrigation to upland crops is once or twice just after seeding or harvesting alfalfa. Water quality investigation showed that the EC values are 0.49 dS/m at the main canal, 0.65 dS/m at the paddy fields, and 0.82 dS/m at the drainage canal. Considering these EC values, it is clear that the accumulated salts in the fields are leached out by irrigation and the impact of drainage water from agriculture on the water quality of the Ili River is not so harmful.

4.3. Water fee

Unit price of water was 0.03 Tenge per cubic meter (1US$ = 120 Tenge) as of the year 2007. Water fee is charged to farms according to the crop types such as for 22,900 m^3/ha water for paddy rice, 8,500 m^3/ha for alfalfa, and 3,700 m^3/ha for wheat. Thus water fee is collected based on the area of crops. As mentioned above, farmers do not irrigate the upland crops. They, however, have to pay water fees for these crops. This is because upland crops get water from groundwater that recgarged by seepage from canals and infiltration from paddy fields. Actually, during irrigation period, groundwater level rises up to around 1 m in the upland crop fields due to lots of seepage from canals and paddy fields while it is deeper than 2 m during non-irrigation period.

4.4. Irrigation efficiency

Annual water intake to the irrigation district is about 700 Mm^3. Out of that, 136 Mm^3 is drained to the Ili River. Since the designed value of the conveyance efficiency is 0.75 and the distribution efficiency is 0.60, system efficiency is estimated as 0.45(=0.75×0.60). That is only 45% (315 Mm^3) of water intake from the river (700 M m^3) reaches the fields. Possible reasons for such low efficiency are: (i) all canals are earthen and (ii) the total length of main and secondary canals is 270 km. Under such conditions, lots of seepage and evaporation occurs during conveyance of water and its distributed to the fields.

4.5. Water balance in the irrigated district

Figure 7 shows the annual water balance in the irrigated district. Cropevapotrans-piration was estimated by using the values for the paddy rice and upland crop fields in the lower Syr-Darya River basin, which is located at almost same latitude as the study area. The estimated evapotranspiration for paddy rice and upland crops was 644 mm and 450 mm, respectively. Multiplying these values by cropped area, water requirement is estimated as about 162 Mm^3. Lots of seepage from canals and paddy fields raises ground water level in the whole farm. The soil water moves upwards by capillary action from the raised groundwater table and becomes available to the upland crops. The overall irrigation efficiency of the irrigated district is estimated to be 0.23. However, considering that the seepage from paddy fields is effective in leaching salts in the field, an overall efficiency is estimated to be 0.45.

4.6. Role of paddy-upland crop rotation

Salt accumulation is progressive in the upland crop fields. Seepage from the paddy fields contains water-soluble salts and the salty water moves upward by capillary action in the upland fields, and as the water evaporates it leaves salt on the soil surface.. In order to leach out the accumulated salts, ‘paddy - upland crops’ rotation is practiced.

5. Conclusion

The paper has analyzed the land and water use in the lower Ili River basin. In order to assess the sustainability and the validity of irrigated agriculture in this area, a detailed survey of water balance in the paddy rice fields, fluctuation of groundwater level, and distribution of salt-affected areas in the whole district is needed.

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3.3. Measures against competition for water-use between riparian countries and land salinization in Syr Darya river basin

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Abstract

We reviewed water-related issues in the Small Aral - Syr Darya River basin as seen in changes in water management. The basin is basically an arid region where water source is unstable and water rights and use among riparian countries are highly discrepant. We analyzed the competition for water use among the upstream and downstream countries and its adjustments and problems that may arise. We also examined the water and salt balance in the irrigated regions, identified the causes of secondary salinization in irrigated farmland and proposed preventive measures. Results of the examinations on water management clarified 4 major issues: (1) problems affecting countries downstream included water shortages in summer and artificial flood damage in winter; (2) problem of irrigation water distribution in the Fergana Valley; (3) salinization of farmland in middle and lower riparian reaches; and (4) deterioration in Aral Sea and neighbouring ecosystems due to drastically lowered water levels. Measures taken in Kazakhstan to conserve the Small Aral and Syr Darya delta area are discussed, and several hydro-political scenarios in the basin are proposed. Concrete measures for appropriate irrigation and better water management are recommended.

1. Introduction

Overcoming regional water problems requires an understanding of both natural hydrological conditions and social and historical changes in regional water policy. Central Asian nations face serious water problems, and we here review the circumstances surrounding water resources in the Syr Darya River basin in terms of water management changes. Two major rivers – the Syr Darya and the Amu Darya – originally flowed into the Aral Sea, once an inland lake that was the world's fourth largest in water area. In the 1960s, the Soviet Union started large-scale irrigation projects in the vast dry steppes extending through the mid and downstream basins of these two rivers. Irrigated land grew from about 4.5million ha in 1960 to about 7 million ha in 1980. During these two decades, the population roughly doubled from 14 million to 27 million, as did the amount of water taken from the rivers, from 64.7 km^3 to 120 km^3 – over 90 percent of which was used for irrigation. By 1999, irrigated farmland occupied 7.90 million ha and water taken from the rivers ranged from 110 to 117 km^3.

The main crops promoted were water-consuming – cotton, rice, wheat, maize, and grasses. The huge increase in water diverted to irrigated areas dramatically decreased water flowing into the Aral Sea, disturbing the balance between water inflow and evaporation from the lake, drastically reducing the lake area and rapidly raising the saline concentration from 10‰ to 35‰. The Aral Sea became divided into the Small Aral in the north and the Large Aral in the south, both of which continue to shrink (Fig. 1). Reduction has been particularly swift in the Large Aral, where water is shallower, especially in the east, and the Large Aral is being separated into eastern and western parts. The combination of these processes has triggered many problems, including the disappearance of fisheries from the Aral Sea, the contamination of basins by agricultural chemicals, the damage to health of local inhabitants including a lower life expectancy, and the deterioration of the environment and basin ecosystems. Water-logging and salinization have plagued irrigated farmland, nearly half of which has been adversely affected by accumulated salinity rendering farmland unusable. After the Soviet Union's collapse in 1991 and the independence of republics around the basins, bitter conflicts arose over water use from the two natural rivers, now internationalized, between countries upstream and downstream. We focus on water issues involving the Syr Darya that emerged after the Soviet Union's breakup.

2. Outline of the hydrological features of the Syr Darya basin

The Syr Darya River arises in the Tien Shan Mountains. It runs through Kyrgyzstan, Uzbekistan (Fergana Valley) and Tajikistan and then flows through Uzbekistan again and enters Kazakhstan. It runs across the Kyzyl Kum Desert and finally flows into the Small Aral. The river is now an international one with a total length of 2,210 km. While Kyrgyzstan, an upstream country, is rich in water resources, Uzbekistan and Kazakhstan, downstream countries, lack these resources because they are located in semi-arid and arid areas, and have to depend on the water from the upstream area.

The hydrological features of the Syr Darya basin can be outlined as follows (Savoskul et al. 2003; Kitamura 2004): the catchment area is 402,800 km^2 and 19.50 million people live in the area (the basins' population density being 48.4 persons / km^2). The average annual precipitation in the basins is 320 mm (128.9 km^3/year), the average annual runoff is 96.3 mm (38.8 km^3/year = 1,230 m^3/s), the runoff coefficient is 0.30 and the specific discharge is 3.05 l/s/km^2. The per capita runoff is 1,990 m^3/year. The amount of inflow into the Small Aral is 5.2 km^3/year or 13.4 percent of the total runoff.

3. Changes in social conditions surrounding water management in the basin

3.1. Construction of irrigation systems and water use during the Soviet era

Under the Soviet Union's 'planned economy' policy, many dams and other irrigation facilities were constructed in the Syr Darya basin, due to the Communist Party's prioritization of cotton and rice cultivation in downstream Uzbekistan and Kazakhstan. Many water facilities, including the huge multi-purpose Toktogul Dam, were built in Kyrgyzstan, located furthest upstream in the basin and rich in water resources. This put several thousand hectares of fertile land and many rural communities and historically important sites under water. These water facilities were used to supply the two downstream nations with irrigation water rather than to produce

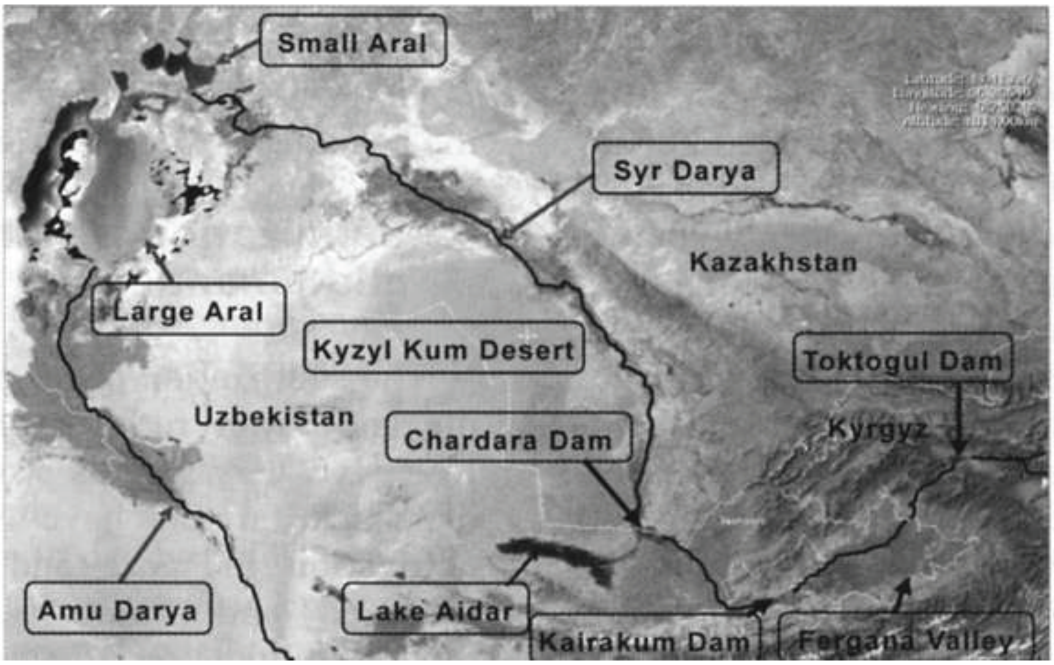

Figure 1. Basins of the Syr Darya River (based on the NASA World Wind 2005).

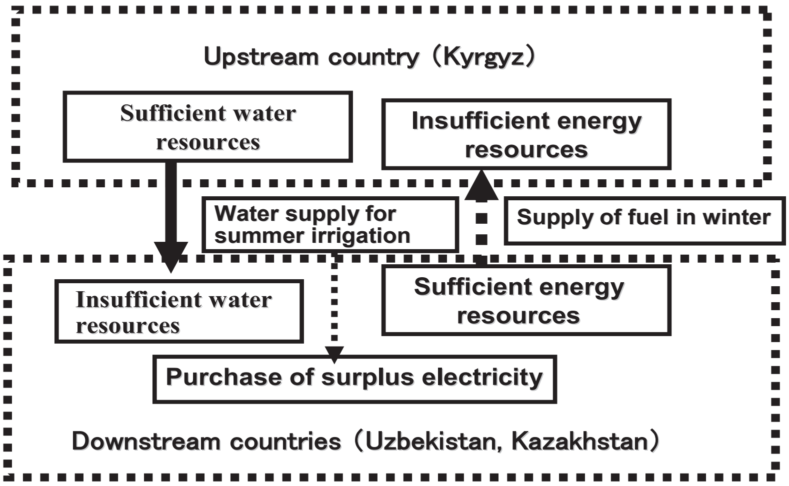

Figure 2. Concept of the barteragreements on water and energy resources between the upstream and downstream countries in the Syr Darya basin.

electricity. About 75% of the annual discharge released for irrigation downstream in the summer months of April to September (Abbink et al. 2005).

The Soviet Government compensated Kyrgyzstan for its lost water and efforts exerted to operate and manage irrigation facilities by supplying coal, petroleum, gas, and other energy resources abundant in the two downstream republics to Kyrgyzstan in addition to preferential budgetary measures. Large-scale irrigated agricultural production promoted in Uzbekistan and Kazakhstan caused various secondary environmental problems as described above, including a shrinking Aral Sea, but the Soviet government avoided competition for water use among the republics in the basin by redistributing resources throughout the entire Soviet Union under the strong control of the Communist Party.

3.2. Problems arising after the collapse of the Soviet Union and water use adjustment

After the Soviet Union's collapse, the independent Central Asian republics concluded the Almaty Agreement in 1992 emphasizing downstream irrigation and environmental issues, all disadvantageous to upstream water distribution. Essentially, the agreement maintained the irrigation policies implemented under the Soviet era's planned economy but disregarded upstream economic development using water resources. The two downstream countries used water from Kyrgyzstan for free irrigation and started selling energy resources to be supplied to Kyrgyzstan with the maintenance costs of its cascaded dams, while being charged international prices for gas, coal and petroleum exported downstream.

Kyrgyzstan decided in the summer of 1993 to use the Toktogul Dam, the largest in the basins with a reservoir capacity of 19.5 billion m^3 and an active storage capacity of 14.5 billion m^3, for power generation in winter. Kyrgyzstan reduced summer water release to 45% of the annual discharge and increased winter release to 55% in winter months (October to March) during the 1990s (Abbink et al., 2005). This triggered a shortage of irrigation water in nations downstream in the summer while its discharge of water for power generation in winter caused floods in the lower reaches of the river. Because the lower reaches of the Syr Darya froze in winter, its conveyance capacity declined, increasing the damage further. The Chardara Dam in Kazakhstan, with a reservoir capacity of 5.7 billion m^3 and an active storage capacity of 4.4 billion m^3, cannot control floods alone and Kazakhstan has to let an excess of about 3.0 billion m^3 in water overflow each winter into the Arnasai Depression in Uzbekistan, next to the dam, and eventually discharge it into the saline Lake Aidar. Lake Aidar has grown into the "second" Aral (Fig. 1). Water flowing into the depression does not reach the Small Aral, mixes with salt water; and loses its value as a water resource.

4. Better water management and ecosystem rehabilitation

4.1. Adjustments in water use and attempts for self-sufficiency by downstream countries

In the circumstance stated above, riparian countries have been working to settle disputes since 1992 (Table 1), basically using barter in water and energy resources between upstream and downstream countries, started in the Soviet era (Fig. 2). The 1998 Framework Agreement on the use of water and energy resources in the Syr Darya basin was helpful in settling disputes in the basin (Scenario 1), but conflicting interests have led to difficulties in implementing it (World Bank 2004). Even with an optimum cooperation among the riparian states, Kyrgyzstan will still need additional power-generating capacity to meet its winter deficit. Downstream riparian states believe that even if they were to honor 1998 Framework Agreement principles in their entirety, Kyrgyzstan will not do so due to persistent energy shortages in the republic during winter (World Bank 2004). Because each country tends to prioritize its own interests and disregard mutual obligations, several agreements have ended in failure (Shalpykova 2002).

Annual barter agreement is extended to late spring when downstream countries need irrigation water and it imposes great pressure on these countries. The two downstream countries adopted the strategy of exporting their energy resources to Europe to acquire foreign currency, and the barter agreement (Fig. 2) thus appears to have its limitations. Cooperation among riparian countries has stagnated after the failures of annual agreements in 2003 and 2004 (Abbink et al. 2005). The two downstream countries are taking measures to cope with floods caused by water discharge for power generation in winter by Kyrgyzstan and the shortage of irrigation water in summer (Scenario 2).
Uzbekistan is now constructing two dams (0.8 billion m^3) in the Arnasai Depression to effectively use the water from Lake Chardara at home. It is also currently constructing two regulating dams, the Razaksay Dam (about 0.7 billion m^3) and Kangkulsay Dam (0.3 billion m^3), as well as proceeding with the design of the Karamansay Dam (around 0.7 billion m^3). These dams could provide additional storage of about 2.5 billion m^3 within the next few years in Uzbekistan, which could replace the equivalent additional discharge from Toktogul in winter and summer in years of normal and/or high-water flow. Though, these dams alleviate Uzbekistan's problems in low-water years, albeit at considerable costs, the reservoirs do not appear to be large enough to achieve self-sufficiency in irrigation water (UNDP 2005).

Kazakhstan plans to build a Koksarai Regulation Dam, which would be capable of storing the quantity of water discharged in winter to the Arnasai Depression (about 3.0 billion m^3), in the location about 100 km downstream from the Chardara Dam. A decision on the construction of a Koksarai Regulation Dam will be made based on an overall evaluation of the benefits expected, the construction costs (around US$ 200 million), possible impact on the surrounding water environment and other related factors. Kazakhstan also constructed the Aitek Head Works about 50km downstream from Kzyl-Orda City, improved the discharge facilities to the Karaozek River, a branch river, and reinforced the conveyance capacity from $300m^3/s$ to $700m^3/s$ (CIGB 2004).

Kyrgyzstan and several organizations, such as the World Bank and USAID, are considering the economic feasibility of two dams, Kambarata No.1 and No.2, which will have a combined capacity of 2,260 megawatts (Scenario 3). Since Kambarata No. 1 would be located upstream of Toktogul reservoir, water could be released to generate almost all of its annual power output in the winter, thus avoiding the release of water from Toktogul (UNDP 2005). As an alternative project to increase winter power generation in Kyrgyzstan and reduce the need for winter water releases from the Toktogul reservoir, a 400 megawatt thermal power plant, Bishkek No. 2, is involved (UNDP 2005). In this plan,

Table 1. Chronology of the water talks after the independence

Year	Water-related talks and events
1992	Almaty Agreement (establishment of the Interstate Coordinating Water Commission (ICWC); the downstream nations received the larger quotas, while the upstream country was given much smaller quotas)
1992-1995	Kyrgyzstan increased electricity production at the Toktogul Reservoir in winter, and reduced water release in summer
1993	IFAS (International Fund for the Aral Sea) was established
1994	CAEC(Central Asian Economic Community) was established
1996	Executive Committee of CAEC formed a "Water and Energy Uses Round Table" to develop a framework agreement addressing the riparian republics competing uses for water. Agreement about the eventual recognition of the indissoluble connection between the water issue and energy problems in the basin (Barter agreement) failed due to interruption of fuel supply to Kyrgyzstan by the downstream nations
1997	Application of the idea to promote the use of money as a replacement for the current water and energy barter unsuccessful (because the issue of payment of operation and maintenance costs became a stumbling block between the upstream and downstream states)
1998:	Syr Darya Agreement: Framework agreement on use of water and energy resources of the Syr Darya River basin
1999	Draft Agreement failed and not signed (Shalpykova 2002)
2001	The law 'On interstate use of water objects, water resources and water facilities of the Kyrgys Republic' enacted (the law states that all the waters in the territory of the country belong to the State and demands that the downstream countries pay for water emanating from Kyrgyzstan).
2002	CACO (Central Asian Cooperation Organization) was established, with the aim of focusing on regional cooperation in water and energy, transport and food security
2003	Annual agreement failed to conclude (UNDP 2005)
2004	Annual agreement failed to conclude (UNDP, 2005)

construction cost, effect in basin-wide water management, and detailed considerations, such as possibility in obtaining riparian countries' approval and evaluation of balance between supply and demand, are prerequisite.

In the basins of the Aral Sea, the Interstate Coordinating Water Commission (ICWC) was established in 1992, and the River Basin (BVO) Syr Darya serves as the ICWC's executive organization in the Syr Darya basin. The ICWC is doing adjustment on irrigation water among the riparian countries, while the BVO Syr Darya is working on the operation of major irrigation facilities (e.g., water-taking facilities for the Syr Darya and its main tributaries), the protection of the ecosystem in the basin and improvement in water quality. But the BVO Syr Darya is poor in fundraising and legal affairs, and it is difficult to say that this body is performing its functions as an international water management organization.

4.2. Farmland salinization and remedial measures in the middle and lower reaches

Increasing salinization of farmland in the middle and lower reaches of the Syr Darya River is causing farmers to abandon cultivation on more and more land. Farmland in the middle reaches is reported to have been salinized at 5.3 tons of salt per ha per year. In a survey conducted in an irrigated area in Zhalaghash (716ha) in the lower reaches, it was observed that 0.6 to 6.2 tons of salt accumulated per ha per year (Kitamura et al. 2000b; Kitamura et al. 2006). A study in the same area showed the occurrence of secondary salinization in rice-based crop rotation widely practiced in the lower reaches of the Syr Darya.

Salinization is basically due almost completely to poor water management as summarized below (Kitamura et al. 2000b; Kitamura et al. 2006):
(1) Heavy seepage losses from the canal system.
(2) Heavy operational losses due to insufficient functioning and poor management of canal system.
(3) Insufficiency of drainage system due to poor management.
(4) Imbalance between inflow and outflow of salts in the area.
(5) Over-irrigation of rice fields.
(6) Application of an eight-year crop rotation system (where flooded fields and drained fields coexist) in an irrigation system. The eight-year crop rotation system is the rotation system in which the irrigated land is equally divided into eight sections and four of the sections are used for rice, three for grass and one let lie fallow.
(7) Poor land leveling and careless field water management.
(8) Introduction of saline river water with TDS more than 1,000mgL^{-1} for irrigation.
(9) Dissolution of accumulated salts from canal systems.
(10) Upward flow of saline soil water from the lower salt-accumulated layers in rice-planted plots due to occasional interruption and resumption of irrigation water supply.

To solve the above problems measures to prevent salinization itself are needed. The following proposals were made in terms of water management (Kitamura et al. 2006):
(1) Avoid mixed cropping with rice and upland crops, and place either upland crops or rice in an irrigation block to control the groundwater table.
(2) Increase irrigation efficiency by minimizing conveyance and field application losses. Specific measures to do this include: lining the canals; using crushing and compaction in constructing canals; improving and repairing canal facilities to optimize water control; improving field leveling; and changing farmers' sense of value for water and introducing proper water pricing.
(3) Avoid excessive soil moisture, and plant trees along canals and around field (biological drainage).
(4) Avoid flooding as much as possible in fields with saline soil layers.
(5) Maintain the system by dredging to maximize drainage functions.
(6) Control groundwater levels in irrigated areas by managing drainage outfall (evaporation pond) appropriately.
(7) Implement quantitative and qualitative control of irrigation and drainage in individual reaches of the river. A key to this is signing an international agreement on irrigation and drainage among riparian countries as soon as possible. Agreement on appropriate interstate water quality standards has yet to be reached and alternatives for reaching different water quality standards have yet to be explored (McKinney 2004).

4.3. Measures taken in Kazakhstan to conserve Small Aral and Syr Darya Deltas

The drastic drop in the Aral Sea water level severely damaged its ecosystem and that of the Syr Darya delta, including wildlife and vegetation. Kazakhstan is constructing an Aklak Dam, soon to be completed, in the delta area in the lowest reaches to conserve the environment and ecology and to improve water use. It will control the upstream water level at 53 m above the sea level – the same as the 1960s level – making it possible to deliver water to the many lakes around the mouth of the Syr Darya, such as Lake Karashalan and Lake Karateren, helping revive delta wetlands.

Even more important is the construction of the Kokaral Dam (crest length: 15km) along the Small and Large Arals (Berg Strait), which would separate the two Arals. This dam was constructed in 2006. The water level of the Small Aral is expected to be maintained around 42 m above the sea level - lower than the 1960s level by 11m - in ordinary years. This will lower salinity from 25g/l (25‰) to 17g/l (17‰), and gradually restore the ecosystem and fisheries. While it appears that the basins of the Small Aral and Syr Darya will be preserved, the Large Aral, after being separated from the Small Aral, is expected to continue shrinking with over 90 percent of the lake eventually becoming land in the next several years.

5. Conclusion

For some ten years after the collapse of the Soviet Union, the upstream country rich in water resources and the downstream countries rich in energy resources continued discussion about the irrigation water agreements on the Syr Darya on the basis of barter trade of these resources. The conclusion of the long term Frame Agreement on the use of water and energy resources in the Syr Darya basin in 1998 is a landmark in regional cooperation for adjustments in water use. The most desirable strategy for riparian countries is to observe the Syr Darya Agreement and restructure the basin-wide cooperation based on mutual complementation in the use of water and energy resources (Scenario 1). In case of difficulty in enforcing this scenario, the downstream countries' most pressing need is to construct water management system to cope with the floods caused by the water discharge for power production in winter by Kyrgyzstan and the shortage of irrigation water in summer. For example, construction of Uzbekistan's 5 regulating reservoirs and Kazakhstan's Koksarai reservoir will greatly improve winter flood and summer water shortage problems (Scenario 2). A decision on the construction of each dam should be made based on an overall evaluation of the benefits expected, construction costs, possible impact on the surrounding water environment and other related factors. To regulate excessive winter release and insufficient summer release by constructing Kambarata No.1 and No.2 dams located upstream of Toktogul reservoir (Scenario 3), construction cost, effect on basin-wide water management, detailed considerations, such as possibility in obtaining riparian countries' approval, evaluation of balance between supply and demand, are a prerequisite.

The future task will be to raise the status of the ICWC and the BVO Syr Darya further by the cooperation of the related countries, international organizations and other stakeholders. In particular, it will be needed to strengthen the latter's capacity for financing, technology and international laws and to expand its organizational functions so as to solve serious problems, such as the measures for replacing antiquated facilities. Measures for conserving Small Aral and Syr Darya Deltas will gradually restore the water environment, ecosystem and fisheries in the region.

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3.4. Towards optimal water management: assessment of the cost effective techniques in irrigation improvement in Nile Delta

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Abstract

In the Nile Delta of Egypt water and agricultural development is needed to maximize the efficient use of scarce water resources. For this an integrated irrigation improvement and management project (IIIMP) was designed to be carried out there. Before applying IIIMP on all the target area, pre-studies were conducted at Kafr El Sheikh Governorate (W10) to test the new designs criteria aiming at reducing the water application cost without sacrificing irrigation performance. The cost reduction includes the measures like reducing pump discharge and use of electricity instead of diesel. To evaluate the new measures indicators used were: water saving, irrigation time, night irrigation time, land saving, etc. Results showed that the total cost of new techniques was 16.5% less as compared to the old techniques. The increase in pump operation hours from 16 to 20 hr/day led to an increase in the average irrigation time for the selected crops in head, middle and end of irrigation canal. It also increased the number of irrigation events for each crop. Due to the new measures, equity of water distribution was achieved on Sefsafa and Meet Yazied canals, but not on El-Mesk canal. It can be inferred that the new techniques, if applied to all target area, will improve the irrigation performance and lower costs.

1. Introduction

In Egypt, full exploitation of the limited water resources is very important, especially through the improvement of irrigation system. The Ministry of Water Resources and Irrigation, Egypt (MWRI) recognized this fact early and considered to take some mitigation measures. Several development projects were started. During 1977 to 1984, Egypt Water Use Project (EWUP) was carried out to improve the on-farm water management programs (EWUP 1984). Similarly, in 1993, the World Bank started the 'Irrigation Improvement Project' (IIP) on an area of 105,000 ha in Mahmoudia, Wasat and Manaifa to improve the irrigation infrastructure, facilitate a more equitable distribution of water and improve on-farm irrigation management. In 2004, World Bank and MWRI initiated the 'Integrated Irrigation Improvement and Management Project' (IIIMP) to increase irrigation efficiency and agricultural productivity as well as drainage and groundwater management, with a target area of 210,000 in the Lower, Middle and Upper Egypt (MWRI Planning Sector 2005).

The IIP attempted to solve, at the Mesqa (tertiary canal) level, the problems of water inequity and supply shortages. Technical interventions of the construction of lined canals and buried pipes increased the conveyance efficiency considerably. Also, a centrally operated pumping system, managed by water users themselves through water user associations, replaced individual pumping units reducing the cost of operation by one third (FAO 2005).

About 90% of the cost was used at on-farm (tertiary canal) level for infrastructure improvement including equipments (pump sets and gates) while 10-15% of the cost was spent on the main canals (MERI and WMRI 2005). In spite of reduction in the operational cost the cost recovery is quite challenging because the potential gains from this irrigation improvement project vary among farmers according to their location along the canal (head, middle, or tail). For example, the field data show that most of the fields have an irrigation interval of less than 8 days for rice crop contrary to the recommended 15 days interval, which means that even during 'off' periods there is irrigation being done (McDonald 1988) and most of the farmers irrigate more frequently than scheduled, but the water supplies are not sufficient equitable. Some farmers use twice as many irrigations as the others and some fields get more than four times as much water (Bekheit 1994). The inequitable distribution of water prior to an improvement project may generate concern among individual farmers regarding their share of potential benefits (Wichelns 1999). One of the options to make recovery easier is to reduce the project cost so as farmers can be encouraged to pay their share willingly. Therefore, there was a need to provide some new cost effective techniques that could be implemented in IIIMP, especially at the Mesqa (tertiary canal) level which should not only improve the irrigation efficiency but also reduce the cost of production. The new techniques such as reducing pump discharge capacity and using electrical power instead of diesel power for the centrally operated pumping stations are a few options to reduce the project cost. Reducing pump discharge rate was expected to reduce over-irrigation by upstream farmers, improve irrigation timings and equity of water distribution, allow enough irrigation water to tail-end farmers, improve cultivation practices and in turn increase crop productivity in the command area. The new techniques were applied in the command area of Sefsafa canal to test and verify the expected outcome. Results were also compared with the IIP project areas.

2. Materials and methods

The Meet-Yazied canal (MYC) command area is located on the northern part of the Nile Delta, Kafr El-Sheikh, Egypt. There are two regulators on Meet-Yazied canal one at El-Mofty (Km 50.2) and second on El-Masharka (Km 59.5) to control water level in the canal. New techniques were applied on the area irrigated with the Sefsafa Canal (SC), a branch canal on MYC (51.9 Km). Effects of applied techniques were compared with the area irrigated with Mask Canal (MC), which is also a branch canal on MYC, and the area directly irrigated from MYC. To compare SC with the MC and MYC at Meska level and on-farm level, eleven Meskas were randomly selected across all the areas as follows: (a) Five Meskas in SC command area with improved water channel (Marwa) and without improved water channels named as P.S. #1, 5, 7, 8, and 11. At each Marwa there were two or three pumping unites; (b)Three Maskas in MC command area named as P.S# 33, 38/20A, and 38/20B; and (c) Three Maskas on the right hand of MYC named as P.S. #51, 61/48, and 61/48

Some new design criteria were applied during the year 2006 in the command area of SC that could be implemented in IIIMP to reduce the installation, operation and maintenance costs. On-farm level, current Marwas (open water channels) in MC and MYC command area were replaced with pipeline Marwas in SC command area. In addition, old valves were replaced with new types (butterfly and ball valves). While, at the Meska level, new techniques applied in SC command area were as follow: (a) the total pump discharge was reduced to 50, 70, 80 and 100 L sec^{-1} instead of 120 L L sec^{-1}, which will ultimately increase the pump operation hours; (b) increase in the height of the water tank (pump discharge water in this tank to keep constant head pressure), and (c) pumps were operated by electricity instead of diesel energy.

To evaluate the effect of newly applied techniques in the SC command area following parameters were studied in SC, and MC and MYC command areas:

1. Total water applied
2. Crop water consumptive use, calculated using CROPWAT computer program (Smith, 1992) considering the modified Penman equation. The climatic data required was interpolated from Sakha as a nearby weather station located in Kafr-El-Sheikh. The annual water requirement per unit area of each crop was computed based on 15-day intervals assuming that the crop will be planted at the middle of its typical local planting period.
3. Water use index (WUI) as the ratio of the total water applied per total water requirements for all selected Meskas.
4. Cropping patterns, using maps with fields' boundaries and revised with agriculture department in the study area. The summer season crops were rice and cotton, and winter crops were wheat and clover. Given crop rotation was applied in all study area.
5. Irrigation time (duration) per unit area for the selected crops, in each season by taking in account the total number of irrigation events and total time of each irrigation event.
6. The distribution of irrigation time during the day and night. The time period from 24:00 to 1:00 is referred as "Time-1"; from 1:00 to 2:00 as "Time-2" and so on until "Time-24". Based on this timing, night hours are considered from Time-19 (7:00 PM) to Time-6 (6:00 AM) during summer season and from Time-17 (5:00 PM) to Time-6 (6:00 AM) during winter season.
7. Land saving ratio due to the replacement of earthen Meskas and Marwas (on-farm ditches) in SC command area by underground pipelines.
8. Total cost (US$) per unit area, including operation cost (fuel/electricity, lubricant, labour, repair and maintenance) and capital cost (pump house construction, pump price and cost of providing electricity to SC command area) for each selected pump station.

3. Results and discussion

3.1. Crop rotation patterns and water requirements

Crop pattern (Table 1) results indicated that in winter season farmers preferred the cultivation of crops in the order: clover (42.5 %) > wheat (29.3%) > sugar beet (21.4%) > other crops (6.7%). In the summer season, the order was: rice (67.8%) > cotton (25.2 %) > maize (2.84%) > other crops (4.2%). Figure 1 shows the crop water requirements (m^3 ha^{-1}) for selected crops (Abou El Hassan et al. 2005). Maximum monthly water requirement was during June for the summer crops and in February for the winter crops.

Table 1. Cropping pattern areas for the selected Meskas (ha^{1}) for winter and summer seasons of 2006/07 in the study area

Selected pump stations	Winter crops				Summer crops			
	Wheat	Clover	Sugar beet	Total*	Cotton	Maize	Rice	Total
Sefsafa:								
P.S. No. 1	7.84	9.24	1.47	19.81	12.6	0.56	5.79	19.79
P.S. No. 5	-	8.36	0.74	11.81	-	-	11.81	11.81
P.S. No. 7	4.73	5.81	5.41	16.78	0.84	-	15.03	16.71
P.S. No. 8	8.31	15.51	7.11	32.52	7.35	1.19	20.18	29.36
P.S. No. 11	10.94	14.37	4.13	29.64	5.46	-	18.9	24.36
Total	31.81	53.28	18.86	110.6	26.25	1.75	71.2	102.04
Meet Yazied:								
P.S. No. 33	2.26	7.19	4.2	13.65	-	0.21	12.71	13.65
P.S. No. 38/20 A	7.84	8.01	5.7	22.05	7.77	1.47	10.29	19.64
P.S. No. 38/20 B	4.02	7.59	2.63	17.22	3.57	1.68	15.65	20.9
Total	14.12	22.8	12.53	52.91	11.34	3.36	38.64	54.18
El-Mesk:								
P.S. No. 51	12.71	19.01	10.29	46.94	11.03	-	24.57	40.85
P.S. No. 61/43	6.02	2.24	4.52	13.19	5.65	0.21	7.35	13.21
P.S. No. 61/48 A	4.00	3.99	1.54	9.41	1.68	0.18	7.56	9.42
Total	22.61	25.23	16.34	69.54	18.36	0.39	39.48	63.47

*Total cropping areas include other crops cultivated in each pump station served area.

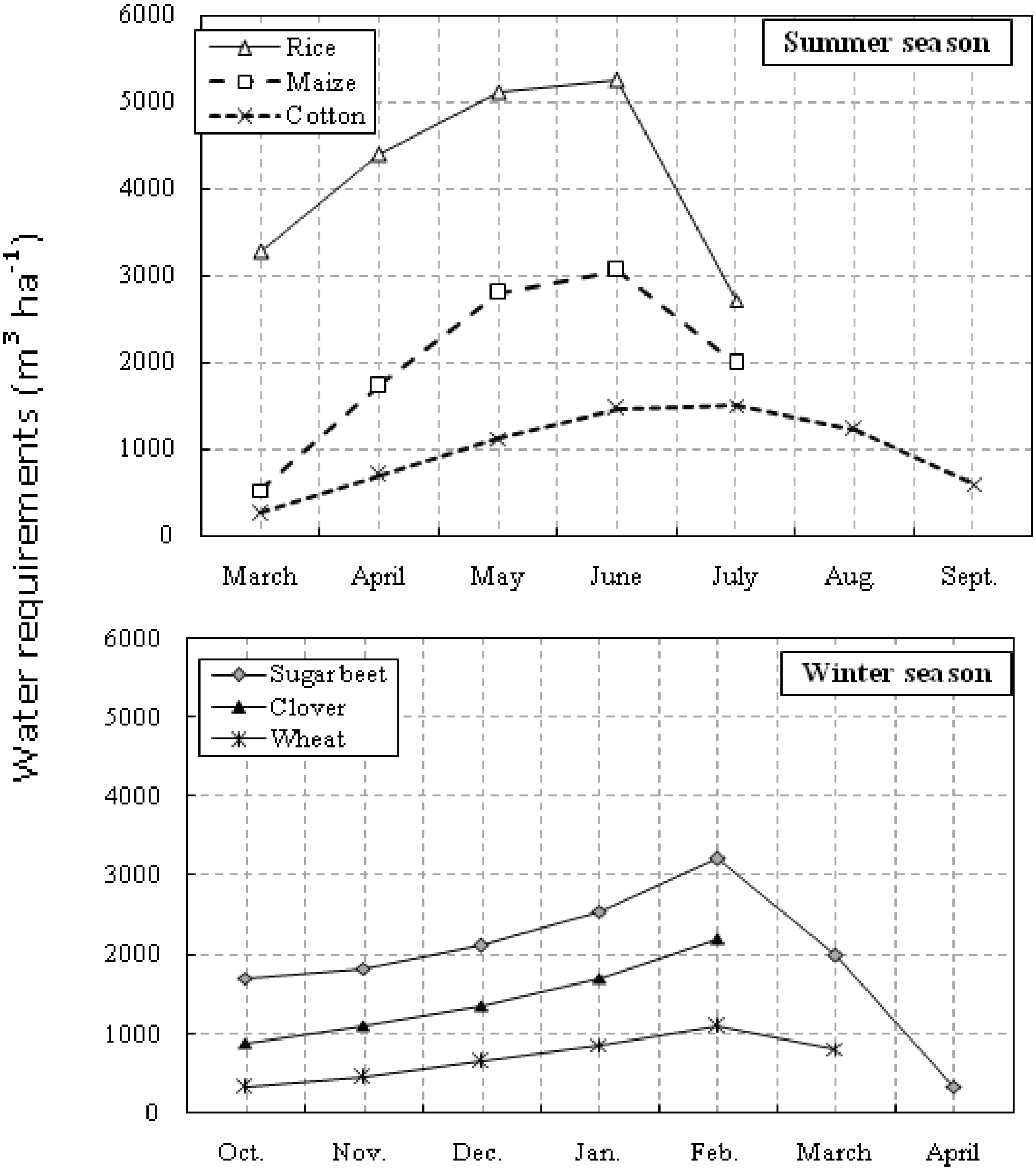

Fig.1. Monthy water requiremensts (m^3 ha^{-1}) for selected crops of summer and winter seasons in the study area.

Table 2. Total pump operation hours, applied water ($m^3\ ha^{-1}$), water requirements ($m^3\ ha^{-1}$) and WUI for the selected pump stations in each irrigation canal

Selected pump stations	Total discharge (L/sec)	Winter season				Summer season			
		[1]Pump operation hours/ha	[2]Applied water ($m^3\ ha^{-1}$)	[3]Water requirements ($m^3\ ha^{-1}$)	WUI	Pump operation hours/ha	Applied water ($m^3\ ha^{-1}$)	Water requirements ($m^3\ ha^{-1}$)	WUI
Sefsafa:									
P.S. No. 1	70	70.5	5139	4073	1.26	100.5	6446	3799	1.70
P.S. No. 5	50	71.3	5864	3961	1.48	116.3	10345	7891	1.31
P.S. No. 7	50	73.2	7153	4449	1.61	103.5	8141	5073	1.60
P.S. No. 8	100	66.4	6781	4344	1.56	95.9	9472	6261	1.51
P.S. No. 11	80	68.3	5023	4189	1.20	99.6	7489	6500	1.15
Average	70	69.9	5992	4203	1.42	103.2	8379	5905	1.46
Meet Yazied:									
P.S. No. 33	120	53.2	3455	4478	0.77	69.3	6637	5979	1.11
P.S. No. 38/20 A	120	59.5	4677	4404	1.06	68.6	7695	5763	1.34
P.S. No. 38/20 B	120	54.8	3510	4178	0.84	59.6	6048	4449	1.36
Average	120	55.8	3881	4353	0.89	65.8	6793	5397	1.27
El-Mesk:									
P.S. No. 51	120	43.0	3110	4348	0.72	61.8	4927	6715	0.73
P.S. No. 61/43	120	42.4	2992	4580	0.65	64.8	4624	6474	0.71
P.S. No. 61/48 A	120	47.8	3546	4244	0.84	64.6	4802	7295	0.66
Average	120	44.4	3216	4391	0.73	63.7	4784	6828	0.70

1) Total pump operation hours including all pumps (2 and/or 3 units) in each station.
2) Total applied water is the ∑of each pump discharge × pump operation hours per unit area.
3) Crop water requirements obtained from each crop area × crop water requirements.

Total water requirements for different summer crops varied in the order: rice (10636 m^3 ha^{-1}) > cotton (6871 m^3 ha^{-1}) > maize (5067 m^3 ha^{-1}). While, for the winter season, crops water requirement varied in the order: sugar beet (5688 m^3 ha^{-1}) > wheat (4207 m^3 ha^{-1}) > clover (3856 m^3 ha^{-1}). Based on crop pattern and water requirements for each crop, the required irrigation water for each pump station have been computed and presented in (Table 2). The computed pump operation hours, applied water and water use index (WUI) for each pump station on each selected irrigation canal are shown in Table 2. The pump operation hours increased on SC both during the winter (69.9 hr ha^{-1}) and summer (103.2 hr ha^{-1}) seasons. In SC, increasing total discharge from 50 to 100 (L Sec^{-1}) decreased the pump operation hours from 71.3 hr (P.S. No. 5) to 66.4 hr (P.S. No. 8). The pump operation hours were relatively less on MYC and MC due to high discharge (120 L sec^{-1}). Pump operation hours during the summer season were higher than winter due to the higher potential evapotranspiration during the summer.

Reducing the water discharge increased the amount of water applied to SC command area (7186 m^3 ha^{-1}) as compared to the MYC (5337 m^3 ha^{-1}) and MC (4000 m^3 ha^{-1}) command areas. Generally, the trend of pump operation hours and applied water was similar. The estimated water requirement for different seasons did not vary significantly for the studied areas. Reducing the pump discharge helped to overcome the problem of over-irrigation by upstream farmers, gave better irrigation timings, improved the equity of water distribution, allowed enough irrigation water to tail-end farmers and improved the cultivation practices in the SC command area.

3.2. Water Use Index

Water Use Index (WUI) was higher in SC command area followed by MYC and MC command area. Reducing the pumps discharge capacity in SC command area increased the WUI (>1) which means more water was applied than the theoretical water demand of the crops as compared to the MYC and MC command areas. Decreasing the pump discharge increased the amount of water applied to meet the crop water requirements. On the other hand WUI values are very low (< 1) for MYC and MC (with the discharge rate of 120 L sec^{-1}) both during the winter and summer seasons. It means that amount of water applied could not meet the water requirements of the crops which may negatively affect the crop productvity. Therefore, WUI values of 1.20 (at pump station No. 11 on SC) during the winter and 1.15 during the summer season achieved with the discharge rate of 80 L sec^{-1} are considered to be the best values for the sustainable agriculture in the area. Before the start of IIP, farmers at the head of distributary canal had an advantage of more available water over those at the tail. But after IIP, no as such effect of location (head, middle or tail) was observed and water level in the canals was sufficient enough for the farmer all along the canal. Among the different pump stations on SC, observed WUI fluctuated between 1.15 to 1.70 during the summer and 1.20 to 1.61 during the winter season. It can therefore be concluded that after the improvement of irrigation system, crop pattern is the most important factor affecting the crop water requirement not the allocation of farm on the irrigation canal.

3.3. Discharge rate and irrigation time

Average irrigation time (h ha^{-1}) for the selected crops (Fig. 2) was higher in SC command area (7.85 hr ha^{-1}) followed by MC (6.51 h ha^{-1}) and MYC (6.36 h ha^{-1}) areas. Decrease of pump discharge increased the irrigation time per unit area. The average

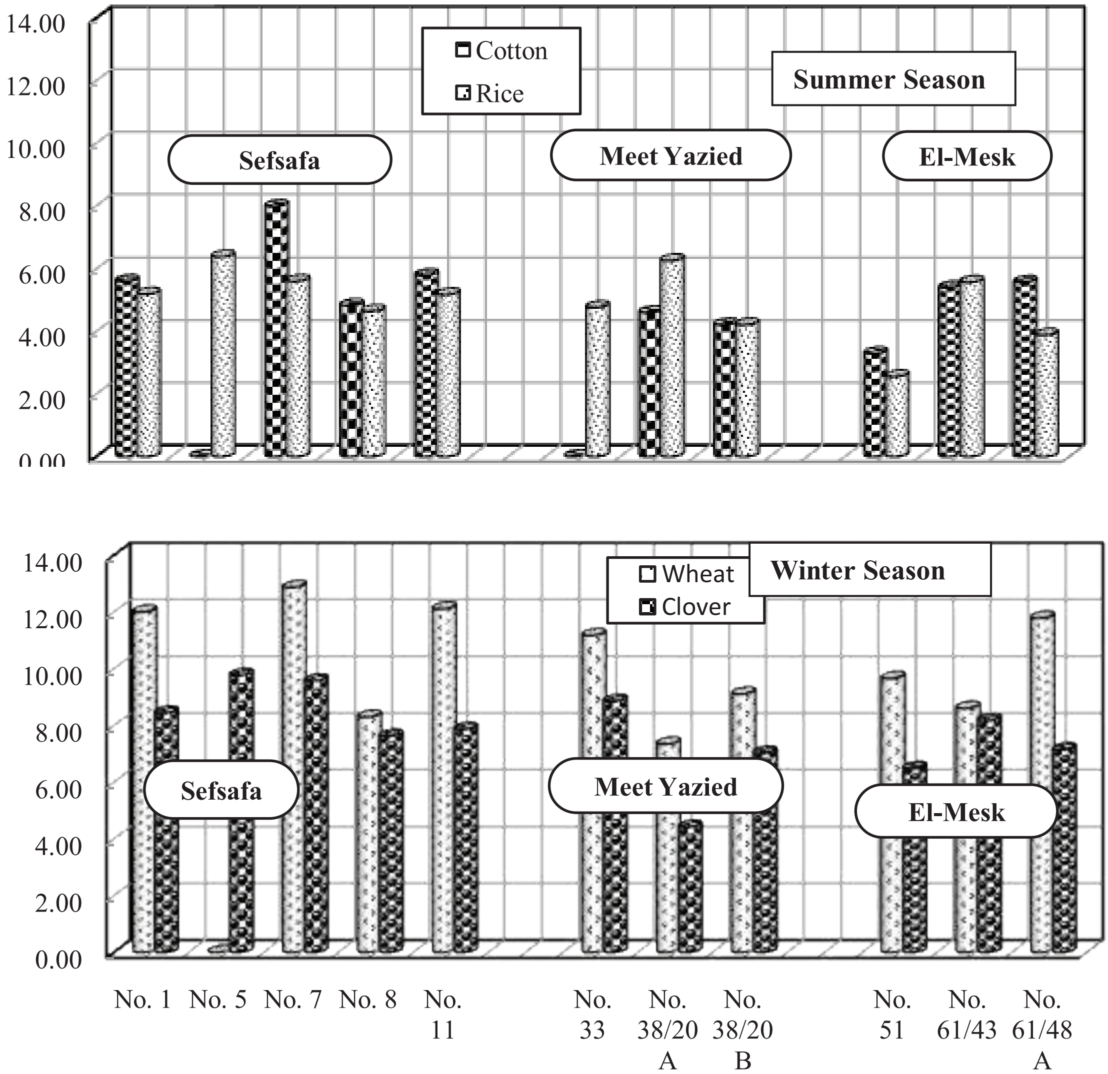

Figure 2. Average irrigation time (hr ha^{-1}) for the selected crop at different Meskas for winter and summer seasons of 2006/07 in the study area.

(summer and winter season) irrigation time on SC, varied in the order 7.81, 8.07, 9.00, 6.35 and 7.73 h ha^{-1} for pump stations No. 1, 5, 7, 8, and 11, respectively. For example, in SC command area pump station No. 1, 5, 7, 8, and 11 have to work for 5.19, 6.38, 5.6, 4.64 and 5.17 h to irrigate 1 ha of rice field. To irrigate the same rice field in MYC and MC command areas, pumps (with discharge rate of 120 L sec^{-1}) will take 5.08 and 3.88 hr, respectively.

Moreover, the time per unit irrigation event was higher for winter crops (8.87 h ha^{-1}) as compared to summer crops (4.95 h ha^{-1}). Therefore, it can be inferred that decrease in pump discharge significantly affected the time of unit irrigation event during summer season and had no effect during the winter. Farmers prefer to irrigate their fields during the day time with high discharge rates (120 L sec^{-1} in MYC and MC command area) which reduces the water level in the canal and the farmers at the tail face shortage of water during the day time. But at the night, water flow in the canal is higher and even some times there is overflow to drainage canal resulting in the wastage of water. The increase in pump operation hours due to the decrease in pump discharge in SC command area helped to keep the sufficient water level in the canal. The effect of reduced pump capacity and increased operation hours on night irrigation was observed. It was noticed that the number of irrigation events in winter season greatly differed among the three canals and the total number of irrigation events were higher in SC command area due to the reduced discharge rates (Fig. 3). During winter, maximum number of irrigation events took place between 3:00 to 18:00 hrs and then decreased. While in MYC and MC command area number of irrigation events were only concentrated

Table 3. Operating cost (US \$ ha^{-1})* and total cost per unit area (US \$ ha^{-1}) for the selected pump stations in each canal of 2006/07 winter and summer seasons

Selected pump stations	Winter season		Summer season	
	Operating cost	Total cost	Operating cost	Total cost
Sefsafa:				
P.S. No. 1	12.01	89.2	5.46	82.6
P.S. No. 5	17.34	115.7	14.68	113
P.S. No. 7	14.47	112.8	10.21	108.6
P.S. No. 8	11.22	80.5	15.12	84.4
P.S. No. 11	13.14	90.3	13.56	90.7
Average	13.64	97.7	11.81	95.86
Meet Yazied:				
P.S. No. 33	21.32	146.5	36.76	161.9
P.S. No. 38/20 A	34.39	105.0	32.95	103.5
P.S. No. 38/20 B	10.61	81.2	30.77	101.3
Average	22.11	110.9	33.49	122.2
El-Mesk:				
P.S. No. 51	9.77	58.1	13.18	61.5
P.S. No. 61/43	28.09	153.3	25.08	150.2
P.S. No. 61/48 A	28.90	154.1	33.48	158.7
Average	22.25	121.8	23.91	123.5

* 1 US$= 5.35 Egyptian Pound (L.E.) on June 2008.

between 4:00 to 11:00 hrs. Similarly, during

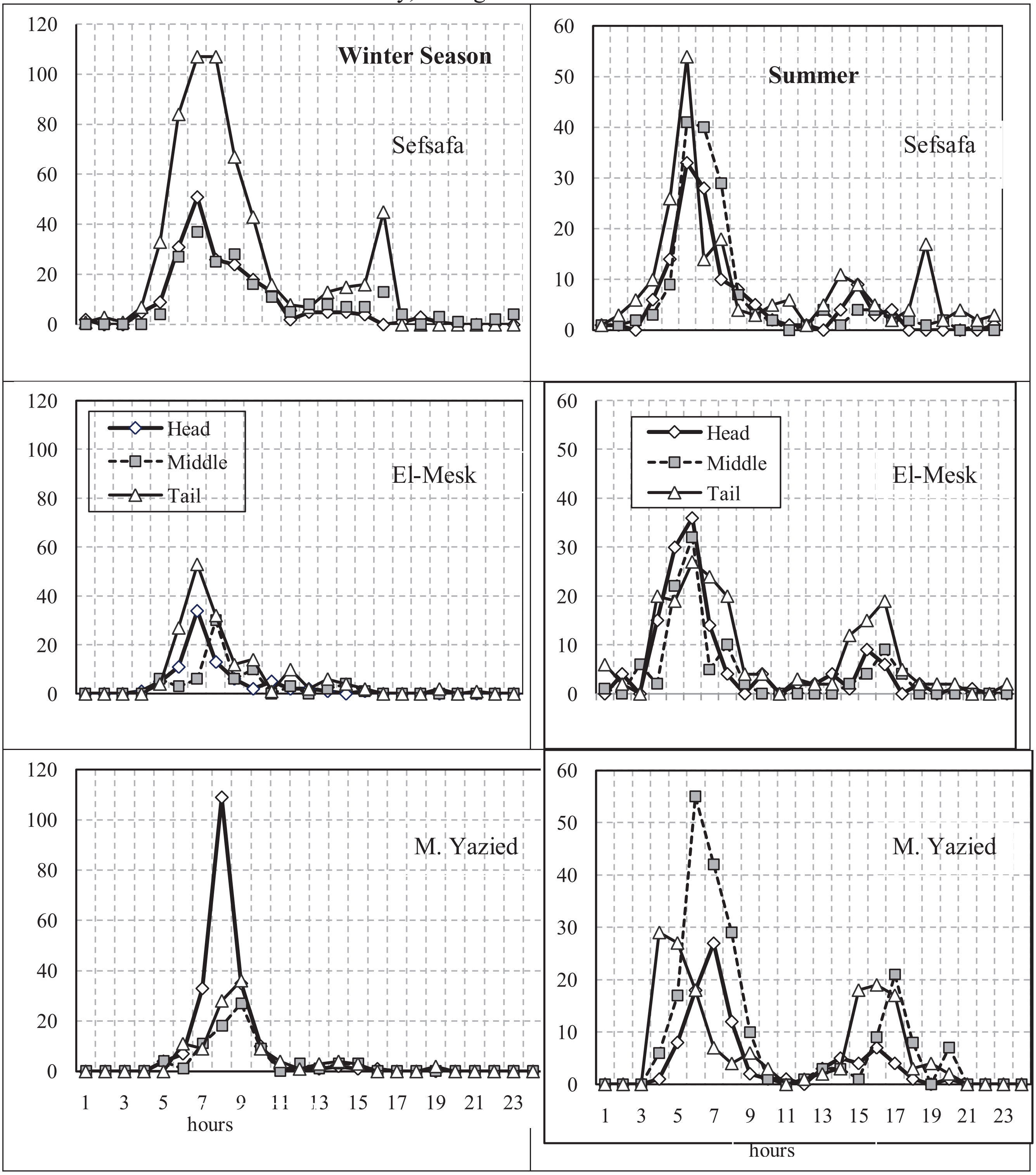

Fig.3. Number of night irrigation events for different locations on selected canals during winter and summer seasons of 2006/07 in the study area.

the summer season, number of irrigation events in SC command area increased from 3:00 to 12:00 hrs and from 14:00 to 21:00 hrs. While in MYC and MC command area, number of irrigation events was higher from 3:00 to 10:00 hrs and from 14:00 to 18:00 hrs.

The number of irrigation events was separated into head, middle and tail of the canal. On SC, the total number of irrigation events was higher on the tail of canal in both seasons. The total number of irrigation events was lower at the head of canal in both seasons. Relatively higher number of irrigation events at the tail on SC canal might be due to the unexpected availability of water in the canal (due to reduced discharge rates) which encouraged the former to over irrigate their forms.

3.4. Land saving

Land saved due to the filling of Meskas and Marwas (on-field ditches) was estimated only in the SC command area where new techniques were applied for the selected Meskas. Land saving was achieved except in the command area of PS # 5 where there were no old Meskas and irrigation was being done directly from SC. The old Meskas were located near the farm roads therefore covering of them saved land for roads or for farm. Underground piped Meskas helped to save a total of 9428 m^2 in SC command area. It can be inferred that this improvement will facilitate the transportation within fields as well as increase the cultivated areas.

3.5. Cost estimation

The operational costs consist of fuel/electricity, lubricant, labour, repair and maintenance cost and capital costs include pump house construction, pump price and cost of providing electricity to SC command area (Table 3). The operational cost was less in SC command area as compared to MYC and MC command area. The reduced cost in the SC command area was mainly due to the difference in the energy cost. The pumps operated with electricity helped to reduce the operational cost while the diesel operated pump units were old and incurred additional maintenance and repair costs. In the scenario of increasing fuel prices the electric power is the suitable alternate to reduce the operational cost in the new project site.

4. Conclusions

Based on the current results following conclusions can be drawn which will be of help in other areas:
(1) Equity of water distribution and crop water requirements can be met through the pump discharge rate of 80 L Sec^{-1} as achieved on SC command area.
(2) Decreasing pump discharge significant changed the irrigation time for summer crops.
(3) Reducing the pump capacity and increasing operation hours in SC led to increase in the number of irrigation events at night which helped to maintain sufficient level of water in the canal without loss of fresh water into the drain canal at night.
(4) Application of new techniques in SC command area helped to reduce the operational and total costs as compared to MYC and MC. Therefore, new techniques are cost effective in addition these techniques improved the physical infrastructure of scheme.

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3.5. An assessment of water and land management: a case study in the North Sinai Development Project in Egypt

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Abstract

Egypt is a country with high population living on only 4% of the total land of the country with limited water resources. One of the practices for the efficient water use is the recycling of agricultural drainage water through direct use and/or blending it with freshwater to extend the limited water supplies and farm land. North Sinai Development Project (NSDP) irrigation canal was designed with the objective to discharge 4.45 billion m^3 (blending agricultural drainage water with fresh Nile water at the ratio of 1:1) in order to bring 260.4×10^3 ha of land under cultivation. This paper provides a brief background on the water resources, agriculture and crop rotation patterns in NSDP. Based on water salinity results, it is recommended to apply irrigation with Nile water and drainage water at 2:1 ratio. In case of serious fresh water shortage, irrigation at 1:1 ratio could be applied temporarily. Although, the original suggested crop rotation did not include wheat, the consumption of wheat increased by 4% from 2006 to 2008. To meet the demand, wheat import increased by 7% in that period. In the recommended crop rotation, wheat has therefore been included, considering the current world food crisis. It is expected that the project area will produce 391,000 tons of wheat each year. For the fast development in NSDP, it is recommended to reallocate and increase the percentagof reclaimed lands to the small farm holders. The computed seasonal water requirement for each crop under different soils for the modified cropping pattern in NSDP has been presented.

1. Introduction

Water scarcity is a major problem and one of the serious constrains in agricultural development in the dry areas. Farmers are under pressure to grow more "crop per drop" and this needs efficient and appropriate irrigation technology (Shahbaz et al. 2006). Egypt has a per capita availability of renewable fresh water resources of 891 m^3 per annum and this is projected to decline to 650 m^3 by 2017. However, for meeting the food security targets of the country there is a need to expand agricultural land. During 1997, the Egyptian government started the North Sinai Development Project (NSDP) that aimed at reclaiming and bringing an area of 260,500 ha under cultivation in the eastern Nile Delta and north-western part of Sinai Peninsula. The Project focused on the reuse of agricultural drainage water by mixing it with fresh Nile River water, to increase the amount of available irrigation water for more land.

The drainage water is being reused in Egypt to produce many conventional grains, forage and feed crops, and salt-tolerant plants and trees. But, many areas have been abandoned from agriculture because of soil salinity and water-logging (Stenhouse and Kijne 2006). Therefore, attention must be given to measures that minimize long- and short-term effects of elevated salinity on soil productivity and water quality. Reuse of drainage water should be combined with conservation measures, particularly when the drainage water has to be managed by source reduction. Integrated planning and management approaches at district or basin scales can also maximize social and economic benefits while safeguarding ecology (Abdel-Dayem et al. 2004).

Water management improvement can reduce the volume of drainage water and make water available for other beneficial uses. Land management should be considered where competition for water is intense and where disposal of drainage water threatens ecologically sensitive areas. In the NSDP, the target area is supposed to be irrigated with the mixture of drainage and fresh water at a ratio of 1:1. The main source of drainage water is Nile Delta but during the next few years the amount of drainage water is going to get reduced due to the better management practices in the Nile Delta area. In this scenario, the 1:1 ratio of drainage and fresh water will not be a pragmatic approach due to the increase in salinity level of drainage water. Therefore, it is necessary to re-assess the available water resources and workout practical solutions to meet the objectives of NSDP.

When a small portion of the NSDP area had been reclaimed and handed over to the migrated farmers, they were given a pre-designed crop rotation plan. But after some time, when new farmers got established, they started to grow new crops with different crop rotations not suggested in the plan. Therefore, there is need to re-evaluate the suggested cropping pattern considering the interest of local farmers. It is also very important for the planners because NSDP is designed to meet the water requirements of the target area based on the suggested plan. This study re-assesses the amount of drainage water from Nile Delta and available fresh water resources to meet the quality irrigation water demand of the target area and the originally suggested crop rotations to readjust the ultimate water demand for the whole NSDP area.

2. Eastern Nile Delta and North Sinai Development Project area

Study area includes the coastal arid zone of the North East Egypt and Sinai Peninsula. Most of the soils are sedimentary formed by ancient Nile River. The total length of NSDP irrigation canal is 222 km. The part in the west of Suez Canal is called El-Salam Canal (89.7 km) and on the right side of Suez Canal is named El-Sheikh Gaber Canal (132.5 km). The drain water is mixed into El-Salaam canal and is carried to El-Sheikh Gaber Canal. Both canals are supposed to irrigate a total of 260,484 ha, covering six governorates, Dakahliya, Damietta, Port Said, Ismailia, Sharkiya and North Sinai. The fresh water intake occurs 3 km upstream of Farskour dam. The drainage water from Farskour, El-Serw and Bahr Hadous drains is mixed with fresh water at 1.28 Km, 18.5 Km and 54.9 Km, respectively. The deficit of required drainage water can be supplemented from the Farskour drain.

3. Water resources of North Sinai Development Project

Of the strategic water budget, 55.5 billion m^3 water reaches Egypt via Nile River, most of it is used for irrigation purposes along Nile Valley and Delta leaving approximately 14.0 billion m^3 of drainage water flowing out to the Mediterranean Sea. The "official" reuse of drainage water increased from 2.6 billion

m^3 in 1988/89 to 5.0 billion m^3 in 1998/99 (Garcés-Restrepo 2005). The NSDP canal is planned to discharge 4.45 billion m^3 water, of which 2.34 billion m^3 will be agricultural drainage water from El-Serw (0.43 billion m^3), Bahr Hadous (1.90 billion m^3) and Farskour drains (to supply the deficit amount of drainage water). Required amount of fresh water to meet the 1:1 ratio of fresh water to drainage water is supplied from Nile River. The amount of discharge water and salinity level of the water from each drain has been regularly monitored.

The mean precipitation in Sinai is 200 mm, most of which goes to the sea, sometimes causing disaster on its way. It is not used efficiently and not counted as a water resource in Sinai. Abou Rayana et al. (2001) reported that the groundwater is also brackish with salinity level ranging from high (TDS=20,000 mg L^{-1}) to low (TDS=300~700 mg L^{-1}). The groundwater with low salinity level is used for domestic and agricultural purposes. Abou Zeid et al. (2002) reported that the salinity levels were high towards Bardawil and Manzilah lakes and were relatively less towards El-Arish valley. In the north coastal areas, about 1,260 wells have been used to discharge 108,500 m^3 d^{-1} water.

4. Suggested and modified cropping patterns for NSDP

Before the start of NSDP, a cropping pattern was prepared for the newly rehabilitated farmers (Fig. 1). In north Sinai, part of the project areas (Tina plain and South of East Qantara) have been completed and handed over to the farmers with the suggested crop rotation plan. In the suggested plan most of the crops cultivated by the local farmers before the start of project in the area were not included. Wheat, barley, tomatoes, cantaloupe were the main crops with the total area of about 38,009 ha and production of about 35,884 ton. The main summer crops were tomatoes, cucumber, cantaloupe and watermelon with the total production area of about 19,302 ha (Abou Zeid et al. 2002). With the passage of time, farmers included new crops in the suggested rotation. Therefore, re-assessment was needed considering the interest of the local famers and to help the project planners, because NSDP was designed to meet the water requirements of the target area based on the suggested crop rotation plan. In this regard, a socio-economic study was also conducted to assist the development of future agricultural plans for farmers in El-Tina Plain (DRI and WRMI 2006). The results indicated that 67% of the studied farmers preferred agricultural crops such as cotton, rice, wheat and alfalfa, 21 % fruits, 8 % vegetables and only 4 % preferred trees.

In the suggested crop rotation, all project area has been divided into three areas based on soil types namely; clayey, sandy and coastal soils. Based on each soil type three-year crop rotations were suggested. Crop rotation patterns were not only selected based on soil type but also on irrigation system. Under sandy and coastal soils sprinkler irrigation was suggested for crops and drip irrigation system for fruits.

Based on the survey conducted by DRI and WRMI during 2006, cropping pattern of local farmers before 1997 and current interest of newly rehabilitated farmers in the area, a new modified crop rotation pattern has been developed (Fig. 1). It can be noticed that the suggested crop rotation patterns have different combinations of crops then the crops cultivated before 1997. For example, wheat and barley (which covered 92% of the total winter crops in Sinai area during 1997) had not been included under any soils type in the original plan. Under the modified crop rotation plan, wheat, barley and Egyptian cotton have been proposed because of their importance in the economy. To maintain the soil fertility, clover (alfalfa) has been included in the new cropping scheme. The land use has increased to 178 % as compared to 167 % previously suggested.

Under clayey soils, short season clover, onion, vegetables and sugar beet had been originally proposed for winter and soybean, rice and sorghum for summer. In the modified cropping pattern, we have included wheat and barley for winter and cotton for summer season. Based on modified cropping pattern, Tina plain is supposed to irrigate 66.7, 16.7 and 16.6 % area for cereals, fodder and vegetables, respectively.

On the sandy soils, planner had suggested fruits, long duration clover, vegetables and potato. But we have included wheat, barley and short season clover for winter and potato and maize for summer season in modified crop rotation (Fig. 1). Based on these modifications, sandy soil is recommended to be irrigated through sprinklers and drips to cultivate 43.3 % area with cereal crops, 20 % area with fodder crops, 26.7 % area with vegetables, and 10 % area with fruits.

Crop rotation originally suggested for loamy soils included fruits, short clover, vegetable and sorghum. In modified crop rotation we have recommended wheat, barley and maize in addition to the earlier suggested crops. Consequently, loamy soils are recommended to be irrigated through sprinklers and drip system to cultivate cereals crops (43.3 % area), fodder crops (26.7 % area), vegetables (20 % area) and fruits (10 % area). These observations will help the government to re-evaluate the modified crop rotation in the area after a few years of application.

5. Land reclamation and allocation

As soon as the area is reclaimed in the Project, it is distributed among the big investors, small investors, and small farmers. The allocation of 50% of the land is for big investors, 15% to small investors and 35% to small farmers and graduates. The study showed that the area used for cultivation by different stakeholders was: small farmers (56.1%) > big investors (31.3%) > small investors (12.3%) in El Tina plain. In the case of South Qantara, the cultivated area was: small farmers (54.5%) > big investors (26.2%) > small investors (19.3%). In general, 29.8 and 75.8 % of Tina plain and South of East Qantara areas were cultivated, respectively, and the small farmers paid most attention. Therefore, we recommend the reallocation of reclaimed lands and increase the percentage of land for the small farm holders.

6. Irrigation water use and efficiency

In general, water balance equation can be described as:

$$I_{agric} = WR + SS + RO + S + P + LR$$

where, $I_{agric.}$ is the water inflow supplied for agricultural sector, WR is the crop water requirement, SS is the change in soil water storage (equal to $D_{aw} - P$, where D_{aw} is the depth of applied water and P is the percolation or depth of water passing through the root zone). The agricultural drainage includes runoff(RO), seepage(S), percolation(P), and leaching requirements (LR) which is very important under new reclaimed soils. The effective rainfall is neglected because the average value is less than 5 mm as reported by Allen et al. (1998). Leaching requirements can be described by equation: $LR = EC_{iw} / (5EC_s - EC_{iw})$, where EC_{iw} is the salt concentration of irrigation water (dS/m), and ECs is the soil salt concentration in the effective root zone (dS/m).

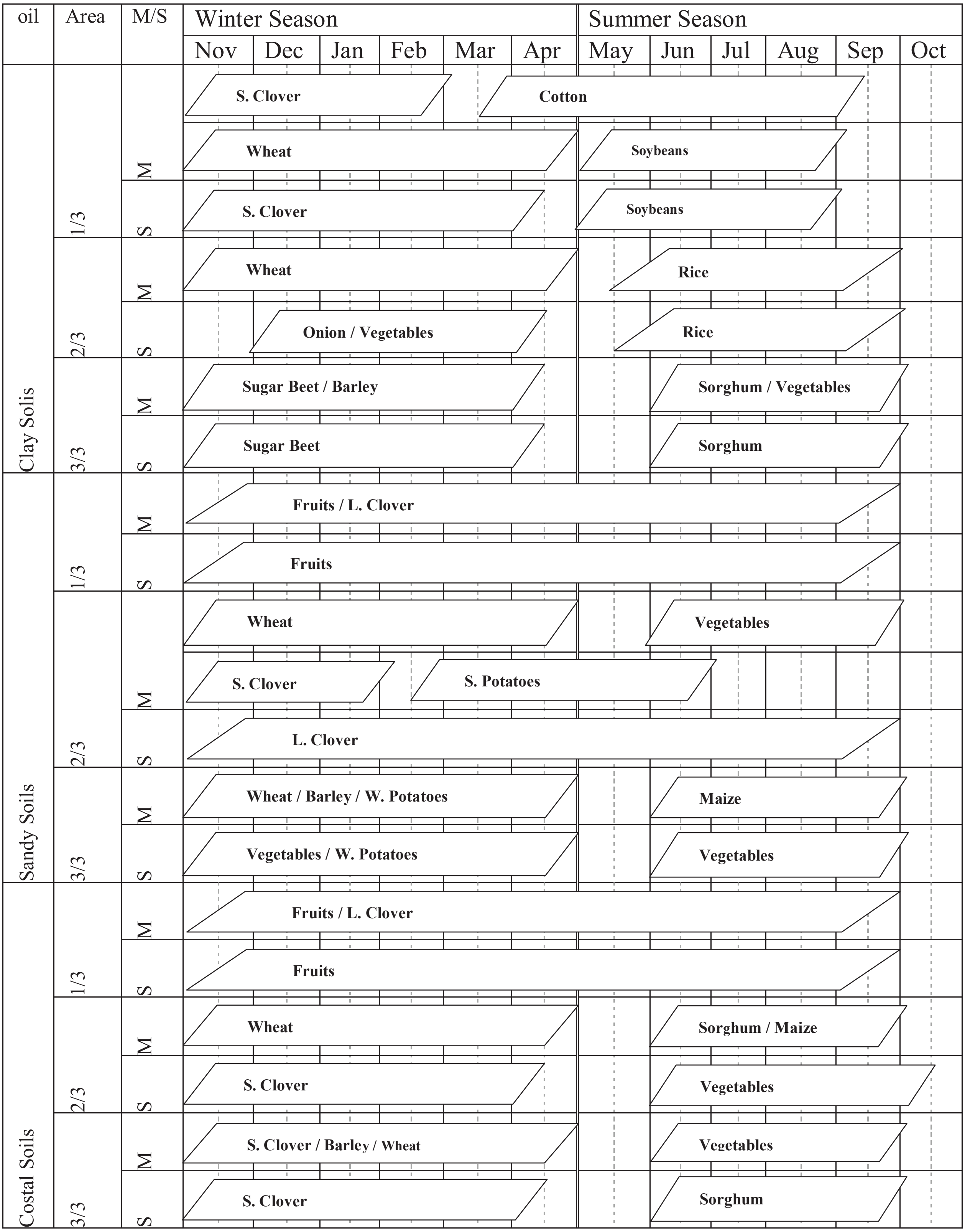

Figure 1. Suggested in the plan (S) and modified (M) crop rotation patterns now recommended for the North Sinai Development Project.

In order to maximize the objective function of I $_{agric.}$, the following relation can be used:

$$I_{agric} \times AIE = WR + RO + S + [EC_{iw}/(5EC_s - EC_{iw})] + D_{aw}$$

where AIE is the overall irrigation efficiency, based on the level of application (field, farm and canal). The overall irrigation efficiency will show the efficiency of the entire operation between the source of water supply and that delivered to the crop as follows:

$$AIE = e_a \times e_d \times e_c ,$$

where e_a is the field application efficiency which defined as the ration between the quantity of water needed and made available for transpiration by the crop. Distribution efficiency (e_d) is defined as the ratio of the amount of water furnished to the field inlets to the amount delivered to the distributor system. Conveyance efficiency (e_c) is the ratio of water released into the distribution system to the water diverted from the source into the conveyance system.

In order to calculate seasonal water inflow from irrigation canal, the command area is divided into blocks based on modified crop rotation pattern for each crop. Then, the seasonal inflow for selected crop can be computed by:

$$I_{agric\,(A/season)} = \sum_{A=1}^{N} I_{agric\,(A/season)} \times \frac{A}{M}$$

where, $I_{agric\,(A/Season)}$ is the total inflow required per season for area A (one crop), and M is the total command area served by irrigation canal. Crop yield of North Sinai development area is assumed to be the same as reported by Agricultural Research Center, Egypt, since the crop receives sufficient irrigation water under same irrigation scheme and efficiency. The annual water requirement per unit area of each crop was computed based on 15-days intervals and presented in Table 1.

Table 2 presents the computed water efficiencies under different soils for modified cropping patterns in North Sinai. Crop water use efficiency (Kg m^{-3}) was estimated as the weight of marketable crops produced (Kg) per unit consumptive use of water. The water utilization efficiency (Kg m^{-3}) was estimated as the weight of marketable crops produced (kg) per unit volume of water inflow to show the effect of water losses. The overall average water use efficiency for the modified crop pattern was 5.14 Kg m^{-3}. There was a big difference between water use efficiency data and water utilization efficiency. This is due to water losses in conveyance before arrival to the field. The differences were also large among different soils. This may be due to different irrigation methods with different efficiencies. Water utilization efficiency of sandy soils was the highest value (4.27 Kg m^{-3}), followed by loamy soils (3.58 Kg m^{-3}), and clay soils (2.69 Kg m^{-3}). It is recommended to use water utilization efficiency as an indicator for yield and water productivity.

7. Salinity of irrigation water

The 1:1 ratio of fresh to drainage water was based on the data on water quality available in 1997 and before but during the last few years reduction in the amount of drainage water has been observed, especially during

Table 1. Water consumptive use, crop water requirements and water inflow under different soils for modified cropping patterns in North Sinai

Crop	Water consumptive use ($m^3\ ha^{-1}$)	Clay Soils			Sandy Soils			Loamy Soils		
		Area (ha)	Water Req. ($10^5\ m^3$)	$I_{agric.}$ (A/Season) ($10^5\ m^3$)	Area (ha)	Water Req. ($10^5\ m^3$)	$I_{agric.}$ (A/Season) ($10^5\ m^3$)	Area (ha)	Water Req. ($10^5\ m^3$)	$I_{agric.}$ (A/Season) ($10^5\ m^3$)
W. Crops										
Wheat	3167	10500	332.6	543.7	25083	794.4	1151.3	25200	798.2	1188.9
S. Clover	1825	3500	63.9	108.7	15050	274.7	449.6	6300	115.0	183.6
Barley	2966	3500	103.9	170.4	10034	297.7	436.8	6300	187.0	280.3
Sugar beet	4286	3500	150.1	241.2	-	-	-	-	-	-
Potatoes	2634	-	-	-	10033	264.3	397.6	-	-	-
S. Crops										
Cotton	5788	3500	202.7	322.4	-	-	-	-	-	-
Rice	10164	7000	711.5	1,109.5	-	-	-	-	-	-
Sorghum	3357	3500	117.6	187.9	-	-	-	9450	317.3	454.2
Maize	4834	-	-	-	30100	1455.1	1885.2	9450	456.9	640.3
Vegetables	3705	3500	129.7	206.6	15050	557.7	742.7	18900	700.3	996.0
Potatoes	3830	-	-	-	15050	576.5	775.7	-	-	-
Soybeans	4930	3500	172.6	272.6	-	-	-	-	-	-
Fruits (Citrus)	7945	-	-	-	15050	1195.8	1670.4	9450	750.9	1095.9
L. Clover	4893	-	-	-	15050	736.4	1130.0	9450	462.4	711.4
Total		42000	1984.6	3163.0	150500	6152.7	8639.3	94500	3788.0	5550.6

Table 2. Water use and utilization efficiencies under different soils for modified cropping patterns in North Sinai

Crop	Water use efficiency ($Kg\ m^{-3}$)	Water utilization efficiency ($Kg\ m^{-3}$)		
		Clay soils	Sandy soils	Loamy soils
W. Crops				
Wheat	2.08	1.27	1.44	1.40
S. Clover	15.8	9.27	9.64	9.88
Barley	1.05	0.64	0.71	0.70
Sugar beet	11.3	7.01	-	-
Potatoes	9.26	-	6.16	-
S. Crops				
Cotton	0.47	0.29	-	-
Rice	0.77	0.49	-	-
Sorghum	1.70	1.06	-	1.19
Maize	1.74	-	1.34	1.24
Vegetables	6.15	3.86	4.62	4.33
Potatoes	6.03	-	4.48	-
Soybeans	0.51	0.32	-	-
Fruits (Citrus)	2.34	-	1.68	1.60
L. Clover	12.8	-	8.34	8.32
Overall efficiency	5.14	2.69	4.27	3.58

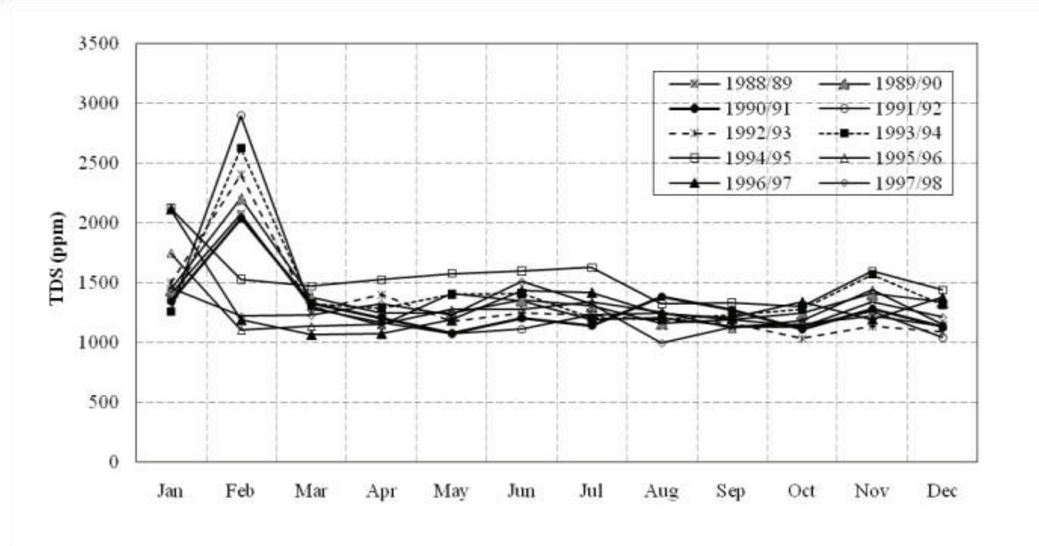

Figure2. Monthly total dissolved solids (TDS) in drains of NSDP during 1988-98.

1993 and 1994. This might be due to the better management practices in the Nile Delta area, which is the source of all drainage water. With the reduction in drainage water, the concentration of total dissolved solids (TDS) has increased. Figure 2 shows the average TDS values of El-Serw, Faraskour, and Bahr Hadous drains from 1988 to 1998. The highest TDS values were recorded in the month of February from 1989 to 1994 which might be due to the less amount of drain water discharge during this month. The relationship between amount of discharge (Q) and TDS concentration in drainage water could be described by a simple polynomial function (r^2=0.7114) developed from the monthly data of El-Serw, Farskour, and Bahr Hadous drains from 1988 to 1998:

$$TDS = 0.725\, Q^2 - 85.13Q + 3688$$

In addition to current available TDS data, water samples were also taken during February 2007 along the main El-salaam and El-Sheikh Gaber canals (carrying blended water) to analyze the soluble cations, anions, EC, SAR and pH by using standard laboratory methods. Eight sites were selected for water sampling from intake of fresh water into El-Salaam canal namely; 1) at intake of El-Salaam canal (Nile river), 2) El Serw drain, 3) at 20.5 km from intake point (after blending at El-Serw drain), 4) Hadous drain, 5) at 57.5 km (after blending at Hadous drain), 6) at 80.0 km from intake point, 7) at 93.8 km from intake point (after El Salaam pump station No. 4), and 8) at 104.6 km from intake point. Sodium adsorption ratio (SAR) was minimum (8) at fresh water intake point of El-Salaam canal (Nile river) and increased to 20 and 19 at last two sampling points, respectively, which were higher than the accepted SAR value (14) for irrigation water (FAO 1985). EC values also increased from the intake point (1.4 dS m^{-1}) to the last sampling point (3.9 dS m^{-1}). The data clearly showed that the TDS values were near the upper limits.

Abu-Zeid (1988) and Kotb et al. (2000) defined the criteria for mixing drainage and fresh water based on the TDS of the drain water. They suggested that at TDS <700 mg L^{-1} water could be used directly, and at 700-1500 mg L^{-1} a blending at 1:1 ratio with fresh water should be used. At 1500-3000 mg L^{-1}, a blending ratio of 1:2 or 1:3 was recommended while at >3000 mg L^{-1} the drainage water was not recommended for use.

Based on this classification, it is clear from (Fig. 2) that the TDS values are near the upper limits, even exceeding the upper limits some time (1994). Therefore, the use of blending ratio 1:1 would not be a pragmatic approach for sustainable agricultural development under NSDP. In the scenario of water shortage in drains and increasing TDS level in blended water, there is need to increase the fresh water sources in El-Salaam and El-Sheikh Gaber canal. Because of the increase in salinity level of irrigation water, it is suggested to replace current blending ratio of 1:1 by 1:2 ratio.

8. Conclusions

Results indicated that the cropping patterns suggested earlier by the planners of the Project had different combinations of crops from the ones cultivated before. In modified pattern, the cropping intensity is 178% as compared to 167% under the plan. Small farmers paid the most attention for to the newly reclaimed land. Hence, it is recommended that the allocation to them should increase. Due to improved management of irrigation water in Nile Delta the quantity of drainage water will decrease, which will result in increased concentration of total dissolved solids (TDS) in the drainage water. This would necessitate additional fresh water resources for the NSDP. It is also recommended to apply irrigation with Nile water and drainage water at a ratio 2:1 instead of 1:1 for sustainable agricultural development in the project area.

Acknowledgment

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3.6. Influence of temperature fluctuations on crack width in irrigation canal

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Abstract

Agricultural irrigation canals have three important functions - hydraulic, irrigation, and structural. The irrigation function is decreased by water leak when cracks occur in the concrete canal. Moreover, cracks sometimes also hasten the decrease in structural function by permitting the invasion of deterioration factors. The hazardous property of cracks is usually judged by the comparison with the allowable crack width. A concrete linear expansion coefficient is about 10μ/ °C in general, and concrete expands and contracts according to the temperature change. Therefore, the width of certain kinds of cracks also fluctuates with temperature. It is therefore possible that the results of evaluation and diagnosis may change depending on the temperature conditions when the crack is measured. In arid area, where daily fluctuation in temperature is quite large, this effect must be considered. In this research, crack width fluctuations in an irrigation canal were investigated. It was observed that the width of cracks in long and thin concrete walls showed yearly and daily fluctuations because of the temperature change. The daily fluctuation band was 1.054mm and the yearly fluctuation band was 0.629mm. These are rather large as compared with the allowable crack width for reinforced concrete canal. Moreover, it was shown that the daily fluctuation ratio in crack width was about 37.8% and yearly fluctuation ratio was 68.6%. These fluctuations must be considered in evaluation and diagnosis of the cracks and their influence on the structure, as well as in designing their repair.

1. Introduction

The irrigation and drainage facilities have hydraulic, irrigation, and structural functions However, the irrigation function gets deteriorated by water leak when cracks occur in the irrigation facilities. Moreover, cracks sometimes accelerate the decrease in structural function as well. For these reasons, the width of the crack is regarded as an important indicator for soundness evaluation and the forecast of the future performance in the functional diagnosis. However, the linear expansion coefficient of concrete is around 10μ/°C in general, and concrete expands and contracts according to the temperature change. Therefore, the width of cracks also fluctuates. As a result, there is a possibility that the evaluation and the diagnosis may lead to different results depending on temperature conditions when the width of the crack is measured. The fluctuations in the width of cracks because of the yearly temperature change have been generally considered in the designing of structure, but the influence of daily temperature change has not been necessarily considered. Attention has to be paid to the cracks that occur in important facilities such as concrete dam and head works. Because the concrete mass is subjected for a long time to the effect of hydration heat, the necessity of considering the influence of short-term temperature change is low. However, heat will conduct into the inside within a relatively short time in the irrigation canal, because it is composed of long and thin concrete walls. Therefore, there is a possibility that the width of the crack may fluctuate with the daily temperature change.

The repair material to be applied to prevent the water leak and further deterioration should be according to the crack width fluctuations (Japan Society of Civil Engineers 2005). Otherwise, the re-cracking of the repair material will occur. The repair material has to have the expansion performance higher than the fluctuation ratio of the width of the crack. It is necessary to determine the width and the fluctuation range of the crack in irrigation canal to decide the expansion performance of the repair material, because the fluctuation ratio is expressed as $\Delta w/w$ where Δw is the fluctuation range and w is the width of crack. Thus, it is important to study the fluctuation characteristic of the width of the crack to enable an appropriate diagnosis and the repair for irrigation canals. Especially, in arid area, where daily temperature change is quite large, its effect must be considered. In this research, crack width fluctuations in an irrigation canal were investigated to clarify the fluctuation characteristic of the width of the crack. Then, their importance in functional diagnosis was examined. Based on the results repair materials of desired expansion ability can be designed.

2. Investigated irrigation canal and examination method

The canal in the Shimane Prefecture in Japan was investigated. The water flows in this canal from east to west. Thus, the wall of the canal in the right bank faces south, and the one in the left bank faces north. The place in the rear of the southward wall was connected to an asphalt road, and the northward wall side was connected to a paddy field. The depth of the water was usually about 5cm when it was the deepest in canal, because this canal is used for drainage. The cracks occurred at the position No.2 and No.5 (Fig. 1), and both were consecutive. These cracks were suspected to be penetrated thermal stress cracks. Moreover, No.1, No.3, No.4 and No.6 in Fig. 1 were joints without any water stop.

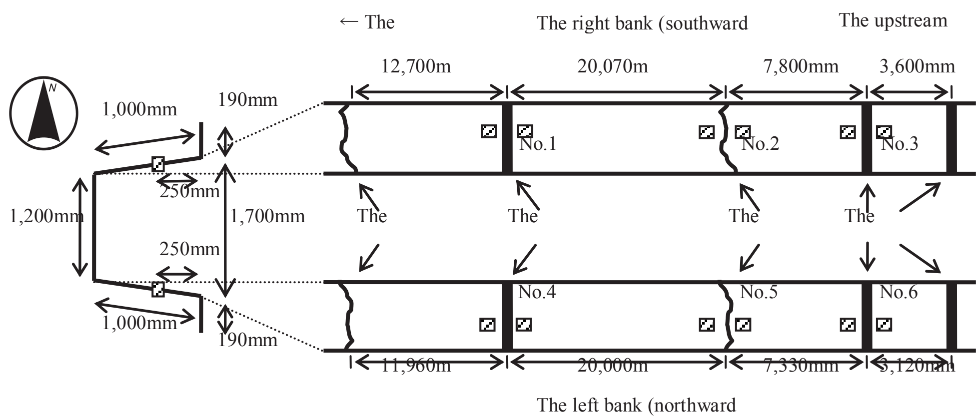

Figure 1. Outline of investigated canal and measurement points.

Daily investigation was done three times in 2006 (Case1: from 15 to 16 March, Case2: from 27 to 28 October, Case3: from 20 to 21 December). These timings were selected as they were non-irrigation periods and so the daily temperature change was relatively large. The apparatus used for the measurement of the crack width fluctuations was the displacement transducer (Sensitivity: about $1{,}500\times10^{-6}$/mm). Additionally, the air temperature and the surface temperature of canal wall were measured. Details of the examination method are shown in Table 1 in the Case1, four points shown in Table 1 were selected as measurement points. In the Case2 and Case3, to obtain more detailed data about the relation between the crack width fluctuations and the temperature change, only No.2 and No.5 were measured at short intervals. In each case, the investigation was continued for more than 24 hours.

In the yearly investigation, the apparatus used for the measurement of the crack width fluctuations was the contact micron strain gauge (accuracy: 0.001mm), and the measurement was based on "Method of test for length change of mortar and concrete, Part 2: Method with contact-type strain gauge (JIS A 1129-2-2001)". Measurement points were No.1 to No.6 (Fig.1). The measurement began on 13 January 2006, and the crack width fluctuation, the air temperature, and the surface temperature of canal wall were measured once a month. All investigations were done at the same time each day (around 10:00 a.m.), to prevent the influence of the daily fluctuation.

The width of the crack was measured by using the laser displacement sensor (resolution: 0.5μm) in the period of Case3 in daily investigation. At that time, the same measurement as yearly investigation was also executed, to clarify the yearly fluctuation ratio by combining the result of the daily and yearly measurements. X and Y coordinates of the canal wall were acquired with two laser displacement sensors, and the width of the crack was measured from the surface shape of the canal wall.

3. Results and discussion

3.1. Results of daily investigation

Figure 2 shows the result of daily investigation. The marks recorded in the upper part of the graph are the weather data on the first and second day of the measurements. As shown in Figure 2 air and surface temperature of canal wall changed in each case, and the maximum temperature was between 0:00 noon and 3:00 p.m., and the minimum between 1:00 to 7:00 a.m. The difference between air and wall temperature was small in the northward side, but in the southward side the difference became large occasionally. It was in the daytime of fair weather when the difference between two

Table 1. Details of daily investigation

Case	Measurement points (Refer to Fig.1)	Period	Apparatus		
			Fluctuation	Air temperature	Surface temperature
Case1	No.2, No.3, No.5, No.6	0::01 p.m. -0:16 p.m.	Displacement transducer	Thermocouple T (CC)	Alcohol thermometer
Case2	No.2, No.5	11:12 a.m. -11:47 a.m.	Displacement transducer	Thermocouple T (CC)	Thermocouple T (CC)
Case3	No.2, No.5	14:47 p.m. -4:57 p.m.	Displacement transducer	Thermocouple T (CC)	Thermocouple T (CC)

temperatures was large. Therefore, it was concluded that the surface temperature of southward wall rose by the radiation of the sun light. In the daytime of fair weather, the difference in surface temperatures between northward and southward walls was about 13-19℃, which is very large as compared with other weather conditions. On the other hand, in the northward side, under rainy and night conditions, the surface temperature of canal wall could be estimated from air temperature, because the radiation effect of the sun light was less.

Figure 2 shows that the width of all cracks and joints fluctuated in a short period of about 24 hours. There are clear relationships between those fluctuations and the temperature changes, namely, the decrease in width of crack with increase of temperature, and vice versa. Thus, it was clarified that the width of cracks in long and thin concrete walls showed daily fluctuations according to short-term temperature change. The actual daily fluctuation ranges are indicated in Table 2. Those values are 0.175mm-0.629mm, which are very large compared with 0.4mm that is allowable crack width (Ishii et al. 2007) for irrigation canal of reinforced concrete. Therefore, there is a possibility that the evaluation and the diagnosis results would be different depending on temperature conditions when the width of the crack is measured. It is therefore necessary to establish the appropriate evaluation and diagnosis standards, which take the daily.fluctuations into consideration

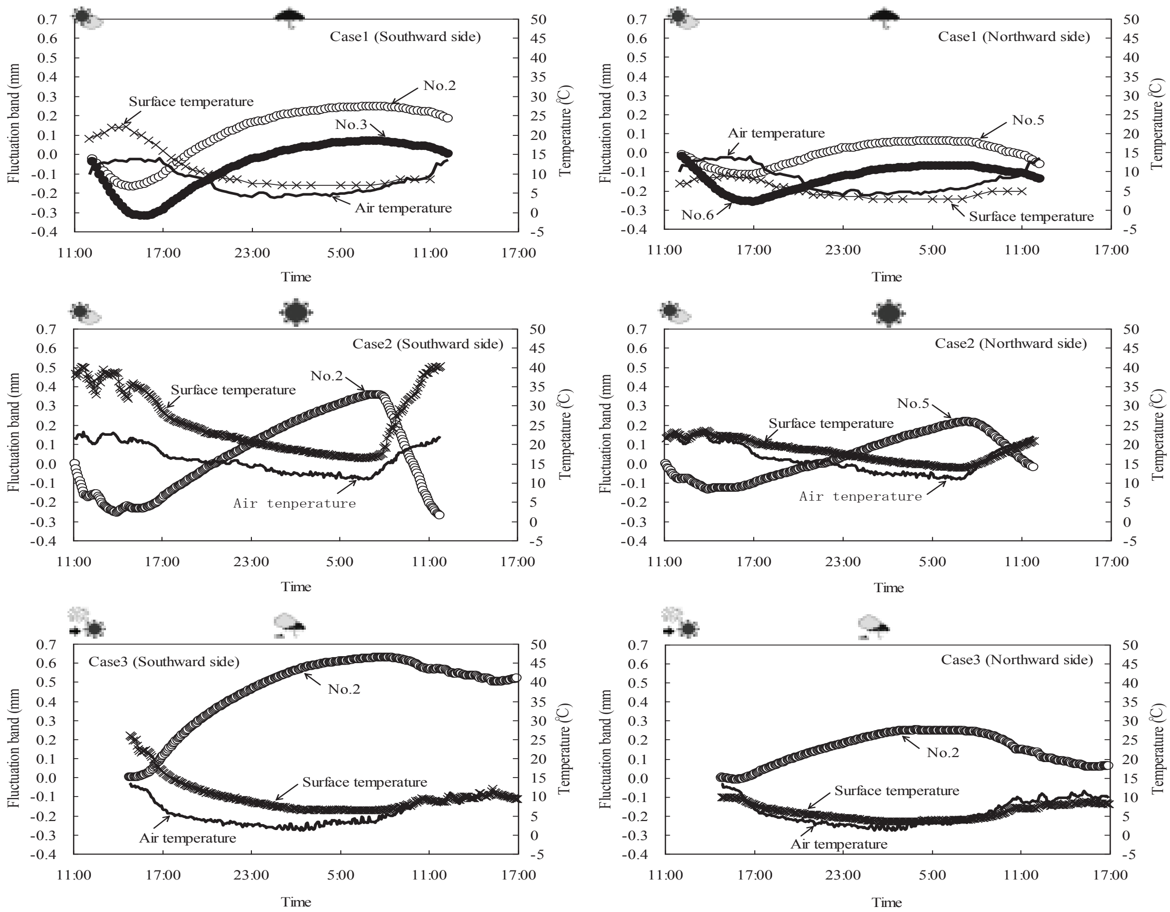

Figure 2. Daily crack width fluctuation and temperature change.

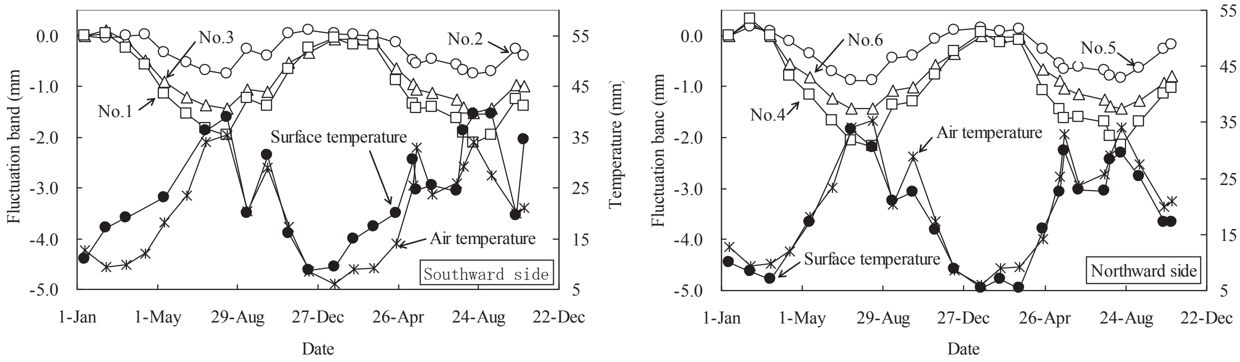

Figure 3. Yearly crack width fluctuation and temperature change.

Table 2. Results of daily investigation

		Actual fluctuation band (mm)	Influential length (Li) (mm)	Fluctuation band per 1m (B/Li) (mm/m)	Difference of surface Temperature* (℃)	Theoretical fluctuation Band** (mm)	Ratio (actual/theoretical)
Case1	No.2	0.415	13.935	0.030	13.0	1.812	0.23
	No.5	0.175	13.665	0.013	5.5	0.752	0.23
	No.3	0.389	5.700	0.068	13.0	0.741	0.52
	No.6	0.189	5.225	0.036	5.0	0.261	0.72
Case2	No.2	0.612	13.935	0.044	21.7	3.024	0.20
	No.5	0.349	13.665	0.026	9.0	1.230	0.28
Case3	No.2	0.629	13.935	0.045	19.2	2.676	0.24
	No.5	0.261	13.665	0.019	6.1	0.834	0.31

*The difference of temperature between the time when the fluctuation indicated upper peak and lower peak.

**Calculated using a following equation. Multiply the linear expansion coefficient and influential length and the difference of surface temperature.

Table 3. Results of yearly investigation

	Actual fluctuation band (mm)	Influential length (Li) (mm)	Fluctuation band per 1m (B/Li) (mm/m)	Difference of surface Temperature* (℃)	Theoretical fluctuation Band** (mm)	Ratio (actual/ theoretical)
No.1	2.161	16.385	0.132	24.6	4.031	0.54
No.2	0.853	13.935	0.061	28.0	3.902	0.22
No.3	1.630	5.700	0.286	25.9	1.476	1.10
No.4	2.485	15.980	0.156	25.9	4.139	0.60
No.5	1.054	13.665	0.077	24.6	3.362	0.31
No.6	1.689	5.225	0.323	25.9	1.353	1.25

*The difference of temperature between the time when the fluctuation indicated upper peak and lower peak.

**Calculated using a following equation. Multiply the linear expansion coefficient and influential length and the difference of surface temperature.

To remove the influence of difference in the length of canal walls (*Li*) on the daily fluctuation range in each measurement point, the fluctuation range per 1m of *Li* (*B/Li*) was calculated. The *Li* is the half of the distance between discontinuity parts (crack or joint) on the upstream side and the downstream side, because it was thought that the canal wall expands and contracts symmetrically. The result (Table 2) confirmed that the *B/Li* were different in each measurement point, the values for southward sides were larger than the northward sides, and the values for joints were larger than the cracks. On the other hand, the surface temperatures of southward sides were larger than the northwards side. Therefore, it is supposed that the expansion and contraction of concrete walls were correlated with surface temperature rather than air temperature. Additionally, it presumed that the fluctuations in cracks were smaller due by the effects of reinforcing bars. Moreover, the theoretical daily fluctuation range was calculated on the basis of the assumption that a concrete linear expansion coefficient is 10μ/℃. The calculated results (Table 2) showed that the actual daily fluctuation range was smaller than the theoretical one. Those ratios between the actual and theoretical ranges were 0.20-0.31 for the cracks. The ratios were 0.52 and 0.72 for the joints. The actual measured values were thus smaller than the theoretical values perhaps because of the frictions between the canal walls and the ground or because the short-term temperature changes were not enough for conduction of heat into the entire wall.

3.2. Results of yearly investigation

The results of yearly investigation are indicated in Fig. 3. Air and surface temperatures changed greatly during the investigation period, because Japan has four seasons. Temperatures were high in summer and low in winter. The yearly fluctuation in each measurement point had a trend similar to daily fluctuations. The surface temperatures were greatly different in the southward and northward walls, similarly to the results of daily investigation. However, clear difference in the fluctuation range in crack and joint width between southward and northward walls could not be confirmed. The fluctuations in the width of the cracks and joints were perhaps affected by the temperature difference among seasons, because the yearly investigation was executed at the same time (about 10:00a.m.) before the difference of the surface temperature would become conspicuous.

In daily investigations, there were no influences of the season change, because the investigation periods were about 24 hours. As a result, the cracks and joints fluctuated according to the surface temperature. Therefore, there were large differences of the daily fluctuation ranges in the width of cracks and joints between the southward and northward walls, because the change range differences of air temperature in a day were not so large (about 10-12℃), and the increase of surface temperature by the sun light was very large. On the other hand, the change range differences of air temperature in a year were very large in the yearly investigation (29.3℃), because yearly investigation periods were very long compared to the daily investigations and the season change occurred in the investigation period.

The influence of the sun light on the temperature of canal walls was limited to the area near the surface, and the temperature in the deep portion is supposed to be determined by the air and ground temperatures. That is, in the yearly investigation, the influence by the season change was larger than the influence by the sun light, as a result, it was thought that the difference of the yearly fluctuation ranges between the southward and northward walls were small, though the surface temperatures were different between the walls. The theoretical yearly fluctuation ranges were calculated using the air temperatures that affect the fluctuations of the width of cracks and joints. The calculated results are indicated in Table.3. The ratio of the actual fluctuation ranges to the theoretical fluctuation ranges had similar trend to results from daily investigation. That is, the ratios in the cracks were smaller than joints (0.23, 0.32). On the other hand, the ratios of the actual fluctuation ranges to the theoretical fluctuation ranges in the joints were much larger, in other words, the ratio of No.1, No.3, No.4 and No.6 in Fig.1 were 0.54, 1.10, 0.60 and 1.25, respectively. This can be attributed to the effects of reinforcing bar because No.1 and No.4 were the contraction joints where the observed ratios are small. Or else, the presence of the larger frictions between the canal walls and the ground by the influential length were longer than at other measurement points. The actual fluctuation ranges were larger than theoretical fluctuation ranges in No.3 and No.6 perhaps because the fluctuations in the cracks were biased to the joint sides due to the strong support in the No.2 and No.5.

3.3. Fluctuation ratio of crack width

To prevent the re-cracking of the materials for the repair of cracks in the irrigation canal, the larger expansion performance than the fluctuation ratio of the width of the crack is required. It is necessary to determine the width and the fluctuation range of the crack to clarify the fluctuation ratio of the width of the crack because the fluctuation ratio is expressed in $\Delta w/w$ by using the fluctuation range (Δw) and the width of crack (w). The fluctuation ratios were calculated from the measurement results of the width of the crack. The width of cracks was measured on 21 December 2006 in Case3.T crack width of No.2 was 2.211mm (measurement time: 0:34 p.m.), and of No.5 was 2.518mm (measurement time: 0:48 p.m.). The ranges of crack width were calculated by using the results of the daily investigation in Case3 and the measured width of cracks. The calculated results are indicated in Fig. 4. The crack width in Case3 ranged from 1.665mm to 2.294mm in No.2, and 2.405mm to 2.666mm in No.5. Additionally, the fluctuation ratios of maximum crack width to the minimum crack width were 37.8% in No.2, and 10.9% in No.5. Therefore, if the expansion performance of the repair material is smaller than 37.8%, there is a possibility that the repair material re-cracks immediately after the repair by the short-term daily fluctuations of the crack width.

The ranges of the crack width in the yearly investigation are indicated in Fig. 5. The range of the crack width in a year was 399mm to 2.252mm in No.2, and 1.539mm to 2.594mm in No.5. Additionally, the fluctuation ratios of maximum crack width to the minimum crack width were 61.0% in No.2, and 68.6% in No.5. Those values were larger than in the daily investigation, so higher expansion performance is required for the repair materials.

It is clear from the above that an expansion performance of more than 68.6% is required to prevent the re-cracking of the repair materials in the investigated irrigation canal. However, the daily fluctuations and yearly fluctuations of the width of the crack are not temporary, and the both fluctuations will be repeating during the service period. Especially, the daily fluctuations give the tensile effect to the repair materials at significant frequency than yearly fluctuations. Therefore, not only the expansion performance to resist the fluctuations of the width of crack, but also fatigue strength to resist the repetitive tensile effect are required to the materials for the repair of cracks in irrigation canals.

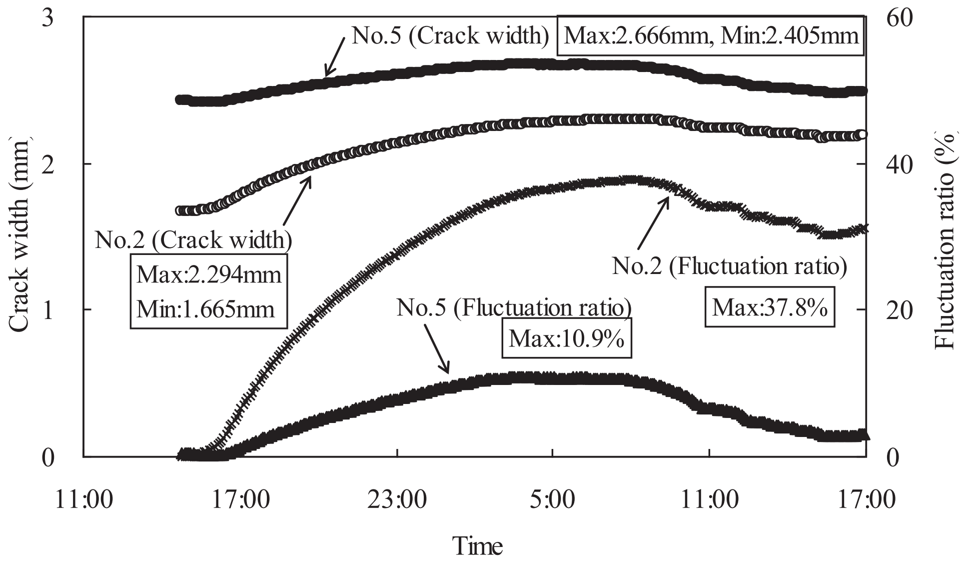

Figure 4. Daily crack width fluctuation and fluctuation ratio.

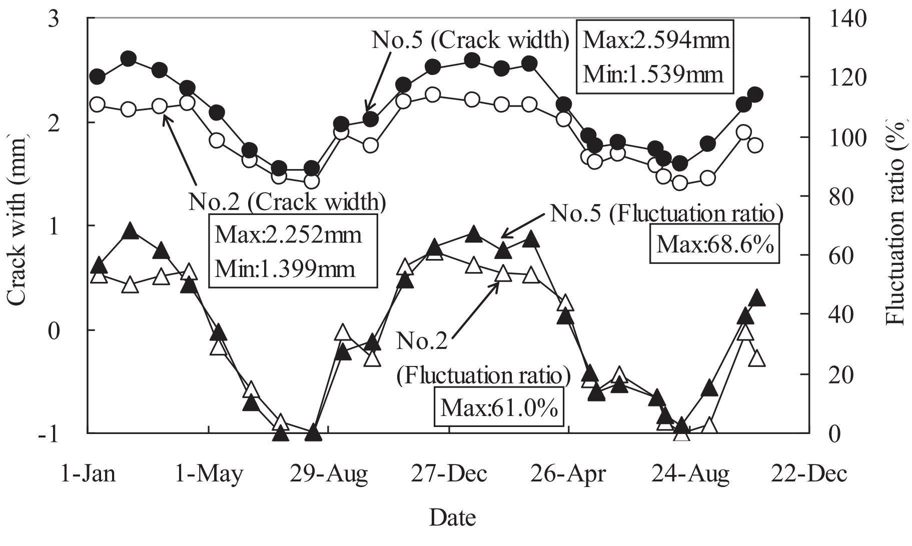

Figure 5. Yearly crack width fluctuation and fluctuation ratio.

It is clear from the above that an expansion performance of more than 68.6% is required to prevent the re-cracking of the repair materials in the investigated irrigation canal. However, the daily fluctuations and yearly fluctuations of the width of the crack are not temporary, and the both fluctuations will be repeating during the service period. Especially, the daily fluctuations give the tensile effect to the repair materials at significant frequency than yearly fluctuations. Therefore, not only the expansion performance to resist the fluctuations of the width of crack, but also fatigue strength to resist the repetitive tensile effect are required to the materials for the repair of cracks in irrigation canals.

4. Conclusions

In this research, investigations for the daily fluctuations and yearly fluctuations of the width of the cracks in irrigation canal were executed. As a result, the fluctuation characteristics of the width of the cracks and the required expansion performance of repair materials were determined. In the irrigation canal composed of long and thin concrete walls, the width of the cracks and joints fluctuates according to the short-term daily temperature change. The daily fluctuation range of the width of the cracks were 0.175mm-0.629mm, which is very large as compared to the allowable crack width of irrigation canal of reinforced concrete.

The largest daily fluctuation ratios of maximum crack width to the minimum crack width was 37.8%, and the largest yearly fluctuation ratios was 68.6%. This information will help in selecting repair material of the required expansion performance to prevent the re-cracking of the repair materials in the investigated irrigation canal. In the arid areas, where daily fluctuation in temperature is quite large, it is expected that the influence on the fluctuation of the width of the crack would be larger than the investigated area.

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3.7. Nutrients leaching and plant uptake from different bio-composts under chloride- and sulphate-dominated saline irrigation

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Abstract

Agricultural lands are often the ultimate place for the disposal of thousands of tones of agricultural wastes produced every year in several cities and towns. Apart from heavy metal contamination, the wastes cause serious non-point source contamination of phosphorus (P) loading in water bodies in many areas of the word. The ameliorative effect of P on plant growth under saline environment has broadened the scope of this hazard. Phosphorus availability from different organic sources or effect of salinity (namely Cl^-) on plant growth has been studied extensively but the knowledge about the interactive effect of saline irrigation, dominated with SO_4^{2-} ions on P leachability and plant availability under different compost amendments is very limited. Therefore, current study evaluated the leachability and phytoavailability of P as well as N and K on a sandy loam soil amended with animal, poultry and sludge composts when applied on a total P equivalent basis of 200 kg ha^{-1} under irrigation with Cl^- (NaCl) and SO_4^{2-} (Na_2SO_4) dominated water. Results showed that concentration of dissolved reactive P (DRP) was relatively higher in leachates under SO_4^{2-} than Cl^- treatments. Compost amendment treatments differed for DRP leaching in the pattern: sludge > animal > poultry > control. Maize (*Zea mays* L.) growth and P uptake was severely suppressed under Cl^- irrigation compared to SO_4^{2-} and non-saline treatments. Although all types of composts were applied on a total P equivalent basis, but maximum plant (shoot + root) P uptake was observed under sludge compost amendment (73.4 mg DW^{-1}) followed by poultry (39.3 mg DW^{-1}), animal (15.0 mg DW^{-1})compost and control (1.2 mg DW^{-1}) treatments. Results have important implications from an environmental point of view as they reveal that irrigation water dominated by SO_4^{2-} has greater ability to replace/leach P, other anions (NO_3^-) and cations (K^+). Variability in P release from different bio-composts applied on a total P equivalent basis suggested that P availability is highly dependent on compost source.

1. Introduction

Continuous application of different bio-wastes in agricultural fields has increased the concentration of N and P in many freshwater bodies, creating severe environmental concerns. Nitrogen accounts for about 80% of the total mineral nutrients absorbed by plants (Marschner 1995). Simultaneously, N is one of the most mobile plant nutrients in soil and it has been reported that diffused N pollution from agricultural land is the major source of N load to surface waters and groundwater in many regions (Kronvang et al. 1996). Because of the mobility of N, availability from organic sources must be known for efficient management of N inputs. In some cases, the abundance of N from amendments has resulted in implementation of P-based application rates. However, little attention has been paid to the availability of N when compost is applied based on P.

Phosphorus desorption is of great interest from the standpoint of plant nutrition and water quality. Because P is considered to be relatively immobile in the soil system (Johnson et al. 1997), less attention has been paid to P subsurface movement/leaching. The movement of P through surface runoff can be controlled via implementation of conservation and nutrient management practices. However, the control of P contamination through subsurface flow will be only effective if P concentrations in soil are reduced to levels that are not considered as a risk for local water bodies. Several studies have shown that organic materials and their decomposition can reduce P fixation in soils (Iyamuremye et al. 1996; Kwabiah et al. 2003). From an environmental standpoint, reduced P fixation will increase the P concentration in soil solutions which will ultimately increase the chance of P mobility to the surface or subsurface. Therefore, the application of organic and artificial fertilizer should use a budget approach to prevent environmental pollution but also increase the crop production.

The agricultural sector is estimated to be responsible for two-thirds of global water withdrawals, accounting for 90% of total water consumption (Shiklomanov, 2007). In the scenario of fresh water shortage, irrigation with saline water is one of the options to meet crop water demands. Application of organic fertilizers to soil is a common practice especially in saline environments due to the ameliorative effects of organic matter on soil conditions and plant growth. Many studies have focused on the effect of saline irrigation on plant growth, response of plants to different organic materials and nutrient leaching under fresh water irrigation, but our knowledge about nutrient leaching and phytoavailability from different compost amendments under SO_4^{2-} or Cl^- dominated irrigation water is scarce. Therefore, further studies are needed to address the phenomenon of increased P desorption/release from soil particles when they are exposed to water dominated by SO_4^{2-} or Cl^- ions. The current study was designed with the objectives (i) to evaluate the phytoavailability of P as well as N and K from different bio-composts applied on a total P equivalent basis (ii) and to evaluate NPK leachability under saline water irrigation. We hypothesized that NPK release and uptake from different bio-composts are influenced by water dominated by SO_4^{2-} or Cl^-.

2. Materials and methods

2.1. Soil and compost analysis

Coarse textured Masa soil was used as a test soil in this study. According to the United Soil Classification System of Japan (2002), the soil is Terrestrial Regosol. The physico-chemical properties of the soil were determined by using standard laboratory procedures (Table 1). Soil samples were digested in a nitric-perchloric acid (5:1) mixture to measure the total elemental concentration of P (IBSRAM 1994). Phosphorus contents in the acid-digest were measured colorimetrically by using the sulfo-molybdo-phosphate blue color method

Table 1. Selected characteristics of the soil and bio-composts used for the study

Properties	Manure			Soil
	Cow	Poultry	Sludge	
EC (1:5) deci S m^{-1}	11.4	10.8	7.04	0.11
pH (1:5)	8.8	8.1	7.8	6.6
Total C (g kg^{-1})	309	323	316	3.0
Total N (g kg^{-1})	23.1	42.7	62.7	0.1
C:N ratio	13.4	7.6	5.1	-
Total P (g kg^{-1})	3.0	5.9	8.4	0.06
Total Al (g kg^{-1})	3.7	0.4	9.3	-
Total Fe (g kg^{-1})	3.3	0.1	12.8	-
Total K (g kg^{-1})	37.3	40.2	26.2	-
Total Ca (g kg^{-1})	5.5	59.7	0.85	-
Texture†	-	-	-	LS

† LS = Loamy sand

(Murphy and Riley 1962) on a spectrophotometer (Model U 2001, Hitachi Corp, Japan). Three bio-composts were used in this study: animal (cow) compost, composted poultry droppings and sludge compost. To measure the total elemental concentration of P, Ca, K, Fe and Al in the composts, samples were digested in a nitric-perchloric acid mixture (5:1). Phosphorus concentration was measured colorimetrically.

2.2. Salinity and compost treatments

Three and half kilograms of soil was weighed and put into wagner pots (height 30cm, diameter 18cm). Required amounts of animal compost (66.6 ton ha^{-1}), composted poultry droppings (33.3 ton ha^{-1}) and composted (sewage) sludge (24.1 ton ha^{-1}) were applied on a total P equivalent basis at the rate of 200 kg ha^{-1} to the soil. An un-amended soil pot served as control.

Artificial saline water for irrigation was prepared by dissolving NaCl and Na_2SO_4 each at the rate of 60 $mmol_c$ L^{-1} (NaCl = 6.51 ± 0.1 dS/m, Na_2SO_4 = 5.75 ± 0.1 dS/m) along with the non-saline control (deionized water).

Irrigation was carried out by the weighing method. The required amount of irrigation water was calculated from the difference between pot capacity plus leaching requirement (25 % of applied water) and the actual weight of each individual treatment. After each irrigation event, leachate was collected for the entire 24 hr period and immediately transferred to the laboratory for chemical analysis. A total of nine leaching events were observed during the growth span of maize crop. Leachates were collected after 8, 12, 18, 22, 26, 29, 32, 38 and 47 d after sowing, which are refereed as leaching event 1, 2, 3, 4, 5, 6, 7, 8 and 9, respectively. To measure dissolved reactive P (DRP), leachate was passed through a cellulose acetate membrane filter (0.2µm). Thereafter, the concentration of DRP in the filtrate was measured colorimetrically. The concentration of NH_4-N in leachate was measured by using the indophenol blue color method, while NO_3-N was measured using the salicylic acid-sulphuric acid method and concentrations were recorded on a spectrophotometer. Potassium concentration in leachate was measured with an Atomic Absorption spectrophotometer.

Pots were arranged in a randomized complete block design on greenhouse benches. Four composts and three saline irrigation treatments in triplicate gave a total of thirty six pots. Eight maize (*Zea mays* L., variety: Yellow dento) seeds were sown (May, 2005) in each pot and thinned to four plants after germination. Maize plants were harvested at two growth stages. The first harvest (two plants) was taken after the three weeks of saline irrigation and the second harvest (two plants) was taken after six weeks of saline irrigation. Roots were collected after the second harvest. Thereafter, they were oven dried and crushed into powder for elemental analysis.

2.3. Statistical analysis

The data collected during the study was statistically analyzed using StatView software (SAS 1999). A probability level of <0.05 was considered significant and means were separated by Fisher's LSD test.

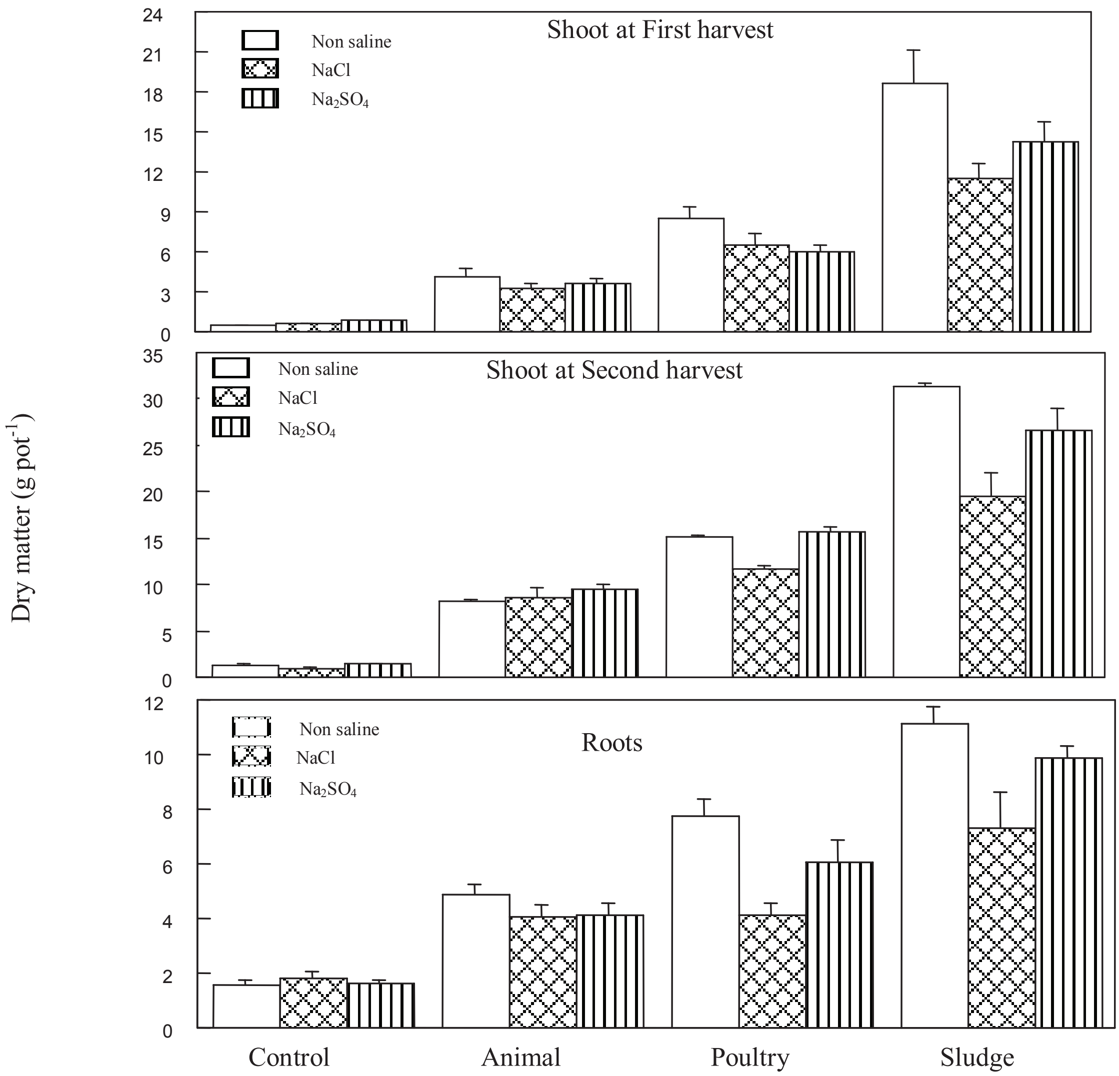

Figure 1. Effect of compost types and saline irrigation on maize dry matter yield. Small bars refer to stander error.

3. Results and discussion

3.1. Dry matter yield

The effect of saline irrigation and compost type on maize dry matter yield is shown in Figure 1. Saline irrigation reduced plant growth under all compost amendments. Among salt types, Cl^- dominated irrigation water severely reduced plant growth and development, compared to SO_4^{2-}. A similar pattern was observed for all plant tissues (shoot and roots) in both harvests. However, compared to SO_4^{2-}, reduction in shoot growth under Cl^- irrigation was higher in the second harvest (20.1 %) than the first harvest (12.7 %). Plant growth varied greatly under all compost amendments (Fig. 1). Pots amended with sludge compost resulted in the highest shoot and root biomass. The adverse effect of salinity on plant growth and development has been reported by other researchers (Mer et al. 2000; Ramoliya and Pandey 2003). The mechanism may involve reduced water absorption, reduced metabolic activities as a result of salt toxicity and nutrient imbalances (Yeo 1983). At the same time, increased Na concentrations in rooting media can impair plant growth and nutrient uptake. The adverse effect of SO_4^{2-} salt on the plants was less apparent than Cl^- because sulphur is considered an essential plant nutrient. Our previous study (Zahoor et al. 2007a) also showed that wheat (*Triticum aestivum* L.) growth was more severely affected by Cl^- than SO_4^{2-} saturated soil. Plant growth under different bio-compost amendments also differed greatly. This can be attributed to the difference in the nature and nutritional status of composts. Nutrient availability from a particular organic source is dependent on many factors such as type or source of compost, method of composting, N and P mineralization rate, plant type and clay content of the soil media. In addition, salinity further complicates the influence of these factors. Plant nutrition and salinity has been reported as a complex phenomenon and the form in which fertilizer is applied to salt stressed plants may influence this salinity-nutrient relationship (Lewis et al. 1989; Martinez and Cerda 1989) which ultimately affects plant growth.

3.2. Nutrients uptake by maize

Plant samples were analyzed for NPK content at the final harvest. All the parameters were significantly affected by compost types and saline irrigation (Table 2). N uptake by plant tissues was affected by saline irrigation and compost amendments (Fig. 2). Irrespective of compost amendments, N uptake by shoot increased more under both saline irrigations than with non-saline treatments while N uptake by roots decreased (Fig. 2). Among salt types, mean N uptake by shoot was higher in Cl^- (4.2 %) than SO_4^{2-} saline irrigation while N uptake increased in roots under SO_4^{2-} (22.6 %) compared to Cl^- irrigation. Nitrogen uptake by plant tissues varied significantly ($p < 0.05$) under

Table 2. Summary of two-way analysis of variance for nutrient uptake

Treatment	Shoot			Root		
	N	P	K	N	P	K
			F value			
Compost (C)	6474**	48.0**	106**	12839**	19.2**	54.5**
Salt type (S)	129**	4.4*	5.8*	1908**	n.s	30.7**
C x S	26.9**	n.s	3.1*	292**	n.s	7.3**

* and ** denote significance level at $P < 0.05$ and $P < 0.01$ respectively, n.s is not-significant.

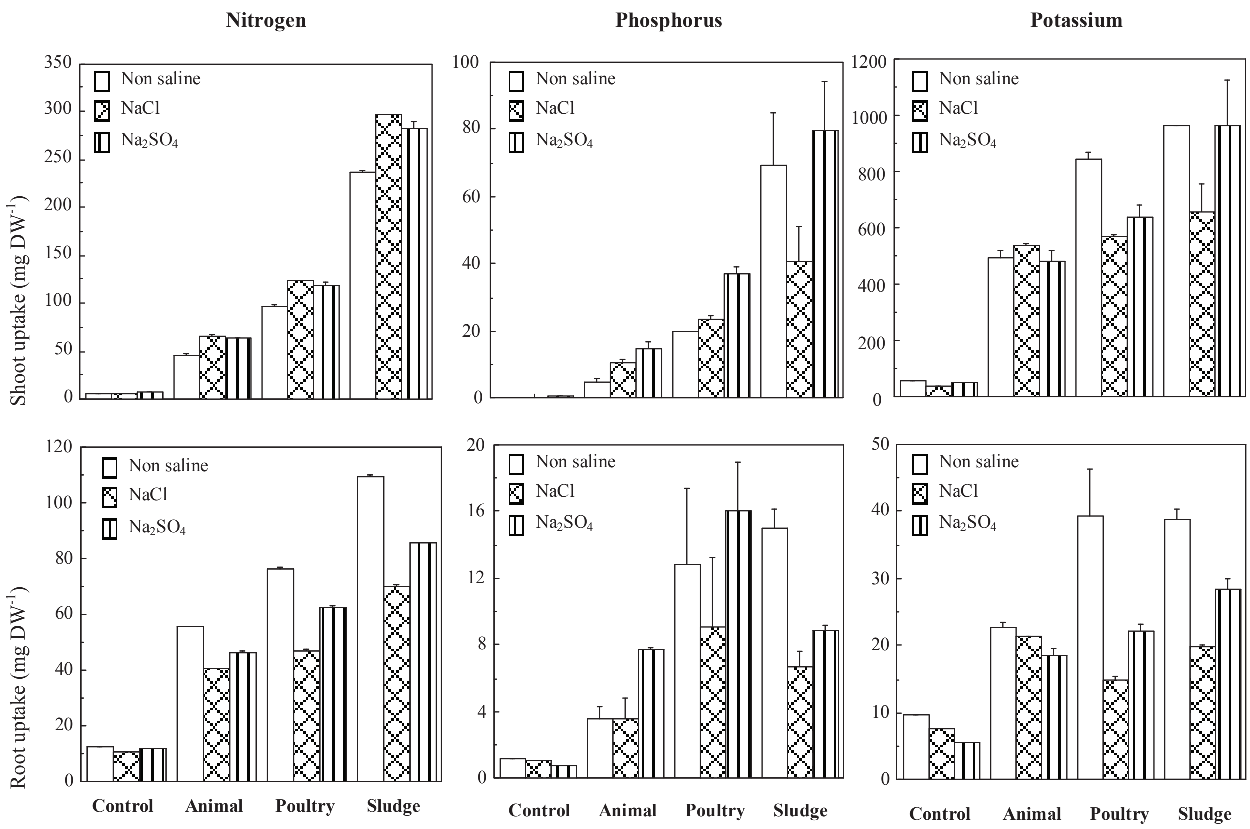

Figure 2. Effect of saline irrigation and compost amendments on nutrient uptake. Small bars refer to stander error and DW stands for total shoot or root dry weight per pot.

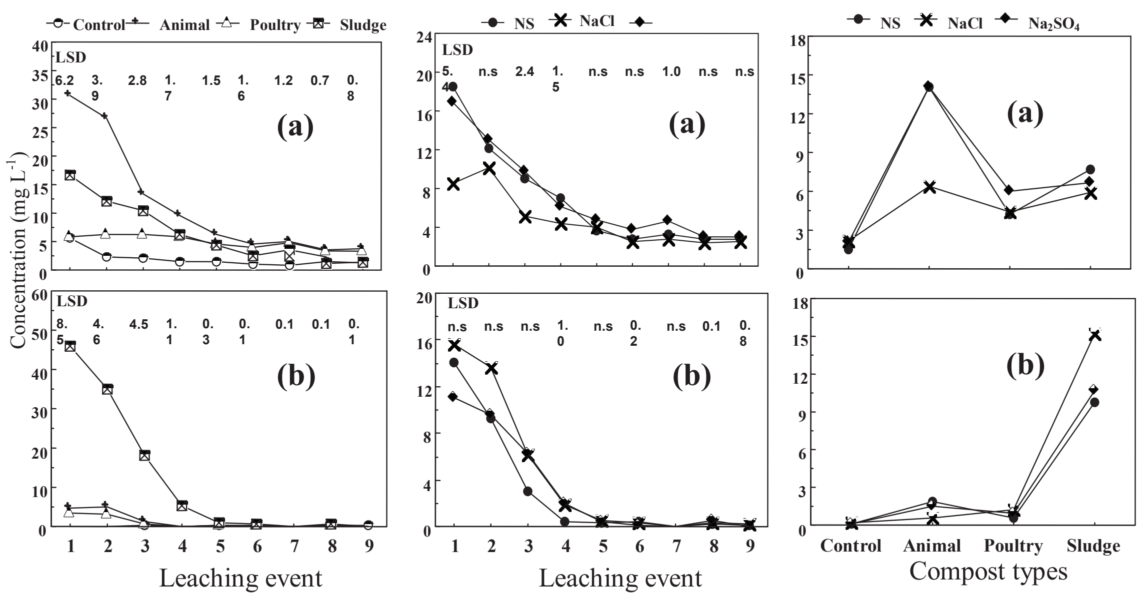

Figure 3. Effect of Cl^- and SO_4^{-2} dominated saline irrigation water on NO_3-N (a) and NH_4-N (b) leaching from different compost amendments. Leaching events 1, 2, 3, 4, 5, 6, 7, 8, 9 refer to 8, 12, 18, 22, 26, 29, 32, 38, 47 days after sowing, respectively. (LSD at P = 0.05, n=3).

different compost amendments (Table 2). Irrespective of saline irrigation, maximum N uptake by shoot and roots was recorded under sludge compost amended pots followed by poultry, animal and control treatments, respectively.

Salt types significantly affected the shoot P uptake by maize tissues under all compost amendments (Fig. 2). Irrespective of compost types, P uptake by shoot and root was higher under SO_4^{2-} saline irrigation as compared to Cl^- and non-saline treatments. Phosphorus uptake varied significantly ($p < 0.05$) under different compost amendments (Table 2). Higher P uptake by shoot was observed under sludge compost amended pots while root P uptake was higher under poultry compost amended treatment (Fig. 2). Potassium uptake was significantly affected by both salt types and compost amendments (Table 2). It decreased with saline irrigation as compared to non-saline treatment under all compost amendments (Fig. 2). Uptake decreased under Cl^- than SO_4^{2-} treatment, but the difference was not significant statistically. Among the compost amendments, the uptake was higher under poultry and sludge compost amended pots as compared to animal compost and un-amended treatments. Uptake by shoot increased in sludge amended pots with non-saline and SO_4^{2-} saline irrigation while root K uptake was higher in poultry compost with non-saline irrigation (Fig. 2).

The influence of salinity on nutrient accumulation in plants depends on many plant and experimental conditions (Irshad et al. 2002). Nitrogen uptake by shoot was relatively higher under Cl^- than with the SO_4^{2-} treatment. Pessarakli and Tucker (1985) also reported significantly higher N concentration in cotton under NaCl stress. Contrary to N uptake by stem, mean P uptake under SO_4^{2-} salinity increased by 77.4 % in shoot and 62.7 % in roots as compared to Cl^- treatment. Our results showed that plants vary not only in the rate by which they absorb an available nutrient, but also in the manner in which they spatially distribute elements within the plant tissues. Higher P uptake under SO_4^{2-} salt saturated pots compared to Cl^- has also been reported by Zahoor et al. (2007a). Manchanda et al. (1982) reported that P availability and its absorption were more adversely affected by excess Cl^- than SO_4^{2-} salt. Potassium uptake by shoot and roots decreased more under saline irrigation than non-saline treatment. Previous studies have also shown that K uptake decreased with increase in salts concentration in root media (Irshad et al. 2002). Meiri et al. (1971) observed that K concentrations in bean leaf-sap increased with increasing salinity and that the increase was more marked under SO_4^{2-} than Cl^- salinity.

Nutrient uptake greatly differed according to the compost type. The overall NPK uptake and plant growth was higher under sludge compost followed by poultry and animal compost. Variability in nutrient avaiulability from different organic materials has been reported by many researchers and many factors have been assumed to be responsible for these differences. Eneji et al. (2001) reported that not only manure type, but soil type can also affect the efficiency of particular manure. In addition to the soil type, the methods used to produce bio-solids and the C:N ratios of bio-solids also affect Na_2SO_4 the mineralization of N (Douglas and Magdoff 1991) and P (McCoy et al. 1986). However, relatively low crop growth and nutrient uptake by animal compost might be due to the abrupt increase in soil pH due to salt accumulation during the saline irrigation at early growth stages of plants.

3.3. Effect of saline irrigation on nutrient leaching

The concentration of nitrate nitrogen (NO_3-N) and ammonia nitrogen (NH_4-N) in leachate varied greatly with each saline irrigation event. The concentration decreased steadily but after 5th leaching, only traces of NH_4-N were detected (Fig. 3). The NO_3-N concentration in leachate was higher in SO_4^{2-} dominated irrigation water as compared to Cl^- treatment (Fig. 3a) while NH_4-N leaching increased under Cl^- than SO_4^{2-} saline irrigation (Fig. 3b). Irrespective of saline irrigation, NO_3-N and NH_4-N concentration in leachate was higher from animal and sludge compost amended pots, respectively. The concentration of DRP was relatively steady during the early three leachings and then started to decrease under both saline conditions (Fig. 4). The concentration was higher under SO_4^{2-} than Cl^- irrigation. Salt types differed for DRP release in the order: non-saline ≈ SO_4^{2-} > Cl^-. Non-saline and SO_4^{2-} saline irrigation substantially increased the DRP concentration in leachate from animal and sludge amended pots (Fig. 4). The concentration of K in leachate also increased under both saline irrigations as compared to non-saline treatment (Fig. 5). Potassium release was relatively enhanced by SO_4^{2-} dominated irrigation water. Potassium leaching was substantially high from animal compost amended pots under all saline irrigations (Fig. 5).

Results of the current study reveal that SO_4^{2-} dominated irrigation water enhanced the NO_3-N, P and K leaching as compared to Cl^- treatment. Other studies have also showed that N mineralization increases under SO_4^{2-} and Cl^- salinity (Koerselman et al. 1994). Higher NO_3-N concentrations in leachate under SO_4^{2-} dominated irrigation water might be due to the high desorption capacity of sulphate ions. Sulphate, being a divalent ion, has more ionic strength to replace HPO_4^{2-} or PO_4^{3-} as compared to Cl^- (monovalent ion) (Zahoor et al. 2008) and the same assumption can be taken for NO_3-N (monovalent ion) release. Leaching of cations like K, Ca and Mg were enhanced by SO_4^{2-} dominated irrigation water (the data of Ca and Mg has not been shown here) (Zahoor et al. 2007b). Among the salt types, DRP leaching was enhanced by SO_4^{2-} dominated water than by Cl^- treatment. The increase in DRP release by SO_4^{2-} might be due to the reduced sulphur (S^{2-}) formed after the input of SO_4^{2-} rich water and precipitation of FeS, which releases P adsorbed to iron into the soil solution (Smolders and Roelofs 1995).

3.4. Nutrient leaching from bio-composts

Nutrient leaching from different compost amendments greatly varied with each irrigation event. Maximum NO_3-N concentration in leachates was recorded from animal compost amended pots, especially in the first few leaching events, followed by sludge compost, poultry compost and control (Fig. 3a). Nitrate concentration from animal compost was relatively higher under SO_4^{2-} and non-saline treatments. The concentrations of NH_4-N leached from sludge compost was higher (about 9 fold) during first 5 leaching events as compared to the other compost amendments (Fig. 3b). Despite the fact that all organic amendments were applied on a total P equivalent basis, the amount of DRP release varied greatly from different bio-composts. The concentration of DRP in leachates was substantially higher from sludge compost and animal compost than from poultry compost or unamended soil (Fig. 4). The concentration of DRP leached from sludge and animal compost amended pots was about six fold and three fold higher than poultry compost, respectively. The leaching of K was also strongly affected by amendment. Animal compost released a substantial amount of K in leachate (Fig. 5). Potassium concentration in animal compost increased up to the third leaching event (248 mg L^{-1}) and thereafter decreased steadily. The concentration of K from poultry and sludge compost amended treatments was relatively steady during all the leaching events.

Nitrate was the dominate form of N leached out from the composts, especially under the animal compost and sludge compost amended pots.

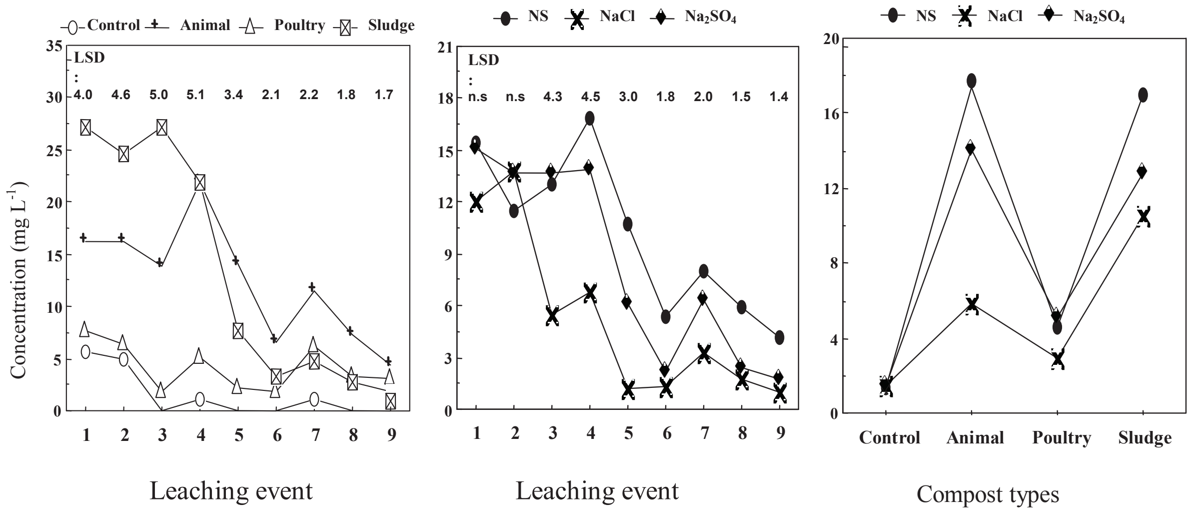

Figure 4. Effect of Cl$^-$ and SO$_4^{-2}$ dominated saline irrigation water on DRP concentration in leachate from different compost amendments. Leaching events 1, 2, 3, 4, 5, 6, 7, 8, 9 refer to 8, 12, 18, 22, 26, 29, 32, 38, 47 days after sowing, respectively. (LSD at *P* = 0.05, n=3).

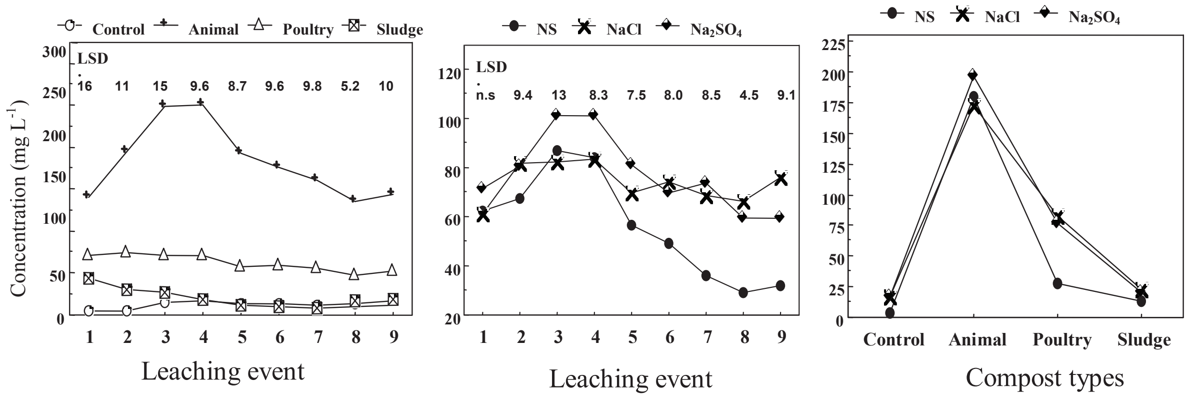

Figure 5. Effect of Cl$^-$ and SO$_4^{-2}$ dominated saline irrigation water on potassium leaching from different compost amendments. Leaching events 1, 2, 3, 4, 5, 6, 7, 8, 9 refer to 8, 12, 18, 22, 26, 29, 32, 38, 47 days after sowing, respectively. (LSD at *P* = 0.05, n=3).

Carefoot and Whalen (2003) also reported higher NO_3-N concentration Compost typesthrough piezometers when soil was amended with an organic or inorganic form of N fertilizers. In the corn production system, mean NO_3-N concentrations in drainage discharge may range from 4 to 43 mg NO_3-N L^{-1} (Jaynes et al. 2001), which is consistent with the NO_3-N concentrations we found in leachate under different bio-amendments. Nitrogen release or mineralization from organic sources depends upon many factors like soil type, C:N ratio and method of composting (Barbarika et al. 1985; Douglas and Magdoff 1991), which ultimately affect its leachability. Higher DRP release was observed from sludge and animal compost than poultry compost and control treatments. Griffin et al. (2003) have reported that after 84 days of incubation at constant soil water status, water extractable P from sandy loam soil was lower from poultry manure when compared to dairy and beef cattle manure. Generally, the quantity of P transported via subsurface pathways has been reported to remain high if the site is fertilized with organic residues because organic P is sorbed less strongly than inorganic P and thus may be leached (Zheng et al. 2001). High variation in DRP leaching from different bio-composts might be due to the difference in the nature of each bio-compost. It has been reported that P release dependents more on the type of P source than the amount of P applied (Zahoor et al. 2008). Potassium release was higher under animal and poultry compost. Potassium is believed to be lost from soils by two processes, removal of harvested plant material, and leaching beyond the root zone. The amount of K leaching is determined by several factors such as drainage (Shepherd and Bennett 1998) and fertilization (Wulff et al. 1998). Soil water K concentrations vary significantly among different soil types (Ulén 1999). Simmelsgaard (1996) observed K concentrations from different soil types as 0.5-1.7 mg K L^{-1} in clay soils, 5-7 mg K L^{-1} in loamy sand, and 10-15 mg K L^{-1} in coarse sandy soil. However the values of K leaching in the current study are about 10 times higher than the K values reported for coarse sandy soil. Higher K values in leachate in the current study are due to the higher native K status of the composts in addition to the coarse textured soil.

4. Conclusions

Results from the current study revealed that nutrient availability from different bio-composts is complex and that nutrient release or uptake depends on many factors under impaired quality of irrigation water. Aluminum (Al), iron (Fe) and calcium (Ca) content play an important role on P fate in soil and are mainly responsible for variability in P availability in different bio-composts. Therefore, it is necessary that when composts are applied on a P equivalent basis, in addition to N and K, concentrations of Al, Fe and Ca should be taken into account for assessing optimum nutrient availability from composts to mitigate nutrient leaching. In addition to leaching, further studies are also needed to focus on P release in drainage water induced by Cl^- or SO_4^{2-} dominated irrigation water.

Plant growth was severely affected by saline irrigation but the effect of Cl^- dominated irrigation water was more severe compared to SO_4^{2-}. However, it was observed that SO_4^{2-} dominated irrigation water leached more anions (NO_3^- and PO_4^{3-}) and cation (K^+) than Cl^-. Plant growth under saline as well as normal (non-saline) conditions was much better under sludge amended pots. From an agronomic point of view, sludge compost can best meet the maize nutrient requirements under saline and non-saline conditions. However, from an environmental point of view, application of sludge compost under impaired water quality would not be a pragmatic approach due to the high release of N and P. If poor irrigation water is the only available choice, then composted poultry droppings would be relatively safer to use. In areas where agricultural lands are the ultimate place for animal and sludge manure disposal, a full insight over compost characteristics and quality of irrigational water is needed. Proper management practices should be adopted in areas receiving high dosages of bio-amendments and irrigated with poor quality water. One possible management practice could be the split application of P sources to reduce higher initial P losses from the soil. Similarly, the combined application of organic and inorganic N and P sources could also help to reduce the problem.

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3.8. Bioengineering solutions for soil protection in continental and Mediterranean climates

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Abstract

A coordinated research was conducted in Bari (Italy) and Beijing (China) to assess the efficiency of grass hedges in soil protection. The research implied the selection of appropriate grasses able to thrive in the typically Mediterranean climate of Bari and in the continental climate of Beijing. While Bari is practically frost free and precipitations are concentrated in the autumn-winter period, in Beijing the frost free season is of only 160 days, winter temperatures drop to –20 °C and 80% of yearly precipitations occur in June-July-August, hence the interest in integrating such different conditions into a coordinated research. After preliminary investigations vetivergrass (*Vetiveria zizanioides)* was selected for Bari and Pennisetum (*Pennisetum alopecuroide*) for Beijing. Experimental plots with rain simulators were equipped at both sites, and the effects of protective grass hedges were tested under different slopes and rainfall intensities. Runoff and transported soil were collected in each plot and statistically analyzed; this permitted to work out empirical models useful to predict the protective efficiency of grass hedges under widely contrasting conditions. The potential of grass hedges in controlling erosion and enhancing soil water content under semi-arid conditions by reducing overland flow was assessed.

1. Introduction

Soil erosion is one of the major environmental problems mankind is facing today. During the last 40 years nearly one-third of the world's arable land has been lost to erosion and the loss continues at a rate of more than 10 million hectares per year (Liu et al. 2004; Huang et al. 2005). With the addition of a quarter of a million people each day, the world population's food demand is increasing at a time when per capita food productivity is beginning to decline.

In spite of considerable research conducted worldwide, large gaps still exist in our knowledge of the erosion-related problems, and in particular of the methods for controlling overland flow and soil transport. In semi-arid regions one additional reason to pursue a reduction in overland flow is because it also makes it possible to enrich groundwater.

The existing cooperation between the Mediterranean Agronomic Institute of Bari (MAI-B), a branch of the CIHEAM *(Centre International de Hautes Etudes Agronomiques Méditerranéennes*), and the Beijing Research Centre for Grass and Environment of the Beijing Academy of Agricultural and Forestry Sciences (BAAFS) and their common interest in studying erosion-related problems encouraged to start a joint research aimed at covering a wide range of conditions, encompassing the typical Mediterranean environment of Bari, Italy, and the Loess Plateau of Beijing, Northern China.

Accordingly, an applied research was conducted during a period of five years, based on a common protocol, with the aim of testing the efficiency of a naturalistic engineering method, namely the grass hedges, in reducing overland flow of sloping lands. The approach was essentially empiric, but the rather ample range of conditions explored, as illustrated below, gives confidence for sufficiently representative and significant results.

2. Materials and methods

The experiments were initially conducted in Bari, in the field of the IAM-B during the years 2004-2005 and later in Beijing, in the field of the BAAFS, during the years 2006-2008. Basically quite similar structures were used and analogous procedures were adopted, which made it possible to compare the results with some limits.

In Tables 1 and 2 the principal characteristics of the experimental structure, the main experimental conditions and the independent variables explored in the course of the experiments are reported; the monitored dependent variables were overland flow and soil transport. Four slope gradients in the plots were explored in both sites, namely 5, 10, 15 and 20%.

Although the experimental plots in Bari and Beijing had different size Table 1, the soil physical properties were similar (Lahmer 2004; Wu et al. 2008), similar rain simulators were installed and the procedure to collect and monitor overland flow and solid transport was the same in both sites (Lahmer 2004; Janushaj 2005; Wu et al. 2008). The procedures adopted to monitor the independent variables reported in Table 2 have been described elsewhere (Lahmer 2004; Janushaj 2005). The coefficient of uniformity of rain distribution, according to Christiansen (1942), was in all cases above 80%.

The protective hedges in Bari were obtained by planting clumps of vetivergrass (*Vetiveria zizanioides* (L.) Nash, recently reclassified as *Chrisopogon zizanioides* (L.) Roberty) while in Beijing two species were selected, namely *Arundinella hirta* (Thunb) Koidz and *Pennisetum alopecuroide* L. However, data referring only to the latter were used for comparison to vetivergrass.

One aim of the combined research was to compare the protective action of different grass hedges under widely different environmental conditions, namely the typically Mediterranean climate of Bari and the continental climate of Beijing; while Bari is practically frost free and precipitations are concentrated in the autumn-winter period, in Beijing the frost free season is of only 160 days, winter temperatures drop to –20 °C and 80% of yearly precipitations occur in June-July-August.

The procedure adopted in the operation of rain simulators was that generally recommended (Sardo et al. 1992), with sets of three one-hour "runs", including an initial "dry run" with dry soil surface, followed 24 hours later by a "wet run", which in turn was followed by a "very wet run" one hour later.

Data related to the two dependent variables 'overland flow' and 'soil transport' were collected at the end of every run and then processed for the statistical analysis. The independent variables 'antecedent soil moisture' and 'pulverization index' were non-significantly correlated to the two dependent variables and therefore were dropped after the first assessments in Bari. As a consequence, the correlations were elaborated only between the dependent variables 'overland flow' and 'solid transport, and the independent variables 'rain intensity, 'plant cover' and 'slope'.

Table 1. Description of the main experimental structure

Site and year	Experimental structure					
	Number of plots	Plot size m	Soil infiltrability mm/h	Rain intensity mm/h	Plant cover %	Total events (runs x plots)
Bari 2004	8	3,0 x 1,0	15	15 - 110	0 - 25	864
Bari 2005	8	"	"	17 - 107	0 - 20	840
Beijing 2006	36	11,0 x 1,5	13	14 - 36	80 - 85	324
Beijing 2007	36	"	"	22 - 62	80 - 90	324
Beijing 2008	36	"	"	22 - 62	6 - 91	648

Table 2. The monitored independent variables

Site and year	Independent variables*					
	R I	HP	Slope	PP	ASM	PI	PC (%)
Bari 2004	X	X	X	-	X	-	X
Bari 2005	X	X	X	-	-	X	X
Beijing 2006	X	X	X	X	-	-	X
Beijing 2007	X	X	X	X	-	-	X
Beijing 2008	X	X	X	X	-	-	X

RI Rain intensity; HP Hedge protection; PP Protective plant; ASM Antecedent soil moisture; PI Pulverization index; PC Plant cover

Table 3. Overland flow (mm/run) as affected by protective hedges and slopes

Slope	Bari 2004 P	Bari 2004 C	Bari 2005 P	Bari 2005 C	Beijing 2006 P	Beijing 2006 C	Beijin g 2007 P	Beijin g 2007 C	Beijin g 2008 P	Beijing 2008 control
5%	0,85	3,83	0,35	3,72	0,63	2,68	0,78	2,45	4,0	9,39
10%	1,09	4,8	0,72	4,32	0,67	3,97	0,96	5,13	5,03	10,68
15%	0,94	4,05	0,68	4,18	1,59	5,64	2,08	9,16	6,36	13,15
20%	1,25	2,98	0,93	6,01	1,55	5,11	4,9	11,89	9,57	16,32

P protected; C control

Table 4. Percentage of reduction in overland flow

Slope	Bari 2004	Bari 2005	Beijing 2006	Beijing 2007	Beijing 2008
5%	77,8	90,6	76,5	68,2	57,4
10%	77,3	83,3	83,1	81,3	52,9
15%	76,8	83,7	71,8	77,3	51,6
20%	58,0	82,5	69,7	58,8	41,4

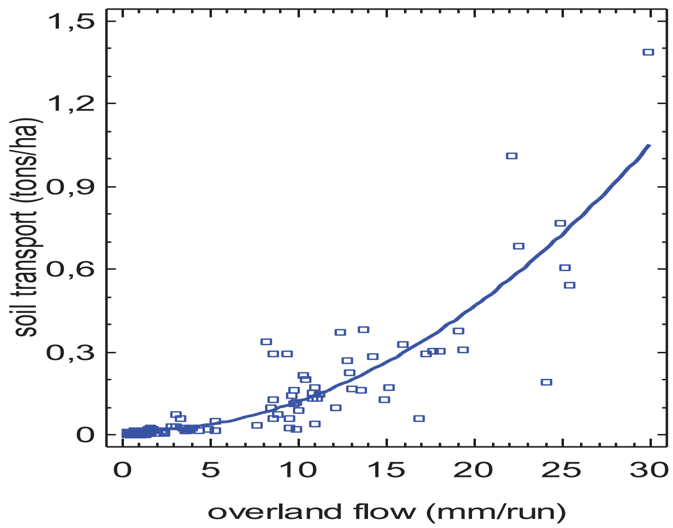

Figure 1. Typical relationship between overland flow and soil transport.

Additionally, the correlations found between the two dependent variables in the five groups of experiments were analyzed. The statistical package Statgraphics Centurion was used for the analysis of the variance and to find simple and multiple correlations.

3. Results

In spite of the different dimensions of the plots in Bari and Beijing and of the different protective grasses, a reasonably good agreement in results was achieved. Table 3 shows the reduction in overland flow obtained through the establishment of protective hedges; there was fairly good consistency of results under the widely different experimental conditions. The Table also shows the response to the various slope gradients.

For a better appreciation of the protective action of hedges the reduction percentages are reported in Table 4. The most of the values were in the range of 70 – 85%, and the lowest values generally were with the 20% slope.

The interest in reduction of overland flow is twofold: on one hand a reduced overland flow implies a reduced soil transport (Fig. 1) and on the other hand the water infiltrated into the soil because of the grass hedges enriches groundwater, which is particularly welcome in the semi-arid environments. Soil transport(Y) was linked to overland flow (X) by second degree polynomial relationships (Fig. 1) in the form: $Y = a + b X + c X^{2}$, where a is a constant and b and c are regression coefficients.

In all cases the coefficients of determination (R^2**),** explaining the variability in the dependent variable soil transport, was considerably high, ranging between 0.65 and 0.85. The second degree polynomial function explains better than the linear relationship the influence on soil transport of the tractive force of overland flow, increasing in a non-linear way (e.g. Gustafson 1941; Kinori 1970).

The simple linear correlations showed a limited influence of single independent variables on overland flow and soil transport; surprisingly, the independent variables rain intensity, slope and plant cover were rather loosely correlated to the two dependent variables. The multiple linear regressions gave better fit, since the combination of the three independent variables was able to explain over 60% and up to 85% of variability in results. This is of interest and can be seen as a significant contribution towards a rational design of protective structures based on naturalistic engineering methods.

4. Conclusions

The coordinated research conducted under widely different environmental conditions aimed at highlighting similarities in responses permitting to draw conclusions of general interest, thus widening the field of applicability of the results. This goal was achieved since basically a good consistency in experimental responses was obtained. The coherent polynomial correlations between overland flow and soil transport convey useful information on soil erosion risk depending on increasing runoff. More interestingly, the research permitted to gain some insight on the extent of the protective action which can be expected from grass hedges and on the possible enrichment of groundwater reserves because of the reduction in the overland flow.

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3.9. Integrated nutrient management strategies for improving soil health and enhancing crop productivity in rainfed agro-ecosystems

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Abstract

Improving and maintaining soil health for enhancing and sustaining agricultural production is of utmost importance for India's food and nutritional security. Climate change and the resultant aberrant weather situations are increasing the vulnerability of rainfed farming. Rainfed agriculture in the semi-arid tropical regions of India faces the twin problems of water 'thirst' and plant nutrient 'hunger'. Due to moisture scarcity these lands are incapable of supporting double cropping. Consequently, the soil organic matter turnover and fertilizer use efficiency is very low. After the harvest of the economic component only negligible amount of residues/stubbles remain in the soil. High temperature-mediated rapid decomposition of organic material reduces its content to a marginal level, reducing soil physical and chemical properties. On the other hand, most of the farmers in these regions are marginal and poor, thus unable to purchase fertilizers. In order to sustain the productivity of dryland crops, it is extremely important to off-set the nutrient depletions through appropriate nutrient management practices. The results from long-term fertilizer experiments conducted in different agro-ecological regions involving diversified cropping systems and soil types have shown that imbalance in fertilizer use, particularly using nitrogen alone, had a deleterious effect on soil productivity and health and the damaging effects in the absence of P and K fertilizer varied in the order: Alfisols>Vertisols>Inceptisols. In a period of less than 10 years, crop productivity in N alone plots came to almost zero in Alfisols. Integrating application of organic manure (FYM @ 10-15 Mg ha^{-}1) with 100% recommended NPK fertilizer doses not only sustained high productivity of dryland crops (finger millet, maize, *rabi* sorghum and pulses) but also maintained soil fertility in most of the cropping systems. The results further revealed that soil type is one of the most important factors affecting fertilizer use efficiency and crop yields. Therefore, sustained efforts are needed to improve and maintain soil through judicious integration of mineral fertilizers, organic and green manures, crop residues and bio-fertilizers so that it nourishes continuous cropping without being irreversibly damaged in the process.

1. Introduction

With globalization, Indian agriculture is passing through a critical phase. It is confounded with increasing crop production, sustainability and environmental quality issues. Of the total geographical area of 329 million ha, 142 million is devoted to agriculture. Rainfed agriculture extends over 97 million ha which is about 68% of the arable land and 55% of the gross sown area. The principal rainfed crops are coarse cereals, pulses, oilseeds and cotton. Contrary to the results of ‘green revolution’ experienced with irrigated crops during mid sixties the productivity rise with rainfed crops has largely been indiscernible. Low productivity of high yielding varieties of rainfed crops is due to paucity and unpredictable soil moisture availablity. Poor soil fertility is another principle obstacle in achieving break through in productivity of rainfed crops.

The rainfed areas are spread out widely in the country and can be broadly classified into arid, semi-arid and dry subhumid. The arid areas forming 19.6% of the total geographical area (329 million ha) are characterised by low and erratic rainfall (<500 mm) and light textured soils. The growing season is very short (upto 75 days) with millets and short duration pulses dominating the cropping systems. Livestock farming forms an important part of the arid ecosystem. The semiarid areas can be further classified into dry and wet. Dry semiarid areas form 12% of the geographical area and receive a mean annual rainfall of 500-700 mm with a growing season of 75-100 days. The soils in the northern part of the country are loamy sand, light sandy loam and medium black soils, whereas in the penninsular part shallow and medium black soils are predominant. The wet semiarid region constituting 25.9% of the grographical area receives mean annual rainfall 750-1100 mm with a growing season upto 120 days. This zone contains sandy loam and loam soils in the north, medium to deep black soils in the central part and red and medium to deep black soils in the south. The crops and cropping systems are quite diverse in the semi arid part of the country depending on the soil type and the length of growing season. Sorghum, cotton, soybean, groundnut and pulses are the major crops grown in this zone. The dry subhumid areas constitute 21.1 % of the geographical area and receive mean annual rainfall of 1100 –1600 mm. The high rainfall in these areas provides opportunity for water harvesting. The soils represent red loams, laterites, alluvial and deep black soils. Rainfed rice is the predominant crop followed by pulses and oilseeds.

Several long term fertilizer experiments carried out in different agroecological regions of India and elsewhere in the world involving diversified cropping systems and soil types have provided very valuable data which are highly relevant for farmers, scientists and policy makers(Dawe et al. 2000 ; Powlson et al. 1998 ; Swarup and Gaunt 1998; Swarup and Wanjari 2000; Swarup et al. 1998, 2000).

2. Over- mining of nutrients

Continuous cropping invariably results in heavy withdrawal of nutrients from soils and its success largely depends upon the judicious application of inputs commensurate with the nutrient uptake. The nutrient uptake values generally provide a reliable estimate of the nutrient requirements under varying agro-ecological regions forming the basis for the development of a sound fertilizer recommendation strategy for realizing higher productivity and maintaining soil fertility. The average uptake of major nutrients by the crops at 100 percent NPK application treatments of selected cropping systems are presented in Table 1 (Swarup 2006).

The uptake of any nutrient is a function of yield and nutrient concentration in the plant. It is apparent that nutrient removal (NPK) can be as high as 620 kg/ha/year. In general, the exhaustive cropping systems in respect of nutrient removals are rice-wheat, rice-rice, maize- wheat and soybean-wheat. A look at differences between the nutrients applied and the nutrient uptake with optimal 100 per cent NPK dose indicated a positive balance of N and P and negative in respect of K on almost all the soils with minor

Table 1. Nutrient uptake in long-term fertilizer experiments under different cropping systems in India

Cropping System	Soil type	Yield(t/ha)	Nutrient uptake (kg/ha/year			
			N	P	K	Total
Maize-wheat-cowpea (F*)	Inceptisols	6.8 - 0.6	240	45	250	535
Rice-wheat-jute fibre	Inceptisols	6.5 – 1.5	250	50	275	575
Maize-wheat-cowpea (F)	Mollisols	9.5 – 1.9	260	65	295	620
Rice-rice	Inceptisols	6.2	150	40	175	365
Soybean-wheat	Vertisols	6.3	285	44	225	554
Soybean-wheat	Alfisols	4.2	220	35	170	425
Fingermillet-maize	Alfisols	6.5	210	42	215	467
Fingermillet-maize	Inceptisols	6.5	245	40	270	555
Groundnut-wheat	Alfisols	2.9	106	18	65	189
Sorghum-sunflower	Vertisols	2.9	89	42	117	248

* fodder; Source: Swarup (2006)

differences occurring in respect of cropping systems.

At the national level it is estimated that annually 34-35 MT of nutrients are removed from the soil, whereas only 24-25 MT are supplied from fertilizers and organic sources thus leaving a negative balance of about 10 MT. The continuous nutrient imbalance can become staggering when we consider the future needs for food. Thus food security is very much related to fertilizer use. For feeding a population of 1.4 billions by 2025, India will need to produce 311 MT food grains. For producing this much food India will need at least 45 MT plant nutrients, out of which at least 35 MT should come from chemical fertilizer sources containing 5.6-8.8 MT P_2O_5 + 2.3 to 4.7 MT K_2O and the rest nitrogenous fertilizers. At least 10 MT nutrients should come from organic manures, crop residues and bio-fertilizers.

3. Fertilizer use efficiency (FUE)

Fertilizer use efficiency refers to the proportion of applied nutrients recovered by the crop. It is commonly expressed as a percentage of fertilizer used by the crop or alternatively in terms of crop yield per unit of fertilizer (e.g. kg grain per kg of applied nutrient). Fertilizer use efficiencies vary widely and usually decrease as fertilizer rates increase. Nitrogen efficiency based on grain yield rarely exceeds 50 to 60 percent and can be as low as 20 per cent. First year fertilizer efficiencies are normally 10 to 30 percent for P and 20 to 60 percent for K, although efficiencies can be greater over the long-term because of the residual properties of these immobile nutrients (Swarup 2002).

4. Lessons from the Long-Term Fertility Experiments

The Long-Term Fertility Experiments carried out in different agro-ecological regions and on important cropping systems and soil types have produced very valuable information for use of planners and extension workers in agriculture as indicated below (Swarup 1998):

- They have clearly established that (a) fertilizer is the key input for increasing crop productivity, (b) continuous use of N alone cannot be relied upon to produce sustained yields, (c) balanced optimum application of NPK, based on soil tests is essential for sustainable high productivity, (d) in highly fertilized (NPK) system the deficiency of micro-nutrients and secondary nutrients will become yield limiting after a number of years and their application will be necessary to sustain high yield potential and (e) the integrated use of optimal doze of NPK and FYM gives better and more sustainable yields and can also correct some of the micronutrient and secondary nutrient deficiencies and soil acidity problems (Table 2).

- As Indian soils are all deficient in N and dramatic increases in yield seen on first application of N alone gives rise to an erroneous notion to the farmers that N alone is enough for high yield. The long-term fertilizer experiments have unequivocally proved that such a practice can lead to disastrous results in intensive cropping systems and balanced fertilizer use is absolutely essential for sustained enhanced productivity.
- Crop yields remain at low level even when fertilizers are applied at 50% of the optimum level. The application of higher quantities of nutrients above the optimum doze (150% NPK) though results in higher yield than 100% NPK but does not seem to be sustainable at the present level of crop production potential.
- Addition of FYM in optimum quantity (10-15 tons/ha) has synergistic effect on improving efficiency of optimum doses of NPK and correcting deficiency of Zn and S in most cases, but the question is of its economics and availability.
- In case of acid soils (Ranchi and Palampur regions) application of N alone has aggrevated the problem of acidity. Application of lime helped in correcting acidity but for attaining high yield potential liming has to be accompanied with optimal doze of NPK. Similarly, application of gypsum based on gypsum requirement of soil is extremely important in attaining high yields and maximizing nutrient use efficiency in alkali soils of the Indo-Gangetic Plains (Swarup 2004).
- The rice-wheat system productivity and soil fertility on long-term basis can be sustained by integrated use of gypsum or FYM with recommended NPK dose in areas having sodic ground water. Pressmud, a byproduct of sugar factory and also economically cheap as compared to gypsum, offers alternate opportunities to the farmers of the Indo-Gangetic plains for efficiently using the poor quality ground water and improve crop productivity and soil fertility (Yaduvanshi and Swarup 2005).
- The notion that continuous application of inorganic fertilizer decreases the organic carbon content of the soil is disproved by the results of the long-term fertilizer experiments as a definite increase in organic carbon was recorded in Inceptisols, Vertisols and Alfisols under NPK treatment over the unmanured treatment (Table 3). Therefore, balanced fertilizer use is extremely important for maintaining soil organic carbon (SOC).
- The continuous application of NPK in optimum dose for years did not improve available P status of Vertisols at Jabalpur and Vertic Ustropept at Coimbatore and crops continued responding to P application indicating that higher dose of P is needed in these soils for sustained high productivity and improving P status.
- There are indications of depletion of K from the native soil reserves in almost all soils and cropping systems despite the continuous application of NPK. Studies carried out in Inceptisols at Bhubneswar showed that higher doses of K are extremely important for sustaining rice-rice productivity.
- Need for application of sulphur has been established by the continuous use of sulphur free NPK at Barrackpore, Bhubaneswar, Jabalpur, Ludhiana Bangalore and Pantnagar centers for obtaining sustained high yields of the dominant cropping systems of the agro-ecological regions represented by these centers.

Table 2. Average grain yield of crops (t/ha) over the years in long-term experiments on yield stability and productivity

Centre	Crops	Control	N	NP	NPK 100%	NPK 150%	NPK+FYM 100%	NPK-S/+S	NPK+Zn/ lime
				INCEPTISOLS					
Barrackpore	Rice	1.6	3.4	3.8	3.9	4.3	4.1	3.0	3.4
(1972-98)	wheat	0.8	2.0	2.3	2.4	2.9	2.5	2.4	2.3
Bhubaneswar	Rice	1.6	2.1	2.2	2.8	3.0	3.5	2.4	2.8
(1973-94)	rice	1.4	2.1	2.8	3.0	3.3	3.7	3.0	3.1
Coimbatore	Finger-millet	1.0	1.2	2.9	3.0	3.2	3.5	2.9	2.9
(1972-99)	maize	0.7	0.9	2.8	3.0	3.2	3.4	2.9	3.1
Delhi (1994-99)	Maize	1.2	1.7	1.8	2.1	2.4	2.4	2.2	2.3
	wheat	2.5	4.2	4.3	4.6	4.9	5.0	4.6	4.7
Hyderabad	Rice	1.1	2.6	3.4	3.6	4.3	4.7	2.8	3.0
(1972-95)	rice	1.0	1.8	2.2	2.6	3.3	3.4	2.3	2.5
Ludhiana	Maize	0.4	1.4	1.8	2.6	2.5	3.2	2.4	2.7
(1971-99)	wheat	1.0	2.8	4.1	4.8	4.9	5.0	4.8	4.8
				VERTISOL					
Jabalpur	Soybean	0.9	1.2	1.9	2.1	2.1	2.2	1.9	1.9
(1972-99)	wheat	1.1	1.4	3.9	4.2	4.4	4.6	4.2	3.9
				MOLLISOL					
Pantnagar	Rice	3.1	4.9	5.0	5.3	5.3	6.0	5.1	5.6
(1972-99)	Wheat	1.5	3.7	3.8	3.8	4.1	4.5	3.8	4.2
				ALFISOLS					
Palampur	Maize	0.3	0.6	2.0	3.2	4.0	4.6	3.6	4.0
(1973-98)	wheat	0.3	0.4	1.8	2.5	3.0	3.3	2.5	3.1
Ranchi	Soybean	0.7	0.4	0.9	1.6	1.5	1.9	0.7	1.8
(1973-99)	wheat	0.8	0.4	2.3	2.6	2.8	3.1	1.7	3.0
Bangalore	Finger-millet	0.6	0.9	1.2	4.3	5.0	4.8	4.2	4.1
(1986-99)	Maize	0.3	0.5	0.8	2.2	2.5	2.6	1.9	2.2

Source: Swarup and Wanjari (2001)

Table 3. Effect of continuous cropping and manuring on organic carbon status of soils (g/kg) under Long Term Fertilizer Experiments

Name of Centre & Soil Type	Treatments				
	Control	N	NP	NPK	NPK+FYM
Ludhiana (Inceptisols)	3.6	3.6	3.7	3.9	4.2
Jabalpur (Vertisols)	5.7	6.8	7.5	7.5	11.2
Bangalore (Alfisols)	4.4	4.5	4.9	5.6	7.5
Ranchi (Alfisols)	3.0	3.0	3.1	3.5	4.0
Bhubaneswar (Inceptisols)	3.8	4.6	5.6	5.6	8.4

Source: Swarup and Wanjari (2001)

The results of the experiments at different locations have clearly brought out the following:

- Yield declines when imbalanced fertilization continued for long periods.
- Yield stagnates or declines when input levels are kept constant and/or sub-optimal.
- There are evidences of a downward shift in the entire fertilizer response function at all levels of fertilizer applications which means lesser increases due to application of same dose of plant nutrients. There is therefore a need for application of heavier doses of fertilizer to obtain same yield.
- Application of FYM over and above 100% of the recommended NPK invariably sustained high productivity over the years.
- Continuous cropping without adequate inputs decreases indigenous soil N, P and K supply.

5. Environmental consequences

Fertilizer N, P and K after their application in soil undergo transformation in physical, chemical and biological processes. For example, dynamics of N in the soil-plant-atmosphere system includes various soil processes (mineralization, immobilization, urea hydrolysis nitrification, volatilization, denitrification and N movement in soil), the processes pertaining to above ground plant growth, and nitrogen uptake by crops. Soil type is one of the most important factors in affecting fertilizer use efficiency and soil productivity (Kumar et al. 1995; Swarup 2002).

Phosphorus after its application in soil is either removed by crop or gets immobilized into various insoluble forms (Fe and Al-phosphate and Ca-phosphate depending on soil pH) and gets fixed in soil clays or organic matter. The use efficiency of P does not exceed 20 percent. Significant amount of P is lost from the soil through surface run off and erosion resulting in eutrophication of water bodies.

Potassium is the most abundant plant nutrient in soil having illitic type of clay mineral. It is more mobile than phosphate and is susceptible to loss by leaching, run off and erosion. The K use efficiency is about 70 percent. Loss of K is a waste but carries no environmental concern. The major environmental consequences related to fertilizer use are: (i) nitrate pollution of ground water; (ii) eutrophication; (iii) ammonia volatilization; (iv) acid rain; (v) green house effect, (vi) damage to crops and soil organisms and (vii) trace element and heavy metals contamination (Swarup 2006).

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3.10. Recycling of organic waste for sustainable management of land degradation in dry areas

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Abstract

Land degradation in dry areas is a major issue because of its adverse impact on agricultural productivity and sustainability. Tons of fertile soils have been disappearing every year from the land surface. Cultivated lands are being degraded by salinity and sodicity. Unsustainable agricultural activities including inadequate soil conservation, cultivation of steep slopes and without adequate fallow periods, less use of animal manure, unbalanced fertilization, and improper irrigation management have a devastating impact on the land resources in arid and semiarid regions. The soils of dry areas are usually low in organic matter. The recycling of organic waste is a viable option for the restoration of degraded drylands. On-farm waste management in degraded drylands not only enhances fertility of soils and sustains organic matter but also effectively preserves the physical, chemical and biological properties of soils. Recycling of on-farm waste such as animal manure and crop residues, and off-farm waste such as sewage sludge and composted refuse is an economical, safe and environmentally sound method to achieve a workable balance between the degradation process and conservation practices for the sustainability of agriculture in dry areas.

Educating people for the recycling of organic waste would favorably address the political, social and economic constraints for the management of drylands. This practice would provide alternative livelihood opportunities, food security and certainly help to alleviate poverty and develop a sound environmental system in dry regions. This paper highlights the option for the utilization of organic waste for the conservation and restoration of land and water resources in dry areas.

1. Degradation of drylands

Land degradation is an important global issue for the 21st century because of its adverse impacts on agronomic productivity, the environment, and its effect on food security and the quality of life. The natural resource base of land, water and vegetation in dry areas is highly fragile and greatly vulnerable to degradation. Dryland regions occupy extensive areas in all continents of the world. These areas are accommodating one sixth of the world's population. The inhabitants of these regions are among the poorest people in the world who totally depend on the renewable natural resources for their livelihoods. Dryland agriculture involves rainfed crop production in regions where limited precipitation generally results in plant water stress. Precipitation is often erratic, both within the growing season and between years. Successful crop production under such conditions depends on stored soil water as well as efficient use of precipitation. The poverty in the dry areas is not only caused by inadequate availability of water for crop, livestock and other enterprises but also by a lack of capacity for sustainable management and use of the available water.

Population pressure along with the demand for more food, fodder and fuelwood in many developing arid and semi-arid countries have generated interrelated economic, social and ecological issues associated with land degradation. Overexploitation of the natural resources by human activities, contravening the old traditions of sustainable management, is leading to massive land degradation triggering a chain of disastrous events and loss of livelihoods.

Land degradation is very common in most dryland areas and can lead to desertification. Drylands are low in soil organic matter and thus prone to physical, chemical and biological soil degradation. Soil physical degradation involves reduction in aggregation, decline in soil structure, crusting, compaction, reduction in water infiltration capacity and erosion (Lal et al. 1999). Soil chemical degradation includes nutrient depletion, nutrient imbalance (toxicity and deficiency), and build up of salts. Biological degradation is related to reduction in activity and species diversity of soil flora and fauna, decline in the biomass C and depletion of soil organic carbon (SOC). The land area affected by strong and extreme physical and chemical degradative processes is estimated to be about 34 Mha (UNEP 1991). Similar to severely eroded lands, these lands may also be taken out of production and converted to restorative land use through planting appropriate trees, shrubs, and perennial grasses.

Some other important biophysical effects of land degradation in dry areas involve soil erosion by water and wind, decline in topsoil depth and a reduction in available water capacity, overgrazing, deforestation, reduction in the soil carbon pool and loss of biodiversity. Land degradation and soil erosion are the most pervasive problems challenging sustainable dryland agriculture. There are 424 Mha of moderately eroded lands (Oldeman 1994) in dry areas.

Management practices that degrade land quality include residue removal, continuous cropping with limited inputs, overgrazing and cultivating soils that are marginal for crop production. Erosion also reduces soil fertility by physically removing nutrients and organic matter from the land. Degraded soil is also less favorable for water infiltration, thus leading to a downward spiral of reduced crop productivity and soil sustainability.

2. Soils of drylands

The world's drylands, 6.31 billion hectares or 47% of the earth's land area, are found in a wide range of climates. Soils also vary widely, mainly including Alfisols, Mollisols and Vertisols (Dregne 1976). These soils are characterized by frequent drought stress, low organic matter content, low nutrient reserves, and especially low N content (Skujins 1991). The soils with a capacity to produce large amounts of biomass under optimal conditions are rather rare in these regions. Drought stress, low germination and high seedling mortality, and low water and nutrient use efficiencies are among principal constraints to high biomass production here. Declining soil fertility and mismanagement of plant nutrients have made agricultural development more difficult in dry areas.

Sustainability of the soil resources in dryland regions is a major concern and this is particularly true for lands that are cultivated. Soil resources must be managed to sustain productivity. Land degradation control implies re-establishing the vegetative cover, conserving soil and water, improving soil fertility, enhancing soil quality, and increasing biomass production. Appropriate tillage and crop residue management practices, well adapted crops, and fertility management are needed for capturing, conserving, and efficiently using water for dryland crop production. Another option to improve production under some conditions is water harvesting, where runoff water from non-cropped areas is concentrated and applied to adjacent cropland.

3. Organic waste for drylands

Organic waste is produced wherever there is human habitation. The main forms of organic waste are household food waste, agricultural waste, and human and animal wastes. In industrialized countries the amount of organic waste produced is increasing dramatically each year. Although many gardening enthusiasts compost some of their kitchen and garden waste, much of the household waste goes into landfill sites and is often the most hazardous waste. Possible uses of organic wastes include use as fertilizer and soil amendment, energy recovery (heat, liquid fuels, electricity), and production of chemicals (volatile organic acids, ammonium products, alcohols).

Applications of waste material as soil amendment may offer a rational waste recycling alternative to current land fill disposal. Moreover, economic issues associated with intensive use of fertilizers have also generated an interest in alternative management systems. Agronomic practices aimed at reducing the dependence on inorganic fertilizers can contribute to the sustainability of agriculture in dry areas. The system productivity and sustainability are inextricably linked with soil fertility and soil organic matter content. Soil organic matter is significantly correlated with soil productivity. Maintaining soil organic matter, therefore, is of critical importance. Beneficial effects of waste amendment applied to the soil in any environment include not only the enhancement of organic matter and supply of essential plant nutrients but also the preservation of soil physical, chemical and biological properties.

Waste amendment is essential to enhancing biomass productivity, increasing water use efficiency and improving soil quality. Several long-term experiments in drylands have demonstrated the importance of judicious use of fertilizer, compost and nutrient management (Fuller 1991; Traore and Harris 1995; Singh and Goma 1995). Use of manure and compost is facilitated by integrating livestock with the cropping system (Chaudhry et al. 1981; Haque et al. 1995; Harris 1995). In Maharashtra state in India, More (1994) reported that application of farm by-products and organic manures improved the quality of sodic Vertisols, enhanced SOC content and increased crop yields. From the environmental perspectives, scientists suggested the need to reliably determine the availability of nutrients in waste products so that wastes can be diverted from landfill and recycled for use as fertilizer and soil amendment. Application of organic waste materials to land must, however, take into account both crop needs and the potential for environmental degradation.

4. Conclusion

Reversal of the prevalent land degradation in dry areas is a major challenge of the new century. With increasing population and improved living standards, the demand for food and forage will force the development of agro-ecosystems into less-favorable regions. This situation has also led to the intensification of cropping system. This has resulted in more rapid exhaustion of soil nutrients. Agro-ecosystems in these areas can be developed and sustained, but careful management is required. Recycling of organic wastes is one of the management options that could effectively ameliorate the land degradation in dry regions. The major source of organic waste for agriculture is animal manure, but small amounts of food processing and other industrial wastes (along with municipal wastes) are also applied to land. Utilization of organic wastes is not only to improve soil physical and chemical properties but also to provide nutrient source for crops. The use of organic wastes along with other appropriate management practices can provide a new opportunity for the effective utilization, conservation and restoration of land resources in the dry areas.

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3.11. Urban growth and land use change effects on water quality and ecosystem in Las Vegas watershed: implications for water resource management in semi-arid areas

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Abstract

The US south-west is experiencing rapid rates of population growth and faces dramatic challenges in the future years from drought and changing ecosystems caused by excessive demand for limited water resources and inevitable global warming. The problem is exasperated by decreasing water quality due to human induced land use change. Nonpoint source (NPS) pollution is one of the largest sources of water quality problems for the US and the rest of the world. It's the main reason that approximately 40 percent of the rivers, lakes, and estuaries in the US are not clean enough to meet basic uses. The problem is particularly severe in the semi-arid regions with perennial low flows, high evaporation and rapid urban growth. In Las Vegas Valley, located in semi-arid southern Nevada, NPS runoff is primarily from return ground water flow, excess watering of lawns and irrigation, and storm water. The rapid urban growth in the Las Vegas Valley during the past four decades has greatly increased the size of urban areas and basin imperviousness and these changes in land use have further increased runoff and pollutant loads. For Las Vegas Valley, there is a particular concern about water quality since the entire watershed drains via Las Vegas Wash (LVW) to Lake Mead, the region's primary drinking water supply. This paper reports the results of non point source pollution monitoring undertaken to describe the spatial and temporal patterns of pollutants in the LVW system. The monitoring stations were selected to evaluate non-point nutrient yields by land use categories (e.g. residential, commercial, golf courses, etc.). The results will provide valuable information for planning best management practices for combating NPS pollution in future and restoration of valuable water resources in arid- and semi-arid regions.

1. Introduction

The US National Water Quality Inventory: *2000 Report to Congress* identified urban runoff as one of the leading sources of water quality impairment in surface waters (USEPA 2002a). The most common urban sources and pollutants of concern are the people and their actions. Uncontrolled or treated runoff from the urban environment and from construction activities can run off the landscape into surface waters. This runoff can include such pollutants as sediments, pathogens, fertilizers/nutrients, hydrocarbons, and metals. Urbanization increases surface runoff, by creating more impervious surfaces such as pavement and buildings that do not allow percolation of the water down through the soil to the aquifer. It is instead forced directly into streams or storm water runoff drains, where erosion and siltation can be major problems, even when flooding is not. Increased runoff reduces groundwater recharge, thus lowering the water table and making droughts worse, especially for farmers and others who depend on water wells.

In Southern Nevada which is undergoing a rapid urbanization, non point sources pollution (NSP) has placed tremendous pressure on the local water resources. With the influx of population and development, changing land use patterns have contributed to more non-point and point source pollution. Storm water, urban run-off, leaches from golf courses and parks, construction, and industrial effluents have been the major contributors of NSP (Reginato & Piechota 2004) in the region. In Las Vegas, the Las Vegas Wash systems provide the second highest input into Lake Mead, the main source of the cities drinking water supply (LVWCC 2005). Here, due to a steady discharge of treated wastewater and runoff from Las Vegas, a formerly ephemeral watercourse is now perennial and supports a significant riparian corridor. The Wash and Lake Mead, immediately downstream, are also home to Federally-endangered species, including the Southwestern willow flycatcher (*Empidonax traillii extimus*) and Razorback sucker (*Xyrauchen texanus*). Therefore, it is important to understand the sources of NPS in the Las Vegas Wash systems. The specific source of the pollutants in urban runoff is generally not known and for a city this big (population over 2 million), it is very difficult. This can only be done by identifying and focusing on small watersheds.

The objective of our research was to establish a comprehensive monitoring program at the Flamingo/Tropicana Wash (a tributary to Las Vegas Wash which merges to Las Vegas Wash just upstream of a major treated effluent discharge point from the City of Las Vegas) to study the impact of NSP so that the temporal and spatial distribution pattern can be identified. This will then be used to study the impact of land use type on NSP. Flamingo/Tropicana Wash can be used as a window into the extent of NSP in the Las Vegas valley.

2. Methods

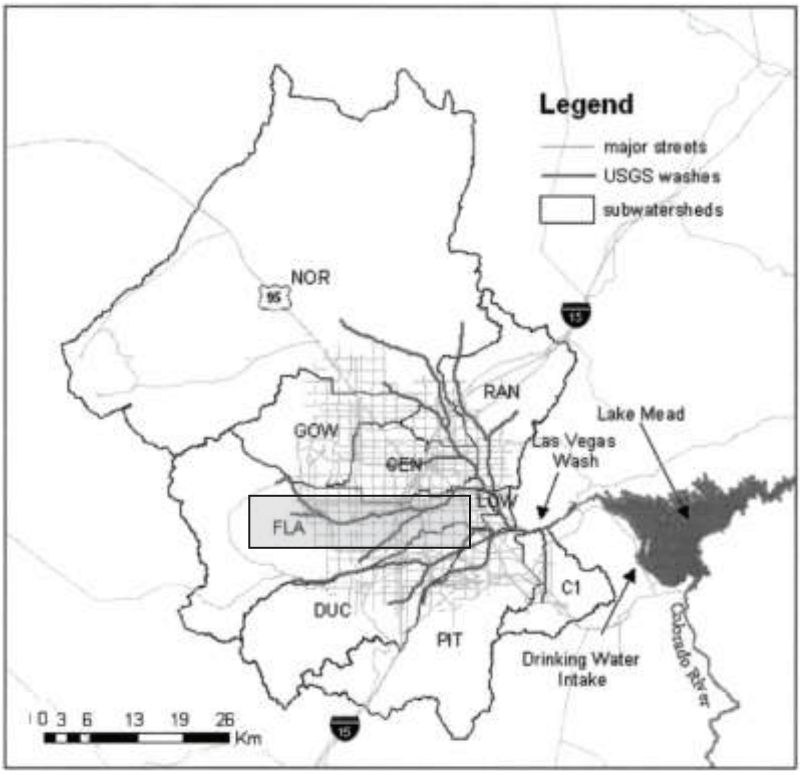
The Las Vegas watershed is comprised of nine major sub-watersheds which ultimately drain into the Las Vegas Wash. Most of these tributaries originate in the outskirts of the main city and are ephemeral and upon entering the urban periphery turn into perennial flow. Each tributary was designed for a specific function and purpose depending on the needs of the surrounding area. While some may be simple concrete channel others have become established wetlands supporting common emergent flora and fauna.

2.1. Study site

Flamingo/Tropicana Wash (referred to as TF Wash here onwards) is one of the major tributaries of the Las Vegas Wash with the total watershed area of 569 sq km, approximately 14% to that of Las Vegas Valley Watershed (Map 1). TF Wash stretches nearly 10 miles starting from the west of Las Vegas Blvd (the famous tourist site 'Strip') and merging with Las Vegas Wash at Nellis and Flamingo Rd on the east. TF Wash passes through various mega hotels in the Strip area to the University (University of Nevada Las Vegas), hospitals, golf courses and so on. Along the 10 miles stretch of TF Wash, five different sites were identified and selected broadly representing various land use types (Table 1). The first sample site, T/F1 is the entry point of the Tropicana wash.

Table 1. Sampling site description at Tropicana/Flamingo (TF) Wash

Site No.	Latitude	Longitude	Streets	Criteria for Selection	Land Use
T/F1	N36º, 06.503'	W115 º, 09.466'	E. Harmon Rd, West of Paradise Rd.	Upstream entry point at Tropicana	Urban center, contruction sites, barren lands
T/F2	N36º, 06.813'	W115 º, 08.824'	Flamingo Rd. and Swenson St.	Constructed riparian wetlands at channel	Business complexes, university school, parks
T/F3	N36º, 07.027'	W115 º, 08.51'	North of Flamingo Rd. on Claymont	Merging point of Flamingo Wash into Tropicana Wash	Recreation center, residential area, business complexes
T/F4	N36º, 07.377'	W115 º, 0.074'	South of Desert Inn Rd. on Eastern Ave.	Outlet point from gulf course	Golf course, hospital, business complexes
T/F5	N36º, 08.535'	W115 º, 03.989'	South of Sahara Ave on Nellis Blvd.	Downstream exit point	Commercial water pump, dense residential areas, construction



Map 1. Map showing Las Vegas Watershed with nine different sub-watersheds (Adopted from Reginato and Piechota 2004).

Upstream of T/F1 is barren lands, and adjacent to the site there is a dense urban center, with multiple construction sites. The second sample site, T/F2 is surrounded by business complexes and is in close proximity to a university and several parks. This site has an established constructed riparian corridor. The third study site, T/F3 is the convergence point for the Flamingo wash with the Tropicana wash. The surrounding land-use includes a recreational park and business complexes. The fourth site, T/F4 is the outlet point from a major commercial golf course, and is also parallel to several healthcare facilities. The furthest most point, T/F5 covers the longest stretch of land, and passes through dense residential areas and construction sites. T/F5 also experiences commercial water pumping.

2.2. Sample collection and processing

Monthly samples were collected from each site beginning March 2007 and ending in August 2008 which included grab water samples for total suspended solids (TSS), turbidity, total dissolved nitrogen (measured as nitrate, NO_3), total phosphorus (TP) and physical parameters such as dissolved oxygen (DO), pH, sp. conductivity, and temperature. Nalgene sample bottles (1 liter) used during sampling were acid rinsed prior to the sampling. Samples were collected from the center of each channel. Water samples were then immediately stored on ice. YSI multi-probe was used for physical parameters and was allowed to equilibrate below the surface of the water before taking measurements. Three (T/F2, T/F4, and T/F5) of the 5 sites were also gauged for discharge measurements. Gauging was done by setting out a transect across the width of the Wash and taking both depth (ft) and flow velocity (ft/s) at even intervals using a HACH/Marsh McBirney Flo-Mate Model 2000.

Total phosphorus content was determined using the colorimetric analysis after persulfate digestion (APHA 2005). Nitrogen was run using automated colorimetric method using a Lachat QC8000. TSS and chlorophyll *a* samples were filtered onto 47 mm TCLP glass fiber filters (GF/F) and processed immediately using standard procedures outlined in APHA (2005). Discharge was calculated by using the midpoint intersection method (Shaw 1998). The discharge data and concentrations were used to estimate the total nitrate and phosphorus loads into Las Vegas Wash on a seasonal and annual basis.

3. Results

YSI multi-probe data did not show a large variation with an annual mean temperature of 20.5 °C (±0.66), pH of 7.9(±0.03) and dissolved oxygen of 9.69 mg/l (±0.23), and specific conductivity of 3.3 mS/cm (±0.24) at all five sites. Discharge data at site T/F2 showed a maximum mean flow of 3.0 cfs during summer months and 0.94 cfs during spring. Similarly, site T/F5 recorded its highest and lowest flow discharges at 5.3 cfs and 1.7 cfs at summer and winter respectively.

Previously, total dissolved nitrogen (nitrate, nitrite and ammonia) measured at these sites showed that NO_3 contributed over 98% of the total nitrogen; hence in this study we used NO_3 to represent total dissolved nitrogen. Annual mean NO_3 concentration was significantly different ($p<0.001$; ANOVA) between the sites. The pair wise comparison (LSD Tukey) test showed sites T/F1 and T/F5 were similar but different from sites T/F2, T/F3 and T/F4. The highest value of annual NO_3 concentration was recorded as 4.35 mg/l (at T/F1) and the lowest was 2.59 mg/l (at T/F2; Fig 1).

Seasonal NO_3 load was estimated based on concentrations and the available discharge data (at sites T/F2, T/F4 and T/F5). Low discharge levels at site T/F1 and accessibility to the site at T/F3 limited our ability to calculate NO_3 loads at those sites consistently. In spring, site T/F2 had the lowest load (6.65E+02 Ton/season) and site T/F5 the highest (5.41E+04 Ton/season; Fig 2). Similarly, during winter months, site T/F2 had 2.30E+03 Ton/season of NO_3 and site T/F5 recorded 6.24E+03 Ton/season, respectively. Summer season recorded highest NO_3 loads at all three sites (T/F2 1.99E+04; T/F4 6.30E+04, and T/F5 1.46E+05 Ton/season).

Mean annual TP concentration was significantly different between the sites ($p<0.001$, ANOVA). The pair-wise comparison test of TP concentration between the sites showed that sites T/F1 and T/F2 were similar but different from sites T/F3, T/F4 and T/F5 (Fig 3). Site T/F1 measured the highest value of TP (94.48 µg/l) and gradually decreased downstream and was lowest at site T/F5 (26.49 µg/l). The TSS values varied between sites and seasons, significantly ($p<0.0001$, Fig 5).

Estimation of TP load showed that site T/F1 (12.78 Kg/season) had the smallest load and the load generally increased downstream in the spring. The most downstream site (T/F5) had the highest load (254 Kg/Season) and that peaked in spring months (Fig 4). The winter season had its highest load at site T/F2 (51.57 Kg/Season) and lowest at site T/F5 (36.05 Kg/Season). The summer months showed gradual increase of TP load from site T/F2 to site T/F5 (downstream), and also overall load was highest compared to other seasons. Estimation of TSS showed that the concentration was highest at T/F 1 and gradually decreased downstream (Fig 5). TSS at the most downstream site was ~ 20 mg/L which was slightly more than half of T/F 1.

4. Discussion

Physical parameters including pH, DO, temperature and specific conductivity did not show any significant correlation with nutrient concentrations at TF Wash. Most of the parameters were within the range of EPA standard (USEPA 2002b) for surface runoff.

The highest concentration of NO_3 was found at site T/F1. This site is the entry point for the Tropicana Wash and receives pollution from a highly populated urban center, the Las Vegas Strip. The Las Vegas Strip had several mega construction sites during our sampling periods. The flow at T/F1 is intermittent; perennial flow originates only after passing the Las Vegas Strip, and is the most probable source of NSP at T/F1. Site T/F2 experienced the lowest concentration of NO_3 within the entire TF Wash in all seasons. Site T/F2 supports a rich riparian wetland community along its entire channel which slows down the flow and perhaps absorbs a lot of nutrients. Interaction between the surface water and emergent plant communities including cattails and different bulrush species might have helped by creating a favorable environment for the nitrogen cycle. Wetlands plant communities help to assimilate NO_3 into organic form and utilize for their growth and reproduction (Kadlec and Knight 1996).

At site T/F3, Flamingo Wash merges with the Tropicana Wash and that might have contributed to a slightly higher NO_3 concentration relative to T/F2. Although site T/F4 passes through a gulf course, contrary to the traditional land use expectation of higher probability of NSP discharge, it had a relatively lower concentration. Our existing results from T/F4 deny the general argument that higher inputs of nitrogen from the excess use of fertilizers are an important non point source pollutant (King et al. 2007) at least at this site. It is possible that the managers of golf course do a good job of treating the NO_3 from the fertilizers.

The NO_3 concentration and loads were highest at site T/F5 at all seasons. The Wash channel from T/F4 to T/F5 has a long stretch with concrete lining which reduces the soil and surface runoff interaction

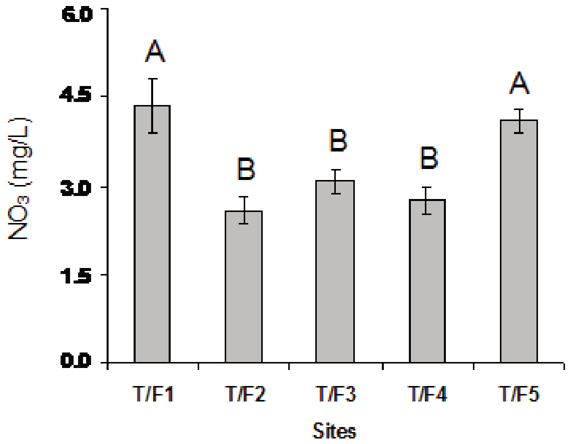


Figure 1. Annual mean nitrate (NO_3) concentration at TF Wash (March 2007-July2008). Letters that differ from one another represent statistically significance ($p < 0.05$, ANOVA).

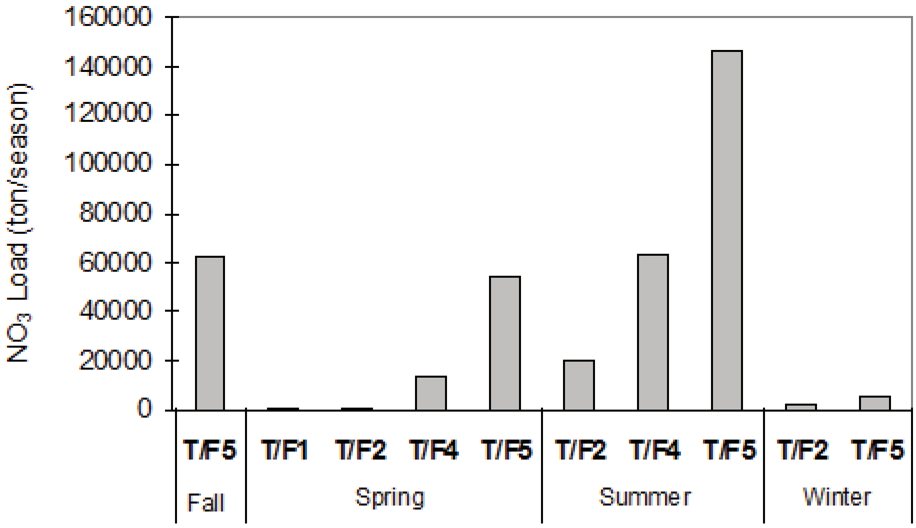


Figure 2. Seasonal variation of nitrate (NO_3) load at TF Wash (March 2007-July2008).

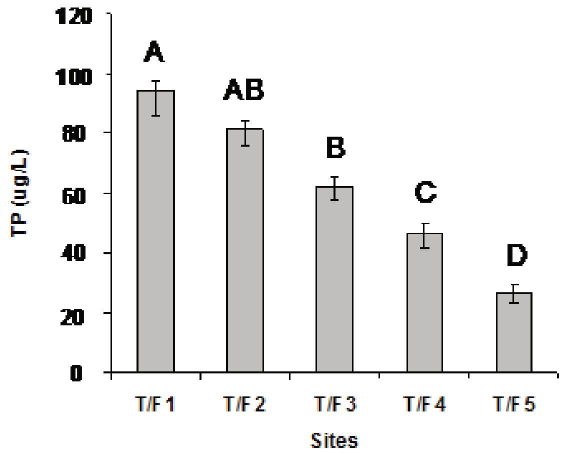


Figure 3. Annual mean total phosphorus (TP) concentration at TF Wash (March 2007-July2008). Letters that differ from one another represent statistically significance (p <0.05, ANOVA).

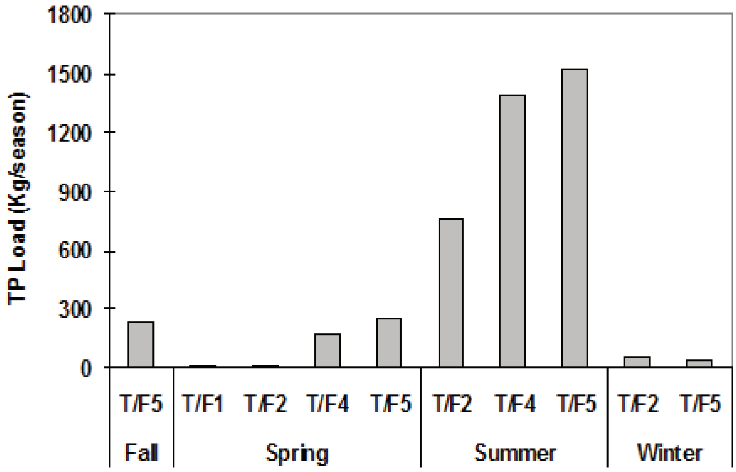


Figure 4. Seasonal variation of total phosphorus (TP) load at TF Wash (March 2007-July2008).

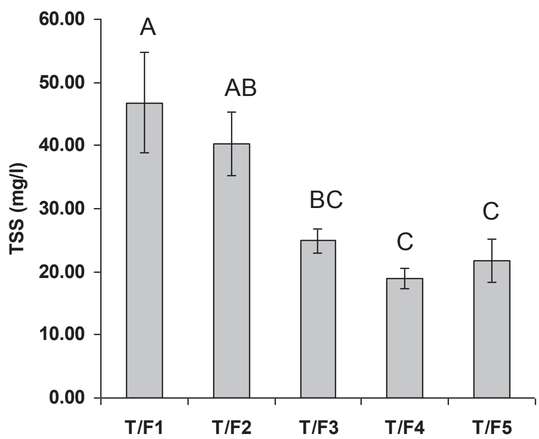


Figure 5. Annual mean total suspended solids (TP) concentration at TF Wash (March 2007-July2008). Letters that differ from one another represent statistically significance (p <0.05, ANOVA).

(Gergel 2005). Among our various sites, the Wash between sites T/F4 and T/F5 appears to have the highest amount of NSP from nearby residents via excess watering of lawns, washing of cars and haphazard dumping of wastes. This may or may not be true and may be due to limited nutrient cycling because of concrete lining and lack of wetlands and riparian plants compared to other sites.

At the start of the TF Wash, T/F1 had the maximum amount of TP. Within Tropicana/Flamingo sub-watershed, barren lands account for 70% of the total land use (Reginato and Piechota 2004). We think that the site T/F1 receives the maximum amount of P from this source as well as from nearby construction sites. Also the fact that TP concentration gradually decreases downstream indicates that T/F 1 gets more P input than the rest of the sites. This can also be explained by the highest TSS concentrations found at T/F1 and overall correlation between TP at TSS at all other sites. This suggests that sediments from the construction sites and urban centers are carrying excess phosphorus to the system especially during the summer months when rainfall is the highest. Throughout the TF Wash several silt trap structures have been constructed and they may have facilitated in reducing TP through sediment depositions. Past research on lake and streams has shown that settling of sediment particles is often associated with decrease in P concentration in the water column (Caraco 1991). The presence of aquatic plants at T/F 2 site may also further facilitate phosphorus uptake from the water column and the sediments increasing nutrient cycling (Vymazal 2006).

Our results suggest that, construction sites, baron lands and urban centers contributed highest NSP compared to other residential, hospitals, golf courses and business areas. At the same time, lush riparian corridor and sediment traps helped remove some of these nutrients. In terms of temporal distribution, not surprisingly, summer seems to be the worst of all seasons. Southern Nevada is one of the driest reasons of the country (i.e., less than 4 inch annual rainfall) and most of that rain comes as a monsoon in summer. Apparently, the monsoon rain compounded with massive urban centers, construction sites and baron lands contributes to higher NSP in the Las Vegas Watershed during the summer months.

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3.12. No-till practices in the drought and salt-affected region of Uzbekistan

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Abstract

Uzbekistan has laid major emphasis on agricultural growth and developing market economy since it became an independent republic. During this transition, large inefficient *shirkat* farms have been disintegrated and a number of small private farms established. The development of these new farms is constrained by limited information on crop potential, soil fertility and on-farm water management. New challenges of crop diversification, salinity, land privatization, etc. have emerged. There is an urgent need to pilot changes in irrigation and agricultural practices in the region in order to address the issue of declining water availability - this is a high priority for the Governments of Uzbekistan and Autonomous Republic of Karakalpakistan, which has witnessed severe droughts in the past. Conservation Agriculture based on no-tillage system, use of manures and crop residues, double cropping with appropriate crops, offers a great potential for sustainable crop roduction, improved water use and soil conservation. Results of some studies on conservation agricultural practices obtained from pilot project sites are presented in this paper.

1. Introduction

On achieving independence, Uzbekistan laid major emphasis on agricultural growth and efforts towards developing its own market economy. During this transition, large inefficient shirkat farms have been disintegrated and a number of small private farms established. For development of this new type of farms there are constraints associated with limited potential and abilities in crop, soil fertility and on-farm water management. During this period, new challenges of crop diversification, salinity, land privatization, etc. have emerged. There is an urgent need to pilot changes in irrigation and agricultural practices in the region in order to address the issue of declining water availability. This is a high priority for the Governments of Uzbekistan and the Autonomous Republic of Karakalpakistan. Farmers have limited experience in water conservation practices and utilizing salt and more drought tolerant crops. The government does not have the relevant technical expertise, but recognizes the need for radical change in both agricultural policy and practices for the region. The Food and Agriculture Organization of the United Nations was therefore requested to assist in introducing effective water and soil management practices and introducing more drought- and salt-tolerant crops on a pilot scale, for possible adoption on a wider scale.

A FAO/TCP/UZB project on “Sustainable agricultural practices in the drought-affected region of Karakalpakstan” (FAO/TCP/UZB/3102) was implemented by the Ministry of Agriculture and Water Resources (MAWR) of Uzbekistan from

October 2004 to September 2007 with technical backstopping from the International Center for Agricultural Research in the Dry Areas (ICARDA). The project was formulated to address the most pressing problem of land degradation in the Republic of Karakalpakstan (KK) that has resulted in reduced agricultural productivity and production and adversely affecting the livelihoods of the population mainly dependent on agriculture. The overall objective of the project was to demonstrate alternative, profitable and more sustainable production methods based on appropriate water and soil conservation practices and 'Conservation Agriculture' (CA) for small private farmers in KK.

2. Drought

Moderate to extreme drought conditions extend across the southern part and much of the eastern and western part of Uzbekistan. According to MAWR, the droughts of 2000 and 2001affected majority of the country's land mass and this was the worst water shortage event in the living memory of the present farmers. The area is naturally arid and, with an annual rainfall of only 110 mm, humans, animals and agriculture are almost entirely dependent on the residual flow in the Amu Darya River for survival. River flow fell dramatically leading to an emergency situation in many areas, particularly in northern districts. In 2005, agricultural losses from drought in Karkalpakstan (KK) were significantly higher as compared to other years but less than in 2000 and 2001. The losses in Chimbay, Shumanay, and Kegeyli *rayons* in 2005 were similar. Drought affected the wheat crop severely in KK last year and the production was the smallest since 1991. Drought can change many long-held convictions. Wheat in Chimbay is normally grown to help the following crops due to rotational benefits, weed control, and moisture accumulation. In 2002, they found that the wheat yields were quite high while they looked for ways to salvage some forage from other dryland crops.

3. Conservation Agriculture

Conservation Agriculture (CA) is particularly useful in dry areas, where low rainfall is the main constraint to growing crops. CA enables the soil to store more of the precipitation that falls during the fallow period, enabling adoption of more intensive crop rotations. The fallow period should be shortened to minimum period or eliminated all together if feasible. The increased numbers of continuous vertical macropores in top soil under CA increase the infiltration of rain water into the ground and the recharge the aquifer. The increased soil organic matter levels improve the availability of water accessible to plants. One percent of organic matter in the soil profile can store water at a rate of 150 m^3 ha^{-1}. The permanent soil cover and the avoidance of mechanical soil tillage reduce the unproductive evaporation of water. As a result, the water use efficiency is increased and the water requirements for a crop can be reduced by about 30%, regardless of whether a crop is grown under irrigated or rainfed conditions (Bot and Benites 2005).

Table 1. Soil moisture in the top soil with no-till corn in the late-vegetative and early-reproductive stages of growth in 2006

Date	Soil moisture (%)	
	Tilled	No-tillage
June 10	13.95	15.51
June 24	16.73	17.01
July 9	13.09	14.51
July 23	10.33	11.72

The reasons for higher yields generally observed under no-till system of the CA were not clearly understood, but it was thought that the benefits could be because of better moisture availability. To verify this, the amount of water in the top 25 cm of soil was monitored in the no-till corn during the late-vegetative and early-reproductive stages of crop growth. The results showed that significantly more water was found at each date of sampling in the no-tillage treatment (Table 1). The moisture on June 24 was similar due to irrigation. However, the moisture declined in the no-till treatment at a slower rate indicating that the moisture was more efficiently used in the no-till treatment

The use of permanent soil cover through crops, mulch or green manure cover crops, in the CA system, complements the zero tillage effects by supplying substrate for soil organic matter build up and for the microbial activity in the soil, which is facilitated by not disturbing the soil. Through protection of the soil surface the mulch reduces evaporation and avoids crusting. It also suppresses weed growth and reduces problems experienced in direct seeding or zero tillage when applied in isolation. In addition, the application of zero tillage and direct seeding technology facilitates the management of residues, which in the conventional tillage systems are often considered a problem.

Mulching is one of the simplest and most beneficial practices for conserving soil and water. Mulch is simply a protective layer of a material that is spread on the top of the soil. It can either be organic such as manure, grass clippings, straw, bark chips and similar materials or inorganic such as stones, brick chips, and plastic. However, both organic and inorganic mulches have numerous benefits. The influence of crop residue on soil moisture content and bulk density in the upper layer of the ground was studied (Table 2). Results indicated that the crop residue increased soil moisture by 3.2% and decreased bulk density by 0.1 g/cm^3. The bulk density decreased due to better development of secondary roots which are located in the upper layer of the soil (Table 2).

Biological activity of the soil is one of the main characteristics of the soil fertility. Freshly cleared soil profile was stuck to the flat emulsified side of a photo paper and covered with the soil. Extracted photo paper was washed to remove the contaminations and was dried in the shade. The protease activity of the soil was studied and was found higher in the soil with crop residue than in the field without crop residue (Photos 1 and 2).

Plant residues positively influence the soil quality, decrease soil density, and increase soil moisture and biological activity of the soil. That is why keeping crop residues on the surface of the field with appropriate machines can improve physiological and biological properties of the soil, ultimately increasing the soil productivity.

Table 2. Influence of crop residue on soil moisture and bulk density

Field number	Soil depth (cm)	Moisture (%)		Bulk density (g/cm^3)	
		Residue	No residue	Residue	No residue
7	0-10	12,2	9,7	1,49	1,60
8	0-10	10,6	6,8	1,56	1,60
Average	0-10	11,4	8,2	1,50	1,60

Manure has been used for centuries as a fertilizer for farming, as it is rich in nitrogen and other nutrients, which facilitate the growth of plants. Liquid manure from cattle and other animals is usually injected directly into the soil to reduce the unpleasant smell. Manure from cattle is spread on fields using a manure spreader. Poultry droppings are harmful to plants when fresh but are valuable fertilizers after a period of composting. A large number of Karakalpak farmers are using green manure to improve soil fertility.

In an experiment, different rates of manure (10 t/ha, 15 t/ha, 20 t/ha), and mungbean and sorghum straw were applied on winter wheat. Effects on soil humus content and yield attributes and grain and straw yield of wheat were studied (Table 3). Taking into account the slow decomposition of organic manure and crop residue it is too early to make definite conclusions about humus content of the soil, but the results obtained are encouraging. The humus content increased remarkably but the effect of organic manure and crop residue on the soil fertility should be further tested in the future.

Photo 1. Protease activity of soil without crop residue.

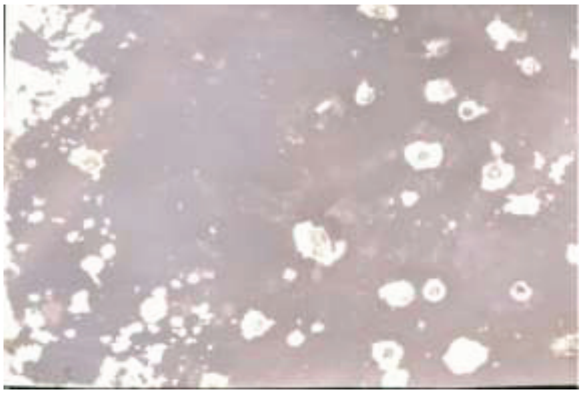

Photo 2. Protease activity of soil with plant residue.

Table 3. Effect of application of mulching material (manure and crop residues) on the humus content of soil and agronomic traits and yield of winter wheat (2005-2006

№	Treatment	Humus content, (%)	Plant height (cm)	Spike length (cm)	Grains per spike	Yield (t/ha)	Yield increase (t/ha)
1	Manure @ 10 t/ha	0.35	52,1	7.15	32,5	2,24	0,61
2	Manure @ 15 t/ha	0.28	56,8	7,4	33,2	2,31	0,68
3	Manure @ 20 t/ha	0.35	62,6	9,2	35,5	2,49	0,86
4	Mungbean res. @ 10 t/ha	0.34	52,5	6,8	27,4	1,85	0,22
5	Sorghum res. @ 10 t/ha	0.31	48,8	6,4	24,0	1,59	-
6	Control	0.21	47,1	6,2	24,6	1,63	-

Table 4. Bulk density of the surface layer of loamy soil for beds and furrows

Field №	Bulk density, g/cm^3			
	2004 (November)		2005 (August)	
	In furrow	On the bed	In furrow	On the bed
3rd	1.39	1.36	1.48	1.47
6th	1.39	1.34	1.51	1.52
7th	1.38	1.27	1.63	1.54
Average	1.38	1.32	1.54	1.51

Table 5. Bulk density in 0-10 cm soil layer as affected by crop residue

Field No.	Bulk density, g/cm^3	
	with residue	no residue
7th	1.49	1,60
8th	1.56	1,60
10th	1.44	1,45
Average	1.49	1,55

Table 6. Dry salt content as affected by mulching

Treatment	**% from air-dry mass of the soil**
Control (no mulching)	0.80
Manure	0.25
Mungbean crop residue	0.50
Sorghum crop residue	0.20

Table 7 Soil moisture (%) as affected by the tillage method

Soil depth, cm	**Conventional tillage**				**Conservation agriculture**			
	before and after irrigation				with no irrigation			
	1st field		10th field		2nd field		12th field	
	25 June	10 Aug.	25 June	10 Aug.	25 June	25 July	25 June	25 July
0-5	1.7	17,5	2,1	15,3	4,3	2,8	9,3	3,6
5-20	4.5	19,6	4,7	21,4	9,1	8,0	11,1	8,9
20-40	9.9	24,5	10,1	23,0	13,1	13,1	13,2	10,8
40-60	11.8	29,0	11,0	27	16,2	20,7	13,9	15,1

The application of manure brought a significant increase in yield contributing characters and grain and straw yield of wheat (Table 3). The increase in the rate of manure application from 10 t/ha to 20 t/ha also resulted in a significant increase in yield and yield contributing characters. The application of manure or mungbean and sorghum residues resulted in significantly higher content of soil moisture in 0–15 cm soil depth as compared to the control which was simultaneously reflected in yield and yield contributing charactersThe soil bulk density in some of the fields of the project demonstration pilot sites, which had been planted for 2004-2006 years with beds, and in fields under a regime of conventional tillage was compared. All fields were irrigated by flooding method, and planted with different crops. The samples were taken just before the first spring tillage event in 2004 to eliminate the effect of recent management practices. In the beds, bulk density was lower than in furrow (Table 4). These data indicate that compaction may decrease in some cases when beds are retained with the minimum-tillage operations as compared with conventional practices (Umarov and Ikramov 1983).

Keeping the crop residues in the field positively influenced the bulk density in the upper layers of the soil (Table 5). Many small secondary roots in the upper layer of the soil were found, which positively affected bulk density

As indicated before, one of the main aspects of the CA practices is to leave crop residues in the field to provide mulching, which will prevent evaporation. Consequently, the salts will not be accumulated in upper layer of the soil. Mulching with sorghum and mungbean crop residues and also with organic manure decreased the salt contents in 0-10 cm soil layer up to 1.6-4 times. (Table 6).

The effect of tillage method on soil moisture showed that soil dried up by the end of June in the conventional tillage and the soil moisture was better conserved in no tillage practices (Table 7).

The above results show that CA, by retaining crop residue on the soil surface, especially under zero tillage, decreases bulk density, conserves soil moisture, decreases evaporation and reduces salt content in the upper layers of the soil. All these are important for attaining sustainable production in the dry areas.

Another important component of CA is diversified cropping systems as an alternative to the mono-cropping or one dominant rotation such as cotton-wheat. Multiple cropping offers much opportunity to provide additional production from the available land resources. Introduction of new technology, based on the no-tillage system, herbicides and residue management, offers an opportunity to adopt double- or multiple-cropping. Fuel for producing agricultural products has become expensive. By using no-tillage and the multi-cropping technique, two crops can be planted with the same amount of fuel required as for one crop in conventional system. Fuel requirement for harvest, processing and transportation would be higher than for single crop production. However, the overall cost of unit production is reduced, and the equipment is used more frequently and labour requirements are spread more evenly through the year.

As farmers move to double-cropping, timing of planting of crops becomes critical. The no-tillage system, by eliminating ploughing and land preparation, reduces the time element while retaining soil moisture and reducing runoff, soil erosion and evaporation. Long-term advantages include improving or at least maintaining soil structure and harvesting at least two crops every year. Besides, double-cropping plays important role in the conservation of soil as it allows crop canopy coverage of the land surface otherwise kept exposed under weedy fallow.

Crop rotation is an integral part of good crop production system. The greatest benefit of a good crop rotation is increased yield. A well-planned crop rotation will help in insect and disease control and maintaining or improving soil structure and organic matter levels. Use of a variety of crops can reduce weed pressures, spread the workload, protect against soil erosion and reduce risk. Legume crops, with their ability to fix atmospheric nitrogen, have become valuable component of crop rotation because of the increased cost of fertilizer nitrogen. Within a crop rotation, different root systems influence different soil horizons and improve the efficiency of the soil nutrient use. In general, the soil structure becomes more stable (Bot and Benites 2005).

In most of the region, the practice of growing cotton and wheat for two or more years is common. Perhaps, the greatest impact of back-to-back years of cotton has been the accelerated spread of cotton boll weevils. The increased number of years of cotton in the rotation is also increasing the susceptibility of Karakalpakstan's soils to erosion. In fact, the structure of soils in cotton-wheat rotation is actually poorer than that of soils that were previously under cotton-alfalfa crop rotation.

The greatest benefit from crop rotation comes when crops grown in sequence belong to totally different families. The response of wheat yield to crop rotation provides an example of the type of response that is possible (Table 8).

The fibrous root systems of cereal and forage crops (including mungbean) are excellent building soil structure. Studies have shown that the benefits of including wheat, and especially wheat plus mungbean, may persist beyond just the following year. Double cropped mungbean after wheat resulted in yield increases compared to when mungbean was not included in 3rd rotation system.

In choosing the crops in a rotation, the economics of the entire crop rotation instead of a single crop in isolation should be considered. Also, any potential threat of an insect or disease problem in the rotation has to be considered. Cover crops in the rotation may also have an impact on diseases and pests, either positive or negative. (Table 9) shows various crop rotations and their potential impacts based on which recommendations can be made. It is not a comprehensive listing of crop problems, but it does highlight the main impacts which one should be aware of.

Table 8. Wheat yield response to rotation. All plots received 140 kg N/ha

Rotation	Wheat grain yields (t/ha)		
	Kuvvat (2005-06)	Ayap usta (2005-06)	Bakht (2005-06)
Cotton-wheat	2.78	2.56	2.10
Cotton-sorghum-wheat	2.47	2.51	2.30
Cotton-sorghum-wheat (+mungbean)	3.35	2.65	3.15

Table 9. Various crops and their potential impacts in rotation under conservation agriculture. Crops having negative impact are not recommended (NR) and those that have no such effect are recommended (R). With some crops there may be a need for caution (C) if used in rotation

Crop to be grown after the previous crop	Previous crop						
	Cotton	**Winter wheat**	**Sorghum**	**Proso millet**	**Sunflower**	**Sesame**	**Legumes**
Cotton	**NR** • yield depression • vascular wilt and other root diseases	**C** • slugs may cause damage in no-till	**R** • May increase density of rice stink bug *O. pugnax*	**R**	**C** • yield depression	**R**	**R**
Winter wheat	**R**	**NR** • yield depression • root diseases	**C** • yield depression • weed escapes may be difficult to control	**R**	**C** • yield depression	**R**	**R**
Sorghum	**R**	**R**	**NR** • yield depression	**R**	**C** • yield depression	**R**	**R**
Proso millet	**R**	**R**	**R** • wireworms	**NR** • yield depression	**C** • leaf diseases • yield depression	**R**	**R**
Sunflower	**NR** • increased risk of Fusarium head blight	**C** • yield depression	**R**	**NR** • take-all • leaf diseases	**NR** • take-all • leaf diseases • yield depression	**R**	**C**
Sesame	**R**	**R** • slugs may cause damage in no-till	**R**	**R** • slugs may cause damage in no-till	**R**	**NR** • yield depression • root rots	**R**
Legumes	**C** • slugs may cause damage in no-till • check for herbicide carryover	**R** • check for herbicide carryover	**R**	**R**	**R** • slugs may cause damage in no-till	**C** • white mould	**NR** • white mould • blackleg • root rots • yield depression • check for herbicide carryover

Legend: (**R**) Recommended; (**C**) Caution; (**NR**) Not Recommended

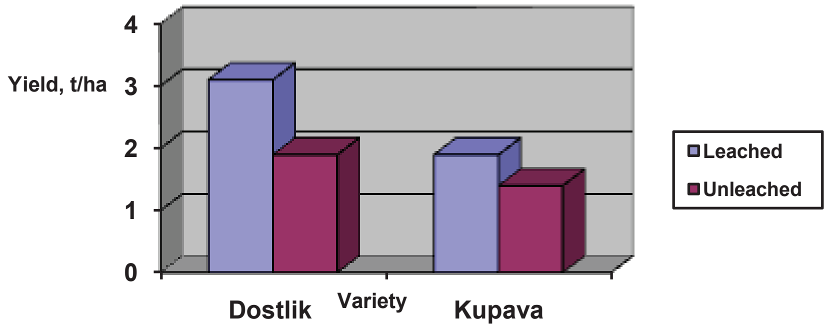

Figure 1. Yield of wheat varieties 'Dostlik' and 'Kupava' in farmers' field with and without soil leaching.

4. Salinity

Salinity is another major problem in the region, particularly under irrigated system because of improper irrigation and drainage methods. The area of saline irrigated lands in Uzbekistan amounts to 2.2 million hectares (low-salinity 1.2 million ha, medium-salinity 0.71 million ha, and strong-salinity 0.29 million ha). An experiment was conducted to examine the effect of salt on plant available water in a heavy clay soil, using a relatively salt-tolerant crop, sorghum cultivar 'Boy jo'khari' and a more salt-sensitive crop, wheat cultivar 'Dostlik'. The plants were then grown in the salt-affected field. Once permanent wilting point was reached plants were harvested, and soil water content was measured. Yield of both sorghum and wheat was reduced in the salt-affected field compared with the non-salt-affected field.

Although bread wheat is relatively more sensitive to salinity than such crops as sorghum, cultivar 'Dostik' has been found to be better under saline conditions than the other cultivars of winter wheat (Figure 1).

Yield of the bread wheat variety "Dostlik" was higher than other varieties planted in the neighbouring farms: in a Satniyaz farmer's field without soil leaching it was 1.9 t/ha and with leaching it was 3.0 tons per hectare. In the neighbouring farmer's field, in Shokharik farm the wheat yield was 1.4 t/ha and 1.9 t/ha, respectively. A total of 4000 m^3/ha water was saved.

5. Conclusion

The practices of conservation agriculture tested in the pilot sites in the project have demonstrated the importance of conservation tillage, bed-planting, use of crop residues for mulching to reduce evaporation and salt build up in soil surface, use of manures in improving humus content, bulk density, water infiltration and conservation, and biological activity of soil, and the value of diversifyimg cropping pattern by introduction of appropriate crops in the rotation. These will help in improving sustainability of production system in Karakalpakstn.

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3.13. Effect of super-absorbent polymers on yield and water use efficiency of red bean (*Phaseolus vulgaris* L.)

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Abstract

The effect of super absorbent polymers on yield, yield component and some physiological characteristics of different red bean varieties under drought stress was studied. Experiments were carried out in field and greenhouse conditions in 2005. First, the possibility of using mannitol at three osmotic potentials (0,-4,-8,-12 bar) for selection of red bean varieties ('Derakhshan', 'D81083' and 'Naz') tolerant to stress during germination was examined. In the field experiment, three varieties were evaluated under normal and drought stress (by change in the frequency of irrigation) conditions with and without application of super absorbent (0 and 7%). In greenhouse experiment, varieties, frequency of irrigation and super absorbent concentration (0, 5%, and 7%) were evaluated. Naz had longer root and higher root length stability than Derakhshan and D81083, indicating better physiological, agronomical and biochemical characteristics in field. WUE was higher in 2-day irrigation interval than 6-day interval. Super absorbent polymer at 7% concentration increased WUE up to 49.2%. Naz showed higher WUE than Derakhshan and D81083. Naz with 7% polymer concentration and 2-day irrigation interval showed higher WUE. Results showed using super absorbent polymers can increase interval between irrigations and it can decrease drought stress effect on plants and thus increase WUE.

1. Introduction

A series of novel copolymer superabsorbents based on monomer acrylamide, potassium methacrylate, and 2-hydroxyethyl methacrylate have been prepared by copolymerization. The experimental results of superabsorbent polymers (SAPs) show a better absorbency in both water and NaCl solutions. The water retention in the soil is enhanced using the above superabsorbents. SAPs can be considered as water-managing materials for agriculture and horticulture purposes in desert and drought-prone areas (Mohana et al. 2002).

De Varennes and Queda (2005) investigated the possibility of using an insoluble polyacrylate polymer to improve the quality of a copper-contaminated soil. Growth of annual medic (*Medicago polymorpha* L.) was stimulated in the polymer-amended soil, such that total biomass produced was three times that of plants from unamended soil. Bakass et al. (2002) studied the kinetic behavior of the reaction of drying soil representing the Marrakesh region of Morocco in the presence of an superabsorbent polymer. The presence of a polymer in the soil diminished the kinetic drying of the soil, which will be of help in reducing the water loss in the process of irrigation. The presence of a polymer in the soil enables a complete modification of the kinetic regimes controlling the soil-drying.

This experiment was conducted to study the effect of super absorbent polymers on yield, yield component and some physiological characteristics of different red bean varieties under drought stress in field and greenhouse conditions.

2. Material and methods

2.1. Laboratory experiment

In this experiment possibility of using mannitol for selection of red bean varieties for moisture stress tolerance during germination was examined by measuring germination as well as root and shoot length and stability. First factor was three varieties and second factor was four levels of osmotic potential (0,-4,-8,-12 bar). A complete randomized design (CRD) with four replications was used. Stability (%) was expressed as: [{Root length(0 Bar) - Root length(-8Bar) / Root length(0Bar)}*100]. Susceptibility (%) was computed as: [100 - Stability].

2.2. Greenhouse experiment

In greenhouse experiment a randomized complete block design (RCBD) with four replications was used. There were three varieties (Derakhshan, D81083 and Naz) as the first factor, three times of irrigations (2,4, and 6 times irrigation) as second factor, and three levels of super absorbent (0,5%, and 7%) as the third factor. For obtaining of 5% concentration of polymer, 240cc water was added to 3 g polymer powder and the gel was mixed with 5 kg soil in a pot. For obtaining of 7% concentration of polymer, 400cc water was added to 5g polymer powder. Various physiological and yield parameters were measured.

2.3. Field experiment

This experiment was carried out at experimental farm of Islamic Azad University-Karaj Branch in 2005 Experimental design was split factorial with four replications. Irrigation treatments (control and withholding water at the beginning of flowering stage) were in the main plots, three red bean varieties(Derakhshan, D81083 and Naz) and two levels of super absorbent (0 and 7%) were the sub and sub-sub plots respectively. The irrigation was given based on soil moisture monitoring by measuring electrical conductivity. When soil moisture content reached 12% the time drought stressed plants were irrigated. At the beginning of flowering, irrigation was stopped up to the end of the crop maturity. For applying SAP, 3200cc water was added to 40 g polymer powder and the gel was poured on the top of a row, and then covered by soil. The stability was determined as : stability=[{seed yield(control)- seed yield(drought stress)/ seed yield(control)}*100] and susceptibility was determined as: [100 - stability].

3. Results

3.1. Laboratory experiment

Results showed significant differences ($P<0.01$) for germination, root and shoot length and root/shoot ratio (Table 1). Increasing soil moisture stress decreased germination, root and shoot length but increased R/S ratio. NAZ variety showed better germination, longer root and shoot, and R/S ratio. Susceptibility indexes with two methods (Habibi et al.1995, and Fischer and Maurer1976) were measured. Both methods showed same results. Based on index for root length, NAZ was resistant and Derakshan was susceptible. The results were the same for shoot length and germination.

3.2. Greenhouse experiment

Results showed significant differences($P<0.01$) among irrigation treatments for seed yield, pod yield, TDW, HI (data shown in Table 2), pod length, number of pod per plant, number of seeds per pods, seed 1000 weight, leaf membrane leakage, chlorophylls a, b, a+b, RWC and WUE. With increasing interval between irrigations all the attributes decreased except the leaf membrane leakage which increased, showing the leaf cell membrane damage.

Varieties and superabsorbent concentrations showed significant differences for all characters. NAZ variety produced 1431.5 g/m^2 seed yield and Derakhshan variety produced 651.8 g/m^2. Superabsorbent polymers increased chlorophyll a, b, a+b, RWC, WUE, yield and yield components, but decreased leaf membrane leakage Susceptibility indexes for seed yield, TDW, 1000 seed weight and HI with two methods were measured. Both methods showed same results. Naz variety for seed yield, TDW, 1000 seed weight and HI showed more tolerance and stability under drought.

3.3. Field experiment

Analysis of variance for seed yield indicated significant differences ($P<0.01$) among irrigation treatments, cultivars and superabsorbent polymer treatments (Table 3). Seed yield decreased greatly (53%) by drought stress. Comparison of cultivars showed thatNaz produced 30% more seed yield (1538kg/ha) compared with D81083 (1084 kg/ha). Derakhshan produced 48% less seed yield (795 kg/ha) compared with Naz.

Means investigations also indicated that superabsorbent polymer (7%) had significant effect on seed yield. Sufficient water is essential for high seed yield production and super absorbent polymer increased available water for use by plant resulting in increase seed yield. There was significant interaction effect of cultivar× superabsorbent polymer and irrigation× superabsorbent polymer (data shown in Table 3). Naz had highest seed yield both in stress and control condition. Application of super absorbent polymer increased seed yield in both condition (control and stress).

Drought stress decreased water use efficiency but superabsorbent polymer increased WUE. Drought also increased membrane leakage but superabsorbent polymers decreased damage of membrane. These results support the results of the greenhouse experiment. Drought also decreased chlorophyll a, b, a+b content but superabsorbent polymers decreased harmful effect of drought on chlorophyll. Relative water content decreased under drought stress but superabsorbent polymers increased RWC. This is important in dry region because it can help roots to absorb water easily. Antioxidant enzymes (SOD, CAT, GPX) increased under drought stress but superabsorbent polymers decreased activity of enzymes. This shows that using superabsorbent polymers protected cells from oxidative effects of free radical oxygen. Drought stress also increased MDA, Di-tyrosine and 8-oh-dG.There was no significant difference among varieties for Di-tyrosine and 8-oH-dG.Susceptibility indexes for seed yield,TDW,1000 seed weight and HI (With two methods) were measured. Both methods showed same results. NAZ variety for seed yield, TDW, 1000-seed weight and HI showed more tolerance and stability under drought.

Table 1 . Mean comparison of treatments in the laboratory experiment

Treatments	Germination (%)	Root Length (cm)	Shoot Length(cm)	R/S
Osmotic potential (Bar)				
0	87.08 a	5.989 a	6.942 a	0.8392 c
-4	80.42 b	5.271 b	5.917 b	0.8683 c
-8	72.50 c	1.496 c	0.9717 c	1.508 b
-12	60.83 d	0.9517 d	0.5492 d	1.699 a
Varieties				
Naz	91.56 a	4.618 a	4.415 a	1.340 a
D81083	74.96 b	3.452 b	3.628 b	1.235 b
Derakhshan	59.38 c	2.211 c	2.742 c	1.111 c

Table 2. Mean comparison of treatments in the greenhouse experiment

Treatments	Germination (%)	Root Length(cm)	Shoot Length(cm)	R/S
Osmotic potential (Bar)				
0	87.08 a	5.989 a	6.942 a	0.8392 c
-4	80.42 b	5.271 b	5.917 b	0.8683 c
-8	72.50 c	1.496 c	0.9717 c	1.508 b
-12	60.83 d	0.9517 d	0.5492 d	1.699 a
Varieties				
Naz	91.56 a	4.618 a	4.415 a	1.340 a
D81083	74.96 b	3.452 b	3.628 b	1.235 b
Derakhshan	59.38 c	2.211 c	2.742 c	1.111 c

Table 3. Interaction of treatments for different traits studied in the field experiment

Treatment Combinations	Seed yield (kg/ha)	1000-Seed weigh	Harvest index (%)	SOD (u/mg protein)	GPX (u/mg protein)	CAT (u/mg protein)
Irrigation x Varieties						
Derakhshan, Control	1120.25c	46.37 a	42.08 c	1152 a	11.70 a	80.57 a
D81083, Control	1537.9 b	40.42 b	44.86 b	1300 a	1152. a	76.72 a
Naz, Control	2002.31 a	26.20 c	47.16 a	1620 a	13.69 a	87.35 a
Derakhshan, Stress	471.17 e	23.78 d	35.23 e	2139 a	17.42 a	121.80 a
D81083, Stress	630.31 d	21.23 e	38.57 d	2392 a	17.08 a	131.30 a
Naz, Stress	1074.95 c	18.21 f	42.13 c	2697 a	20.03 a	150.39 a
Irrigation x Superabsorbent						
Control, 0%	1323.61 b	38.89 a	43.50 a	1399 c	12.42 c	79.75 c
Control, 7%	1783.35 a	40.44 a	45.90 a	1316 c	12.19 c	83.35 c
Stress, 0%	587.61 d	18.20 a	37.34 a	2689 a	20.20 a	141.17 a
Stress, 7%	863.34 c	23.95 a	39.95 a	2130 b	16.15 b	121.82 b
Varieties x Superabsorbent						
Derakhshan, 0%	649.60 d	31.76 c	37.36 a	1773 a	15.30 a	104.92 a
Derakhshan, 7%	941.82 c	38.40 a	39.96 a	1519 a	13.82 a	97.45 a
D81083, 0%	918.07 c	27.71 d	40.46 a	1988 a	15.04 a	109.32 a
D81083, 7%	1250.13 b	33.95 b	42.97 a	1704 a	13.56 a	98.70 a
Naz, 0%	1299.17 b	20.17 f	43.45 a	2371 a	18.59 a	126.14 a
Naz, 7%	1778.08 a	24.23 e	45.85 a	1947 a	15.13 a	111.60 a

4. Conclusions

The experiments show that varieties with longer root and higher stability under high osmotic potential in laboratory may have higher seed yield stability in greenhouse or field experiments under drought stress. Results also showed varieties with longer root length in laboratory may produce higher antioxidant enzymes, so indirectly help us selection of drought tolerant genotypes.

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3.14. Improving barley productivity (*Hordeum vulgare* L.) under saline and calcarious soil conditions

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Abstract

This study was conducted in field, during the 2005-2006 and 2006-2007 seasons at two research stations, to evaluate the effect of three foliar application (Biomajic 2.5 kg/ha, KCl 2% and tap water) and three biofertilizer treatments (seed inoculation with Nitroben, Seryalen and control) on growth, yield and its components, as well as the biochemical aspects of barley plants grown under saline (at Wadi Sadr Agricultural Experiment Station in South Senai) and calcareous (at Maryut Agricultural Research Station, near Alexandria) soil conditions. Biomajic and KCl as a foliar application could correct the metabolic disturbance under stress conditions as reflected in improved plant growth, yield components and yield, as well as chemical composition as compared with the control. However, KCl foliar spray produced the highest significant mean values for all the traits under saline soils during both the seasons. Under calcareous soil conditions, Biomajic foliar application was superior to other treatments in both the seasons. Plant growth, yield components and yield as well as chemical composition of barley plant was improved with application of two biofertilizers under both saline and calcareous soil conditions. Inoculation of seeds with Seryalen gave best effects under both saline and calcareous soil. However, the improvement with different bio fertilizer treatments was better under calcareous soils than under saline soils.

1. Introduction

Barley *(Hordeum vulgare* L.) is an important cereal crop because of its many uses. It is grown under wide range of environmental conditions, but generally in areas where water supply is limited and where crop production depends mainly upon rainfall. Barley has bean grown as the main cereal crop in the most of the rain-fed areas of the Western North Coast in Egypt (El- Sayed et. al.2003). However, the yield are low. Application of improved cultural practices could raise productivity and minimize the wide gap between the high and low yield environments. Limited water availability is one of the most widespread environmental constraints on plant growth and yield. Many investigators studied the effect of water deficit on barley yield and its components.

Foliar aG60pplication and bio-fertilizer are considered to have potential for improving plant growth and correcting the nutritional imbalance caused by growing plants under saline and calcareous conditions (El-Agamy et al. 1991; Sallam 1992). Recently, there has been growing interest in increasing salt tolerance of plants by using foliar application of biostimulants (e.g., biomagic) or seed inoculation with biofertilizers. (Abdel- Hameed 2002; Ismail 2002). Moreover, the application of K was recommended as effective agent for improving growth, yield and some chemical composition of barley plant under saline soil (Ozoris et al. 1984). Therefore the aim of this investigation was to evaluate the effectiveness of foliar application of Biomagic and KCl treatments and biofertilizers (i.e., Nitroben and Seryalen) on growth, yield attributes, and yield of barley plant grown under saline and calcareous soil conditions.

2. Material and methods

Studies were made during 2005/2006 and 2006/2007 growing seasons at Wadi Sudr Agricultural Experimental Station, Desert Research Center South Sinai Governorate (saline soil) and at Maryut Agricultural Research Station, Desert Research Center, at Maryut region (sandy and calcareous soil) to evaluate the effect of three foliar application treatments (KCl 2% , Biomagic 3kg/fed. and tap water as a control) and three bio-fertilizer treatments (Nitroben1kg/fed, Seryalen 800g/fed and control) on the performance of barley. Seeds of barley cultivar Giza 123 were planted on 15th November at the rate 70 Kg/fed at the two locations. The plot size was $6m^2$ (2mx3m) with 12 rows, 25cm apart with 2m length. Organic manure and calcium super phosphate (15.5 % P_2O_5) at the rate of 25 m^3 and 31 kg P_2O_5/fed, respectively, were applied during tillage. Ammonium nitrate at the rate of 70 kg N/fed. was added in two equal doses at 30 and 60 days after sowing. Plants were irrigated. Directed foliar-spraying applications were done twice, 45 and 75 days after sowing, using Tween 20 as wetting agent.

The experiment included 9 treatment combinations of three different foliar applications x three bio-fertilizer treatments. Treatments were arranged in a split plot design with three replications. The main plots devoted to the foliar application treatments and bio-fertilizer treatments were allocated in the sub plots. The soil analysis of Wadi Sudr showed that the soil was sand having a pH of 7.6, EC of 10.3 dSm^{-1} and an ionic composition of 29.0 meq/L of Ca++, 33.8 Mg++,85.3 Na+ and 1.3 K+, 12.7 HCO_3^-, 85.7 Cl^-, and 50.2 SO_4^{--}in the saturation paste. The soil analysis of Maryut farm showed that the soil was sandy clay-loam, having a pH of 7.8, EC of 4 dSm^{-1} and an ionic composition of 15.5 meq/L of Ca++, 5.3 Mg++, 24.7 Na+ and 0.8 K+, 3.2 HCO_3^-, 15.3 Cl^-, and 6.2 SO_4^{--} in the saturation paste. The EC of irrigation water was 9.7 dSm^{-1} at Wadi Sudr and 2.8 dSm^{-1} at Maryut.

Plant samples were taken at 60 and 160 days after sowing (tillering and harvesting stages) to determine plant height (cm) , no. of tillers/plant, fresh and dry weights/plant and flag leaf area(cm^2) at tillering stage. Plant height (cm), no. of grains/ spike, 1000-grain weight (g), grains yield (ton/fed.) and straw yield (ton/fed.) were recorded at harvesting time. The materials of the first sampling were dried and ground into a fine powder and used for chemical analysis (total carbohydrates, total N, Na^+ , K^+ , Ca^{++} and Mg^{++} .

Data were subjected to the statistical analysis of variance according to Steel and Torrie (1960). LSD was used to detect significant differences at 0.05 level.

3. Results and discussion

3.1. Growth traits

Data (Table 1) show that plant height, no. of tiller / plant, fresh and dry weights/plant, as well as flag leaf area, significantly increased with Biomagic and KCl foliar application treatments as compared with control (tap water). However, KCl resulted in the highest mean values for all growth traits at saline site while Biomagic was best at the calcareous soil site in Maryut.

Table 1. Effect of foliar application on growth traits of barley at tillering stage under saline and calcareous soil in 2005/2006 and 2006/2007 seasons

Foliar application	At saline soil					At calcareous soil				
	Plant height (cm)	No. of tillers/ plant	Fresh and dry weights g/pl		Flag leaf area cm^2	Plant height (cm)	No. of tillers/ plant	Fresh and dry weights g/pl		Flag leaf area cm^2
			F	D				F	D	
	2005 / 2006									
Control	46.1	1.1	3.5	0.9	18.4	76.7	2.8	5.8	2.7	23.1
Biomagic3 Kg/fed.	47.7	1.3	4.4	1.0	18.6	82.1	4.4	7.5	3.5	24.2
KCl 2%	51.7	1.8	5.5	1.2	19.6	78.4	3.4	6.1	3.1	23.4
L.S.D. 5%	0.77	0.10	0.22	0.09	0.18	0.21	0.15	0.06	0.17	0.23
	2006/ 2007									
Control	50.9	1.1	4.6	1.5	18.4	81.3	2.8	6.7	3.2	23.1
Biomagic3 Kg/fed	52.7	1.3	5.3	1.8	18.2	87.0	4.4	8.5	3.8	24.2
KCl 2%	56.6	1.87	6.6	2.1	19.6	83.3	3.4	7.1	3.3	23.4
L.S.D. 5%	0.22	0.11	0.86	0.06	0.61	0.47	0.10	0.13	0.14	0.27

Table 2. Effect of bio-fertilizer on growth traits of barley at tillering stage under saline and calcareous soil in 2005/2006 and 2006/2007 seasons

Bio fertilizer	At saline soil					At calcareous soil				
	Plant height (cm)	No. of tillers/ plant	Fresh and dry weights g/pl		Flag leaf area cm2	Plant height (cm)	No. of tillers/ plant	Fresh and dry weights g/pl		Flag leaf area cm2
			F	D				F	D	
	2005 / 2006									
Control	47.1	1.2	3.8	0.9	18.4	77.8	3.2	6.0	2.9	23.1
Nitroben (1Kg/fed)	48.4	1.4	4.5	1.0	18.8	79.1	3.5	6.5	3.1	23.6
Seryalen (800g/fed)	49.9	1.7	5.0	1.1	19.4	80.4	3.9	6.8	3.3	24.0
LS.D. 5%	0.65	0.08	0.19	0.07	0.14	0.68	0.14	0.07	0.04	0.195
	2006/ 2007									
Control	52.0	1.2	5.1	1.6	18.4	82.5	3.2	7.0	2.9	23.0
Nitroben (1kg/fed)	53.3	1.4	5.3	1.8	18.4	83.7	3.5	7.4	3.4	23.6
Seryalen (800g/fed)	54.9	1.6	6.1	2.0	19.4	85.4	3.9	7.8	3.6	24.0
LS.D. 5%	0.26	0.08	0.76	0.10	0.54	0.23	0.12	0.11	0.07	0.24

These results are in agreement with those obtained by EL-Sokkary (1973) who reported that desert calcareous and saline soil supply lower amounts of K to plants than alluvial soils and using KCl as a foliar application improved osmoragulation and corrected the adverse effect of salinity, improving salt tolerance of some field crops (Farrag 1978; EL-Kadi et al. 1979; EL-Bagouri et al. 1983; Wassif et al.1983; Shukla & Nukhi 1985; Dahdoh 1986). Biomagic is a biological promoter of macrobial origin (El-Sibaie 1995). It contains many of the biological products which affect the plant growth and productivity and increase the plant immunity to microbial diseases. It contains N, P, K and all the trace elements especially Zn , Mn , Fe required by the major plants in a very suitable formulation (Khalil et al. 1997).

Growth traits of barley plants werea significantly improved by applying biofertilizer treatments of Nitroben and Seryalen as compared with the control under both saline and calcareous soils (Table 2). Generally, inoculation of seeds by Seryalen biofertilizer recorded the highest significant mean values. Similar results were reported by Ribaudo et al. (1998) and Kundu and Sharma 1994).

Interaction effects of the treatments revealed that KCl foliar application along with Seryalen seed treatment was best under saline soil condition while Biomagic foliar application with Seryalen biofertilizer was the best under calcareous soil condition. Abdel-Hameed (2002) also showed that the interaction between biofertilizer with the biostimulant Biomagic as afoliar application gave the highest average number of flowers per inflorescence in olive trees.

3.2. Yield and yield attributes

Data (Table3) showed that Biomagic and KCl foliar application resulted in significant increase in the yield and yield components of barley as compared with the control under both saline and calcareous soil conditions. These results may be mainly due to the role of KCl and Biomagic as a stimulus to growth characters of barley plant which was reflected on yield and its components.

Yield and its components were also significantly increased by seed inoculation with Nitroben and Seryalen under both saline and calcareous soil conditions (Table 4). The positive response to the application of biofertilizer treatments could be due to the role of such treatments in the osmoragulation of plants under saline and calcareous soil conditions (Satti and Lopez 1994). These results are in agreement with those recorded by Abdel- Hameed (2002).

Interaction of the two treatment factors was significant in affecting the yield. Inoculation barley grains with Seryalen along with spray of KCl 2% recorded the highest significant mean values for yield and its components as compared with other combinations under saline condition during both seasons. Meanwhile, inoculation of barley grains with the same biofertilizer treatment along with the spray of Biomagic gave the highest significant mean values for yield and yield components under the calcareous soils during both seasons. These increments are in agreements with that obtained by Abdel- Hameed (2002) and Ismail (2002) on olive and pea plants, respectively.

3.3. Chemical composition

Chemical analysis of plants (Table 5) showed the positive effect of foliar application treatments on carbohydrates and protein accumulation in shoots of barley at tillering and in grains at maturity compared with the control under saline and calcareous soil.

Table 3. Effect of foliar application on yield and its components of barley at harvesting stage under saline and calcareous soil in 2005/2006 and 2006/2007 seasons

Foliar application	At saline soil					At calcareous soil				
	Spike length	Grains per spike	1000 grain wt (g)	Grain yield (t/fed)	Straw yield (t/fed)	Spike length	Grains per spike	1000 grain wt (g)	Grain yield (t/fed)	Straw yield (t/fed)
	2005 / 2006									
Control	11.5	36.7	40.3	1.644	2.101	16.1	47.0	49.0	2.047	2.700
Biomagic	12.7	37.5	42.6	1.711	2.367	19.2	49.4	56.2	2.334	2.956
KCl	15.1	38.7	46.0	1.989	2.589	17.4	47.7	52.6	2.200	2.800
L.S.D. 5%	1.60	0.64	0.37	0.150	0.335	0.67	0.756	0.78	0.159	0.265
	2006/ 2007									
Control	14.5	36.6	42.3	1.744	2.186	19.1	47.0	50.8	2.144	2.800
Biomagic	15.1	37.6	44.7	1.811	2.256	21.8	49.4	57.2	2.433	3.058
KCl	17.1	38.7	47.6	1.992	2.389	19.9	47.6	54.3	2.300	2.900
L.S.D. 5%	0.14	0.56	0.11	0.010	0.038	0.12	0.344	0.12	0.169	0.285

Table 4. Effect of bio-fertilizers on yield and yield components of barley at harvest under saline and calcareous soil in 2005/2006 and 2006/2007 seasons

Bio fertilizer	At saline soil					At calcareous soil				
	Spike length	Grains per spike	1000 grain wt (g)	Grain yield (t/fed)	Straw yield (t/fed)	Spike length	Grains per spike	1000 grain wt (g)	Grain yield (t/fed)	Straw yield (t/fed)
	2005 / 2006									
Control	11.9	36.4	41.5	1.667	2.122	16.3	46.6	50.9	2.126	2.733
Nitroben	13.7	37.7	43.0	1.711	2.289	17.6	48.2	52.7	2.278	2.822
Seryalen	14.8	38.9	44.3	1.897	2.345	18.8	49.2	54.1	2.378	2.900
L.S.D. 5%	1.53	0.80	0.61	0.139	0.262	0.59	0.70	0.69	0.159	0.265
	2006/ 2007									
Control	14.2	36.4	43.5	1.767	2.219	19.1	46.6	52.6	2.222	2.833
Nitrobn	15.7	37.7	44.9	1.814	2.389	20.5	48.1	54.1	2.378	2.924
Seryalen	16.8	38.8	46.2	1.967	2.422	21.1	49.3	55.6	2.478	3.000
L.S.D. 5%	0.10	0.49	0.13	0.149	0.135	0.11	0.42	0.15	0.169	0.165

Table 5. Effect of foliar application on carbohydrates and protein content (%) of barley shoot and grain under saline and calcareous soil in 2006/2007 season

Foliar application	At saline soil				At calcareous soil			
	Shoots		Grains		Shoots		Grains	
	Carbo.	Protein	Carbo.	Protein	Carbo.	Protein	Carbo.	Protein
Control	43.6	11.4	57.1	9.2	49.6	13.2	59.3	7.1
Biomajic.	45.4	11.9	59.0	10.6	50.7	15.3	61.4	12.5
KCl	46.9	13.1	59.4	11.1	48.6	14.6	59.9	11.9
L.S.D. 5%	1.01	0.43	1.45	0.78	1.03	0.02	0.55	0.22

Table 6. Effect of bio-fertilizers on carbohydrates and protein contents of barley shoot and grain under saline and calcareous soil in 2006/2007 season

Bio fertilizer	At saline soil				At calcareous soil			
	Shoots		Grains		Shoots		Grains	
	Carbo.	Protein	Carbo.	Protein	Carbo.	Protein	Carbo.	Protein
Control	43.9	11.6	57.4	10.0	43.5	12.4	52.1	10.1
Nitroben	45.3	12.2	58.7	10.2	49.7	14.4	60.1	11.6
Seryalen	46.7	12.6	59.4	10.7	50.4	14.9	61.9	12.1
LS.D. 5%	1.05	0.04	0.99	0.01	1.05	0.05	0.79	0.03

Table 7. Effect of foliar application on proline and mineral composition of barley under saline and calcareous soil in 2006/2007 season

Foliar application	At saline soil					At calcareous soil				
	Na^+	k^+	Ca^{++}	Mg^{++}	Prol.	Na^+	k^+	Ca^{++}	Mg^{++}	Prol.
Control	16.2	29.9	2.5	0.26	0.74	13.8	16.0	3.8	0.32	0.58
Biomajic	16.2	30.2	2.2	0.32	0.83	13.0	19.1	3.1	0.23	0.73
KCl	15.6	30.8	2.0	0.35	0.87	13.5	18.7	3.3	0.27	0.69
L.S.D. 5%	0.88	0.13	0.03	0.01	0.04	0.05	0.01	0.03	0.07	0.04

Table 8. Effect of Bio fertilizer on Proline and minerals composition of barley under saline and calcareous soil in 2006/2007 season

Bio fertilizer	At saline soil					At calcareous soil				
	Na^+	k^+	Ca^{++}	Mg^{++}	Prol.	Na^+	k^+	Ca^{++}	Mg^{++}	Prol.
Control	17.2	26.3	2.5	0.28	0.76	14.0	17.3	3.7	0.29	0.61
Nitroben	15.8	31.3	2.2	0.32	0.82	13.5	13.1	3.3	0.28	0.68
Seryalen	15.0	33.2	2.0	0.34	0.87	12.9	18.6	3.2	0.26	0.72
LS.D. 5%	0.12	0.07	0.01	0.01	0.03	0.08	0.05	0.01	0.03	0.07

Accumulation of carbohydrates and protein in dry shoots and grains of barley plants was also significantly increased with the different biofertilizer treatments of Nitroben and Seryalen as compared with the control under saline and calcareous soils (Table 6). Generally, inoculation of seeds by Seryalen biofertilizer marked the highest mean values of carbohydrates and protein contents under calcareous and saline soil as compared with the inoculation of seeds by Nitroben.

Interaction of the two factors showed that the carbohydrates and protein contents of barley plants were markedly increased with foliar application of KCl along with the Seryalen seed treatment under saline soil condition. Biomagic and Seryalen combination proved best under calcareous soil condition.

Data in Table 7 show that foliar application treatments induced an increase in proline, K and Mg and a decrease in Na content. Biomajic was better than KCl foliar application treatment under calcareous soil and reverse was true for saline soil.. These results are in agreement with those obtained by Hassan (1989) on wheat plants. Lauchli and Stelter (1982) and Groham et al (1990) indicated that increasing crop tolerance to salinity is correlated with increasing K/Na ratio, as was the case with KCl application in our study.

Table 8 reveals that the maximum mean value of Praline, K and Mg contents were obtained with Seryalen as a biofertilizer treatment under saline and calcareous soil conditions as compared with the other biofertilizer treatments. Combination of KCl foliar application with Seryalen seed treatment was the best under saline condition, while Biomagic with Seryalen was best under calcareous soil condition.

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3.15. Role of olive trees irrigated with poor quality water in sustainable development in desert areas

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Abstract

Unexploited poor quality water from aquifers exists in many dry areas of the world where increasing lack of fresh water is threatening large populations. A 22 years old commercial Egyptian field model proves clearly that olive *(Olea europaea),* with its hardy nature, drought resistance, tolerance to salinity, and low water requirement, can play a vital role in sustainable development and soil conservation in some harsh arid regions. In this model, the poor natural resources, namely infertile sandy soil and extremely poor quality water, became valuable income-generating resources for creating new communities and new green barriers in the desert. Such development has been accomplished through integrated grove management, relying on innovative field techniques and good agricultural practices. For millennia, the rural area of Egypt has remained restricted to the banks of Nile, never exceeding 4% of its total surface area, because of the dependence of its agriculture on Nile River. Consequently, the Nile Valley and the Delta region have a population density of some 2,000 inhabitants per km^2, amongst the highest in the world. The development of this model has raised hopes of reducing such high population densities by permitting establishment of communities in the desert. Irrigation management in this model focused on reducing negative impacts of using the poor quality water on the environment, particularly the soil. In fact, the soil structure over the years has improved with improved infiltration, water holding capacity, and drainage.

Introduction

Unexploited poor quality water from aquifers exists in many dry areas of the world where the progressive lack of fresh water is about to threaten large populations therein. To appreciate the value of using such poor quality water whenever possible in agriculture to secure food and/or income for local communities, it is imperative that the Egyptian situation with respect to its water and land resources be discussed. Growing fully irrigated olive trees , totaling 14400, under unfavourable arid conditions in the Egyptian Eastern Desert through the application of integrated grove management; it has been possible to prove that olives can be an excellent cash crop in some arid regions of the world. Where other fruit trees die, the olive tree has proven to thrive.

2. Egyptian water and land resources-past and present

Within a region of arid desert characteristics, Egypt encampasses more than one million km^2 land area on the North Eastern corner of Africa and the tip of Western Asia under arid and hyper-arid climatic conditions.

With the exception of Sert Bay in Libya, its northern coast is located at the most southern latitude of the Mediterranean basin and therefore and unlike its regional neighboring states to the north-east and to the west, Egypt suffers from rain scarcity which under the impacts of global climate change does not exceed 150 mm at the best concentrated on its Mediterranean coastal strip. This rainfall occurs only during the winter season in the form of scattered showers, therefore it can not be considered as a reliable source for sustainable irrigation. Due to other limited water resources, rural lands cover about 4% only of the total area of the country.

In spite of such harsh conditions Egypt's deep-rooted history is based on an agriculturally sustained economy. Most archaeological sites showing the majesty of the ancient Egyptian Civilization of all different dynasties were found either in the close vicinity of the Nile River or within remote isolated oases where pockets of agricultural communities have settled for centuries around naturally flowing artesian springs and in recent history around drilled water wells. These were the main sources providing water.

Agricultural was concentrated within such regions wherever water was available. Land around the Nile, being fertile from flood silt deposits, was used utilizing basin, furrow and flood irrigation systems in growing wheat, barley, corn, lettuce, onions, some fruit trees and vegetables. Around the oases the land was grown with date palms being naturally the desert forest or as traditionally called "the Desert Queen", olives, figs, pomegranate, few grapes and to some extent wheat, barely, maize and vegetables for inhabitants essential consumption. Olive growing thrived from the Ptolemaic period onwards. Olive oil was used in cooking, lighting, cosmetics, medicine and mummification. In Saqqara close to the Giza pyramids, scenes in the tomb of King Titi, from the Sixth Dynasty (2600 BC) show olive fruits and trees. In the Egyptian oases the main cash crop, as it has always been, is dates followed by olives.

In the early stages of civilization development, the need to use water from the Nile River taught ancient Egyptians how to engineer its course through embankments, troughs, trenches and channels to divert the floodwater for both irrigation and land reclamation. By 2100 BC a 19 km channel to Lake Moeris (Mariout) was constructed. They invented water-lifting devices using simple hydraulic basics such as the Shadoof (a bucket set on one end of a counterweighted pole), the Archimedean screw (a cylinder containing a wide-threaded screw turned by the hand) and the Saqia (water wheel). From their experience with artesian bores, the Ancient Egyptians were also advanced in drilling wells in search for water. In an endless desert and throughout the history to modern times, the Nile meant for Egyptians life itself.

During the last four decades, traditional agriculture lands within the Valley and the Delta have been facing degradation caused by different factors: salinization and water logging as a result of traditional flood irrigation; moving sand dunes, which cover 16% of the land surface; urban encroachment and topsoil skimming; delta shoreline facing the Mediterranean subjected to excessive erosion rates caused by sea level rise (SLR) and reduced silt depositions from the Nile; marginal lands subjected to degradation by the above causes or because of limited water resources are abandoned by farmers leading to more desertification.

Average annual rainfall in most parts north of Cairo does not exceed 50 mm. Rainfall can in some years reach 80 to 200 mm on a very narrow strip on the North West land territory facing the Mediterranean and also on another narrow strip in the Sinai North West coastal region. In these regions, nature has trained the inhabitants, who have been living there for thousands of years, on water harvesting practices. These include surface man-made embankments, which direct the water to man-constructed underground shallow water reservoirs or to aboveground reservoirs where the soil is impermeable. Direct irrigation from rain in these regions is restricted to perennial trees grown in small valleys where the soil in localized spots may have high water holding capacities. The flora and fauna that grow in such regions are characterized by drought resistance with low water requirement. Olives, palms and figs are the main fruit trees grown under such conditions. Aside from rainfall, which cannot be taken into account for sustainable agriculture, the 1997/1998 water estimates indicated that the country needed 65.1 billion m^3/year for agriculture, municipalities, industrial, navigational and electricity requirements which was covered by the limited water resources totaled 66.1 billion m^3 , mostly from Nile flow but also from drainage and grey water and deep aquifers. The per capita water consumption rate at that time amounted to roughly 1000 m3/year. This figure is estimated to drop down to 650 m^3 by year 2025 and by much lower when the population has doubled as expected by year 2050 if the present rate of growth is not reduced.

The above critical situation calls in general for a more efficient sustainable management strategy of water and land resources with emphasis on the underground aquifers especially non-exploited ones or those with poor water quality to be utilized in increasing the cultivated area after reclamation. The strategy should aim at optimizing, conserving, improving and developing such resources. To secure the needs of the increasing population and the future of its coming generations it is necessary to create new communities on new reclaimed and sustainable developed land. Therefore, during the last three decades massive measures have been taken by the government and private sector investors to resolve the looming water and land issues: by launching numerous mega agriculture reclamation projects like the Southern Valley Development (Toshka) project adding 540,000 feddans (1 feddan=0.45 ha) of new lands; improving water use efficiency and reducing losses through expanding and improving the drainage system of old lands and recycle land drainage water by mixing with fresh Nile water; growing non-strategic crops such as fruit trees (currently with surplus for export) in new reclaimed land using drip irrigation system to improve water use efficiency; expanding the basic infrastructure specifically tarmac roads and electricity to the desert where underground water is available to attract private investments in land reclamation.

3. Egyptian “Field Model” of growing olive under desert conditions, infertile soil and poor quality water

The area is located at a latitude of 30º 26' 10" N, a longitude of 32º 09' 21" E and an altitude of 69 - 73 masl. It is bordered by Suez canal on the eastern side and by Wadi El Tumilat depression on the north. The climatic conditions are typical of arid desert with hot summers and mild winters and scarce rain (< 25 mm). Seasonal sand storms occur during spring with wind velocity that can reach up to 100 km/hr (known locally as Khamaseen) causing soil erosion / scouring and building up and shifting of sand dunes, normally associated with abrupt heat waves (33° C up to 42 C°). Light intensity is generally high due to cloudless sky. Humidity Ranges from a mean minimum of 48% in April up to mean maximum of 68% in November.

Two types of aquifers characterize the underground water resources in this region; the main unconfined fluvial aquifer under-laid by thick Miocene deposits of marine origin and the local confined to semi-confined fluviomarine ones. The Grove is located on the southern boundaries of the main fluvial aquifer having its minimum thickness of 50 meters and highest salinity of >5000 ppm which increases vertically downwards towards the underlying Miocene marine sediments. Therefore the pumped water is characterized by being rich in Calcium, Sulfate, Sodium and Chloride as typical salts of old marine origin. At its Northern boundaries the aquifer posses a greater thickness of 350 meters and the water is characterized by lower salinity of <2000 ppm. The water is taken from the tubewell of 12" casing diameter, 141 m deep equipped with electrical submersible $48m^3$/hr pump with 4" discharge pipe. The static water level was – 64.9 m in 1988, gradually dropped to – 66.1 m in the first 4 years and then gradually regained same static level of – 64.9 m. The salinity in the water was around 5000 ppm in 1988, and it gradually increased to about 7000 ppm in 2008.

The soil of 85% of the grove area is permeable sandy loam with deep drained profile. Varying with the ground level elevation, about 10% localized section spots have 2 clayey hard pans within the profile; one between – 15 and – 70 cm and the other between – 165 and – 300 cm. On the remaining 5% the hardpan extends from – 80 to – 135 cm.

A total of 16,400 olive trees were planted with different intensive densities of 400 trees/ha (5m x 5m), 278 trees/ha (6m x 6m), 303 trees/ha (6m x 5.5m) and high density of 606 trees/ha (6m x 2.75m). The cultivars mostly used were 'Picual', 'Manzanillo', both exotic, and 'Cipreccino', 'Aggezi' with its sub cultivars ('Shami', 'Akks', 'El-Massery' and 'Sinnara'), 'Toffahi' and 'Hamed', all local. In some area cultivars like 'Korronike', 'Dolcy', 'Coratina', 'Frantoio' and 'Kalamata' were also planted. In 1988, 2000 olive trees + 6000 citrus trees were planted. During 1989-90, 6000 olive trees were planted to replace the citrus trees that were not growing well due to water salinity and because of the root stock (sour orange) not suitable for the sandy loam soil and the desert environment. In 1998, 6400 olive trees were planted, of which 2400 trees belonging to Cipreccino cultivar were used as windbreaks. High yields were obtained in the preceding years, which encouraged the plantation of high intensive density of 6m x 2.75m. In 2008, 2000 olive trees were planted for oil production which will be trained for semi-mechanical harvest. This will be the first commercial trial in Egypt of its sort. The average yield levels were 22.8 kg/tree in 1998 and 78.8 kg/tree in 2003. Yield from 2004 to 2006 were nearly in the same range. But in 2007 the bearing was poor because of the weather conditions during late winter and spring (hot winds during flowering), hence yield was not recorded. In 2008, when again the weather was inconducive because of extremely low temperatures that reduced the number of female flowers, the yield of local cultivars was 38 kg/tree, while the harvesting in the exotic cultivars was still underway and yield expected was about 25 kg/tree.

4. Why olives under these conditions?

The challenges facing land reclamation on the above location are many. Starting with building up fertility of soil, which in addition to being poor already has a high sodium adsorption ratio (SAR) of 11 to 15 along its cultivable profile, there is the challenge of using poor quality water that requires the selection of a suitable crop and implementing of managing practices that should aim at preventive measures and integrated problem solving to aid in controlling the harmful impacts of salt accumulation on both the plants and the soil. Adoption of such practices in olive grove has resulted in relatively high yields. Proper leaching of salts and the use of soil amendments has been an integral part of the Integrated Grove Management System (IGMS). Olives are characterized as being drought resistant with low water requirements, moderately salt tolerant and can be commercially grown on poor but well-drained soils. The local climatic conditions satisfy chilling requirements and most importantly are characterized by appropriate day and night as well as seasonal temperature fluctuations needed for olives to produce high yields. The negative impacts on flowering by seasonal irregular sand storms and heat waves during spring can be minimized through adequate water management, nutrition and windbreaks, all a part of IGMS strategy.

5. Procedures used in growing olive trees on the marginal lands with saline water

5.1. Planting

Pits 700-800 mm in diameter and 900-1100 mm in depth are excavated and backfilled with a balanced mixture of the excavated soil, composted organic manure, gypsum and some macro elements namely phosphate, potassium, magnesium and sulfur. The incorporation of compost provides a buffering zone against salt accumulation from the irrigation water. It also improves water and nutrient holding capacity of soil and improves its microbiological activity. Gypsum is used not only to meet the high calcium requirement of the olive tree but also to lower the soil pH and to aid in leaching sodium salts to overcome the expected build up of impermeable salt sealants, created from the use of water with high total dissolved salts (TDS), which may create waterlogging of the soil. In spots having hardpans, extra quantities of compost and gypsum are used to serve as a binding agent to the fine clay encouraging formation larger and water-stable aggregates improving drainage and aeration at the localized spots. Fresh manure is never used, as decomposition in the soil is decelerated and the acid gases released during anaerobic processes slowdown the root system development. Composted manure also contains less salt than fresh manure. If hardpans are found while excavating the pits, a 5” hole is augured, starting from the bottom of the pit to a depth of 5.5 m from the soil surface, and filled with 5-10 mm of fine gravel to function as a localized drain to prevent increased salts accumulation.

After backfilling, gypsum is spread on the soil surface in 2 m strips along the rows and is incorporated through 3 deep rips along and across the rows. The process is also intended to break up the shallow clayey hardpan, which would affect the root penetration and soil water infiltration. The rips have been found to persist for long time. The topsoil is then leveled and the pits are reformed with small depression to prevent water runoff.

5.2. Irrigation

Irrigation system used is drip irrigation. The author has developed a new method named ‘Spear Irrigation’ aimed at reducing the negative impact of accumulated salts and encouraging the development of a deep root system. Deepening of the olive tree root system is necessary under the local conditions of the grove to improve water use efficiency due to less fluctuation in soil moisture and temperature in the deeper soil layers. Improving water use efficiency should reduce salts accumulation, and consequently the leaching requirements. Such a system also provides the trees with better anchorage against winds and efficient support for heavy crops. The spear irrigation system comprises of a 600 mm long LDPE 18 mm Ø lateral pipe. The pipe is perforated all the way through its length like a mesh and is driven into the ground at a distance of about 120-150 mm from the trunk at an angle of 30°- 45° to the vertical. The water flows from the dripper into the buried spear pipe through a micro tube of 4 mm Ø and through the perforated holes and the lower open end of the pipe directly into the root zone bulb. The upper open end of the pipe is kept 50-70 mm above ground exposed to light thus preventing the roots from penetrating the small holes and clogging the water flow. While it is a semi subsurface irrigation system, it produces a symmetrically shaped water bulb not very much affected by environmental factors such as wind or exposure to sun. This symmetrical shape encourages growth of well-distributed root system.

The point of water application is of paramount importance when using poor quality water as change in it can result in redistribution of salts from areas of low root activity to highly active root zone. If change becomes necessary, it should be only done in winter when the root activity is low. It is highly recommended to install the dripper on the southern side of the trunk to compensate for accelerated dryness on this side caused by being exposed to more sunlight. Salts will accumulate more on this side restricting the roots growth. The case is clearly manifested while the trees are juvenile and not providing enough shade on the ground surface. A dripper clogged for some time could be a real threat to the survival of an olive tree with the water quality used in this 'Field Model'. Therefore the irrigation system must be subjected to strict, frequent operability inspections in addition to injecting cleaning agents like sulfuric and phosphoric acids into the irrigation network. Given the low water holding capacity of the soil, the prevailing climatic conditions and the poor water quality, the irrigation strategy is characterized in general by frequent small applications on short intervals with periodically increased doses to satisfy leaching requirements.

In summers, daily irrigation is necessary.To ensure the salts are continuously leached and the extra water for leaching is efficiently used, the daily irrigation cycles are applied one day as a heavy irrigation followed by a light irrigation the following day. The heavy irrigation = $X/2 + 0.2X$ while the light irrigation = $X/2 – 0.2X$, where X = water requirement in two days.

In winters, the normal irrigation cycle is 3 times/week. During this period all factors influencing water requirements are at their lowest values including the TDS of the irrigation water. While the roots are in a relative resting period, an extra heavy irrigation is applied toleach salts accumulated during the season into deep soil horizons and to fill the water bulb underlying each tree with less saline water. Three weeks before floral bud swelling, another heavy irrigation is applied, followed by 7-10 days of no watering when evapotranspiration allows. This is done to apply some stress on the trees to enhance uniform flowering thus leading to a better fruit set and improved yields. Uniform flowering is an advantage for uniform ripening, facilitating efficient harvesting management.

Olive tree trunk is very sensitive to salts injury. Salts moving upwards on the lower trunk cause bark necrosis. The best method to control is to coat the trunk up to a height of 150 mm from the ground surface with clear polyurethane paint every second or third year. The poor quality water used is very corrosive; therefore the use of special alloy material for the pump and other metallic components is a major requirement.

5.3. Training and pruning

Over the years a strategic plan for training and pruning of olive trees has been developed which aims at producing earlier crops as well as reducing the natural genetic tendency for alternate bearing. Lower crotched trees are favored as they will control evaporation losses from wetted areas leading to efficient water use and reducing build up of salts in the top soil profile.

5.4. Managing soil quality after establishment of trees

Whereas the poor infertile soil of this model is subjected to a long-term plan of development, improvement and protection against harmful salts accumulation, during the first 6 – 7 years from planting the trees is very important. During the winter season, while the trees are in a relative resting physiological stage, a circular trench is excavated around each tree starting close to the planting pit outwards. The trench is then filled with the excavated soil mixed with the similar materials to those used during initial pit preparation. During the process roots pruning is also done. This practice is repeated every second year moving outwards from the trunk and deeper than the previous year trench. Consequently, this practice results in preventing the roots from confinement and encourages them to move out and downwards. Other advantages are improving oil structure and increasing its buffering and water holding capacities as well as providing a renewable store house for added nutrients.

While performing the above operation, any signs of water logging or salts accumulation within spots of bad drainage are dealt with through drilling more vertical 5.5 m deep drain holes. At the early years of performing this operation, perforated PVC pipes were used as a casing for the fine gravel but it has been found later that it is cheaper and more efficient to fill the holes directly with gravel.

Fertigation is not appropriate for this field model because of poor quality of water. Instead, it is recommended to give fertilizer through drilling conical holes using a pointed ¾'"bar and filling them with a mixture of mineral fertilizers to act as slow release. The holes can go as deep as 600 mm and they are drilled encircling the tree within the wetted zones of active feeder roots. The process is performed 4 to 5 times during the active growing season from March to end of October. The fertilizers mix varies in its composition and quantity every time to meet the specific physiological stage demand of the tree.

5.5. Plant protection

Weed control is essential for high water use efficiency. While the land is not reclaimed, seeds of minor desert native weeds are dormant and once they receive water and start to grow, they are easily controlled by direct hand pulling due to their very limited population and shallow roots. The real threat comes from non-desert species, which thrive under the well-aerated sandy loam soil; therefore quarantining all imported materials from the first day is the most efficient preventative measure. Organic manures are composted to kill any present seeds by the generation of heat. Pots of seedling trees are quarantined before planting for as long as it takes to ensure that they are free of any foreign weeds. The training of the trees with lower crotches assists in eliminating the presence of weeds.

The main pests are olive scale (*Parlatoria oleae*) and the larvae of the Olive Shoot Moth "Jasmine Moth" (*Margaronia palpita unionalis*). The olive scale can be kept under control through the use of winter oil once a year. Although the Olive Shoot Moth can have 4 - 7 generations per year, control by using chemicals is kept to a minimum. Even under the worst cases it has never exceeded three times per year. This is simply achieved through spraying only at reaching a threshold of 40%. The advantage of this tactic is that during the first 8 to 12 days a hot wave can destroy the larvae and the non-hatching eggs and thus eliminating the need for chemical control and also this lapse in time gives natural predators the chance to contribute in lowering the damage. Lately, a biological control has also been used with great success. This method involves the release into the Grove of an egg parasitoid (*Trichogramma evanescens*), which is bred under lab conditions.

6. Conclusions

Under Integrated Grove Management System, using poor quality water to irrigate olive trees on well-drained soils is very much viable without profound negative impacts on yields and soil conservation. Under desert environment and similar conditions to this "Field Model", olives can play an important role in protecting the soil from wind erosion and degradation and can help in arid land development and sustainability plans. Conserving and upgrading soil conditions can become a profitable venture when associated with growing the right environmentally adaptable crop. Negative impacts of using poor quality water with respect to soil salinization have been observed on shallow soils with bad drainage. Improving the drainage characteristics of such soils can considerably reduce such impacts and make it useable for growing olive trees. Under the "Field Model" conditions it has been observed that the most salt tolerant varieties are in descending order: Naballi, Hamed, Picual, Aggezi Shami, Aggezi Akks, Aggezi Sinnara, Coratina and Frantoio. On the other hand, sensitive varieties in descending order are: unidentified non-local variety, Toffahi, Mission and Manzanillo.The olive tree can adapt to a wide range of micro environmental conditions within its traditional growing regions. The reflection of these micro conditions on all agronomic practices should be recognized by growers.

3.16. Sustainable soilless technique to combat soil-borne diseases and salinity for greenhouse growers - Success story of Omani grower

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Abstract

The climatic conditions of the arid environment of Oman necessitate the use of protected agriculture for the production of high value vegetable crops. Salinity build-up and soil-borne diseases are the major constraints for greenhouse growers in Oman. Despite all efforts, including soil replacements and heavy chemical treatments, the growers were incurring increasing losses. Such problems are forcing the growers to abandon their greenhouses. Soil-less (hydroponics) production system was introduced under a joint research program between ICARDA and the Agriculture Research Center in Oman. Different production systems were developed depending on the type of crop. Yield and crop quality were superior compared to production from the traditional soil techniques. This outcome has encouraged private growers to adopt different soilless systems. The first adoption occurred in Al-Farsy farm in Samail where yield and quality were low due to salinity build up. The system was designed to suite the existing greenhouses using locally available materials. The closed hydroponics system was installed in one multi-span greenhouse (1440 m^2) in 2005. Technical backstopping and training was provided by ICARDA and the Ministry of Agriculture scientists. Integrated production and protection management practices were implemented.

The capital cost for installing the hydroponics system was recovered within 3 growing seasons. High yield with superior quality was obtained the year round with significant reduction in water and fertilizer use and labor cost. A detailed description of the system, yield and income are presented in the paper.

1. Introduction

Oman is located on the southeast coast of the Arabian Peninsula. It borders the United Arab Emirates on the northwest, Saudi Arabia on the west and Yemen on the southwest (Wekipidia 2008). Oman is the third largest country by area in the peninsula after the Saudi Arabia and Yemen. The climate varies from region to region. The coastal areas is hot and humid in summer, while the interior is hot and dry, with the exception of some higher locations, where it is temperate all year round. The southern region has a benign climate. The country's rainfall is generally low and irregular, although heavy local rains are sometimes experienced, with the exception of the southern region, where heavy monsoon rains regularly occur between June and September (OmanInfo 2008).

The climatic conditions of the arid environment of Oman necessitate the use of protected agriculture for the production of high value vegetable crops. The research activities on Protected Agriculture started in 1992 at Rumais Agricultural Research

Center (Osman, 1998). The number of greenhouse has started to increase rapidly in private farms due to good income generated by growers. In addition, the protected agriculture has been also encouraged by the Ministry of Agriculture by providing 50% subsidy on GH costs to the growers. The major crop under protected agriculture in Oman is cucumber. Green house vegetable production is becoming the fastest growing sector of the land-based agricultural industry in Oman. Most of the green houses or plastic houses in use are of single span and a small number are multi-span made of galvanized pipes with polyethylene plastic cover (180-180 micron), and evaporative cooling system (pad and fans).

2. Problem statement

In Oman greenhouses are used almost exclusively to produce cucumbers. The continuous use of same soil and practices in the greenhouses in raising cucumber has caused major problems. Salinity build-up and soil-borne diseases are the major constraints. Seedling losses up to 25% are common despite a high number of fungicide applications. Crops receiving over 20 fungicide applications per season are common and fungicide resistance is consequently emerging as a serious risk on many farms (M. Deadman 2007). Despite all efforts including soil replacements and heavy chemical treatments, the losses were increasing and many growers abandoned their greenhouses.

To address and tackle the problems of increased soil salinity and soil borne diseases, soilless (Hydroponics) production system was developed through a joint research program between ICARDA and the Agriculture Research Center, Ministry of Agriculture in Oman. Different production systems were developed for different crops. Yield and quality were superior compared to production from the traditional soil techniques which encouraged private growers to adopt the system (Moustafa et al. 2006a). After proving success, ICARDA in collaboration with the Ministry of Agriculture has started to implement on-farm trials on hydroponics production system under farmers' condition and management.

3. Soilless production system

Soil is the most abundant growing medium, and its function is to provide anchorage, nutrients, air and water to the plants rooting system (Duddly 1992). However, soils do pose serious limitations for plant growth, at times. Presence of disease-causing soil organisms and nematodes, unsuitable soil reaction, salt accumulation due to irrigation, soil compaction, poor drainage, degradation due to erosion, etc. are some of them. In greenhouses, agricultural practices in soil will increase the soil-borne pathogens such as nematodes and accumulate salinity. Moreover, the present conventional growing system in soil results in the waste of a lot of fresh water due to runoff and deep percolation. In arid countries, rapid evaporation from the soil surface may also lead to salinity problems.

In the hydroponics systems, soil related constrains are likely to disappear and save growers the expenses of soil sterilization and application of hazardous agro-chemicals. The system offers opportunities to provide optimal conditions for plant growth and therefore, higher yields can be obtained compared to conventional soil base agriculture. One can receive 200-1000% increase in yield with only half of the time and space required in comparison to traditional soil horticulture (Urban Farming OZ 2008).

Soilless techniques also offer a way of improving water-use efficiency and obtaining better water and fertilizer management in crop production. The advantages of soilless culture over normal soil bed systems have been described in detail by Moustafa et al. (2003).

There are two main types of soilless cultivation: (a) Open system, where plants are grown in containers or channels filled with an inert high water-holding capacity medium; water and nutrients are supplied and appropriately maintained through drip irrigation and the surplus nutrients and water is allowed to run off as waste. (b) Closed system, where plants are grown in pipes or channels lined with polyethylene, with a film of nutrient solution circulating through the roots and back to a catchments tank, providing good contact between the solution and air, sufficient to maintain the oxygen level required by the roots without additional aeration of the solution.

The higher yield with less water and other agricultural inputs makes the hydroponics system more profitable for growers. For example in a study carried out in Turkey, economic aspects of soilless and soil-based greenhouse cucumber production were analyzed. Net return obtained from cucumbers grown in a mixture of perlite and zeolite was 25% higher than the same in conventional soil-based production (Sait Engindeniz 2008). Study in Spain on fig (*Ficus carica* L.) soil-less culture revealed that the soilless production prevented all the inconveniences of traditional farming, allowed irrigated farms to double their yield (from 4500 kg/ha up to 81,000 kg/ha per year), and permitted a 90% reduction in water use (Melgarejoa 2007).

Tomato cultivation under soilless (open) system showed that there was improvement in the quality so that the average marketable yield was 92.1%, while in-soil cultivation it was only 77.0% (Maboko 2008). Productivity of lettuce in open field hydroponics was studied and compared with soil production by ICARDA. The system has successfully operated since early 2008 by Mirak farm in UAE. Land productivity of lettuce in hydroponics was three times higher than that of soil. Similarly, productivity per unit of water was about 13 times higher.

In Kuwait, agro-economic comparison between vertical soilless and traditional soil bed systems was conducted based on the cost and production data reported by a private farm in Al Wafrat. The greenhouse area used in the study was 20,000 m^2 and 6,000 m^2 for the soil bed and hydroponics systems, respectively. The number of seedling in both systems was 100,000. The total cost of production in the vertical soil-less system was 40% less than soil beds, while production per unit area increased by four times and productivity per unit of water increased by 70%. (Moustafa et al. 2006b)

Hydroponics production system can be used for production of high quality cut flowers. For example, in Turkey, carnation production yield and quality in soil and soilless culture was studied. Standard carnation varieties (‘Turbo’ and ‘Oasis’) were grown on beds containing pumice and the production of flowers and their quality characteristics (vase life, stem length, flower diameter and weight) were determined. Flower yield of ‘Turbo’ and ‘Oasis’ varieties grown in pumice was respectively 22% and 19% higher than in soil, and stem length was much longer in soilless culture (Kazaz 2008).

ICARDA through Research-4-Development program, in close collaboration with national agriculture research and extension systems (NARES) of many countries in CWANA, developed, enhanced and simplified number of soilless production techniques because the systems in large scale could be very complicated and needing trained management and sensitive measurement tools. Various simplified hydroponics systems for growing cash crops, including cucumber, tomato, pepper, musk melon, green bean and strawberry, were tested in research stations in collaboration with NARES, specially in Arabian Peninsula countries, and started to transfer them to private farms and growers (ICARDA Annual Report 2007).

4. Materials and methods

Simple soilless production system was introduced to and adapted by one of the Omani growers, Mr. Abdullah Farsi, who was facing many problems with his cucumber production in green houses. Young plants were dying at a very early stage (70% wilting) and fully grown plants were weak and dying as a result of nematode infestation. Salt accumulation was high and negatively affected plant growth. Despite soil treatments such as washing and drenching with pesticides, the problem was sever and the loss was high. Soilless production system (hydroponics) was a good answer for such problems. The hydroponics system was designed with flexibility to adjust to different crops such as cucumber, tomato, lettuce and strawberries.

The greenhouses were double spam with 18m width and 40m length. The system was designed to have 16 growing channels using cement blocks (10x20x40cm) and covered with black polyethylene sheets. The fertigation system started from a catchment tank where water and nutrients were mixed in right balance and pumped to plants through drip lines. Excess nutrient solution was collected from the growing channels by gravity to a drain line and back to the catchment tank. The feeding system was automatically controlled in which the pH and EC of the nutrient solution was carefully monitored and adjusted twice a day using portable meter.

During the production periods, Integrated Production and Protection Management (IPPM) techniques were applied to ensure a full protection and eliminate the use pesticides. The IPPM components include: GH climate management, irrigation and fertilization management, agro-management practices, mechanical protection, biological control, and chemical control. On the job training were provided to growers, technicians and extension agents by ICARDA scientists during system installation and different production periods.

5. Results and discussion

During the production period ICARDA scientists and MoA researchers and extension agents visited the farm on regular basis to advice and provide technical backstopping. The results of the first crop were highly promising. After five growing seasons, Mr. Al Farsi reported no wilting (Figure1) and production was excellent in terms of quantity and quality (Figure 2). Comparing with his previous production in soil and with other growers water productivity was very high. The productivity per unit of water at Al Farsi farm reached 76.5 kg/m^3, which is significantly higher than that of 38 to 43 kg/m^3 in soil reported in Rumais Research station in Oman (Al Rawahy et al. 2004). Land productivity in hydroponics reached 17kg/m^2 while at Al Farsi farm while it was 7kg/m^2 for cucumber grown in soil at Rumais Research Station in Oman (Al Rawahy et al. 2004)

The economic benefit of the cucumber production with soilless system for the first five growing seasons is illustrated in Table 1 & 2. The fixed asset cost, consisting of the cost for the greenhouse structure and costs of materials and installation of the hydroponics system in each growing seasons (considering 4 seasons per year) is about OR 350 (US$ 951). Total income of the 3 greenhouses in five growing seasons reached to OR 2,5521 (US$ 2500) per GH per seasons (**Error! Reference source not found.**). The cost of establishing the hydroponics system was OR 1,000 (US$2,717) for each GH. The net profit/m^2 was OR 1.3 (US$ 35).

Figure 1. Comparison of seedlings in the soil (left) and soil-less culture (right) systems. Many plants used to wilt in soil culture practiced in the past.

Table 1. Capital (investment) cost (Omani Rial) for the establishment of three greenhouses (each 700m^2) and hydroponics system in them at Al Farsi Farm

Items	Cost
GH establishment (3 GH)	16,500.00
Establishment of Hydroponics system (3GH)	3,000.00
Total	19,500.00

Figure 2. Comparison of production status before (left) and after the adoption (right) of soilless culture system.

Table 2 - Production cost (running cost) (in Omani Rials) and income for first five growing seasons 2004-2005 in Al Farsi farm (3 GH each 700m^2)

Item	**Cost / Benefit (5 Production seasons)**	**Average/season**
Production Costs in 3 GHs	10,066.00	2,013.20
Total Cost (including the depreciation for GH structure and Hydroponics system)	11,816.00	2,363.20
Total Income from 3 GHs	25,521.60	5,104.32
Net benefit (3 GH)	13,705.60	2,741.12
Net Benefit /GH	4,568.53	913.71
Net benefit/m^2	6.51	1.30

Figure 3. Mr. Al Farsi's new GH complex

In an earlier agro-economic study for cucumber production in soil under greenhouse, the net profits were 0.8OR/m^2 (22US\$/m^2).The study was conducted in Oman during 2004 (Al Rawahy et al. 2004).

The excellent profits gained by Mr. Farsi after installing hydroponics system in his farm has encouraged him to expand the numbers in his farm to 30 GH.

6. Conclusion and recommendation

Lack of sufficient soil and water is a major limiting factor for agricultural development in the Arabian Peninsula. Soilless production techniques under the greenhouses would provide a practical solution for improving water and land productivity. Simplified hydroponics system for easy management by small growers should be developed and adopted by growers in the Arabian Peninsula. Further research-for- development activities are required to solve specific and local problems to enhance the adoption rates. Equally important is to enhance the research facilities and capacity of human resources of NARES in the AP

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3.17. Increasing crop productivity in drought affected Afghanistan

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Abstract

Afghanistan is a relatively dry country with annual average rainfall of about 305 mm. Agricultural productivity has declined markedly as a result of the prolonged conflict, which has damaged the agricultural infrastructure and considerably reduced the area under effective irrigation. The prolonged drought (1999-2004) has also resulted in total failure of rain-fed cropping, and reduced the water available for irrigated agriculture. Food prices, particularly wheat and wheat flour, have increased by 60-80% across Afghanistan in the past few months that have pushed at least 2.55 million people into high-risk food-insecurity. Considering above, rapid increase of food-production is urgently required which can only be achieved through replacing low yielding varieties with improved and high yielding varieties. However, convincing tradition-loving Afghan farmers about such a change is very challenging. In an attempt to make them believe in new high yielding varieties, a total of 1,049 demonstration plots of wheat, rice, mung bean and potato were established in Eastern Afghanistan during 2005/06, 2006/07 and 2007/08. Best agronomical practices were promoted through these demonstrations. Improved wheat varieties (Lalmi-2 and Mazar-99) exhibited an average 69% higher yield over traditionally grown local ones. High yielding potato variety Kufri Chandramukhi yielded up to 64% higher than the local; yields of mung bean (NM-92 and NM-94) and rice (Kunduz-1) were, respectively, 67 and 55% higher than the varieties currently grown by the farmers. These results are attracting farmers to adopt high yielding improved varieties which are expected to increase food-security in Afghanistan that is hit by long conflict and frequent droughts.

1. Introduction

Afghanistan is a relatively dry country with annual average rainfall of about 305 mm. Wheat accounts for about 70% of the area devoted to cereals and 75% of food grain production. The next important cereal crop rice is planted on about 0.21 million ha in the country where as potato occupies some 90% of the area planted to vegetables. Agricultural productivity in Afghanistan has declined markedly as a result of the prolonged conflict, which has damaged the agricultural infrastructure and considerably reduced the area under effective irrigation. Conflict is rated by FAO as the most common cause of food insecurity (FAO 2005).

The prolonged drought (1999-2004) has also resulted in total failure of rain-fed cropping, and reduced the water available for irrigated agriculture. The productivity levels of major staple crops are far low even by regional standards as evident from (Table 1). It is a massive task to rebuild agriculture in countries affected by conflict and/or natural disasters (Erskine and Nesbitt 2009). Large yield gaps of staple crops are major cause of concern. The narrowing of the yield gap requires integrated and holistic approach including appropriate concept, deployment of new technologies, Source: FAO, 2007 promotion of integrated crop management, adequate supplies of inputs and farm credit, and strengthening and linkage of research and extension. Reducing yield gaps is imperative to increase yield and production, improve the efficiency of land and labour use with sustainability, and to reduce the cost of production. Concerted action through participatory approaches can minimise yield gaps. This will help in attaining the goal of taking back the agricultural production to at least pre-conflict level which is often a goal during rehabilitation (Longley et al. 2007). Use of improved crop varieties coupled with best crop management practices is the most effective way to increase agricultural production. Non-availability of quality seed of high yielding varieties (Bishaw and van Gastel 2008) and progressive loss of technical knowledge of researchers, extension workers and farmers appear to be the major constraints responsible for large yield gaps in Afghanistan.

Considering above, rapid increase of food-production can only be achieved through replacing low yielding varieties with improved varieties along with the modern package of practices. However, convincing tradition loving Afghan farmers for such a change is very challenging. The most convincing way to do that is by showing good results in the fields managed by their peers and located in or near their villages. Research all over the world has shown that the farmer-to-farmer communication is the most important tool of knowledge dissemination influencing other farmers to adopt advanced agro-technologies. Performing demonstrations, using a farmer's participatory approach, can show the farmers the advantage of new agro-techniques over the traditional ones. Considering the weaknesses of the post-war extension system in Afghanistan, need and utility of participatory demonstrations has particularly increased.

International Centre for Agricultural Research in the Dry Areas (ICARDA), through its programs, is contributing to improve the food security in the country since 2002. Within the framework of this program, an attempt was made to increase agricultural productivity and rural incomes by demonstrating available improved technologies in farmers' fields, focusing on improved varieties of field crops that are adapted to local conditions and appropriate crop management practices. ICARDA working in close cooperation with the extension personnel of the Ministry of Agriculture, Irrigation and Livestock (MAIL) and the Faculty of Agriculture at the University of Nangarhar, developed a technology transfer program to demonstrate

Table 1. Comparison of productivity levels of major food crops: Afghanistan vs neighbouring countries

Crop	Productivity ($t\ ha^{-1}$)				
	Afghanistan	Iran	Pakistan	India	Asia
Wheat	1.73	2.34	2.77	2.67	2.85
Rice	2.18	5.55	3.19	3.21	4.22
Potato	15.00	24.95	19.88	16.42	15.58
Cereals	1.72	2.58	2.75	2.52	3.49

Source: FAO, 2007

production technologies in farmers' fields. This paper compares the performance of improved varieties in the demonstration plots and discusses the significant contribution of economic benefits of these technologies demonstrated to the farming community and their impact on the society at large.

2. Methodology

2.1. Project sites

The project was implemented in three contiguous provinces in Eastern Afghanistan, namely Kunar, Laghman and Nangarhar. A total population of 1.8 million are distributed in 1,238 villages of 42 districts in these three provinces (Table 2). A total of 187,720 farmers were distributed in these three provinces cultivating wheat, rice, potato and mung bean as major food crops. Potato is a newly introduced crop in Kunar province. Four districts each in Laghman and Kunar and nine districts in Nangarhar were selected for laying out the participatory demonstrations.

2.2. Laying Participatory Demonstrations

Selection of demonstration site was done in close collaboration with the Agriculture and Extension Departments of MAIL, local 'shuras' and communities where extension agents from respective districts played crucial roles. Demonstrations focused on four staple food crops (wheat, rice, mung bean and potato) during three (2005-08) cropping seasons. The area allocated for demonstrating the technologies was 0.2 ha in case of wheat and rice and 0.1 ha land in case of potato and mung bean.

These demonstrations encompassed a limited number of variants, focusing on very specific aspects, so that farmers can easily interpret the results. Lalmi-2 and Mazar-99 (wheat), Kunduz-1 (paddy), Nayab 92 and NM 94 (mung bean), and Kufri Chandramukhi (potato) improved varieties were used in demonstrations. Besides the improved varieties, best agronomic practices such as use of optimum fertilizer and seed rate; weed control; and using transplanting method for paddy were also included as components of demonstrations. Nursery demonstrations for rice to produce vigorous and healthy seedlings for transplantation were established. Seed rate of 125, 60, 35 and 2500 kg for wheat, rice, mung bean and potato respectively per ha was used. Also application of 250 kg ha^{-1} Urea fertiliser for wheat, paddy and potato, and DAP fertiliser of 125, 125, 125 and 250 kg ha^{-1} of wheat, rice, mung bean and potato, respectively was demonstrated.

From selection of demonstration sites till harvesting of the crops, regular interactions were held with farmers to provide information on best practices for each of the target crops. Such interactions were held through one-to-one discussions, group deliberations and field days. A total of 1,049 farmer-participatory demonstrations (422, 309 and 318 in 2005/06, 2006/07 and 2007/08 respectively) were established. They were managed by the farmers themselves throughout the cropping season with the technical assistance received in the form of trainings on agronomic practices and participation in field days.

2.3. Provision of inputs

Seed and fertilizer required for laying out the demonstration plots in were given free of cost to the participating farmers. All agronomic and post harvest operations in the demonstration plots were undertaken by farmers with technical assistance from ICARDA and the MAIL.

2.4. Baseline survey

In 2006, a baseline survey was carried out in Kunar, Laghman and Nangarhar provinces covering 12 target districts to collect information on household

Table 2. Characteristics of selected target provinces in eastern Afghanistan

Description	Kunar	Laghman	Nangarhar	Total
Total area (ha)	387,600	172,000	636,885	1,196,485
Population ('000)	340.80	392.80	1,148.60	1,882.20
Number of villages	321	405	512	1,238
Number of farmers	38,609	53,253	95,858	187,720
Number of districts	15	5	22	42
Number of selected districts	4	4	9	17
Irrigated wheat area (ha)				73,000
Irrigated rice area (ha)				27,000
Irrigated mung bean area (ha)				590
Irrigated potato area (ha)				1,777

Source: FAAHM Section, MAIL 1386 and 1387 (2007 and 2008 reports).

characteristics, agricultural production practices and existing constraints with particular reference to crops, varieties and seeds. The main objective was to determine farmer's practices and preferences as benchmark indicators against which achievements or changes will be measured following implementation of the project.

Purposive and multi-stage random sampling technique was adopted for the selection of sample. In the first stage, 12 districts were selected purposively in the three provinces where project activities will be implemented. Furthermore, 48 villages from a total of 400 villages in 12 districts (12%) were selected purposively. Then, each district was divided into four clusters and one village from each cluster was selected on random basis. In the next stage, a systematic random sample of one fifth of the farmer households was selected and interviewed. On an average 50 households per village were taken into consideration for selecting 10 farmer households. Thus the sample included a total of 480 farmers from 48 villages distributed in 12 selected districts in the three provinces.

2.5. Monitoring and data capture

***Monitoring operations of demonstrations*:** After establishing demonstrations in each year, an operational calendar was developed and monitoring system installed and implemented during the cropping season.All field operations (land selection, planting, fertilization, weed control, roughing, harvesting) were monitored and evaluated. Demonstrations were evaluated by regular recording and analysis of data on key indicators of crop performance such as: quantity and cost of all inputs, including the contribution of farmer in kind such as farm labor, yield due to all technology options put together, estimates of gross margins and net revenues from technologies, and the number of farmers visiting demonstrations and participating in field days.

Data collection: In order to estimate economic benefits that can be obtained by using demonstrated technologies, yield data was collected for both improved and local varieties from all the locations over a period of three years. Data were collected on labour and material inputs used in the demonstration plots as well as used by farmers growing local varieties using traditional management practices. Market prices for wheat, potato, rice and mung bean as food grains in 2008 were used in estimating the gross income generated from improved and local varieties. By-products of crop cultivation such as straw and fodder were also valued. Production costs were estimated using quantities, prices of purchased inputs and opportunity costs of household-owned inputs. In order to account for the farmers' labor and management provided to the production operations, 10% charge was imputed to the sum of variable costs. In all cases, a 10% charge was imputed to the sum of variable costs to account for interest on operating capital and miscellaneous expenses not captured during the itemized data collection.

3. Results

3.1. Baseline survey

Wheat is a strategic crop highly contributing to food security followed by rice, potato and mung bean. The potential for increasing productivity through the use of quality seed of improved varieties is higher in Laghman and Kunar provinces whereas improving crop management practices may be more appropriate in Nangarhar province.

The majority of farmers grew local and old improved varieties such as 'Mexipak' and 'Inqilab' (Nangarhar), 'Zardana' and other local wheat (in Laghman) and 'Bakhtawar', 'Inqilab' and 'Zardana' (in Kunar). Similarly, most farmers in Nangarhar and Laghman provinces grew traditional rice varieties such as 'Basmati', 'Japani', 'Parmal' and 'Sela' with exception of 'Kunduz 1' which was recently introduced by ICARDA. Farmers preferred improved varieties with lodging tolerance, higher yield and disease and pest tolerance. However, higher cost, non-availability of seeds and lack of credit are the main constraints for not using quality seed of improved varieties.

Farmers, on average allocated 5 jeribs for wheat followed by 3 jeribs for rice, 2 jeribs for mung bean and 1 jerib for potato per household in the three provinces (1 jerib = 2000 m^2). Majority of farmers did not use chemical fertilizers, which can be attributed to their low purchasing power or the poor quality of fertilizers in local markets. Factors limiting crops production, in order of importance, included poor quality fertilizers, poor quality seeds, weeds, plant diseases and pests and water shortages. In general, there is less access to market network and other problems in order of importance included low product price, high transportation costs, poor roads, poor market information and distance to the market.

3.2. Comparison of yield between demonstration plots and farmers' fields

Based on data obtained from 1,049 participatory demonstrations on four target crops during 2005-08, an average 63.6% yield increase was recorded over the local varieties (Table 3). Improved wheat varieties (Lalmi-2 and Mazar-99) exhibited an average 69% higher yield over traditionally grown local varieties. High yielding potato variety Kufri Chandramukhi yielded up to 64% higher than the local varieties; whereas yields of improved mung bean (Nayab 92 and NM 94) and rice (Kunduz-1) varieties were respectively 67 and 55% higher than the varieties currently grown by the farmers. A yield gap reduction to the extent of 1.84 Mt in wheat, 2.25 Mt in rice, 0.86 Mt in mung bean and 8.95 Mt in potato is anticipated due to adoption of improved technologies. These results are attracting farmers to adopt high yielding improved varieties which are expected to increase food-security in Afghanistan.

Table 3. Comparison of average yield of improved (Imp.) and local varieties of target crops during 2005-08

Crop	2005/06 (t ha^{-1})		2006/07 (t ha^{-1})		2007/08 (t ha^{-1})		Average of three years (t ha^{-1})			
	Imp.	Local	Imp.	Local	Imp.	Local	Imp.	Local	Difference	difference%
Wheat	4.54	2.18	4.50	3.11	4.50	2.73	4.52	2.67	1.84	69
Rice	5.71	3.64	6.15	3.76	7.16	4.86	6.34	4.09	2.25	55
Mung bean	1.95	1.38	2.21	1.20	2.30	1.30	2.15	1.29	0.86	67
Potato	22.11	10.03	24.28	18.24	22.59	13.87	22. 99	14.04	8.95	64

Table 4. Comparison of cost of cultivation of improved and local varieties of major staple crops in eastern Afghanistan (in US $ per ha)

Cost Particulars	Wheat		Rice		Mung bean		Potato	
	Improved	Local	Improved	Local	Improved	Local	Improved	Local
Total labour cost	328	546	300	611	264	231	587	471
Cost of seed	44	59	39	23	33	46	1342	578
Cost of fertiliser	133	215	205	169	73	84	296	292
Cost of gunny bags	40	24	56	36	19	11	204	125
Other materials	22	30	30	23	12	37	184	99
Cost of management	57	87	63	86	40	41	261	156
Int. on working capital	62	96	69	95	44	45	287	172
Gross cost	686	1,057	763	1043	485	496	3,162	1894
Grain yield (t ha^{-1})	4.52	2.67	6.34	4.09	2.15	1.29	22.99	14.04
Straw yield (t ha^{-1})	6.78	4.01	9.51	6.14	3.23	1.94	0.00	0.00
Grain price (per Mt)	700	700	400	400	535	535	230	230
Straw price (per Mt)	63	63	35	35	80	80	0	0
Gross returns	3591	2121	2869	1851	1408	845	5288	3229
Net returns	2905	1064	2106	808	923	349	2126	1336
Difference in net returns		1840		1299		574		790

Table 5. Anticipated area and income from the adoption of the demonstrated technologi

Crops	Difference in net income (US $ / ha)	Current area (ha)	Anticipated area with modern technologies (ha)		Total increase in income anticipated due to adoption (US $)	
			2008/09 (3% adoption)	2009/10 (4% adoption)	2008/09	2009/10
Wheat	1,840	73,000	2,190	2,920	4,030,295	5,373,727
Paddy	1,299	27,000	810	1,080	1,051,805	1,402,406
Mung bean	574	590	18	24	10,157	13,543
Potato	790	1,777	53	71	42,129	56,172
Total					5,134,386	6,845,849

3.3. Comparison of per ha difference in income from adoption and non adoption of demonstrated technologies

The analysis indicated that the per ha difference in the net income due to adoption and non-adoption of demonstrated technologies will be US $ 1,840, 1,299, 574 and 790 for wheat, rice, mung bean and potato, respectively (Table 4). This income difference can be a good evidence to convince the traditional farmers the advantage of adopting modern technologies.

3.4. Anticipated area and income

It is anticipated that the farmers in the three target provinces will adopt the demonstrated technologies at the rate of 3 and 4 per cent in the first and second year, respectively, after three years of demonstrations. Due to this adoption, farmers will cultivate an area of 2190, 810, 18 and 53 ha of wheat, paddy, mung bean and potato during first year and 2,920, 1,080, 24 and 71 ha during second year in all the three target provinces. Income to the tune of US $ 5.1 and 6.8 millions is anticipated from cultivation of these staple crops with modern technologies (Table 5).

4. Conclusions

The study has confirmed that participatory demonstration is the most effective and powerful tool to convince traditional and conservative farmers to cultivate improved varieties by adopting modern agro-techniques and in turn contribute to educing yield gaps of major staple crops in Afghanistan. A significant yield gap reduction in wheat, rice, mung bean and potato is anticipated especially due to adoption of demonstrated varieties and associated technologies. Department of Extension of Ministry of Agriculture, Irrigation and Livestock has to play an important role in further spreading these technologies in other provinces as well.

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3.18. Genotypic variation in grain yield and related traits in response to different nitrogen levels under a heat-stressed environment

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Abstract

It would be an advantage economically and ecologically to have high-yielding wheat genotype that could attain maximum yield at low N input. A historical set of 12 bread wheat cultivars released for a heat stressed environment was grown for two seasons to investigate genotypic variation in response to four N fertilization levels. The N levels were: 0 (0N), 43 (1N), 86 (2N) and 129 (3N) kg/ha split-applied at three-leaf and tillering stages. Significant differences were found between the N levels and genotypes for almost all studied traits. Addition of N increased chlorophyll content, canopy temperature depression (CTD), biomass and grain yield of all genotypes. However, the magnitude of the response varied greatly among the genotypes. Averaged across seasons, increasing N level from 0N to 1N increased grain yield with a range from 4% in Argine to 45% in Wadi Elneel. Similarly, increasing N level from 0N to 2N and 3N resulted in grain yield increases ranging from 13% in Condor to 69% in Nesser for 2N, and from 34% in Debeira to 87% in Khalifa for 3N. These increases associated significantly with the increases in chlorophyll content (r = 0.75), CTD (r = 0.78), and biomass (r = 0.86). On the other hand, genotypes showed mixed reactions in response of harvest index (HI) to increasing N levels. For example, the HI of Nesser increased by 14, 15 and 10% under 1N, 2N and 3N, respectively, compared to 0N, while Beladi, Giza 155, Condor and Debiera showed different decreasing trends with addition of more N. It is concluded that genotypes differentially responded to N levels in terms of various traits suggesting the existence of wide variability in N utilization efficiency among the studied genotypes.

1. Introduction

Thousands of modern dwarf wheat (*Triticum aestivum* L.) cultivars with high-yielding potential, highly responsive to nutrients, especially N, have been released for use in both favorable and marginal environments since the start of the "Green Revolution" era in 1960s. It is generally believed that these cultivars demand high N level to maximize their yield (Le Gouis et al. 2000; Guarda et al. 2003). However, it would be an advantage economically and ecologically to have a high-yielding genotype that could attain maximum yield at low N input especially in the light of global climate changes (Baric et al. 2007). It has been reported that some recently developed cultivars outyielded both earlier semidwarfs and old tall cultivars at all nitrogen levels (Ortiz-Monasterio et al. 2001). More efficient N use in wheat production presents a current challenge for breeders and agronomist to minimize environmental hazards and at the same time maximize yield needed to feed the growing world population.

Considerable genetic diversity in wheat for nitrogen uptake and utilization efficiencies has been reported (Le Gouis and Pluchard 1996; Ortiz-Monasterio et al. 2001; Baric et al. 2007). Wheat genotypes with a high harvest index and low forage yield have low plant N loss and increased N use efficiency (Kanampiu et al. 1997). However, although nitrogen use efficiency is genetically controlled, some environmental factors such as drought and heat stresses could modify the genetic effects. High temperature during grain filling stage is reported to reduce N remobilization from the stems of wheat (Tahir and Nakata 2005). However, N fertilization under heat stress was found to increase biomass production and canopy temperature depression (Ali 2000). These traits are known to be important for wheat productivity under heat stress conditions (Amani et al. 1996; Reynolds et al. 1998; Tahir et al. 2005). So far, differential genotypic response to different N fertilization levels has been rarely addressed under dry heat stress environment. This study investigated genotypic variation in response to four N fertilization levels under a dry hot irrigated environment using a set of cultivars released during the last five decades for the heat stressed areas of Sudan.

2. Materials and methods

An experiment was conducted at the Gezira Research Station Farm (GRSF), Wad Medani, Sudan for two seasons, 2006/07 and 2007/08. The soil of the GRSF is classified as heavy clay soil, having a pH of about 8.1 and low organic matter content (0.05). Twelve genotypes of wheat were selected to represent a historical set of cultivars released during the last five decades for the dry, hot irrigated environment of Sudan. The genotypes were tested under four levels of nitrogen; 0 kg N/ha (0N), 43 kg N/ha (1N), 86 kg N/ha (2N) and 129 kg N/ha (3N) split-applied in the form of urea at three-leaf stage (second irrigation) and tillering stage (fourth irrigation). The recommended dose of phosphorus in the form of super phosphate at the rate of 43 kg P_2O_5/ha was applied by furrow placement prior to sowing.

Seeds were mechanically sown in plots having eight rows, 5 m long and 0.2 m with a seed rate of 120 kg ha^{-1}. Seeds were dressed with Gaucho (Imidacloprid 35% WP) for the control of pests mainly termites and aphids. The experiment was irrigated frequently to avoid any water stress. Weeding was done manually. The experiment was arranged in a randomized complete block design with three replications. The experimental site was free from major wheat diseases and no serious lodging occurred.

Chlorophyll content was indirectly measured using a chlorophyll meter (Minolta SPAD-502 meter: Minolta Camera Co., Japan), recording in SPAD unit. Five measurements were taken from five flag leaves in each plot and averaged. Canopy temperature depression (CTD), the difference between crop canopy temperature and air temperature, was measured in the early afternoon after flowering, utilizing an infrared thermometer (Model No. 110.2L, Everset interscience Inc, USA).

A net area of 2.4 m^2 (4 rows by 3 m) was hand harvested from the ground level in the first season and 4.8 m^2 (6 rows by 4 m) in the second season. The harvested material was bundled and left to dry for at least 10 days, then weighed, threshed and the grain was weighed again to give biomass and grain yield. Harvest index was calculated as the ratio of grain yield to biomass weight.

Data were subjected to analyses of variance for each season separately and then combined analyses were carried out after the error mean squares were tested for homogeneity. Only the combined data for both seasons are presented. Simple correlation coefficients were calculated among different traits using genotype means across N levels (n = 48).

3. Results and discussion

Significant differences were found between the N levels and genotypes for all studied traits except genotype differences for chlorophyll content. Addition of more N over 0N increased chlorophyll content, canopy temperature depression (CTD), biomass and grain yield of all genotypes. However, the magnitude of the response varied greatly among the genotypes, although the genotype x N-level interactions for various traits were not statistically significant.

Addition of 1, 2 and 3 N-levels increased the mean chlorophyll content of the 12 genotypes by 13, 21 and 22% respectively over the no N treatment (Table 1). Genotypes Giza 155, Bohaine, Imam and Tagana showed less than 10% increase in chlorophyll contents at 1N compared to 0N. On the other hand, genotypes Condor, Argine, Wadi Elneel, Elnielain and Beladi showed more than 14% increase in chlorophyll content at 1N compared to 0N. Tagana and Condor showed the lowest (13) and highest (36) percent increase in chlorophyll content at 2N, respectively. At 3N, the chlorophyll content of Giza 155 increased by 15% while that of Condor increased by 28% compared to 0N.

Averaged across seasons and genotypes, CTD increased by 30, 57, and 67% at 1N, 2N and 3N, respectively, compared to that at 0N (Table 2). At 1N, the CTD of Debeira increased by 19% while that of Giza 155 showed an increase of 53% compared to 0N. Nesser and Giza 155 were the top responding genotypes to the addition of 2N. In contrast, Elnielain and Debeira were the least responding genotypes. Similarly, the most and least responding genotypes to the addition of 3N were Giza 155 and Elnielain, respectively.

Mean biomass of the 12 genotypes increased with increasing rates of N (Table 3). At 1N, Argine showed only 1% increase in biomass while Wadi Elneel showed 43% increase compared to that at 0N. The increase in Condor was 27% while that in Wadi Elneel was 65 at 2N. Khalifa and Nesser were the two contrasting genotypes in the at 3N compared to 0N.

Significant differences in grain yield among N levels and genotypes were found (Table 4). Increasing N level from 0N to 1N, 2N and 3N resulted in increases in grain yield by 24, 44 and 55%, respectively, across all genotypes. Increasing N level from 0N to 1N increased grain yield with a range from 4% in Argine to 45% in Wadi Elneel. Increasing N level from 0N resulted in grain yield increases ranging from 13% in Condor to 69% in Nesser for 2N, and from 34% in Debeira to 87% in Khalifa for 3N. Genotypes Khalifa, Imam, Bohaine and Elnielain showed continuous increases in grain yield with increasing rates of N. In contrast, addition of more N above 2N did not improve the grain yield of Wadi Elneel, Tagana and Nesser. Most of the increase in grain yield of the latter genotypes resulted from the addition of 43 kg ha^{-1}. Similar results for the responsiveness and efficiency of wheat genotypes to the addition of N have been reported (Ortiz-Monasterio et al. 2001; Baric 2007).

Genotypes showed mixed reactions in response of harvest index (HI) to increasing N levels. For example, the HI of Nesser increased by 14, 15 and 10% under 1N, 2N and 3N, respectively, compared to 0N, while Beladi, Giza 155, Condor and Debiera showed decreasing trends with addition of more N (Table 5).

The increases in grain yield under the four N levels correlated significantly with the increases in chlorophyll content ($r = 0.75$, $P < 0.001$), CTD ($r = 0.78$, $P < 0.001$), and biomass ($r = 0.86$, $P < 0.001$). However, some genotypes efficiently used the increases in biomass and CTD under high N levels for higher grain yield production (e.g Khalifa, Elnielain), while others were less efficient (e.g. Giza 155, Tagana).

Table 1. Mean chlorophyll content (SPAD) of 12 bread wheat genotypes grown for two seasons under four N levels at Gezira Research Station Farm, Wad Medani, Sudan

	N level			
Genotype	0N	1N	2N	3N
Beladi	37.6	45.0 (20)	49.0 (30)	44.5 (18)
Giza 155	39.7	41.4 (4)	47.4 (19)	45.6 (15)
Condor	34.4	39.5 (15)	46.8 (36)	44.2 (28)
Debeira	36.9	41.2 (12)	43.0 (17)	44.7 (21)
Wadi Elneel	37.0	44.1 (19)	45.6 (23)	46.5 (26)
Elnielain	36.7	43.7 (19)	45.7 (25)	46.5 (27)
Nesser	37.7	42.9 (14)	44.6 (18)	46.1 (22)
Argine	37.6	43.4 (15)	44.6 (19)	46.6 (24)
Imam	39.3	42.6 (8)	45.9 (17)	47.0 (20)
Tagana	38.8	42.5 (9)	43.9 (13)	46.4 (19)
Khalifa	39.0	43.8 (12)	45.0 (16)	47.4 (22)
Bohaine	37.6	40.2 (7)	44.2 (18)	44.2 (18)
Mean	**37.7**	**42.5 (13)**	**45.5 (21)**	**45.8 (22)**
SE mean (N x G)		1.80		
CV %		10.3		

Number in parentheses is the percent difference relative to 0N.
*** Significant at P = 0.001; NS, not significant.

Table 2. Mean canopy temperature depression (°C) of 12 bread wheat genotypes grown for two seasons under four N levels at Gezira Research Station Farm, Wad Medani, Sudan

	N level			
Genotype	0N	1N	2N	3N
Beladi	3.9	5.1 (32)	6.1 (59)	6.9 (78)
Giza 155	3.2	4.9 (53)	5.7 (77)	6.6 (106)
Condor	3.1	4.0 (29)	4.6 (47)	5.5 (76)
Debeira	4.1	4.9 (19)	5.7 (40)	6.7 (62)
Wadi Elneel	3.6	4.8 (33)	5.7 (56)	6.0 (67)
Elnielain	4.3	5.4 (26)	5.8 (36)	5.7 (33)
Nesser	3.3	4.3 (29)	6.1 (86)	5.4 (62)
Argine	4.0	4.9 (22)	6.2 (53)	6.4 (59)
Imam	4.0	5.1 (28)	5.9 (47)	6.1 (52)
Tagana	3.9	5.2 (35)	6.8 (75)	7.3 (88)
Khalifa	4.4	5.3 (21)	6.5 (47)	7.1 (61)
Bohaine	3.3	4.4 (32)	5.3 (60)	5.3 (61)
Mean	**3.8**	**4.9 (30)**	**5.9 (57)**	**6.2 (67)**
SE mean (N x G)			0.45	
CV %			21.2	

Number in parentheses is the percent difference relative to 0N.

Table 3. Mean biomass (kg/ha) of 12 bread wheat genotypes grown for two seasons under four N levels at Gezira Research Station Farm, Wad Medani, Sud

	N level			
Genotype	**0N**	**1N**	**2N**	**3N**
Beladi	6005	6981 (16)	8447 (41)	9533 (59)
Giza 155	5474	7079 (29)	8276 (51)	9679 (77)
Condor	5128	6206 (21)	6519 (27)	8661 (69)
Debeira	5853	7188 (23)	8101 (38)	8907 (52)
Wadi Elneel	4982	7148 (43)	8203 (65)	8522 (71)
Elnielain	5854	6934 (18)	8590 (47)	9215 (57)
Nesser	5089	6454 (27)	7465 (47)	7363 (45)
Argine	5547	5575 (1)	8385 (51)	9081 (64)
Imam	5433	7007 (29)	7924 (46)	9187 (69)
Tagana	5332	7253 (36)	8657 (62)	9439 (77)
Khalifa	4908	6729 (37)	7923 (61)	9402 (92)
Bohaine	5470	6444 (18)	7786 (42)	8104 (48)
Mean	**5423**	**6750 (25)**	**8023 (48)**	**8924 (65)**
SE mean (N x G)		444.4		
CV %		15.0		

Number in parentheses is the percent difference relative to 0N.

Table 4. Mean grain yield (kg/ha) of 12 bread wheat genotypes grown for two seasons under four N levels at Gezira Research Station Farm, Wad Medani, Sudan

	N level			
Genotype	**0N**	**1N**	**2N**	**3N**
Beladi	1923	2178 (13)	2558 (33)	2716 (41)
Giza 155	2000	2445 (22)	2722 (36)	2994 (50)
Condor	2272	2558 (13)	2561 (13)	3188 (40)
Debeira	2323	2668 (15)	3023 (30)	3104 (34)
Wadi Elneel	1988	2874 (45)	3145 (58)	3167 (59)
Elnielain	2306	2730 (18)	3314 (44)	3783 (64)
Nesser	1835	2603 (42)	3100 (69)	2889 (57)
Argine	2201	2283 (4)	3166 (44)	3364 (53)
Imam	2011	2510 (25)	2887 (44)	3352 (67)
Tagana	1952	2715 (39)	2979 (53)	2826 (45)
Khalifa	1985	2760 (39)	3101 (56)	3704 (87)
Bohaine	2129	2525 (19)	3103 (46)	3477 (63)
Mean	**2077**	**2571 (24)**	**2972 (44)**	**3214 (55)**
SE mean (N x G)		206.6		
CV %		18.7		

Number in parentheses is the percent difference relative to 0N.

Table 5. Mean harvest index (%) of 12 bread wheat genotypes grown for two seasons under four N levels at Gezira Research Station Farm, Wad Medani, Sudan

	N level			
Genotype	**0N**	**1N**	**2N**	**3N**
Beladi	31.7	31.3 (-1)	30.3 (-4)	28.4 (-10)
Giza 155	36.7	34.4 (-6)	32.8 (-11)	30.8 (-16)
Condor	44.3	41.4 (-7)	39.7 (-11)	37.5 (-15)
Debeira	39.8	37.1 (-7)	37.2 (-7)	34.9 (-12)
Wadi Elneel	40.1	39.8 (-1)	38.3 (-4)	37.0 (-8)
Elnielain	39.6	39.1 (-1)	38.3 (-3)	41.4 (5)
Nesser	35.9	40.7 (14)	41.2 (15)	39.4 (10)
Argine	39.6	41.2 (4)	37.8 (-5)	37.6 (-5)
Imam	36.8	35.5 (-3)	36.5 (-1)	36.5 (-1)
Tagana	36.7	37.7 (3)	34.0 (-7)	30.3 (-17)
Khalifa	40.9	41.6 (2)	38.9 (-5)	39.4 (-4)
Bohaine	39.3	39.6 (1)	39.9 (2)	42.9 (9)
Mean	**38.4**	**38.3 (0)**	**37.1 (-3)**	**36.3 (-5)**
SE mean (N x G)		1.70		
CV %		11.1		

Number in parentheses is the percent difference relative to 0N.

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Genotypes differentially responded to N levels in terms of various traits suggesting the existence of wide variability in N utilization efficiency. Genotypic variability observed in this study for N utilization efficiency and responses supports the idea of including low-input selection environments to maximize selection gains for breeding programs targeting production with low N input (Van Ginkel et al. 2001; Brancourt-Hulmel et al. 2005). However, this should not be done at the expense of grain quality which is expected to decrease under low N input.

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3.19. Biological nitrogen fixation by faba bean grown on heavy metal contaminated soil with application of ^{15}N technique

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Abstract

A greenhouse experiment was conducted to evaluate the effects of bacterial and fungi inoculation on faba bean plants grown on heavy metal contaminated soil. Bioremediators such as bacteria, fungi, yeasts and actinomycets (BFYA group) were also applied for avoiding the toxic effect of such metals. *Rhizobium* inoculation with or without BFYA had a positive effect on percentage of nitrogen derived from fixation (BNF). The BNF was not much affected by the biofertilization treatments. In some cases, i.e. *Azospirillum brasilense* + BFYA, arbuscular mycorrhiza (AM), or AM+ BFYA, the Ndfa values were negative because the fixing plant had a higher $^{14}N/^{15}N$ ratio than the uninoculated non-legume reference crop. It seems that Ndfa values were erratic when BFYA treatment was included. Nodulation (numbers and dry weight) was improved by the biofertilizer application both in the presence and absence of BFYA.

1. Introduction

Wide areas have been irrigated with sludge effluent for several years in Egypt (Abdel Aziz 2005). The soils of these areas have gone out of crop production because of accumulation of heavy metals. Soil microorganisms are sensitive to long-term exposure to moderate concentrations of heavy metals (Giller et al. 1993). Therefore, microorganisms most tolerant to heavy metals have been used as bioremediators. Also, *Rhizobium* and arbuscular mycorrhizal (AM) fungi have been found to act as bioremediators (Abdel Aziz 2005). In this regard, Leyval et al. (1991) observed that shoot accumulation of Zn, Cu and Pb decreased with mycorrhizal colonization at high concentrations of the metal in the medium.

Inoculation of legume plants with AM fungi and *Rhizobium* was found to have a synergistic beneficial effect on plant growth, nodulation and nitrogen fixation (Daft and El-Giahmi 1978). Nodulation and BNF require a high P status in the host which can often be improved by the mycorrhizal endophyte. The beneficial effect of dual inoculation with AM and *Rhizobium* was reported in soybean (Pacovesky et al. 1986), ground nut (Krishna and Bagyaraj 1983), cowpea (Islam et al. 1980) and chickpea (Subba-Rao et al. 1985) on nodulation, nitrogen fixation, growth and yield as well as P content. Also, the dual inoculation effect on P and Zn was examined on green plants, using ^{32}P and ^{65}Zn, by Johri and Adholeya (1986). A marked increase in uptake was obtained as compared with control or the use of AM alone. El Ghandour and Galal (1997) reported that the inoculation of faba bean with Rh+AM increased shoot dry weight as well as number and weight of nodules and could affect a saving of about 80% in the need for use of N and 50% of P fertilizers.

Dewan and Subba Rao (1979) studied seed inoculation with *Azospirillum brasilense* and *Azotobacter chrococcum*, in relation to root biomass of rice plants and found significant improvement. Similar increases in root biomass were noticed with wheat plants (Galal 1993). Raverkar and Knode (1988) reported that, inoculated peanut with *Rhizobium* strain and/or *Azospirillum lipoferum* enhanced nodulation, N content and yield under field conditions, while a mixed inoculant of these two dizotrophic cultures had an adverse effect on these parameters as compared to the single inoculant. Also, they noticed synergistic effects of *Azospirillum* with *Rhizobium* as well as with *Azotobacter* in different legumes. Mixed cultures of *Azospirillum* and *Rhizobium trifolii* strains inhibited nodulation in clover plants (Plazinski and Rolfe 1985). Bashan et al. (1990) found *Azospirillum* to enhance the mineral uptake by soybean plants. Moreover, *Azospirillum brasilense* applied before *Rhizobium* increased nodule formation and the susceptibility of host roots to *Rhizobium* infection, which was attributed to a stimulating effect of hormones excreted by *Azospirillum*. These hormones could stimulate or decrease nodulation by *Rhizobium* (Okon and Hadar 1987).

The effect of heavy metals on BNF was studied at Rothamsted Experimental station in the long- term sewage sludge plots (McGrath et al. 1988; Giller et al.1989). The populations of *R.leguminosarum* were found ineffective and there was a significant reduction in N_2 fixation compared to the unamended control. The sludge-borne heavy metals, primarily Cd, Zn, and Cu, were thought to be responsible for this. However, Obbard and Jones (1993 and 2001) reported the presence of *Rhizobium* capable of developing effective symbioses with white clover grown in soils highly contaminated with heavy metals. They also concluded that heavy metals might have quantitative effect on the free-living population of rhizobia. Abdel-Aziz et al. (1997) found that faba bean nitrogen content was significantly improved with sewage sludge application and vesicular arbuscular mycorrhiza (AM) inoculation, and the best result was obtained with addition of 2 % sewage sludge, irrespective of the source. The addition of 4 % sewage sludge decreased the studied parameter.

In the present study, done under green house, we aimed to follow up the effect of biofertilizers (AM, *Rhizobium* and *Azospirillum brasilense*) either alone or in combination with BFYA group on nodulation and BNF of faba bean on a soil contaminated with heavy metals.

2. Materials and methods

Pot experiment was carried out in the greenhouse of the Soil and Water Research Department, Nuclear Research Center, Atomic Energy Authority, Egypt to evaluate the impact of BFYA (heavy metal tolerant group) and biofertilizers (fungi and bacteria) in reducing the impact of the heavy metal-pollution of soils on biological nitrogen fixation in faba bean.

Soil samples were collected from surface layer (0 – 40 cm) of different sites of Al-Gabal Al Asfar farm, Abou-Zaabl, Egypt, in September 1998. The sites were cultivated and treated with sludge effluent for more than 60 years. From this, the microbial community used for this pot experiment was isolated. The soil was sandy loam (64% sand, 27% silt, 9% clay), had a pH of 6.5, OM content of 7.03 %, N content of 0.323%, available P 1.66 ppm, EC 1.9 dSm^{-1}. The heavy metal content (ug/g soil) was: 433.05 Pb^{2+}, 1037.0 Zn^{2+}, 10.1 Cd^{2+}, 474.0 Ni^{2+}, 28.7 Co^{2+}, 417.0 Cu^{2+}. Total count of bacteria (CFU/gm dry soil) was 5.15 X 10^6 and that of the Nitrogen fixing bacteria was 5.9 X 10^6.

Seeds of faba bean (*Vicia faba* cv. Giza 40) and wheat(*Triticum aestivum* cv. Sids 1), as a reference crop needed for quantifying Ndfa using isotope dilution technique, were provided by the Agricultural Research

Center (ARC), Ministry of Agriculture, Giza, Egypt.

Two types of microbial inocula were used:

1. Biofertilizers and nitrogen fixers; an effective strain each of the symbiotic and the asymbiotic nitrogen fixers was obtained from Agricultural Microbiology Department, ARC. These were *Rhizobium leguminosarum* biovar *vicia* (Rh) (mixed culture of ARC 207 and ICARDA 441) and *Azospirillum brasilense* (Azo) No. 40; and arbuscular mycorrhiza (AM). Spores of mycorrhizal inoculum were isolated using the wet-sieving (Gerdemann and Nicolson 1963) from fertile soil, which had been cultivated with several crops in the Soil Microbiology Laboratory, Soil and Water Department, Atomic Energy Authority.
2. Heavy metal-tolerant group of microflora (BFYA group) comprising of bacterial (B), fungi (F), yeast (Y) and actinomycets (A) isolates. A mixture of BFYA group was isolated from two sources: (a) Nile down-stream of delta Barrage and pure water (El-Rahawy drain Water), provided by Department of Microbiology, Faculty of Science, Al-Azhar University. The bacterial isolates included *Micrococcus luteus*, *Pseudomonas diminuta* and *Pseudomonas facilis*. Fungal isolates included *Aspergillus fumigatus* and *Aspergillus fiaccum*. Yeast isolate included *Candida curvata*. Actinomycets isolate included *Streptomyces sannanesis*. (b) Microflora in the collected soil samples isolated in the Department of Soil and Water Research, Nuclear Research Center, Atomic Energy Authority and identified in the Department of Microbiology, Faculty of Science, Al-Azhar University. The isolates included *Aspergillus parasiticus* and *Fusarium oxysporum.*

Soil collected from Al-Gabal Al-Asfar farm was packed in 48 pots (28 cm height, 25 cm diameter) each containing about 6.5 kg soil. Rock phosphate (Rp) as phosphorus source (27.5 % P_2O_5) from Safaga was applied as a finely (100 mesh) ground natural product at rate of 0.5 g Rp pot^{-1}. Basal dose of potassium sulfate was also added at rate of 0.5 g pot^{-1}. Four plants were grown per pot under greenhouse condition. Nitrogen was applied in the form of labeled ammonium sulfate at the rate of 0.15 g per pot (5% atom excess) at 15 days after sowing. A complete randomized blocks design, with different treatment combinations (Table 1) using the above mentioned nine isolates of heavy metal-tolerant group and three of biofertilizers type, was used. At maturity stage (120 days), plants were harvested, separated in seeds, shoot and root, dried at 70 ^{o}C until constant weight, and weighed (data not given here). Plant parts were analysed for N content and isotopic dilution ($^{14}N/^{15}N$ ratio).

The data were subjected to ANOVA statistical analysis followed by multiple range test Duncan's (MRTD) according to SAS (1989).program.

3. Results

3.1. Nodulation

Nodule number and weight (Table 1) of faba bean plant increased with Rh inoculation combined with BFYA. Similarly, increased nodule number was recorded with dual inoculants (Rh+AM; Rh+Azo; Azo+AM)) combined with tolerant organisms. For instance, the treatment of Rh+AM + BFYA was the best amongst the dual and composite inocula. Averaged over all inoculant treatments, nodulation was improved by BFYA. Nodulation was significantly affected by application of BFYA as compared to untreated soil. This can be attributed to large population (2 x 10^8) of native or re-inoculated *Rhizobium leguminosarum* biovar *vicia,* which might have caused nodulation.

Table 1. Effect of inoculation with different biofertilizers and BFYA group on number and dry weight of nodules of faba bean plan

Treatments	Number of nodules per pot		Dry weight of nodules (g per pot)	
	-BFYA	+BFYA	-BFYA	+BFYA
Control	53.0c	89.7abc	0.150bc	0.167abc
Rh	67.0bc	118.7a	0.163abc	0.267a
Azo	62.7bc	91.0abc	0.180abc	0.147bc
AM	71.0bc	86.3abc	0.160abc	0.167abc
Rh+Azo	90.3abc	83.7abc	0.120c	0.24abc
Rh+AM	80.3abc	99.3ab	0.163abc	0.237ab
Azo+AM	92.7abc	63.7bc	0.150bc	0.160abc
Rh+Azo+AM	65.7bc	70.0bc	0.177abc	0.133bc
Mean	72.84	87.8	0.158	0.190
LSD (0.05):				
BFYA (A)	11.96		0.032	
Biofertilizers (B)	23.92		0.065	
Interaction (AxB)	33.83		0.091	

3.2. Biological nitrogen fixation (Ndfa)

Rhizobium inoculant had a positive effect on percentage of plant nitrogen derived from atmosphere (Ndfa %) both in the opresence and absence of BFYA group (Table 2). Under inoculation with Azo and AM alone there was decrease in the Ndfa (the values were negative) both in the absence and presence of BFYA. The reduction was particularly high in the absence of BFYA. The faba bean plant under these treatments had a higher $^{14}N/^{15}N$ ratio than the non-legume reference crop (wheat). These results can be attributed to the enhancement in the fertilizer N uptake by faba bean plant under AM and Azo treatments (Table 3). Composite inocula induced higher percentage of nitrogen derived from fertilizer (Ndff%) with BFYA inoculation than those recorded without BFYA goup. Consequently, N-fertilizer was efficiently utilized by faba bean treated with *Azospirillum brasilense* and arbuscular mycorrhizal fungi as compared to other treatments including the control.

Faba bean plants under the treatments of *Azospirillum brasilense* and arbuscular mycorrhizal fungi had more access to N derived from fertilizer; therefore their symbiotic N_2 fixation process was inhibited. Dual inoculation with Rh+Azo showed high percentage of BNF when combined with BFYA as compared to the absence of BFYA group. Opposite was the effect of BFYA when dual inoculation with Rh + AM was done. This is difficult to explain.

Interaction between BFYA group and biofertilizers was significant. Rhizobium inoculation either alone or in dual or composite inoculum resulted in higher absolute values of BNF when soil was treated with BFYA than without.

4. Discussion

Rhizobium is known to enhance nodulation either alone (Abd El-Ghafar, 1988) or in combination with the lower nitrogen levels (Saad, 1990; Abd El-Ghaffar, 1988; El-Ghandour et al., 1996; and Galal, 1997). Dual inoculation with Rh+Azo stimulates nodulation in soybeans (Singh and Subb Rao, 1979) peanuts (Raverkar and Knode, 1988), broad beans (Fayez et al., 1988). Biomy (2000) indicated that *Rhizobium* isolates of Al-Gabal Al-Asfar site did not lose their

Table 2. Effect of inoculation with different biofertilizers and BFYA group on percentage of nitrogen derived from air (Ndfa %) and uptake of BNF (mg per pot) by faba bean seeds

Treatments	**Ndfa %**		**Ndfa mg pot-1**	
	-BFYA	+BFYA	-BFYA	+BFYA
Control	18.4	51.6	35.37e	200.8bcd
Rh	51.09	49.83	232.1bc	158.3cd
Azo	-70.0	-42.1	-222.2fg	-193.6f
AM	-118.6	-86.6	-309.0gh	-377.6h
Rh+Azo	43.97	52.8	219.1bcd	296.1ab
Rh+AM	50.94	45.9	241.4bc	382.4a
AM+Azo	50.6	53.7	116.8de	278.4ab
AM+Rh+Azo	-60.07	48.3	-165.5f	315.6ab
Mean	-4.2	21.7	18.5	16.6
LSD (0.05):				
BFYA (A)			35.71	
Biofertilizer (B)			71.43	
Interaction (AxB)			101.0	

Table 3. Effect of different biofertilizers and BFYA inoculation on percentage of nitrogen derived from fertilizer (Ndff%) and fertilizer N uptake by seeds of faba bean seeds

Treatments	Ndff %		Ndff mg pot-1	
	-BFYA	+BFYA	-BFYA	+BFYA
Control	28.7	16.7	59.6	58.0
Rh	17.1	17.7	79.5	56.7
Azo	59.6	49.5	18.8	23.3
AM	76.8	65.3	198.8	128.9
Rh+Azo	19.7	16.6	97.3	96.3
Rh+AM	17.8	19.9	83.0	158.7
AM+Azo	17.3	16.3	40.3	119.1
AM+Rh+Azo	15.5	17.5	54.6	136.8
LSD (0.05):				
BFYA (A)			17.9	
Biofertilizer (B)			35.8	
Interaction (AxB)			50.6	

capacity to infect the faba bean roots even after having been exposed to continuos application of sludge-borne heavy metals for many years. This means that such polluted area may have *Rhizobium* isolates possessing ability to survive under high levels of heavy metals, available nitrogen and other bio-toxic substance present in sludge.

Presence of large number of rhizobia in the soil might be one of the most important factors that determine efficient nodulation (Ibekwe et al. 1995). As noted by Giller et al. (1989), increasing rhizobial concentrations added to contaminated soil above 107 cells per g, effective nodulation was observed. Results of our study also showed that nodulation and BNF increased by application of rhizobial inoculation at a fairly high rate ($2x10^8$ cells per g soil). This is in agreement with the results of Giller et al. (1989) who reported that inoculation with effective *Rhizobium* resulted in effective N_2 fixation. Regarding the effect of AM on nodulation, our findings agree well with those of Azcon-Aguilar and Barea (1981) and Kucey and Paul (1982) who reported that VAM positively influenced plant nodulation and nodule activity. Also, our results are in agreement with those of El-Kherbawy et al. (1989), who found that nodulation was induced by dual inoculation with (Rh+VAM) in a soil with a pH of 7.2.

Giller et al. (1989 and 1993) reported that sludge might have a negative effect on the indigenous rhizobia. On sludge-added soil in our study, application of BFYA with biofertilizers induced increments in nodulation perhaps by altering the adverse effect of heavy metals. Data on nodulation in the present research agree with the data of VAM inoculation in the soil amended with different rates of sewage sludge as reported by Abdel-Aziz et al. (1997). Saad (1990) also found that nodule dry weight was greater in mycorrhizal plants than non-mycorrhizal ones.

The nodulation in faba bean under un-inoculated treatments indicated the presence of native faba bean rhizobia in the soil used in this study. This was confirmed also by isolation study done on the soil used (Table 1). Biomy (2000) reported that faba bean plants nodulated on mast Egyptian soils as they are commonly inhabited with faba bean rhizobia. Presence of *Rhizobium* in our soil can be attributed to the presence of sludge organic matter which could have helped the survival of *Rhizobium* in soil during the dry periods (Lowendrof 1980) or by improving soil aeration

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Theme 4. Biodiversity conservation and utilization

4.1. Genetic diversity in the core subset of bread wheat (*Triticum aesitivum* L.) evaluated for water deficit revealed by agronomical characterszation and molecular markers

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Abstract

Since the beginning of this century, productivity and total area of wheat in Egypt had been stable and had helped reach wheat self sufficiency. But, increasing population is creating more demands for increased food production under limited water resources that are under further stress because of global warming and climate change. Increasing the wheat area could be an excellent way to meet the demands, but it would necessitate development of cultivars adapted to deficit water situation. In this study 72 different wheat accessions from Egypt, Sudan, Yemen and CIMMYT were evaluated for tolerance to water deficiency under sandy soil conditions in the 2005-2006 and 2006-2007 growing seasons. Five different moisture regimes, ranging from severe water stress (177 mm/year) to normal irrigation water (520 mm/year), were used under gradient line-source irrigation system. Cluster analysis indicated that six genotypes performed well under water stress, while 14 genotypes were medium. WUE data showed 17 genotypes performed well under water stress conditions. Using genotypes yield under favorable and water stress conditions the evaluated genotypes were classified into four groups. Group A displayed inadequate adaptation to both water stress and favorable regimes. Group B was specifically suitable under moisture stress but not under favorable conditions. Group C performed well under favorable conditions only. Group D performed acceptably under both conditions. So the genotypes in both groups B & D are of use to plant breeders. Isozyme analysis indicated that there was much variability between and within the four groups. The agronomical data and dendrograms based on RAPDs and ISSRs analysis were somewhat similar, suggesting that information will be useful to identify diverse wheat germplasm capable of withstanding water scarcity.

1. Introduction

In Egypt, wheat is a major food staple in the diet of the people. The per capita consumption is about 150 kg per year. Despite the significant growth in Egyptian wheat production, the country is currently importing around 50% of its wheat.

Higher productivity being basic need for increasing total crop production in a country like Egypt, where land is limited, efforts have been directed to increase productivity in the country since 1981. As a result the wheat productivity has increased from 3.3 t/ha in 1981 to 6.4 t/ha in 2000s.

Since the year 2000, the productivity (around 6.4 t/ha) has remained constant and the area has stayed around 1.3 million hectares, leveling out total wheat production around 8.3 million metric tons Only two high yielding improved cultivars, ‘Sakha 93’ and ‘Giza 168’ have been adopted on about 60% of the total wheat area contributing to about 58% of total wheat production. The remaining high yield-potential cultivars and old varieties cover about 40% of the total wheat area. Thus, the increase in total wheat production in Egypt in the last five years has depended more on increasing the cultivated area rather than the productivity of the cultivars.

Using DNA-marker based genetic similarity (combined RAPDs and SSRs analysis) study Abdel-Tawab et al. (2006), divided ten high-yield potential Egyptian commercial cultivars into only two genetic groups, one of which included the above two cultivars. Moreover, 27 improved wheat genotypes were split into only four polymorphic genetic groups using RAPD's DNA-marker based on sharing common ancestors (Abdel-Ghani 2006). This higher genetic similarly could reduce the amount of genetic variability of wheat genetic tock cultivars and their progeny in breeding program (Gupta et al. 1999;, Koebner and Summers 2003; Kraakmaan et al. 2004). Therefore, improving wheat productivity in would need introducing diverse genotypes.

Almost the entire wheat cultivated area occurs as narrow stripe of land along the River Nile and in the central part of the Nile Delta. Egypt has to look for new areas to sustain increases in wheat production. There is potential for increasing total wheat area only along the eastern and western flanks of the Nile Valley. However, the production in these moderate to low potential terrains is limited mainly by water scarcity and infertile soils. Increasing wheat production could therefore be a difficult task. Competition for water resources is expected to increase threefold in the next decades because of alarming population growth, increasing food demands and high rate of soil reclamation. Climate change is also projected to be rendering the management of water resources more difficult in arid and semi-arid countries (Mendelsohn 2000; Watson 2002). Egypt is entirely dependent on irrigation from the River Nile, where 55.5 billion cubic meters of water allocated. The Nile offers about 97% of Egypt’s renewable supply, while the rest is from scattered rains and limited ground water. The annual per capita freshwater resources have been declining from 930 m^3 since the end of the last century and it is expected that the availability would drop to near 350 m^3 by the year 2025. The climate change is also exacerbating the loss of biodiversity. Therefore, it is essential to understand how to minimize losses, assure beneficial use and increase the efficiency of use of limited resources to increase crop productivity under changing climates. The genetic capacity of the crop plants to withstand the adverse environmental conditions is the key to sustained production (Abdel-Ghani, 1999, 2006; Abdel-Ghani et al. 1993, 1994; Eagles et al. 2001; Koebner and Summers 2003; Tawfelis 2006; Van Sanford et al. 2001).

There are considerable differences between wheat genotypes to withstand water deficit (Abdel-Ghani, 1999; Blum 1996). However, only a few have been found to be satisfactorily productive under water stress (Turner 1997, 2004). Assessment of inbuilt diversity in the collected accessions by growing them under a variety of conditions, and characterizing them is essential to identify material for improving wheat genotypes for water scarce situations. Several researchers have reported that Gradient Line Source Sprinkler Irrigation System can produce a nearly linear water application with the amount of irrigation declining as a function of distance from the sprinkler line (Hanks et al. 1976; Pfeiffer et al. 1991; Singh 2001). Using molecular marker techniques in cereals has proved promising to accurately estimate the genetic differences/resemblance among genotypes at the DNA level by direct sampling of the genome (Cao et al. 1999; Garner et al. 1994; Kim and Ward 1997; Medini et al. 2005; Messmer et al. 1993; Pfeiffer et al. 2005). It also speeds up the process of identifying genetically diverse individuals and populations.

The improvement in water-stress tolerance in the wheat depends on understanding the range of genetic variation available by exploring the performance of wheat lines under water shortage. This investigation aimed at generating this information by using modern tools of creating differential water supply and studying genotypic differences at molecular level.

2. Materials and methods

The test system included ten sprinklers spaced at 9 m. The system was operated at 2.5 bars with a discharge of 1.5 m^3/hr/sprinkler, which produced a wetted radius approximately 12 m. The water distribution data shown in Figure 1 was collected just after planting and periodic checks throughout the growing season showed almost identical results. The relative sprinkler application rate was uniform along the length of each row of the plot. The basic amount of irrigation water provided uniformly included 386 m^3/feddan (92 mm) to ensure sowing and complete emergence.

Seventy-two bread wheat genotypes (18, 37, 16 and 1 from Egypt, Sudan, Yemen and CIMMYT, respectively) were evaluated for water deficit under sandy soil conditions at Ali Mubarak Research Station, ElBustan, South Tahrir, during 2005-06 and 2006-07 growing seasons (Table 1). The soil was low in available N (7-15 ppm) and organic matter (0.07-0.09 %) and had a water holding capacity of about 6-10 %. All the work was conducted through Pant Genetic Resources Department (Bahteem Gene Bank). A randomized complete block design with two replicates was used for allocating the genotypes. Each genotype was placed perpendicular to the Sprinkler Line Source experiencing five water regimes.

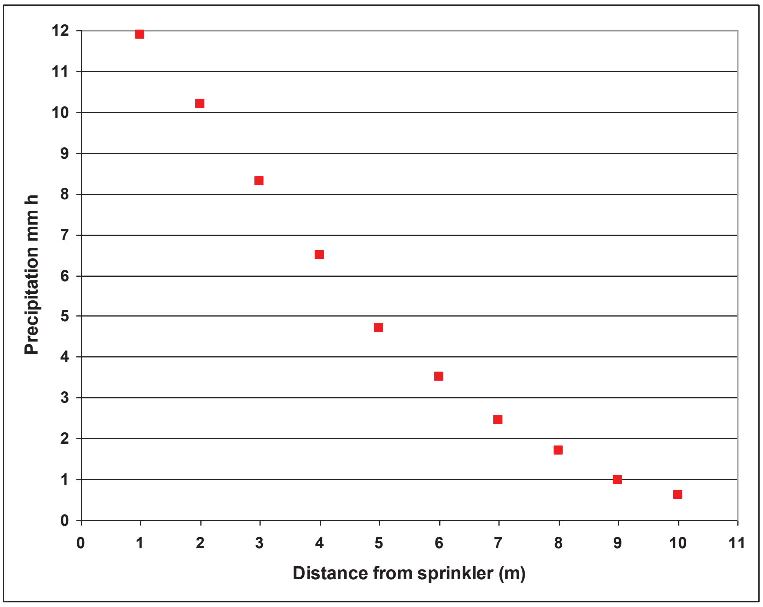

Figure 1. Discharge of water (mm/h) at different distances (m) from the sprinkler head.

Table 1. Plot number, pedigree and origin of 72 wheat landraces evaluated under line source irrigation system at El-Bustan on sandy soils

Plot #	Pedigree or Cross	Origin	Plot #	Pedigree or Cross	Origin
1	22SAWSN-184	SUD	**37**	Fow-2/SP8036	SUD
2	ELAME4SA-464	SUD	**38**	MNCH 3*BCN CMBW 90 YS 756-0T0PM-14Y-010M-010M-010Y-5M-	EGT
3	22SAWSN-166	SUD	**39**	Sids **1**	EGT
4	TR135 / GP NO4// Condor	SUD	**40**	KAUZ/STAR	SUD
5	FANG60/SERI-21USA	EGT	**41**	22SAWSN-77	SUD
6	GAA"S"/Opata	SUD	**42**	BSP93-21 OSAF	SUD
7	KAUZ/WEAVER	SUD	**43**	Gemmeiza 9	EGT
8	OASIS/SKAUZ//4*BCN	SUD	**44**	TEVEE"S"/TDINA	SUD
9	HP 1744-OIND	EGT	**45**	Giza 168	EGT
10	CMBW90Y341-0TopM	SUD	**46**	KAUZ/KAUZ/STAR	SUD
11	BL1724	SUD	**47**	BARBETTI	SUD
12	F4 200/2001 # 427	SUD	**48**	KUZ*2/BOW//KAUZ	EGT
13	Kauz//Bow/NRI	SUD	**49**	Pc970 X G155 X Bow"s"….	SUD
14	KAUZ/GYS/KAUZ	EGT	**50**	Giza 165	EGT
15	G. 155/ Nai 60//Deb	SUD	**51**	UP2338	SUD
16	22SAWSN-45	SUD	**52**	Super Seri # 2	SUD
17	G. 155/7C//Inia/3/Nielain	SUD	**53**	KUZ*2/MNV//KAUZ	EGT
18	CAZO/KAUZ//KAUZ	EGT	**54**	22SAWSN-27	SUD
19	Sahel 1/ KAUZ	EGT	**55**	1 YSN	YEM
20	EALME4SA-167	SUD	**56**	2 YSN	YEM
21	OASIS/SKAUZ//4*BCN	EGT	**57**	3 YSN	YEM
22	Kauz*2//SAP/MON/3/Kau	EGT	**58**	4 YSN	YEM
23	22SAWSN-72	SUD	**59**	5 YSN	YEM
24	KAUZ"S"	SUD	**60**	6 YSN	YEM
25	Son64 /Ske//IR64A/3/G.155	SUD	**61**	7 YSN	YEM
26	SERI/NKT//2*KUZ	EGT	**62**	8 YSN	YEM
27	KAUZ//ALTAR 84/ADS	EGT	**63**	9 YSN	YEM
28	OASIS/SKAUZ//4*BCN	SUD	**64**	11 YSN	YEM
29	TEVEVEE"S"/SHUHA"S	SUD	**65**	12 YSN	YEM
30	HAHN/2*WEAVER	EGT	**66**	13 YSN	YEM
31	BOBWHITE-1//MN72131/PVN	SUD	**67**	14 YSN	YEM
32	Lni 60/Giza155	SUD	**68**	15 YSN	YEM
33	NS732/HER//CASKOR	SUD	**69**	Sahel 1	EGT
34	Ttila/3/CRC/Chen…	SUD	**70**	Yacora	CIMMYT
35	KUZ*2/SOW//KAUZ CRG 905-13Y-010M-0Y-0HTY	EGT	**71**	Hadramout	YEM
36	El Nielain	SUD	**72**	Halba	YEM

Each water regime included six rows 2 m long and 20 cm apart. Seeding rate was 400 grain/m^2 and the agronomical practices were as recommended. At maturity, 2 m from each of the four central rows was harvested. Data were obtained for grain yield and its components.

The effectiveness of the studied germplasm to withstand water stress was evaluated as water use efficiency according to Vites (1965): WUE = Grain Yield kg / Applied Water m^3. Grain Yield Response index (GYRI) was calculated according to Abdel-Ghani and Awad (1999); Fageria and Barbosa Filho (1981) as follows:

GYRI =

(Yield under high water supply ─yield under low water supply) ÷ (High water─low water)

Using this index, four groups were identified: A) Non-efficient and non-responsive (NENR); B) Efficient and non-responsive (ENR); C) Non-efficient and responsive (NER); and D) Efficient and responsive (ER).

Diversity values based on phenotype classifications were calculated through cluster analysis. Classification methods, such as hierarchical cluster analysis (Kaufman and Rousseeuw 1990), are used to investigate patterns of phenotypic diversity existing in germplasm collections and to separate homogeneous subgroups from a heterogeneous population to form core subsets (Brown 1989; Franco et al. 2006). Group average hierarchical cluster analysis, using GenStat C (Version 7) program, was done to develop dendrogram subgroups.

RAPD (Table 2) and ISSR (Table 3) based PCR and their combinations were used to determine the correspondence between agronomical characterization - and DNA marker-based genetic similarity. A binary matrix reflecting the presence (1) or absence (0) of each RAPD or ISSR band was generated for each genotype. Genetic distances among the studied as well as similarity matrices were done using Gel works 1 D advanced software UVP-England program. The distance matrix generated was used to obtain a dendrogram by the un-weighted paired-grouping method with arithmetic averages, using GenStat C (Version 7) statistical program.

3. Results and discussion

There was large genetic variability between the accessions in their reaction to restricted irrigation. In general, the variable water stress treatments significantly affected average productivity. It was about 3.6 t/ha under 520 mm to about 0.9 t/ha under 177 mm. However, reducing total applied irrigation water from 100% to 80% dropped average yields only slightly to 3.3 t/ha (Fig. 2).

Cluster analysis indicating that six genotypes performed well under water stress, while 13 genotypes showed

Table 2. List of the RAPD primers and their nucleotide sequences used in the study

No	Name	Sequence	No	Name	Sequence
1	OP-B09	5` CTCACCGTCC 3`	**5**	OP-B05	5′ GTGACCCCTC 3`
2	OP-A11	5′ CCTTGACGCA 3`	**6**	OP-B07	5′ GGCGGTCTTT 3`
3	OP-A17	5` GGG CGG TAC T 3`	**7**	OP-B12	5′ CCTTGACGCA 3`
4	OP-A19	5` AGG TTG CAG G 3`	**8**	OP-C05	5` GATGACCGCC 3`

moderate performance with an average productivity ranging from 4.2 to 4.8 and 1.2 to 1.6 t/ha under high (520 mm) and low water (177 mm), respectively (Table 4). However, these genotypes showed moderate kernel weights with relatively higher kernels per spike. Numerous studies in the past have revealed evidence of genetically opposite relationship between grain weight and grain number. The ungrouped genotypes # 66 and 43 reflected higher yields under water stress, probably due to moderately and relatively higher grain per spike. On the contrary, the other groups and ungrouped individuals exhibited low yields and yield components, especially under deficit water. The genotypes showing good yield potential under reduced water conditions could be used as a sources of genes contributing to moisture stress adaptation, but its performance at the highest level of moisture supply is not the best indicator (Abdel-Ghani 1999; Blum 1996; Turner 1997, 2004).

Table 3. List of ISSR primers and their nucleotide sequences used in the study

No	Name	Sequence	No	Name	Sequence
1	HB08	5` GTGTGTGTGTGTGG 3`	4	HB13	5` GAGGAGGAGGC 3`
2	HB10	5` GAGAGAGAGAGACC 3`	5	HB15	5` GTGTGTGTGTGTGC 3
3	HB12	5` CACCACCACGC 3`			

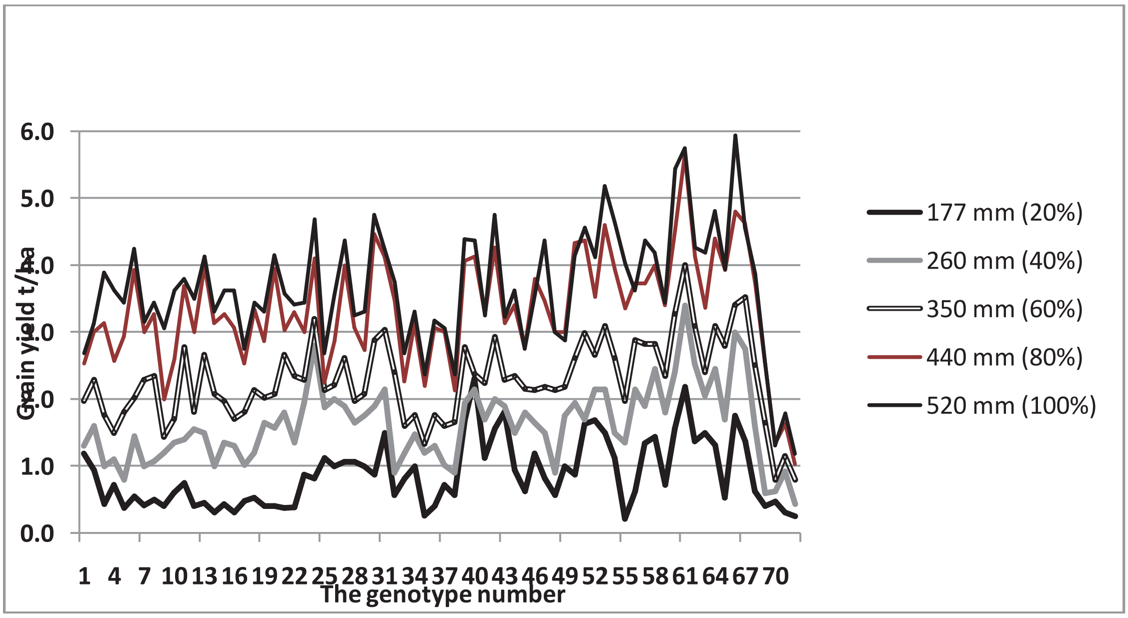

Figure 2. Grain yield (t/ha), averaged over two seasons, of 72 wheat genotypes planted under gradient Line Source Irrigation System to provide 5 levels of moisture supply.

Table 4. Average yield and yield components from group average cluster of 72 wheat genotypes

Group Number	No. of entries	Biomass (H)	Biomass (L)	*Red. %	Grain Yield (H)	Grain Yield (L)	Red. %	HI (H)	HI (L)	1000-KW (H)	1000-KW (L)	Red. %	Grain/spike (H)	Grain/spike (L)	Reduc %	Water stress tolerance
1	3	13.8	3.8	73	3.6	1.2	66	25.9	32.2	36.3	31.6	13	42.7	19.2	55	**
2	28	14.4	3.8	74	3.0	0.5	83	20.8	13.3	31.7	23.9	25	46.1	20.2	56	S
3	2	12.5	4.4	65	2.2	0.7	68	17.6	16.0	31.3	21.5	31	62.7	15.5	75	S
4	4	13.1	5.3	60	3.3	1.2	64	25.2	22.6	28.2	25.1	11	49.4	29.0	41	*
5	4	16.3	3.5	78	3.6	0.6	83	22.1	17.1	33.2	29.4	11	49.6	15.8	68	*
6	2	18.8	5.3	72	4.8	1.2	75	25.5	12.7	31.1	24.4	22	50.6	20.0	60	**
7	6	13.6	5.2	62	4.2	1.6	62	30.9	30.4	39.3	34.6	12	46.6	21.1	55	***
8	10	18.1	5.5	70	3.2	0.7	78	17.7	21.8	35.5	30.4	14	48.9	14.7	70	S
9	7	16.3	3.8	77	3.4	0.5	85	20.9	12.3	30.5	22.0	28	46.0	19.7	57	S
Ungrouped																
Entry No.	18	16.9	1.3	93	3.4	0.4	88	20.4	32.0	41.0	23.3	43	44.7	11.6	74	S
	30	15.0	3.8	75	4.8	0.7	85	31.7	18.7	33.7	13.3	61	15.6	11.0	29	S
	43	12.0	5.5	54	3.0	1.8	40	25.0	32.7	40.7	35.0	14	44.7	30.4	32	*
	66	17.8	5.5	69	5.9	1.8	69	33.1	32.7	43.8	36.9	16	58.3	39.8	32	**
	69	11.1	3.9	65	2.6	0.4	85	23.3	10.3	19.4	9.8	49	36.7	10.0	73	S
Average		**15.0**	**4.3**	**71**	**3.6**	**0.9**	**75**	**25.2**	**21.8**	**34.0**	**25.8**	**24**	**45.9**	**19.9**	**57**	

* Biomass & Grain Yield (t/ha) ** H (High Water)= 520 mm, L (Low Water) = 177 mm

Using the WUE values resulted in three main groups for withstanding water deficit; (i) high, as WUE values under water stress obviously surpassed those under favorable water conditions, (ii) medium, as the values under both conditions tended to be similar and (iii) low, as values under favorable water conditions dramatically exceeded those under water stress (Table 5). Higher values of WUE may indicate that genotypes can utilize soil water more efficiently under water deficit (Angus and Herwaarden 2001; Richards et al. 2002). Recently, several authors provided that conserving irrigation water could be done under the Egyptian conditions through the genotypes with lower yield losses and improved WUE (Abdel-Ghani, 1999; Ouda et al. 2007; Khalil et al. 2006; Khater et al. 1997; Mohamed and Tammam 1999).

Additionally, using yield productivity under favorable (520 mm) and water stressed (177 mm) conditions the evaluated genotypes were classified into four groups (Fig. 3). Genotypes in group A "NENR" (30 accessions) proved inadequately adapted to both water stress and favorable regimes. Genotypes in group B "ENR" (11 accessions) could be alright in moisture stress because they exceeded above average yield (0.9 t/ha) under water deficit, but did not have above average yield (3.4 t/ha) under favorable water conditions. In contrast, the 13 accessions in group C "NER" could stand out against those of B as contributing only well under favorable water conditions. However, the genotypes in group D "ER" (18 accessions) performed acceptably under both deficit and surplus water conditions. So the genotypes falling in the ER group are most desirable from a plant breeder's point of view for producing high yield at both low and high levels of applying irrigation water. In addition, genotypes under group ENR are also desirable because they exhibit reasonable average yields under water deficit. Therefore, breeding for water stress could consist of the selection and breeding of genotypes adapted to low water availability in along with a high efficiency in the utilization of water applied (Abdel-Ghani et al. 1994; Black 1966; Blum 1988).

Figure 3 shows how 72 different wheat accessions varied in their performance under water stress and favorable water regimes and how they were classified into four groups. This two-dimensional grouping could symmetrically scale yield data of the different genotypes across the favorable water level and severe water stress level proportionally to their performance under both conditions. However, the innermost located genotypes could posses intermediate yield and also be responsive over the studied water regimes (**Yan et al. 2000**). Therefore, seeds of 16 accessions (Table 6), far from the center of the above chart, four from each group out of the 72 genotypes, were selected and subjected to fingerprinting based on DNA markers.

The eight RAPD 10-mer arbitrary selected primer combinations succeeded in amplifying DNA fragments and produced a total of 107 bands. The number of bands amplified by primer combination varied from 12 to 15. A total of 68 bands were polymorphic across the entire sample. The percentage of polymorphic markers varied from 50 to 80 % (Fig. 4).

Cluster analysis (similarity index), based on RAPD-GS analysi, described as a dendrogram for the genetic relationships among the 16 wheat accessions, separated them into two main genetically diverse groups at level of similarity of 85.0% (Fig. 6). The first clustered 11 accessions into three sub groups, two of them (A & C) encompass low water stress as a common feature, but also shows the accessions of group B, which is characterized as high water stress tolerant. On the other hand, the second main group takes account of group D; higher yield and water stress.

Table 5. Average yield and WUE under high (un-stressed) and low water (stressed) supply conditions of 72 wheat landraces

Tolerance group	No. of genotypes	Grain yield (t/ha)		WUE (kg/m^3)		Genotype #
		Stressed	No stress	Stressed	No stress	
High	12	1.7	4.7	0.97	0.90	40, 61, 43, 66, 52, 39, 51, 60, 42, 63, 53 & 31.
Medium	10	1.3	3.7	0.71	0.74	58, 67, 62, 57, 64, 46, 1, 54, 41 & 25.
Low	50	0.6	3.5	0.34	0.65	The rest

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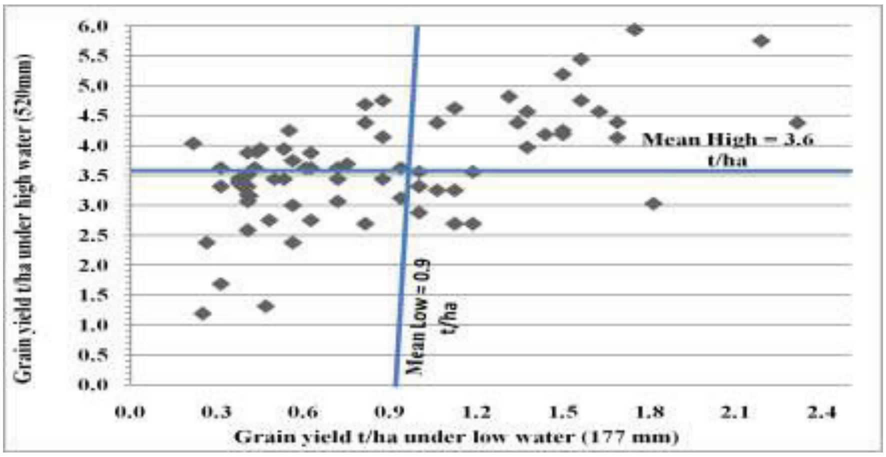


Figure 3. Average grain yield (t/ha) for 72 bread wheat genotype under high water (520 mm) and water stress (75 mm).

Table 6. Groups identification of the 16 wheat accessions representative sample out of the 72 studied genotypes to be subjected to molecular genetic work

Group	Accession number	Accession plot #
A (Non efficient nonresponsive, NENR)	13, 15, 14, & 16	38, 70, 71 & 72
B (Efficient nonresponsive, ENR)	12, 9, 10 & 11	1, 41, 43 & 49
C (Non-efficient responsive NER)	7, 5, 6 & 8	6, 24, 47 & 55
D (Efficient responsive, ER)	4, 3, 2 & 1	53, 60, 61 & 66

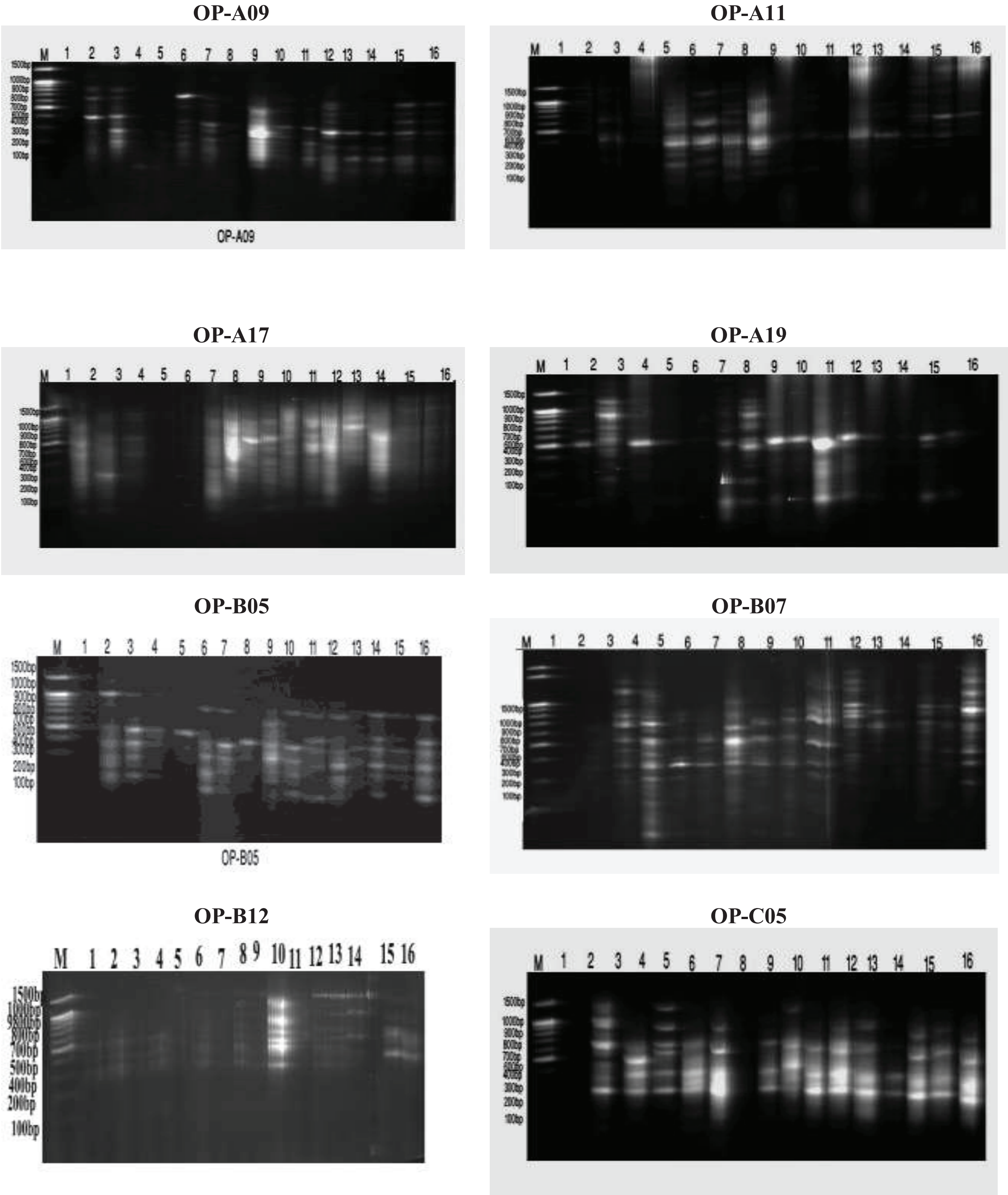
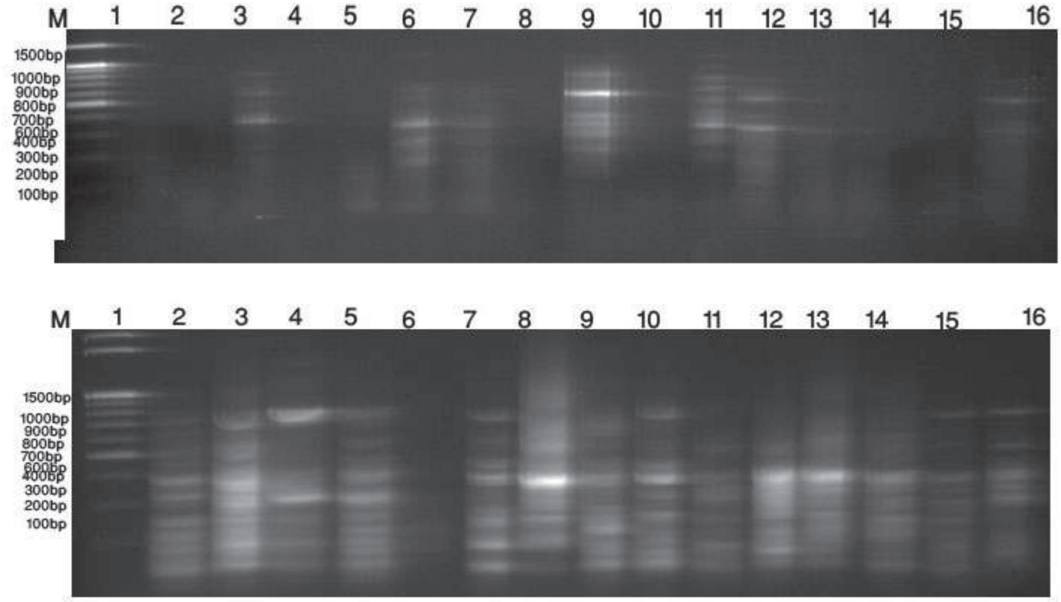


Figure 4. DNA polymorphism of the 16 wheat genotypes amplified with eight RAPD primers.



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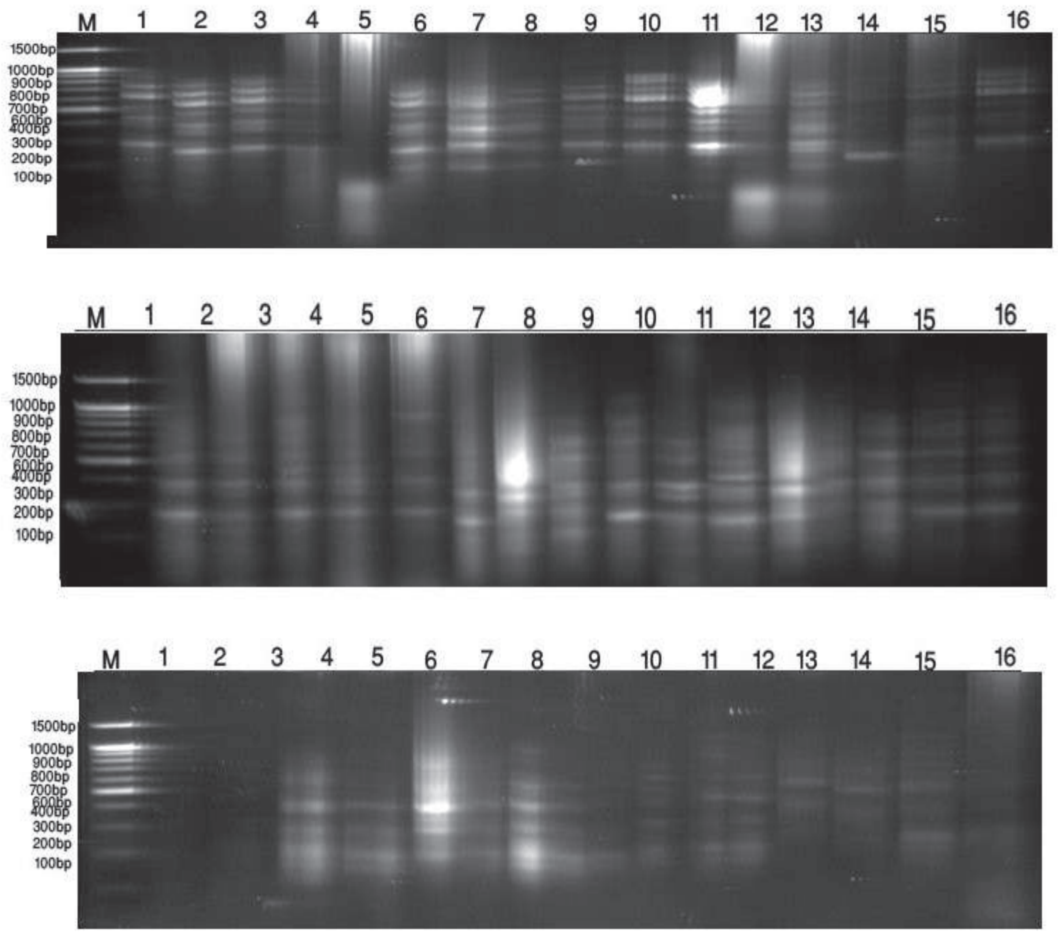

Figure 5. DNA polymorphism of the 16 wheat genotypes amplified with five ISSR primers.

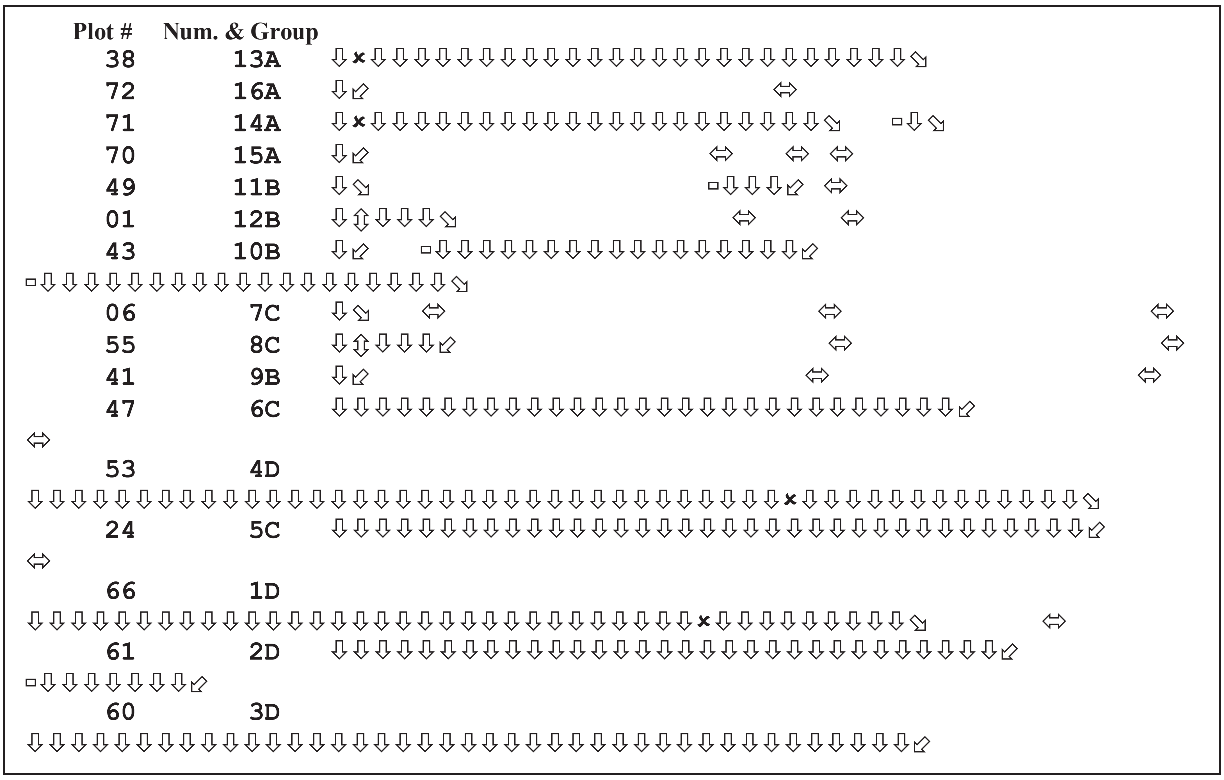

Figure 6. Dendrogram for the genetic distances based on RAPD analysis among 16 wheat accessions selected from four main groups differ in yield and water stress resistance.

In general, the five ISSR primers provided a total of 57 bands. The number of bands amplified by primer combination varied from 9 to 13 %. A total of 43 bands were polymorphic across the entire sample. The percentage of polymorphic markers varied from 64 to 100 % (Fig. 5). This cluster analysis tends to be more precisely separating the accessions into two main groups according to grain yield potential. The first clustered seven accessions into two sub groups (A & B) enveloping low potential, but group B that withstands water stress. On the other hand, the second main group had two sub groups, C and D, as unique higher yield potential. However, in group three, accessions from group D clustered together as higher yield and water stress, similar to their agronomical characterizations. Moreover, two accessions; #66 (1D) and #43 (10B), remained ungrouped germplasm (Fig. 7).

The effectiveness of DNA markers for estimating genetic similarity may depend on the nature of the markers and the genotypes (Soleimani et al. 2002). On the other hand, three factors may control the precision of genetic resemblances: the number of markers, the uniformity of their distribution in the genome, and the information they offer (Landgrebe et al. 2002; Messmer et al. 1993; Schut et al. 1997). The dendrogram consequentially from compiling the two DNA based systems split the 16 accessions into two main clusters (Fig. 8). The first one was separated into three different sub-clusters, where three accessions from each of group C (NER) and group B (ENR) were brought together in a sub-cluster. The four accessions of group A (NENR) were placed in the third sub-cluster, which divided

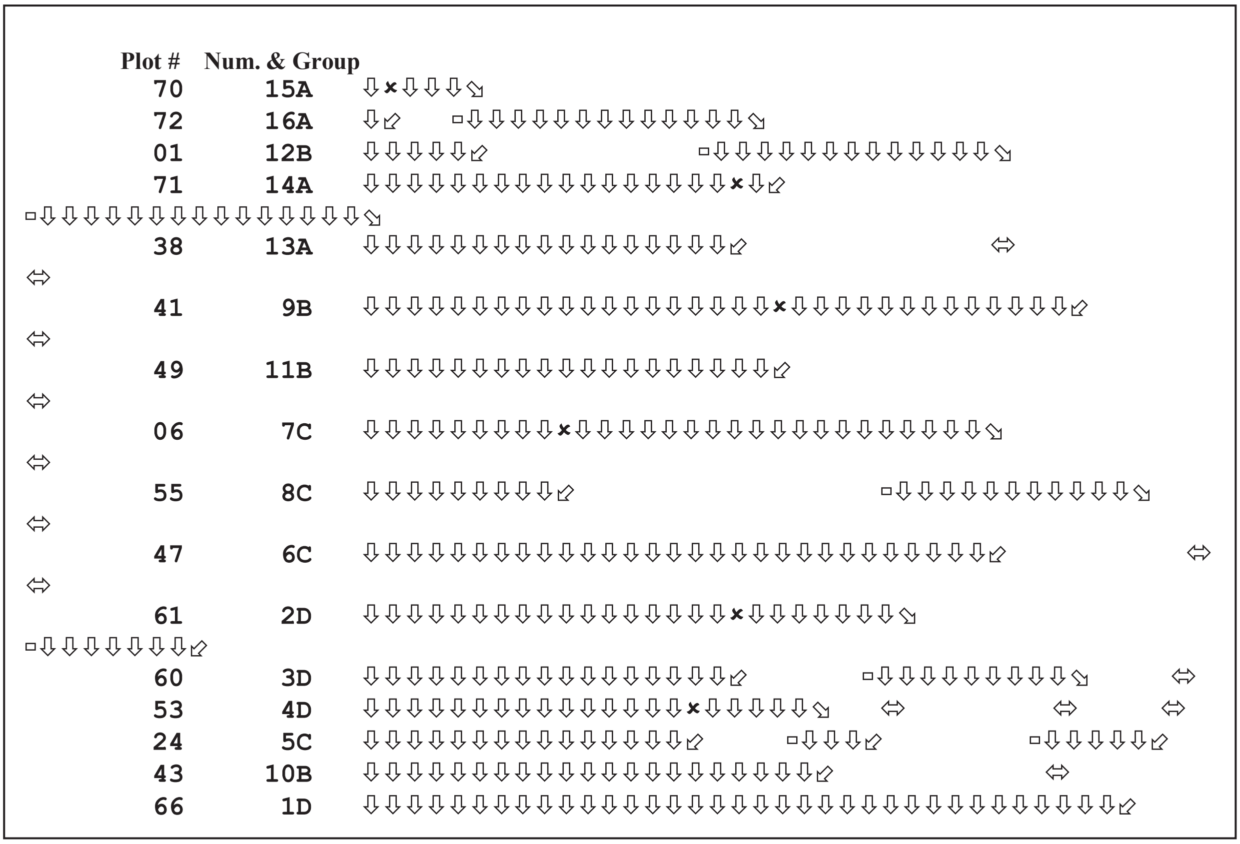

Figure 7. Dendrogram for the genetic distances based on ISSR analysis among 16 wheat accessions selected from four main groups differ in yield and water stress resistance.

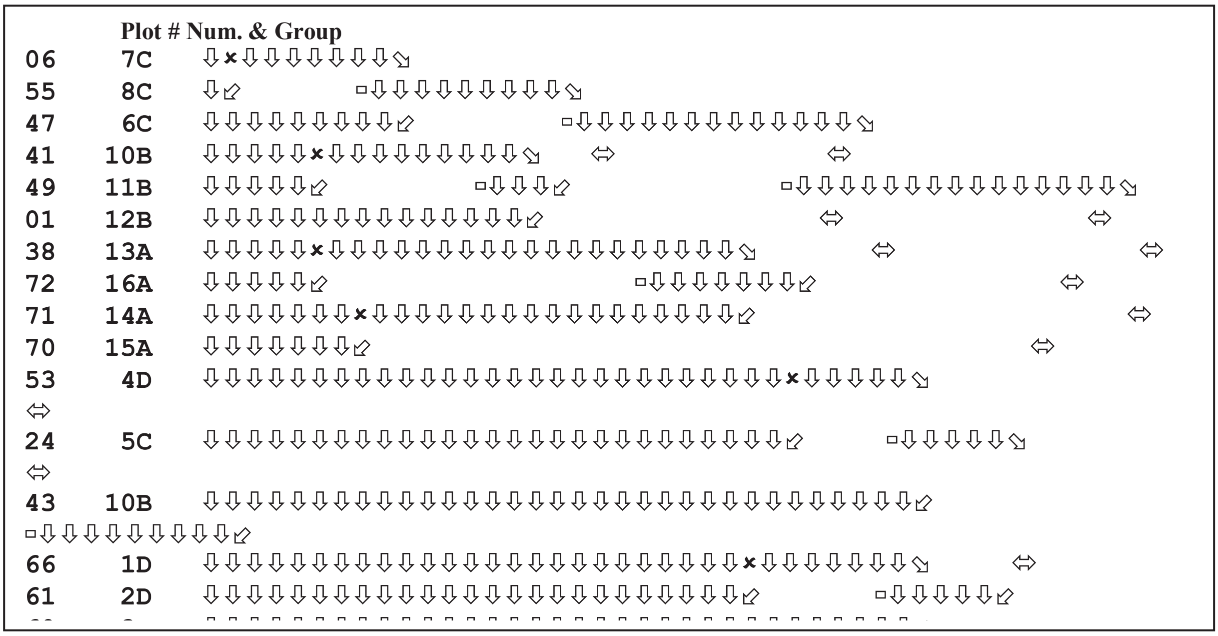

Figure 8. Dendrogram for the genetic distances based on RAPD and ISSR combined data among 16 wheat accessions selected from four main groups differ yield and water stress resistance.

further into two sub-clusters. The second main group included mainly the accessions selected from group D, which was described as an efficient group under water stress and responsive for higher grain yield (ER). The three accessions (# 60, 61 and 66) clustered together as representatives of group D have evolved under Yemen rainfed conditions and consequently, may have water stress adaptation alleles. Moreover, this main group expressed a sub-cluster comprising the accessions #53 (4D) and #24 (5C) with a common ancestor "Kauaz" and high yield potential. The accession #43; Gemmeiza 9 (10B) were distributed as unique genotypes and could have alleles enduring water stress.

In this investigation, some likeness between agronomical characterization and DNA markers was not surprising since the assessment of genetic relationships among different germplasm fundamentally was estimated through several approaches (Abdel-Tawab et al. 2006; Helms et al. 1997; Karamanos and Papatheohari 1999; Kim and Ward 1997; Medini et al. 2005; Pfeiffer et al. 2005, Schut et al. 1997; Wang et al. 2003). This sensible relationship between agronomical and DNA estimates could show how the different wheat germplasm realistically performed under favorable and moisture stress regimes. Numerous studies proposed that the estimation of genetic relationships among germplasm might be improved by combining agronomical characterization and DNA marker into an index to decrease the effect of the independent inaccuracies of both of them (Abdel-Ghani et al. 2007; Cox et al. 1985; Schut et al. 1997; Van Becelaere et al. 2005; William et al. 2003). Wheat genotypes incorporating high yield and adaptation to highly variable conditions, especially water stress, can play an important role in food security in Egypt. In general, Egyptian farmers tend to use more water than crops need due to the immediate short-term production objectives and traditions. On the contrary, improved germplasm can genetically withstand water stress eliminating the need for excessive irrigation water. This will encourage the use of deficit irrigation in the targeted areas, taking account of the availability and sustainability of water resources, gaining higher water productivity. Utilization of both agronomical characterization and DNA markers to measure variation in germplasm adaptation to stress conditions might necessitate more investigations and decision on a specific, optimal and sampling strategy. Moreover, these advances could permit using wheat genetic variability, especially that in the wheat wild relatives, for developing stress tolerant cultivars adapted to changing climate

Acknowledgments

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Theme 5. Range management and forage and livestock production

5.1. Performance of crosses of Damascus goat with the local Barki raised by Bedouins at the arid costal zone of Egypt

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Abstract

The objective of the study was to assess the performance of the Damascus crossbreds versus the local Barki goats under the Bedouin conditions in the arid (<150 mm annual rain fall) costal zone of western desert (CZWD) of Egypt and its socio-economic impact on the producers. In the early 1980's, some 78 Damascus bucks were distributed to Bedouins over the arid CZWD with the intention of introducing 25 % of the Damascus goat blood to the native goats. The study covers 159 breeders. Individual performance (milk, kid and reproductive performance) of random samples from different crosses and local Barki goats in 30 flocks was recorded. After two decades of initiating the crossbreeding program, three-quarters of the studied flocks are using Damascus crossbred bucks and more than 80% of their flocks are of Damascus crossbreds. The main advantages of the Damascus crossbreds, as reported by the breeders, were their heavier body weight, better body conformation, and equally important its higher milk production. The higher selling price of their kids was around 50% higher than the normal market price. Damascus crossbreds were heavier at the first mating than Barki by more than 7 kg and earlier in age by more than 3 months. The litter size did not differ. The superiority of Damascus crossbreds in their milk production amounted to 48% during suckling. More importantly, milking continued for 2-3 months after weaning, providing the breeders with surplus milk. The results indicated that the Damascus crossbreds are well adapted to the prevailing arid environment, poor ranges and harsh management conditions in the CZWD. In summary, crossing local Barki with the Damascus goats doubled the income of the breeders from raising their goats. Such practise can be recommended for out scaling in other arid areas of the north east region.

Introduction

The study was carried out in the area of Coastal Zone of Western Desert (CZWD), Egypt, which runs from Alexandria East to the Libyan border for about 500 km. It is a dry area with rainfall <150 mm /year. The Eastern region has small areas of newly reclaimed lands. The climate ranges from Mediterranean in the North to semi-arid in the South. Temperatures of 39°C occur in July and August and 5°C in January, and in some winter days may reach freezing point. Winter is the main rainy season starting from mid October to mid March. Occasional rains may occur in April and May.

Transhumance grazing starts from the North on annuals and opportunistic barley (January - March) and crop residues (March – June) and continues towards the South on perennials (July – September). Out of the limited grazing season, animals depend mainly on supplementary feeding .The grazing area is heavily overstocked with small ruminants, and estimated (Galal et al. 2005) to meet 30% of the stocks feed requirements. When supplemented by locally produced barley, the area may meet about 45% of the stocks requirements.

There are some one million heads of sheep and goats, which contribute substantially to the family income and nutrition, and are used as subsistence and survival reserve in years of drought. They also serve as a source of savings and social prestige. Under the situation of degraded rangelands, feed expense is a major constraint, and low productivity of local breeds and improper management practices add to the list of constraints. Most Bedouins producers keep sheep and goats together. Meat production is the primary product, with some milk mainly for home consumption.

'Barki' is the indigenous goat, small headed with straight profile, covered with long hair. Body weight ranges from 35 to 40 kg. Milk production is relatively low, averaging 80 kg during a lactation period of 145 days (Aboul Naga et al. 1987). *Damascus* is considered to be potential animal genetic resources in the NE and is the preferable goat breed of the West Asian region (Syria, Turkey, Lebanon, Jordan and Palestine). Beside its adaptability to the dry agro-ecological conditions in the region, it combines high milk productivity with good kid performance and fertility.

The breed has been introduced to some other countries in the Near East (NE), such as Cyprus, Egypt and most of the Arabian Gulf countries. The successive selection program in Cyprus has developed the breed to international levels in its milk production and kid performance (Mavrogenis 2005). Early in the 1980s some trials were carried out for improvement in milk and kids production of the local Barki goats through crossing with the imported Damascus ('Shami') goats. The present study aimed to asses such long term crossbred trial with the Bedouins in the dry CZWD of Egypt, for possible up- and out-scaling in other parts of West Asia and North Africa (WANA).

2. Plan of work

The objectives of the study were to measure the productivity of the Damascus crossbred goats versus the local Barki goats under the breeders' conditions in the dry area of Egypt and to assess the socio-economic impact of these crosses on the Bedouins livelihood.

The crossbred program started in the early eighties through the importation of batches of Damascus goats from Cyprus to the CZWD of Egypt and cross them with the native desert goats (Barki). Encouraed with the results of the on-farm trial (Aboul-Naga and El-Shobokshy 1981), a group of 78 Damascus bucks were imported and distributed to the breeders over the area from Borg-Arab to Barani (extended over 500 km). The breeding plan was to introduce 25 % of the Damascus blood to the local goats. Over the period 1994-1999 another batch of 10 pure Damascus and 15 crossbred Damascus x Barki bucks were distributed by Marsa-Matroh National Resources Project (supported by the World Bank) over the area from Fouka to Salloum. The work was continued since then by the breeders themselves.

The present study covers 159 breeders in the area from Borg-Arab to Barani. The Eastern (E) region covers the area from Alexandria to Alamain and the Western (W) region extended from Alamain to Salloum. Each region consists of three sub-regions. The Eastern region has Borg-Arab 40 Km to Alexandria, Hamam 60 km from Alexandria and the last is Alamain sub region 100 Km from Alexandria. While the Western region consists of Raas-Hekma 230 Km to Alexandria, Matrouh 290 Km to

Alexandria and Barani sub-region about 430 Km from Alexandria. The areas in between are mainly mine fields from World War II, with limited livestock activities.
A questionnaire was designed to collect information on the breeding program, flock management and input/outputs parameters for each flock with the breeders. Individual head performance (milk, kid and reproductive performance) of random samples from different Damascus crosses and local goats in 30 flocks were measured and recorded. Monthly visits were made to each of these flocks to take repeated measurements of the daily milk production, reproductive performance and body weights of the produced kids (5-10 animals from each breed group /flock according to their availability).

3. Results and discussions

The breeders were widely distributed over both Eastern (E) and Western (W) regions (64 and 95 flocks, respectively). Almost all flocks were mixed flocks of sheep and goats. There were only a few flocks having either sheep (3%) or goats (8% in E and 9% in W).

About 29% of the flocks in both regions had fewer than 50 head (Table 1). There are clear sub- regional variations in this regard. Those with more than 200 heads (31%) were mainly in E region, directly associated with the availability of extra feed resources in the recently reclaimed lands (Hamam) rather than the availability of natural ranges in Matrouh and Barani. The percentage of goats (Table 2) was either less than 20% of the flock (37%) or 20-50% of the flock (45%), with a wide sub-regional variation, in contrary to the flock size trend. Thus, the sub-region of more feed resources (Hammam) raises more sheep, while the region relaying on natural ranges raises more goats (Matrouh and Barani).

Bedouins in the studied area were basically transhumant pastoralists, who were grazing sheep, goats and camels on the rangelands under well established traditional system, developed in response to the availability and seasonal variations in rangeland conditions. Grazing extended from December to March which differs from one year to another depending on the erratic rainfall. The ranges extend on a narrow strip of 10-25 Km parallel to the coast, where it gets much wider in the west of Matrouh (Barrani). Rangelands have largely deteriorated over the last few decades due to increasing pressure of man and animal. The area adjacent to the coast has shifted to tourism and fruit tree production which pushes the grazing area southward (Aboul-Naga et al. 1987).

Almost two-third of the breeders in both regions would remain on the move for a period of two months or more, seeking better pastures. Shalaby (1999) reported that most of the flocks move to the southern plateau of the NWCZ (15-40 km inland) during the rainy season. At the end of the rainy season they moved to the lower northern plateau (5-15 km inland) and coastal zone (about 5 km inland), where they graze available rangeland with some grain supplement. Thirty percent of the breeders, mainly at Borg-Arab where reclaimed lands have expanded at the cost of the range lands, did not relay on natural ranges for feeding their flocks.

During summer and autumn, animals were fed mostly on straw and concentrates. Mix of feed resources was used over the year, to which rangelands contributed only 30-40%. After the cereal harvest, the animals would move into barley fields, grazing on crop residues till late summer. In fall and winter, before the rainy season, the animals depend largely on grains (barley/wheat) plus straw and/or feed concentrates. During drought years, large flocks were transported outside the region to the irrigated lands, in the Nile-

Table 1. Number of breeders and flock size in both E and W regions and sub-regions

Item	E			W			Total
	BA	HM	AL	RH	MT	BR	
No. of breeders	31	12	21	19	57	19	159
Flock Size:							
<50 head (%)	32	0	10	47	37	21	29
50-100 head (%)	16	8	14	11	23	42	20
100-200 head (%)	20	0	29	16	23	21	20
200 head (%)	32	92	47	26	17	16	31

BA=Borg-Arab , HM=Hamam, AL=Alamain, RH=Raas-Hekma, MT=Matrouh, BR=Barani.

Table 2. Percentage of goats in the flock

Item	E			W			Total
	BA	HM	AL	RH	MT	BR	
No. of breeders:	31	12	21	19	57	19	159
% of goats:							
20 % of the flock	30	92	57	32	26	32	37
20-50 % of the flock	35	0	33	64	54	53	45
>50 % of the flock	35	8	10	4	20	15	18

Table 3. Dissemination of Damascus crossbred (DC) with breeders

	E			W			Overall %
DC %	BA	HM	AL	RH	MT	BR	
≤ 50 DC bucks	20	25	20	11	4	11	11
> 50 DC bucks	80	75	80	84	84	89	63
≤ 50 DC does	39	100	29	21	9	21	21
> 50 DC does	52	0	10	74	86	79	61

Valley where they grazed on crop or vegetable residues. High consumption of concentrate feeds and grains became the main feeding regime in Alamin, Matrouh and Barrani during winter (58 - 62%) and summer (58 - 82 %).

The study showed that 65% of the breeders in both E&W regions were relaying on family labour for daily farm activities, while 29% of the breeders hired external labours. In general, adult males undertook the task of land preparation, crop harvesting and herding of the flocks. Boys assised in these activities, particularly in herding. Women and girls took care of watering, feeding of the stocks and milking of animals. They were also engaged in home cottage industries such as dairy and wool processing.

Four water resources were identified in both E and W regions. Almost all breeders (97%) in W used groundwater and cisterns for domestic use, livestock and tree cultivation (olives and figs), while in the E, 92% of the breeders depended on water tanks and canal water.

There was wide dissemination of Damascus crossbred goats with the breeders over the last two decades (Table 3). Seventy four percent of the flocks studied had Damascus crossbred bucks, while 82% had Damascus crossbred does. This was particularly conspicuous in W and Borg-Arab sub-region in E (near the Breeding Research Farm).

Damascus crossbred does constitute more than 50% of the flocks in W sub regions, more than 90% of the breeders are using Damascus crossbred bucks in their flocks. Damascus and their crossbred bucks/does constitute about two thirds of the studied breeders' flocks versus one-third Barki bucks/does.

The advantages of the Damascus crossbred goats over the local Barki, as indicated by the breeders (Table 4), were mainly, heavier body weight, better body conformation (33%) and higher milk production (32%); the other advantage was (22%) 50% higher selling price of the kids in the market (22%).
The advantages were much clearer in the mind of the breeders in W than in E where many respondents were non specific in listing the advantages of the Damascus crossbred. However, 90% of them were specific of no constraints in breeding Damascus and DC goats. The only constraint raised by a number of breeders in W was the higher feeding requirements of the Damascus bucks.

As mentioned before, the objective of the crossbreeding trial was to introduce 25% of Damascus blood into the local Barki goats. The results showed that the crossbreeding planes had continued by the breeders in the same direction all over the last two decades. Number of 25% Damascus crosses was increasing of the 1st crossbred especially in Borg-Arab and Matrouh sub-regions (where the distribution of Damascus bucks started). Percentage of ½ Damascus bucks was 29% of the available bucks in the studied flocks, while it was 26% for ¼ Damascus bucks. Percentage of 25% Damascus does was 36%, almost equal to the Barki does (38%), and higher than1st crosses (Table 5). Flocks in the W region had higher percentage of DC does (range75 to 85%). On the other hand, Hamam and Alamain flocks had only 6 and 10% of their flocks as 1st and 25% Damascus crossbreds, respectively. Introduction of Damascus crosses started recently in these areas, and their dissemination is still limited.

Almost 94% of the breeders indicated that ½ Damascus crossbreds were heavier at 1st mating than the Barki, the percentage was slightly less (84%) for the 25% crossbred (84%). Around 60% of the breeders reported that Damascus crosses (either 1st or 2nd cross) were earlier in age at first mating than the Barki (Tables 5 and 6). Only one third of them indicated that Damascus crossbred was similar to the local Barki..

Table 4. Advantage and constrains of the Damascus and DC goats as indicated by the breeders

Criteria	E			W			Total
	BA	HM	AL	RH	MT	BR	
No. of breeders:	31	12	21	19	57	19	159
Advantage							
1. Heavy body and better conformation (%)	41	10	28	35	33	43	33
2. Higher milk production (%)	25	13	14	35	35	32	32
3. Higher selling price of kids (%)	23	10	10	25	32	25	22
4. Non specific (%)	9	67	48	5	0	0	13
Constrains							
1. No constrains (%)	74	92	90	32	46	58	65
2. Sensitive to cold weather (%)	3	8	5	0	0	11	7
3. High feeding requirement (%)	10	0	5	32	40	21	20
4. Some seasonality (%)	13	0	0	16	2	5	8

Table 5. Reproductive performance of ½ Damascus vs. the local Barki goats

Item	E			W			Total
	BA	HM	AL	RH	MT	BR	
No. of ½ DC does:	159	15	0	175	153	243	745
Age at first mating							
Mean of superiority (month)	2.6	4.4	0	4.0	3.3	4.4	3.7
Earlier than Barki (%)	52	75	0	100	44	55	57
Same (%)	38	25	50	0	50	45	37
Later (%)	9	0	50	0	6	0	6
Weight at first mating							
Mean of superiority (Kg)	3.3	3.3	0	8.3	13.3	0	7.1
Heavier than Barki (%)	91	100	100	100	94	89	94
Same (%)	4	0	0	0	6	11	5
Lighter (%)	4	0	0	0	0	0	1

Table 6. Reproductive performance of 25% Damascus vs. the local Barki goats

Item	E			W			Total
	BA	HM	AL	RH	MT	BR	
No. of 25% DC does:	184	8	62	55	699	72	1080
Age at first mating							
Mean of superiority (month)	3.5	2.4	1.4	4.1	3.9	4.5	3.3
Earlier than Barki (%)	41	50	29	100	65	55	60
Same (%)	47	25	71	0	31	45	34
Later (%)	12	25	0	0	4	0	6
Weight At First Mating							
Mean of superiority (Kg)	6.2	0	11.8	4.5	6.8	0	7.4
Heavier Than Barki (%)	100	100	71	100	92	0	84
Same (%)	0	0	29	0	8	45	11
Lighter (%)	0	0	0	0	0	55	5

Table 7. Means for litter size of Damascus cross and Barki goats

Factor	No	Litter size Mean ± SE
Breed group of does: ½ Damascus	63	1.23 ± .10[a*]
25% Damascus	43	1.22 ± .11[a]
Barki	76	1.29 ± .09[a]
Season of kidding: Autumn months	106	1.07 ± .07[a]
Spring months	63	1.32 ± .08[b]
Summer months	13	1.34 ± .16[b]

Table 8. Superiority of milk production of Damascus crossbreds over local Barki goats

Superiority %	E			W			Total
	BA	HM	AL	RH	MT	BR	
	1st Damascus cross						
No. of Doe:	**159**	15	0	175	153	243	745
Suckling milk	35	76	0	74	49	68	48
Post weaning milk	82	100	100	100	100	100	97
Post weaning milking period (Days)	64	65	46	72	64	69	63
	25% Damascus cross						
No. of Does:	184	8	62	55	699	72	1080
Suckling milk	58	0	101	87	78	65	79
Post weaning milk	100	100	95	90	90	89	96
Post weaning milking period (Days)	43	61	61	61	70	57	59

Table 9. Means for kid body weight at different stages

Factor	No	7 days wt (kg) Mean ± SE	60 days wt (kg) Mean ± SE	120 days wt (kg) Mean ± SE
Breed group:				
1st cross Damascus	86	3.00 ± .12[a*]	8.10 ± .65[a]	14.70 ± 1.50[a]
25 cross Damascus	103	2.86 ± .10[a]	8.64 ± .55[a]	13.37 ± 1.29[b]
Barki	41	2.72 ± .14[a]	8.94 ± .99[a]	14.24 ± 1.84[a]
Season:				
1(Oct-Feb)	124	3.08 ± .08[a]	10.83 ± .47[a]	16.25 ± .82[a]
2 (Mar-May)	88	3.08 ± .08[a]	9.17 ± .51[a]	14.65 ± 1.07[a]
3 (Jun-Sept)	18	2.42 ± .14[b]	5.68 ± .93[b]	11.41 ± 2.08[b]

Those indicated lower performance for Damascus crosses, were negligible

The earliness superiority of Damascus crosses in age at first mating averaged 3.7 months over Barki for the ½ Damascus and 3.3 months for the 25% Damascus. The weight superiority was 7.1 kg in average for the ½ Damascus and 7.4 kg for 25% Damascus over the local Barki.

On the other hand, the three breed groups were insignificantly different in their litter size (Table 7). The only factor which showed significant effect on litter size was season of mating. Autumn and winter kidding were significantly of lower litter size than spring and summer kidding in different breed groups. It is worth mentioning that the normal practice by the breeders is to run the bucks with the flocks all the year round utilizing the non seasonality of the local Barki. While does do mate and conceive at different seasons, higher litter indicated better ovarian activities in the autumn mating. On the other hand, Damascus crosses performed well in breeding round the year like their Barki parents, although seasonality has been reported for their Damascus parents (Mavrogenis 2005).

The biggest advantage of the Damascus over the Barki was its higher milk production. Barki goats were developed under arid conditions, mainly for their good mothering ability including suckling milk. The Damascus goats were developed as milking goats with heavier body weight. This was reflected in clear better performance of the 1st and ¼ DC in post weaning milking over the local Barki. The normal practice of the breeders is not to milk their Barki does after weaning, while they continue milking their Damascus crossbred does after weaning for 2 months for crossbred does (58%) and by 3 months in 29% of them. Post-weaning milking period decreases slightly for the 25% DC than the first cross (Table 8).

Measuring milk production on 239 does of the 3 breed groups from kidding up to 12 weeks (suckling period) showed that ½ Damascus does achieve its peak milk production at 4-6 weeks. Where Barki does has its peak during the first three weeks. The 25% DC shows higher milk production from the 7th week and their after. At which they performed significantly better than the 1st cross. Parity and litter size showed the expected trend for daily milk yield with significant effect in the first 3 weeks only due to parity.

Barki kids performed well during suckling period, whereas Damascus crossbred kids had heavier body weights at 4 month age than the Barki. Breed groups did not show significant differences in their kid body weights from birth till weaning. Season of kidding had highly significant effect on kid body weights. Significant differences were found between summer kidding season (months 6-9) and both winter (months 10-2) and spring (months 3-5) seasons (Table 9).

4. Conclusions and recommendations

In conclusion, the results have indicated that the Damascus crossbred are well adapted to the prevailing conditions, poor ranges and harsh management conditions in the arid area of the CZWD. The 25% Damascus crossbred does gave more than double milk production than the native Barki, and their kids performed better at market. Moreover, crosses with the local Barki, enabled the crosses to breed more than once per year. Crossing local Barki with the Damascus goats doubled the income of the breeders from raising their goats than when raising local goats. Such practise can be recommended for out-scaling in similar arid areas of the NE.

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5.2. Effect of exposure to solar radiation on body fluids and thermoregulation of pregnant Egyptian Baladi goats

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Abstract

Effect of direct sun light for 3 hours on changes in body fluid compartments and thermoregulation was studied on 22 mid-term pregnant, 2 to 3 years old, Egyptian Baladi goats under hot summer conditions of August. Ambient temperature (Ta), black body temperature (Tbb) and relative humidity (RH), and physiological parameters were recorded at 10:00 hrs (before offering water and food to the animals) and after exposure to solar radiation for 3 hrs (from 12:00 to 15:00) on each animal in the same sequence. The parameters measured were rectal (Tr), skin (Ts) and ear (Te) temperatures, respiration rate (RR), body fluid compartments (total body water, TBW; extra cellular fluid, ECF; intra cellular fluids, ICF; interstitial fluids, ISF; plasma volume, PV; and blood volume, BV) and plasma and blood parameters (hematocrit, Ht; AST, ALT and creatinnine). Exposure to solar radiation increased Tr, Ts, Te and RR, and decreased TBW, mainly due to a significant reduction in ICF. PV and BV increased indicating that an increase in evaporative cooling did not reduce PV. As percentage of TBW no significant changes occurred in ICF, ECF and ISF, while PV and BV increased. Consequently, changes in TBF, ICF, ECF, ISF, PV and BV after exposure were not due to changes in body weight but because of the shifts in body fluids between different compartments. It could be concluded that pregnant Egyptian Baladi goats suffer from severe heat stress when exposed to direct solar radiation and their main adaptive mechanisms is to increase evaporative cooling (RR), and internal conduction (increase in Te), to minimize heat gain through convection, conduction and radiation (increase Ts), and to maintain skin evaporation (increase PV). The significant increase in Tr may be an efficient thermoregulation mechanism to minimize excessive water loss through evaporation.

1. Introduction

In many parts of the world, goats are the species of preference for animal producers due to their better performance under harsh environments than other domestic ruminants, especially in predominantly semi-arid regions (Battacharya 1980; Kababya et al. 1998 and Silanikove 2000; Mengistu 2007). It is postulated that the better performance of goats under harsh environments is due mainly to their efficiency in meat and milk production, low cost of maintenance, their great adaptation to the harsh environments and their inherent suitability for small-scale production.

Excessive heat stress in dry areas may cause hyperthermia and potentially have several physiological side effects and economical impacts on the livestock industry. The physiological disorders may include the aberration of reproductive functions (Roth et al. 2002), oxidative stress and enzymatic dysfunction (David et al. 2001), and electrolyte imbalances (Augustinsson et al. 1986; West et al. 1991). This can eventually lead to reduced meat quality (Kadima et al. 2004) and severe economical losses resulting from increased mortalities and decreased overall animal performance (Hahn and Mader 1997). Darcan and Güney (2008) stated that livestock production is negatively affected by the detrimental effects of extreme climates; consequently, alleviation of these effects is important to maintain good productivity.

Goat and sheep breeds which are native to dry regions possess basically the same physiological mechanisms for maintaining their fluid thermoregulatory homeostasis as other breeds; however, they have developed strategies to use to the utmost the regulatory systems in order to cope with heat stress and scarcity of food and water (Silanikove 1992). Dmi'el (1986) reported that heat defense mechanisms in goats are related to their water balance and the mode of heat stress. Solar radiation stimulates sweating in the fully hydrated animal, and as the animal becomes dehydrated sweating from the trunk subsides but it still sweats on the head which makes it possible to keep the head region cooler.

The aim of the present study was to investigate the effect of acute heat stress (exposure to solar radiation) on fluid balance and thermoregulation of pregnant goats.

2. Material and methods

The study was conducted on 22 pregnant Baladi goats (2-3 years old) at the Sheep and Goat Research Farm, Animal Production Department, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt to investigate the effect of exposure to solar radiation on the physiological parameters. The animals were confined in semi-open pens day and night throughout the period of the experiment. The pens provided enough shade and ventilation in summer. The animals were fed hay and a concentrate ration according to their body weight requirement (NRC 1981). Animals were allowed to drink water ad-libitum twice daily. The experiment was carried out in summer season during August.

Measurements were taken at morning (10:00) before offering water and food. The animals were then exposed to solar radiation for 3 hrs (from 12:00 to 15:00) after which the measurements were again taken on each animal in the same sequence. Black bulb temperature was recorded (Hafez 1968) under shade and under direct solar radiation. Ambient temperature (AT), black bulb temperature (Tbb) and relative humidity (RH) were recorded while measuring physiological responses. A hygrometer hanging from the roof of the shed, at a level of about two meters from the ground was used to measure RH. Parameters measured before and after exposure to solar radiation included: rectal temperature (RT) using a standard clinical thermometer inserted into the rectums for 5 cm length, skin temperature (ST) and ear temperature (ET) using a tele-thermometer, and respiration rate (RR) recorder by counting flank movements per minute, concomitant inward and outward movement was considered to be one respiration. All possible precautions were taken to avoid disturbing the animals during counting. The respiration rate was counted before measuring the body temperature.

Body fluids volumes were determined in each animal before and after exposure to solar radiation. Total body water (TBW) was determined using antipyrine method (Weiss 1958). Extra cellular fluid (ECF) was determined by sodium thiocyanate method (Hix et al. 1959). Plasma volume (PV) was determined by Evan's blue method (Kennedy and Millikan 1938). A blank sample was withdrawn from the jugular vein before injection with the dyes in which hematocrit (Ht) was tested (Bauer 1970). Blood samples were collected in heparinized tubes and centrifuged at 3000 rpm for 15 min to obtain plasma. The plasma was stored at (-18^{o}C) in glass vials with plastic stoppers till the assay was performed. Blood volume (BV) was derived from the plasma volume by the following equation (Hodgetts 1959):

BV (in ml) = PV/100-(Htx0.94) x 100

Statistical analysis was carried out using SAS program (SAS 1988). Paired t test was run to test the significance between the values before and after exposure to solar radiation.

3. Results and discussion

3.1. Meteorological data

Data in Table 1 reveal goats were under heat stress after exposure to solar radiation. Under direct solar radiation, the AT and Tbb were higher than the upper critical temperature of goat and exceeded the limit of heat tolerance of goats as reported by Lu (1989) and Dahlanuddin and Thwaites (1993). Lu (1989) stated that the limit of heat tolerance for goats is between 35 and 40 °C, while Dahlanuddin and Thwaites (1993) reported that goats reached the limit of their heat tolerance at 40-45°C ambient temperature.

3.2. Thermorespiratory responses

Exposure to solar radiation increased RT significantly ($P<0.01$) from 39.3 to 40.1 °C (Table 2). This result is in agreement with many authors (Shalaby et al. 1989; Kumar and Singh 1994; Sevi et al. 2001; and Randina et al. 2004). Shalaby et al. (1989) studied the latent effect of exposing goats to solar radiation; they found that after 3 hrs of exposure the rectal temperature was higher by about 0.71-1.15°C than before exposure. The significant increase in RT after exposure to solar radiation was due to absorption of energy from direct sunrays and insufficient heat dissipation response. The above results indicate that the Tbb under direct solar radiation exceeded the upper limit of heat tolerance of the pregnant Egyptian Baladi goats.

Exposure to solar radiation also increased ST significantly (Table 2). Similar results were found on non-pregnant goats by Shalaby and Johnson (1993), Kumar and Singh (1994), and Khalifa et al. (2000, 2002). Randina, et al. (2004) reported that the overall average of goats' skin temperature was significantly positively related to ambient temperature. Hales (1973) stated that adjustment of skin blood flow is an important mechanism in mammalian regulation of heat exchange between the body "core" and the surface "shell" and subsequent heat transfer between the body and its environment. Kibler et al. (1970) reported that the widening of differential temperature between core and periphery will in turn initiate circulatory adjustments, and alter the thermal conductivity of the tissues. In the present study, exposure to solar radiation decreased the temperature gradient between skin and rectal temperatures (RT-ST) from 1.58 to 1.12 °C indicating that exposing the pregnant goats to solar radiation altered the regulation of heat exchange between body core and surface causing an increase in internal conduction. On the other hand, the temperature gradient between skin and ambient temperatures (AT-ST) changed from -3.15 under shade to 1.43 °C after 3hrs of exposure to solar radiation (Table 2) indicating that in pregnant goats non-evaporative heat exchange was the mechanism for heat loss under shade and

Table 1. Meteorological data before and after exposure solar radiation

	Before		After	
	Mean.	S.E	Mean.	S.E
Ambient temperature (AT, °C)	34.6	0.48	40.4	1.79
Relative humidity (RH, %)	45.6	3.51	50.1	2.58
Black bulb temperature (Tbb, °C)	38.1	0.46	44.5	0.71

Table 2. Mean ± S.E. of rectal (RT), skin (ST) and ear (ET) termperatures and respiration rate (RR) before and after exposure solar radiation

Parameter	**Before**		**After**		**Diff.**	**%**	**p**
	Mean.	S.E	Mean.	S.E			
RT°C	39.32	0.09	40.10	0.14	0.79	2.00	**
ST°C	37.74	0.19	38.98	0.18	1.24	3.29	***
ET°C	36.79	0.29	38.88	0.30	2.10	5.70	***
RR r/min	46.73	3.63	63.96	4.58	17.23	36.87	**

* Significant at p≤0.05 ** Significant at p≤0.01

Table 3. Mean ± S.E. of hematocrit value and body compartments fluids (in liter) before and after exposure to solar radiation

Parameter	Before		After		Diff.	%	p
	Mean.	S.E	Mean.	S.E			
Ht	27.28	0.58	30.76	0.69	3.49	0.77	NS
T.B.W	20.27	0.70	19.91	0.72	-0.36	-1.76	**
I.C.F	13.12	0.48	12.79	0.54	-0.33	-2.52	*
E.C.F	7.14	0.28	7.12	0.28	-0.03	-0.36	NS
I.S.F	5.72	0.25	5.64	0.24	-0.09	-1.50	NS
PV	1.42	0.05	1.48	0.04	0.06	4.23	*
BV	1.94	0.07	2.08	0.07	0.14	6.96	*

* Significant at p≤0.05 **Significant at p≤0.01

heat gain under direct solar radiation. Khalifa (2003) reported that the rate of heat loss by non-evaporative means depends on the temperature gradient between the skin and the external environment, so heat is gained if the environment is warmer than the skin.

The ET increased by 2.095 °C after exposure to solar radiation (Table 2). Similar results had been reported by many authors (El-Sherbiny et al. 1983; Khalifa et al. 2000, 2002). El Sherbiny et al. (1983) stated that ET increased linearly with the increase in air temperature from 10 to 40°C. Due to the increase in ET after exposure, the gradient between rectal and ear temperatures decreased from 2.53 to 1.22 °C. Consequently, this increase in ET under heat stress reflects the increase in peripheral blood flow (vasodilatation) which is one of the main adaptive mechanisms against heat by increasing internal conduction.

Respiration rate RR increased significantly, from 34.56 ± 0.47 before exposure to 46.72± 3.63 r/min, after exposure to solar radiation representing 17.2% increase (Table 2). Ghosh et al. (1993) and Randina et al. (2004) stated that RR of goat was significantly positively related to AT. Exposure to high ambient temperature or to direct solar radiation increased significantly respiration rate of goats and sheep (Bianca and Kunz 1978; Shalaby et al, 1989; Kumar and Singh 1994; Khalifa et al. 2000, 2002). Khalifa (1982) noted that the significant increase in minute ventilation of Barki ewes during the first 2 hrs of exposure to solar radiation was accompanied by a significant increase in respiration rate while tidal volume did not differ significantly. However, after 4 hrs of exposure both RR and tidal volume increased significantly, which affected gas exchange and increased wash out of CO_2.

Dahlanuddin and Thwaites (1993) found that the upper limit of heat tolerance in goats was at 40-45°C ambient temperature as indicated by respiration rates which increased significantly ($p<0.01$) from 66 to 162 r/min. and reached its maximum at 40°C. El-Sherbiny et al. (1983) found that the respiratory frequency of Egyptian Arabi and Zaraiby goats increased significantly at air temperature above 30°C from about 20 r/min. to more than 120 r/min. at 35 and 40°C.

It could be concluded from the above results that Egyptian Baladi goats suffer from severe heat stress when exposed to direct solar radiation as indicated by significant increase in RT and RR. The main adaptive mechanisms of goats to tolerate such conditions are the significant increase in evaporative cooling (RR), increase internal conduction or vasodilatation (significant increase in ET) and significant increase in ST to minimize heat gain through convection, conduction and radiation. The significant increase in RT may be an efficient means of thermoregulation to minimize excessive water loss through evaporation.

3.3. Body fluid compartments

Exposure to solar radiation decreased significantly TBF (by 1.762 %) due mainly to a significant reduction in ICF (2.522 %) while only a slight reduction (0.364 %) occurred in ECF (Table 3). The insignificant reduction in ECF was accompanied by 1.503 % reduction in ISF with significant increase in PV and BV. These results indicate that although TBF and ICF decreased significantly after exposure to radiation a significant increase in PV occurred. Similar results were found by Mishra et al. (1983). The significant increase in PV and BV in the present study could be considered as an adaptive mechanism to compensate the effect of heat stress on water loss through evaporative cooling.

Table 4. Mean ± S.E. of volume (ml) of body compartments fluids as percentage of body weight before and after exposure to solar radiation

Parameter	Before		After		Diff.	%	p
	Mean.	S.E	Mean.	S.E			
T.B.W	72.28	1.50	70.96	1.53	-1.32	1.83	**
I.C.F	46.81	1.15	45.55	1.30	-1.26	2.69	*
E.C.F	25.47	0.66	25.41	0.72	-0.06	0.25	NS
I.S.F	20.43	0.65	20.12	0.66	-0.31	1.53	NS
PV	5.04	0.06	5.29	0.09	0.25	4.94	*
BV	6.89	0.11	7.41	0.18	0.52	7.57	**

* Significant at $p \leq 0.05$ ** Significant at $p \leq 0.01$

Table 5. Mean ± S.E. body compartments fluids as percentage of total body fluid before and after exposure to solar radiation

Parameter	Before		After		Diff.	%	p
	Mean.	S.E	Mean.	S.E			
E.C.F	35.26	0.71	35.88	0.92	0.63	1.77	NS
I.C.F	64.75	0.71	64.12	0.92	-0.63	0.97	NS
I.S.F	26.22	0.71	28.41	0.87	0.19	0.71	NS
PV	7.03	0.18	7.47	0.09	0.44	6.23	*
BV	9.60	0.23	10.45	0.16	0.84	8.77	*

***Significant at $p \leq 0.05$**

Similar results were obtained when body fluid compartments were expressed as percentage of body weight (Table 4) indicating that the changes in TBF, ICF, ECF, ISF, PV and BV after exposure were not due to changes in body weight but to changes in shifts in body fluids between different compartments. The decrease in TBF% after exposure is in accordance with Kalanidhi et al. (1979) who found that the water space (TOH) as percentage of live weight in sheep was less in summer than in winter. They explained the reduction in TBF under heat stress by higher water turnover rates during summer indicating higher water requirement for evaporative cooling.

On the other hand, as percentage of TBF (Table 5) no significant changes occurred in ICF%, ECF% and ISF%, while PV% and BV% increased significantly. These results indicate that the significant increase in PV and BV after exposure was not due to changes in TBF but to shift of fluids from ISF to PV.

The significant increase in BV under direct solar radiation is an adaptive mechanism against heat. Whittow (1968) reported that the increase in BV is important in the content of two main responses evoked by maintaining homothermy-peripheral vasodilatation and sweating. Saxena and Joshi (1980) stated that the increase in plasma volume during hot season is important for maintaining homeothermy-peripheral vasodilatation and sweating, enabling evaporative heat loss. Okab et al. (1992) and Shebaita (1993) suggested that BV can be used to identify heat tolerant animals. Chronic heat stress had no significant effect on PV and BV as El-Sayed (1988) and Makinde (1993) found that PV and BV of goats did not differ significantly between seasons.

An increase in cortisol level after heat stress was suggested by Parrott et al. (1987) to define PV in sheep exposed to acute heat stress. A shift of fluids from extra vascular tissue space or digestive tract to plasma was also suggested to occur as a result of exposure to heat stress Chaiyabutr et al. (1987). The previous authors also stated that the increase in blood volume during acute heat stress was accompanied by an increase in both plasma and cell volumes. It can be observed that the present values of PV and BV were lower than those obtained by Smith and Sherman (1994).

3.4. Hematocrit value (Ht)

Table 3 indicates that exposure to solar radiation caused an insignificant increase in Ht value. Similar result was found by More et al. (1978) and Khalifa et al. (2002). Roman et al. (1978) found that thermal stressed ewes had higher packed-cell volume than non heat stressed animals

4. Conclusions

Pregnant Egyptian Baladi goats suffer from severe heat stress when exposed to direct solar radiation as indicated by significant increase in RT and RR. The main adaptive mechanisms to tolerate such conditions are the significant increase in evaporative cooling (RR), increase in internal conduction or vasodilatation (significant increase in ET), significant increase in ST to minimize heat gain through convection, conduction and radiation, and increase in PV to maintain skin evaporation. The significant increase in RT may be an efficient means of thermoregulation to minimize excessive water loss through evaporation.

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5.3. Pasture and forage status in Egypt - limitations and opportunities

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Abstract

Egyptian agriculture is almost entirely dependent on irrigation as there is no effective rainfall except in a narrow band along the northern coast. Agriculture uses about 58.5 billion m^3 of water. Because of limited water resources, agricultural land is limited to 3.49 million ha, which is only about 3.4% of the total area. The population is increasing at 1.3 million per annum and has reached about 79 million. Therefore, there is wide gap between the total consumption and the production of food and feed. In spite of the wide gap between demand and supply of feed, there has been a very rapid increase in livestock population to meet the high demand for animal products. Recorded share from animal protein is about 21g per capita and it is planned to increase to 23g. The recent increase in animal wealth depends mainly on imported concentrates as the local feed production is insufficient. In order to reach self sufficiency in animal products, this feed shortage will have to be overcome. There are many problems constraining feed production in the country but there are also good opportunities for augmenting it. Examples include: increasing the productivity of berseem by more than 20%; optimizing berseem consumption to get 25% saving on its use; converting farm residues and agro-wastes, estimated to be more than 30 million MT, to unconventional feed; introducing new berseem variety 'Fahl' (single-cut type) in the rotation before wheat and after early maturing rice and corn; expansion of alfalfa into newly reclaimed lands; establishing management system to alleviate the degradation of the pasture lands in the northern Coast and Sinai; introducing technology of making corn and sorghum silage after harvesting grain in hybrids staying green at maturity; improving the productivity of summer forage crops; introducing new forage crops suitable for marginal lands and tolerant of the harsh conditions; and replacing area planted with fodder corn ('Darawa') to corn for silage and/or other forage crops having higher productivity and nutritive value. Existing limitations and opportunities are discussed in details.

1. Introduction

Egypt lies in the north-eastern corner of the African continent, with a total area of about one million km^2. The Egyptian economy has traditionally relied heavily on the agriculture sector for food, feed, fiber and other products. Limited water and land and rapidly growing population require continuing intensification of production on a limited natural resource base, to get higher yields per unit area, greater input efficiencies and reduced negative environmental effects through greater knowledge base and superior management. Changes in the socioeconomic environment brought about by changes in urbanization and higher incomes and the need for more export earnings are other drivers for intensification and have led to changes in production from static to dynamic systems.

In response to these demands and changes, Egypt has developed national agricultural policies and plans to improve and sustain production. Agricultural Strategy to year 2017 has been developed to articulate efficient use of natural resources in an environmentally sustainable manner (FAO 2003). This strategy deals with potentials and constraints to agricultural growth and identifies key elements to improve agricultural-sector policies, institutions and investment.

Egypt is facing shortage in animal products despite the abundance of cattle and buffaloes and continuous rise in the livestock population in last fifteen years (Table 1).

In spite of the fact that Egypt has most of the essential factors to achieve self-sufficiency in animal products, the local production is not sufficient to fulfill the demand due to the lack of local feed. Experience in animal husbandry, space for and breeds of all animals, labor, health-management facilities, etc. are all available in the country, but the availability of feed is limiting the attainment of self-sufficiency and intended export.
Hathout (1987) stated that the successful development of animal wealth in Egypt depends mainly on getting through two bottlenecks: making feed available and the genetic improvement of local livestock. He stressed that the policy makers should give the feed availability first priority. Although there is a dearth of reliable follow-up recording system for livestock and available feed, Hathout (1987) attempted to have estimates of the available and the expected feed sources and animal feed requirements in 1982 and 2000, respectively**.** The estimated feed balance in 2004 based on Hathout (1987) and El-Ashry (2007) is shown in Table 2. The sources of available feed, the total nutritive value in terms of total digestible nutrients (TDN) and digestible crude protein (DCP) are presented in Table 3.

The total available feed was about 9.6 and 1.5 mil metric tons of TDN and DCP, respectively in 1982. The percentage of self-sufficiency was 75.6 and 112.4% and 65.6 and 68.2 for TDN and DCP in 1982 and 2004, respectively. Apparently the self-sufficiency percentage is decreasing. It is very difficult to have precise estimate of feed balance without getting reliable records of livestock numbers and available feed. The real number of animals and available feed may be different than what is recorded and real estimate of feed balance must be attempted to enhance our planning and strategies in the future to reduce the gap.

2. Feed sources in Egypt

Good quality roughages: Egypt mainly depends on irrigated forages for feed, which contribute about 18% of the value of field crops and are grown on about 1.3 million ha including long-season berseem (*Trifolium alexandrinum* L.), short-season berseem, alfalfa (*Medicago sativa* L.), forage sorghum (*Sorghum sudanese* L.), Sudan grass (*Sorghum sudanese* (Piper) Stapf.), fodder maize (Darawa) *(Zea maize* L.) 112,481 ha, corn for silage and minor forages such as cowpea (*Vigna synsis* L.), fodder beet (*Beta vulgaris* L.), elephant grass (*Pennisetum purpuremum* Schumach), amshoot *(Panicum repens* L.) and Green fenugreek (*Trigonella foenum-graecum*) about 5,410 ha. Area, productivity and production of such fodder crops are presented in Table 4.

Forage crops consist mainly of fresh berseem during the winter time and as hay during summer time, representing about 50% of available local feed, where as

Table 1. Trend in animal species numbers during (1990- 2006)

Year	Cattle	Buffaloes	Sheep	Goats
1990	2,617,835	2,897,467	3,363,635	2,400,000
1995	2,995,901	3,017,726	4,220,270	3,131,288
2000	3,529,720	3,379,410	4,469,131	3,424,756
2006	4,609,781	3,937,233	5,385,404	3,877,346

Source: Ministry of Agriculture and Land Reclamation, Dep. of Agric. Economics, Cairo, Egypt.

Table 2. Estimated feed balance for animal wealth in Egypt

Year	1982		2000		2004	
Total feed (tons)	**TDN**	**DCP**	**TDN**	**DCP**	**TDN**	**DCP**
Available	9,625,000	1,536,000	13,629,000	2,235,000	9,700,000	1,535,000
Required	12,735,000	1,367,000	18,132,000	2,173,000	14,790,000	2,250,000
Balance	-3,105,000	+196,000	-4,503,000	+ 62,000	- 5,090,000	- 715,000
% Self Sufficiency	**75.6**	**112.4**	**75.2**	**102.9**	**65.6**	**68.2**

After Hathout (1987) and El-Ashry (2007

Table 3. Sources, nutritive values and percentages of total available feed in Egypt in 1982

Source	Available TDN (t)	% of total	Available DCP (t)	% of total
Good roughages; Berseem (fresh & hay) & other forages	5,775,000	60.0	1,375,000	77.8
Poor roughages (Straw)	1,400,000	14.5	5,000	0.3
Grains & seeds	1,404,000	14.6	102,000	6.6
Milling byproducts & oilseed residues	1,045,000	10.9	234,000	15.3
Total	**9 624 000**	**100**	**1,536,200**	**100**

Adapted from Hathout (1987).

summer forage crops contain Darawa, millet, sorghum, cowpea, Sudan grass, corn for silage, which represent about 5% of the available local feed. Alfalfa provides feed all the year around and represents about 5% of the available local feed.

Poor quality roughages: Poor roughages include straw of cereal crops (wheat, rice, and barley) and faba bean and berseem straw, representing about 14.5% of the available local feed (Table 3).

Concentrates: Concentrates include grains and seeds of various crops, representing about 14.6% of available local feed. Also the oilseed cakes from cotton, flax, canola, etc. as well as the bran resulting from milling of wheat and rice, represent about 10.8% of available local feed (Table 3).

3. Challenges facing agriculture development

Scarcity of water resources: Egyptian agriculture is almost entirely dependent on irrigation as the country has no effective rainfall except in a narrow strip along the northern coastal areas. The availability of a reliable water supply from the High Dam in Aswan is governed by the existing water-sharing treaty with the countries of the Nile Basin under which 55.5 billion cubic meters per annum are allocated to Egypt. Total water resources available now in Egypt are estimated at 73.8 billion cubic meters annually (Table 5). Total amount of water in use is about 62.6 billion cubic meters, out of which Agriculture share from water budget is about 81%.

Wide gap between available and required feed and food: Rangeland in Egypt is very poor because it has no effective rainfall, utmost 200 mm unequally distributed throughout the season and on limited areas. Egypt depends mainly on Egyptian clover (berseem) as the main forage crop. There is wide gap between the available and the required feed, and the gap is showing an increasing trend as indicated before.

Competition between berseem and wheat for land: There is strong competition for land allocation between berseem and wheat, especially on the old land where productivity is the highest for both crops. The increase in cereals is on the expense of fodder, cotton and faba bean (Table 6). Although there is a wide gap between the available and the required feed, there is a very rapid development in the animal wealth to meet the high demand for animal products. Recorded share from animal protein is about 17 g per day in 1997 and is planned to increase to 21g per capita by 2017 (FAO 2003). The new development in animal wealth depends mainly on concentrates, where their main raw materials are imported from other countries.

Rapid increase in the livestock numbers: Animal production contributes about 30% of the total value of agricultural GDP. Three production subsystems could be identified in Egypt. These include traditional extensive, intensive, and semi-intensive subsystems. The first subsystem is characterized by low production inputs and outputs and holding of few animals. It is practiced for sheep, goats, cattle, buffalo, and poultry. The intensive production subsystem has high inputs and outputs and accounts for a very large number of animals. This subsystem is practiced for the production of exotic poultry and cattle. About 60% of white meat comes from intensive production. The semi-intensive subsystem depends on improved local breeds and husbandry techniques. It is practiced for lamb and calf fattening and producing locally improved chickens. To date, dairy production falls short of fulfilling consumption needs. Total Egyptian fluid milk production is currently estimated at 3.8 million metric tons resulting in a per capita availability of 5.5 kg, which is significantly lower than in other developing countries. Moreover, productivity is far below corresponding levels in developed countries.

Table 4. Area, productivity and production of forage crops in Egypt, 2006

Crop	Area under crop (ha)	Productivity ($t\ ha^{-1}$)	Production (1000 t)
Berseem (Long season)	695,907	71.17	49,528
Berseem (Short season)	197,463	28.49	5,626
Alfalfa	23,810	93.80	2,233
Darawa	112,481	26.86	3,021
Sudan grass	2	85.71	0.171
Elephant grass	12	83.09	0.997
Fodder sorghum	2,605	30.54	80
Amshoot	4,712	38.37	181
Cowpea	600	26.10	16
Corn silage	2,860	37.12	106
Fodder beet	32	59.52	2
Green fenugreek	54	18.25	0.986

Source: Ministry of Agriculture and Land Reclamation, Dep. of Agric. Economics, Cairo, Egypt.

Table 5. Available (potential amount) of water resources (in billion m^3) annually.

Source	Potential amount	%	Amount in use	%
Nile water	55.5	75.2	51.7	82.6
Ground water	11.3	15.2	5.2	8.3
Reuse of agricultural drainage water	5.0	6.8	3.7	5.9
Treated sewage water	1.5	2.0	1.5	2.4
Rainfall	0.5	0.8	0.5	0.8
Total	73.8	100	62.6	100

Source: Adapted from Abouzeid (1992) and FAO (2003).

Table 6. Changes in area harvested by crop group (million ha)

Crop Group	1980-84		1990-91		2000-01		2005-06	
	Area	%	Area	%	Area	%	Area	%
Cereals	1.995	42.6	2.247	46.2	2.545	44.3	3.041	48.52
Food Legumes	0.138	2.9	0.154	3.2	0.175	3.0	0.098	1.56
Fiber Crops	0.479	10.2	0.403	8.3	0.315	5.4	0.232	3.71
Sugar Crops	0.111	2.4	0.128	2.6	0.191	3.2	0.215	3.44
Oil Crops	0.083	1.8	0.031	1.9	0.116	2.1	0.109	1.74
Fodder Crops	1.278	27.3	1.126	23.1	1.176	20.0	1.045	18.63
Fruit	0.168	3.6	0.234	4.8	0.478	8.2	0.549	8.77
Vegetables	0.433	9.2	0.481	9.9	0.696	11.8	0.844	13.47
Total	**4.582**	**100**	**4.805**	**100**	**5.750**	**100**	**6.266**	**100**

Source: Ministry of Agriculture and Land Reclamation, Dep. of Agric. Economics, Cairo, Egypt.

4. Opportunities

Increasing productivity of Berseem: Althogh Berseem occupies about 1.2 million ha, it has not received enough research and development attention compared to cereal crops. In spite of developing high-yielding berseem cultivars and making their breeder and basic seeds available through the Forage Crops Research Program (FCRP) for producing certified seed by the Central Administration of Seed Production (CASP), the certified seed produced by CASP is sufficient to covers less than 1% of the cultivated area. Farmers have traditionally produced their own seed or purchased their requirements from the local markets. However, the quality of such seed on local markets is rather poor. The public sector plays almost no role in forage seed production. The amount of seed produced through research stations is very small relative to domestic and foreign demands. Demand for berseem seed is high due to its annual growth habit and its high sowing rate under Egyptian conditions

Due to the unique characteristics of Egyptian forage crops and the numerous ecotypes and varieties present, especially for berseem and alfalfa, large amounts of these seeds are exported to many countries. Exported berseem seed (7400 t) was the major component (86%) in all seed export and reached about 29,000 t in 2007. Considering the progress which has been achieved in cereal productivity, it is relatively feasible to make progress in berseem productivity as well, which could result in releasing area for wheat. If there is a big gap in feed which is likely the case, we could not expect the wheat area to be increased. To eliminate this possibility we have to find different approaches to increase feed.

Optimizing consumption of Berseem: Most farmers, especially the small holders, feed their animals on berseem only *ad libitum* starting from middle of November till the end of May when Berseem is available. Small farmers suffer severe feed shortage during the summer time. Berseem fodder has more than 20% protein on dry basis and it covers about 96% of animal energy requirement and 177% of protein requirement during winter season (Oct. to May). Feeding on Berseem only is considered imbalanced because of less energy and excess protein. In addition, due to the low percentage of dry matter, especially in the first cut, the intake is very low and it could result in bloating and diarrhea, which cause loss of nutrients. Consequently, we have to look for another source of feed, to get a balanced ration and at the same time saving the excess berseem.

Corn- and sorghum-silage from stover: Egypt grows about 0.7 milion ha of corn for grain and about 100,000 ha of grain sorghum annually. After harvesting, most of the straw is unusable and can cause problems of rodents and insects. If this straw could be used immediately after harvesting ears and grains to make silage, it could be substitute feed for about 20% of consumed berseem. Currently, most of corn and grain sorghum area is planted with hybrids, which stay green at maturity. Silage made from the straw of these hybrids directly after harvesting by adding molasses is comparable in nutritive value to 60-70% of the silage made from the whole corn plant. The estimated corn and grain sorghum straw in Egypt ranges between 1.5 – 2.0 mil. MT annually. The estimated total digestible nutrients (TDN), crude protein (CP) and the digestible protein (DP) are 56.6%, 5.67%, and 3.11%, respectively (Bendary et al. 2001). As more than 90% of large animals (cattle and buffalos) are owned by small farmers, silage made from corn and sorghum straw would be ready for feeding by the end of September to October, which is a very critical time for feed availability. In addition to using the silage made from corn and sorghum straw to fulfill the feed gap, it could be used with Berseem as balanced ration, which will lead to saving at least 20% of the consumed berseem as well as achieving higher productivity due to balanced diet. Transfer of such technologies to farmers should be high priority for research and extension agencies.

***Recycling farm residues and agro-wastes to unconventional feedstuff*:** The crop residues and wastes cause huge hazards to the environment if they are left without recycling. Converting them to non-traditional feedstuff offers excellent opportunity to meet feed shortage and reduce environmental threat. Upgrading the nutritive value of the residues through treatments and additives is possible. For example, in India wheat straw is treated with urea (4 kg urea dissolved in 65 liters of water, sprayed or sprinkled on 100 kg of straw) and stored for 10 days. Its digestibility improves by 40-45% and the voluntary feed intake by 86-100%. Crude protein content increases from 3.5 to 7.5 % and growth rate by 200-250 g a day. The treated straw contains 55-57% TDN and 3-4% DCP. Most of the wheat straw in Egypt is consumed without any treatment. The amount of wheat straw produced annually is about 8 million tons (table . Daily gain rate from using the same amount of feed will be doubled due to transferring the technology of treating the straw with urea to farmers. Similarly, converting corn and sorghum straw to silage in the right time will improve its nutritive value. Rice straw is burned in the field by rice growers to clear there land for the following crops. This practice is causing environmental problems to Egypt. Now, technology to convert the rice straw immediately after harvesting to silage with high nutrition value is adopted, which could deal with both feed and environmental problems at the same time. Amount of farm residues is estimated roughly to be more than 25 million tons (Table 7). In addition, feed from other farm wastes (i.e. poultry manure and wastes from potatoes, tomatoes, oranges, grapes, and dates) is estimated to be about three million tons. Results of numerous research works showed no big differences between traditional and non-traditional feedstuff regarding the chemical analysis and amino acid contents, nutritive values, average of body weight gain, feed consumption and conversion and feed efficiency.

Introducing single cut-type Berseem into early-maturing cereal rotations: Availability of early-maturing rice cultivars has made the harvest early (starting from middle August), much before mid of October that was common with traditional varieties. This has led farmers to plant their winter crops such as earlier than before, resulting in mismatching of different growth stages of crop with the appropriate environmental conditions and thus lower yields. Moreover, planting wheat earlier than recommended could result in higher probability for infection with rusts, especially yellow rust. A practical technology to prevent farmers to give up early planting, which is not recommended, is to advice them to plant single cut Berseem cultivar 'Fahl' after rice and before wheat. Fahl fits very well to overcome all constraints that are existing under the prevailing rotation. It helps in improving soil fertility and yield of subsequent wheat crop. Studies on the carry-over effect of including berseem as preceding crop to wheat showed an increase in grain and straw yields of 600 kg and about 1500 kg per ha, respectively, compared with the prevailing rotation. 'Fahl' is harvested after the summer forages are all consumed and before the winter forages become available. Fahl productivity ranges from 35 to 60 t per ha as green fodder with high dry matter percentage, which would allow the farmers to use it green or for hay making. Currently, about 126 000 ha are planted with early-maturing rice cultivars. This area, and all the area planted with corn scheduled to be sown to wheat can be planted with Fahl berseem.

Improving productivity: Large areas are planted to summer crops such as forage sorghum, Sudan grass, forage pearl millet, fodder maize (Darawa), etc. Possible ways of increasing the productivity are through generating technologies such as developing high-yielding cultivars, optimum cultural practices, producing high-quality seed and transferring them to the farmers through the extension agents. Directing the attention to improving the productivity of forage crops could result in similar increases as have been achieved with cereal crops. Despite the large area devoted to these crops, the research funds allocated is not comparable to other crops such as cereals.

Expansion of alfalfa cultivation in the newly reclaimed lands: There is a strong trend now towards expanding alfalfa cultivation on newly reclaimed land in the desert. That area is about 63,000 ha. Local ecotypes of alfalfa indigenous to Egypt present in the oases are extremely non-dormant and are highly adapted to harsh conditions because they have been grown for a long time in the desert. They offer opportunity to make varietal improvement. Furthermore, local alfalfa varieties (i.e. Siwa, Ismailia 1, Nubaria Synthetic), characterized by high levels of tolerance to salinity and drought, have gained recognition in Gulf Countries as well as in Argentina, resulting in increased export demand for seed. Argentina is currently seeking to import about 2500 t of alfalfa seed annually. Establishing one ha in the newly reclaimed lands could result in creating sustainable and integrated cropping system as well as giving possibility of expansion of area occupied with wheat in old land with two ha. Wheat productivity is higher (around 6.5 t ha^{-1}) in the old land than in the new land (2.4 t ha^{-1}). Moreover, alfalfa productivity in the light soil is higher than in the heavy soil. Transporting alfalfa as hay or cubes could be easily carried out. Alfalfa as forage crop has remained of minor importance except on fringes of the Nile Valley and Delta. It is also grown in Aswan and Qena Governorates as well as the western Desert Oases. Recently alfalfa acreage has increased to become the main forage crop in reclaimed desert areas. It is widely adapted perennial legume that enriches the soil due to its high ability in fixing atmospheric nitrogen withstand drought, heat and other harsh conditions. Seed yield of alfalfa from the most productive fields can exceed 1200 kg ha^{-1}. Expansion of alfalfa cultivation in the

Table 7. Various sources of crop residues and their availability

Crop residue	Average amounts available annually (tons)	Availability Times
Rice straw	3 484 701	Sept./Oct.
Wheat straw	7 295 385	Oct./Nov.
Corn straw	3 207 645	Sept./Oct.
Bagasse	8 687 354	March/April/Oct.
Cotton straw	1 760 209	Sept./Oct.
Barley straw	543 878	April/Dec.
Lentil straw	5 897	March/April
Fenugreek straw	4 295	March/April
Chickpea straw	28 841	March/April
Lupine straw	7 526	March/April
Faba bean straw	607 997	March/April
Groundnut straw	6 031	Oct./ Nov.
Total	25 639 759	

Source: MALR (2003)

newly reclaimed lands will enhance the sustainability of the land and reduce the feed gap.

Replacing Darawa by corn for silage and/or other higher productivity and nutritive value forage crops: More than 92,000 ha are planted to Darawa. Replacing it with corn for silage could result in significant increase in both production and productivity and in net returns.

Introducing new forage crops: Egypt has large areas of marginal and waste lands and water of poor quality, which could be used economically under special conditions. Many species could fit under these conditions as forage crops such as fodder beet which can be introduced into the marginal lands as well as the salt-affected soils in the old lands. Many varieties of fodder beet have been evaluated such as Monovert, Monored, Rota, Poly aurea, Brigader and Polygronigia and some varieties have gavin a productivity of more than 250 t per ha. Introducing new forage crops, such as *Cynara cardunulus*, which fit with the expansion in the marginal lands and tolerate the harsh conditions can prove promising. The problems of soil salinity, water quality and the downward trend in soil productivity have become serious problems for agriculture. For example, the new project of El Salam Canal in North Sinai where more than 0.21 million ha, are under reclamation and currently irrigated by 1:1 mixture of fresh and drainage water, there is a limitation for cultivation of commercial crops. Fodder beet could help resolve this limitation. In Sahl El Tena, East Port Said, a forage crop such as Amshoot is widely distributed due to its potential for salt tolerance. Therefore, efforts must be made to spread the adapted forage crops to marginal and waste areas.

Establishing viable management system to alleviate the degradation of the pasture lands in the Northwest Coast and North Sinai: The degradation of natural resources in Matrouh and Sinai governorates is part of an endemic cycle of poverty, lack of viable production alternatives, and uncoordinated regional development. The agricultural system in Matrouh governorate, in contrast to most other agricultural activities in Egypt, is mainly based on rainfed land use, and in particular on animal production. Livestock production is occuring either through grazing of rangelands or through opportunistic barley cultivation with both grain and straw used for feeding of small ruminants or cattle. Traditionally, rangeland grazing was the basis of livestock production of the area. The grazing lands, especially in the coastal area, have evolved over time. During the last few decades they have been exposed to degradation caused by transformation into agricultural land (increase water and wind erosion), by overgrazing leading to further erosion and narrowing of the botanical composition. Increasing animal numbers have disturbed the balance between available forage and carrying capacity. Rough estimates of carrying capacity vary from 0-24 feeding unit (F.U.) per ha in dry years to 95 F.U ha^{-1} in good years, with an average of 48 F.U. ha^{-1}. Actual grazing land available per sheep unit is estimated at 7 ha. The stocking density however, varies considerably during the grazing season. Most flocks graze the southern rangelands during the rainy season, but have to abandon this pasture in the dry season due to lack of water. This lack of water is an important factor in restricting the use of the rangeland, and in protection of its quality. Possible ways to alleviate the degradation are to maintain and, where possible, improve existing grazing lands (coastal, low plateau and high plateau) through:

a) Developing a tree seedling nursery capacity in the villages, and planting, in cooperation with local land users, of improved fodder trees and shrubs.
b) Enhance soil stabilization by planting of windbreaks, using trees or shrubs with nutritive value.
c) Identifying useful local grassland species, developing seed collection and multiplication and over-seeding selected rangelands with seeds of

good nutritive local grasses and legumes species.

d) Applying restricted grazing when possible.

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5.4. Coping with climate change and risk management strategies for a sustainable livestock and rangeland systems in the WANA region

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Abstract

Global demand for livestock products is expected to double during the first half of this century, as a result of the growing human population, and its growing affluence. Over the same period, we expect big changes in the climate globally. The dramatic expansion of crop production for biofuels is already impacting on the resources available globally for food production, and hence on food supply and cost. Food security remains one of the highest priority issues in WANA region, and livestock production has a key role there. Livestock systems in WANA countries are characterized by rapid change, driven by factors such as population growth, increases in the demand for livestock products as incomes rise, and urbanization. Climate change is adding to the considerable development challenges posed by these drivers of change. However, there are considerable gaps in our knowledge of how climate change and increasing climate variability will affect livestock systems and the livelihoods of the people who depend on them. There is an urgent need for detailed assessment of localized impacts and for identifying appropriate options that can help livestock keepers adapt to climate change and increased climate variability. Responding to the challenges posed by global warming will require a paradigm shift in the practice of agriculture and in the role of livestock within the farming systems. Global warming cannot be separated from the future role of the diminishing world supplies of fossil fuel and the impacts on food security of replacing fossil fuels with fuels derived from biomass. Managing the production risk caused by the variability of feed availability is the central issue of livestock production in the WANA region. The high cost of droughts and the increasing vulnerability of agropastoral communities led many governments in the region to intervene with various forms of drought assistance, mainly subsidies. These interventions are costly to governments and use resources that could otherwise be spent for development purposes. The future of livestock sector in the WANA region appears uncertain. Countries will witness an increasing budget load for livestock production and import. Research conducted by NARS and ICARDA over ten years within the Mashreq/Maghreb project that addressed crop-livestock integration, community development and improving livelihoods of agropastoral communities in 8 countries of WANA, suggests integrated technical, institutional and policy options to help building coping strategies: (i) Help livestock keepers build strong institutions that can facilitate both collective and individual adaptation and response to climate change and other external pressures, both short and long term; and assure the participation of the livestock keepers in devising coping and risk management approaches to climate change though awareness building,

collective action; (ii) The increased pressure on rangelands will require an innovative approach to their sustainable improvement and management including institutional solutions for access to communal/collective ranges; (iii) Better use of local natural resources with an emphasis on water harvesting and judicious use of adapted indigenous plant species, such as cactus and fodder shrubs, and introduction of feed blocks using agricultural by-products as well as treated straw; (iv) More attention should be paid to devising efficient animal nutrition and health management options; (v) Better integration of cereals and livestock production should be pursued, with more attention to the value of straw and fallow replacement with adoption of adequate rotations and conservation agriculture techniques that would increase feed production while maintaining the natural resource base for sustainable development; (vi) Use of biotechnology as a potentially effective tool to breeding drought resistant forages and cereals and to sustaining biodiversity (livestock and feed sources) as measures to cope with climate uncertainties; (vii) Improved livestock capacity to cope with climate change through the identification and improvement of local breeds adapted to the local feed resources and tolerant to heat / cold stress; and (viii) Develop early warning systems building on local knowledge, livelihood strategies, and modern tools to forecast information on biophysical, economical, and markets environment to agropastoral communities.

1. Introduction

Rangelands in the dry areas of WANA can be described as non-arable, i.e., land not suitable for crop production, because of the low (< 200 mm) and highly variable rainfall, shallow soils, high percentage of rocks, steep slopes, or a combination of these characteristics. The rangelands contribute significantly to the livelihoods of some of the poorest and vulnerable populations in the world primarily by providing grazing for livestock. Rangelands are estimated to cover 555 million ha of WANA, constituting 90% of the estimated degraded dryland in the world (Lal 2002). Short and long-term climatic drought variability, which affects the availability of grazing resources and sometimes also livestock drinking water supplies, associated to land use change, fuel wood collection and improper grazing practices (overgrazing and early grazing) are the main causes of rangeland degradation. In North Africa for example, the perennial biomass of the steppic vegetation has decreased from 1000-1500 kg DM ha-1 to 200-500 kg DM ha-1 in 50 years (Le Houérou 2000). Depending on the year, these rangelands contribute nowadays between 10 to 25% to livestock needs, compared to 65 to 80 % in 1960.

Small ruminant (SR) production is an important component of the agricultural sector in most of arid WANA countries. During the last fifty years the region has been facing a substantial increase in SR populations driven by more demands for animal products, primarily meat and milk. Adhesion of WANA countries to world trade agreements put them at a comparative disadvantage for SR production as not being competitive at a global level. Investment in agricultural sector and particularly in low rainfall areas has been very low. Climate change exacerbated this unfavorable environment and led to more water scarcity and poverty, resulting in an increased risk and vulnerability of herders (Nefzaoui et al. 2008). Small ruminant production systems in these areas are facing serious challenges to their sustainability (Alary and El Mourid 2007) deriving from: i) climatic constraints represented by the low and erratic rainfall and the high incidence of droughts, affecting the productivity of rangeland ecosystems and the livelihoods of the population; ii) the desertification spiral which accelerated during the droughts of the 1980s and the late 1990s, coupled with changes in livestock and range management practices; iii) technical constraints underpinned by shortages in improved technologies to restore the ecological integrity, function and services of the degraded rangeland ecosystems, as well as the absence of monitoring and early warning systems; iv) socio economic limitations, including the high poverty and vulnerability rates of the population which are exacerbated by unstable feed and animal market conditions and limited diversification of income sources; and v) institutional obstacles linked mainly to continued cross-lawful inefficiencies on issues dealing with land use, coupled with the inadequate capacity of local institutions for land use control and management, and weaknesses in the system of incentives for adoption of improved land management practices, and in the drought mitigation approaches (Nefzaoui et al. 2008; Alary and El Mourid 2007).

The pastoral and agropastoral societies went through deep mutation during the last decades which includes (Bourbouze 2000):

- Dismantling of traditional organizations (informal institutions/community-based organizations);
- Privatization of communal rangelands and the development of barley and tree cropping;
- Regression of animal mobility with the sedentarization of the population. Only poor herders remain full transhumant;
- Increasing demand for livestock products leading to an increasing pressure on rangelands and subsequent degradation;
- Increasing reliance on supplemental feed;
- Mechanization (water and feed transport) that modified the management of rangeland;
- Inequality between poor and rich herders (less opportunity to purchase feed, drought mitigation policies favor pastoralists with large flocks).

In the mid-20th century, the mobility pattern of the pastoralists was perfectly matched to accessibility and availability of forage and water. With the mechanization of water transportation and the reliance on supplemental feed, animals can be kept continuously on the range, which disturbs the natural balance and intensifies the degradation process (Sidahmed 1996; Nefzaoui 2002, 2004). Mechanization profoundly modified rangelands' management in the steppes of the WANA. Water, supplements and other services are brought by trucks to flocks. As a result, the family is settled close to cities to have access to education and health services, and only sheepherders move up with their flocks to target grazing areas.

Production systems are intensifying and it is possible nowadays to find in the steppe a continuum between intensive fattening units that are developing in peri-urban areas and along the main transportation axes, mixed grazing-fattening systems and pure intensive systems where hand feeding is only used to provide feed supplements to animals. In addition and when terms of trade conditions are favorable, herders in WANA are switching from permanent livestock production to "opportunistic livestock production".

Off-farm income and immigration are playing an increasing role in pastoralists' economy, especially to young generation. The overall impact is not known but migrants are reinvesting their earnings in livestock production and hold onto their right to access (and cropping) even during an extended absence. This fact is causing difficulties to the overall community management of rangelands. On the other hand, off-farm labor represents a complementary activity to livestock production and a risk management strategy and may actually improve community homogeneity and cohesion (Nefzaoui 2002).

Inequality between poor and rich herders has been accentuated during the last decades due to several factors. The poorest herders, i.e. those with the smallest flock size, are the ones affected most severely by rangeland degradation since they have less opportunity to purchase feed and rely mostly upon free range resources. Second, the drought mitigation policies have favored pastoralists with large flocks over those with small flocks since they are more often organized into associations in order to benefit from these actions (Hazell et al. 2001)

2. Expected impacts of CC on livestock & rangelands

In smallholder crop-livestock and agro-pastoral and pastoral livestock systems that concern and sustain the livelihoods of an estimated 1 billion people in the world have a much more limited environmental footprint compared with populations in developed countries. Livestock are particularly important for increasing the resilience of vulnerable poor people, subject to climatic, market and disease shocks through diversifying risk and increasing assets (Krishna et al. 2004).
Is pastoral climate change a problem? Not *per se,* because pastoralism is an adaptive strategy to a stressful environment. Pastoralists are the most capable to adapt to climate change, since pastoral livelihoods are shaped to deal with scarce and variable natural resources and climate change could conceivably lead to the extension of territories where pastoralism could show comparative advantages. A much greater threat is likely to be posed by the food: feed: fuel conflict providing reduced feed supplies.

There are many ways in which climate change may affect negatively livestock and livestock systems; they include water, feeds, biodiversity, and livestock (and human) health (Thornton and Herrero 2008). There is quite a lot of information on some of these impacts and much less on others.

- Water: Coupled with population growth and economic development, climate change impacts will have a substantial effect on global water availability in the future.
- Feeds: Changes in land use, primary productivity of rangelands, species composition and quality are expected to occur.
- Biodiversity: Climate change will accelerate the loss of genetic and cultural diversity in agriculture already occurring as a result globalization (Ehrenfeld 2005).
- Livestock health: Major impacts on vector-borne diseases: expansion of vector populations into cooler areas (higher altitude areas, such as malaria and livestock tick-borne diseases) or into more temperate zones (such as bluetongue disease in northern Europe). Helminth infections are greatly influenced by changes in temperature and humidity (Thornton and Herrero 2008).

There are areas in which the impacts of changing climate and climate variability are fairly well understood at an aggregated level. But there are major gaps in our knowledge of the localized impacts which seriously inhibit current pro-poor targeting of adaptation options.

Much greater threat is likely to be posed by the food: feed: fuel conflict leading to reduced feed supplies. This is the debated daily in media and international fora. It is obvious that producing ethanol or biodiesel from biomass is not economically cost-effective. An attractive alternative option would be gasification of fibrous biomass within an integrated livestock-based farming system (Preston and Leng 2008).

3. Adaptation strategies of pastors to CC

Changing environments may provide suitable conditions for the expansion of pastoralism, as the flexibility and mobility afforded by pastoralism may increasingly provide security where other sedentary models fail. Pastoralists are the most capable to adapt to climate change, since pastoral livelihoods are shaped to deal with scarce and variable natural resources and to tackle difficult and uncertain agro-ecological conditions, and climate change could conceivably lead to the extension of territories where pastoralism could show comparative advantages (MacOpiyo et al. 2008).

Many possible adaptation options do exist, such as local institutions and empowerment, science and technology, and risk management to enhance system resilience. All these options aim at increasing the adaptive capacity of poor livestock keepers and agropastors. Given this range of options, there is a real need for methods and tools to assess what may be appropriate and where? This includes the collation of toolboxes of adaptation options and the identification of the domains where these may be relevant, at broad scales through the use of spatial analysis, and at more localized scales through more participatory, community-based approaches.

Most national and international climate change policy documents hardly recognize traditional and indigenous coping strategies. This needs to be rectified. Indeed, traditional and indigenous peoples "may have valuable lessons to offer about successful and unsuccessful adaptations which could be vital in the context of climate change". Because of their long dependence on nature they have developed strategies to cope with climate change and extreme natural events which still have as much relevance today as they did hundreds of years ago.

3.1. How herders traditionally manage drought?

Agropastoral societies have developed their own strategies for coping with drought. These strategies include (Hazell 2007; Alary et al. 2007):

- mobile or transhumant grazing practices that reduce the risk of having insufficient forage in any location;
- reciprocal grazing arrangements with more distant communities for access to their resources in drought years;
- adjustment of flock sizes and stocking rates as the rainy reason unfolds, to best match available grazing resources;
- keeping extra animals that can be easily sacrificed in drought conditions, either for food or cash;
- investment in water availability—wells, cisterns, and water harvesting;
- diversification of crops and livestock (agropastoralism), especially in proximity to settlements, and storage of surplus grains, straw and forage as a reserve in good rainfall years;
- diversification among animal species (sheep, goats, cattle, camels, donkeys) and different breeds within species;
- Income's diversification into non-agricultural occupations, particularly seasonal migration for off-farm employment in urban areas.

However, recent infrastructural and demographic changes (e.g. urbanization) have made such knowledge less effective. In a recent study conducted within ICARDA Mashreq/Maghreb project in Chenini agropastoral community, Southern Tunisia, perception of drought and livelihood strategies to mitigate drought has been investigated using “sustainable livelihood approach” (Sghaier et al. 2008). Main coping strategies for drought mitigation were: Transhumant mobility, food and feed storage, increased utilization of local feed supplements (barley grain, wheat bran, olive cake, etc.), trees pruning, range resting, immigration, increasing importance of goat husbandry as goats adapt better to harsh conditions than sheep, governmental subsidies for feed supplements, irrigation of olive trees, and reduced productivity of cereals/barley (Figure 1).

3.2. Institutions and empowerment of agropastors

There is no integration of indigenous knowledge into development planning, and so people are becoming more powerless. IUCN recommends that communities must be actively involved in policy making at all levels, from local to international. It is suggested that development agencies should use indicators extracted from local know-how of agropastors to prepare relief instead of just relying on satellite imagery. Promoting community-based organizations and empowerment will support adaptation (Garforth 2008):

- help build strong institutions that can facilitate both collective and individual adaptation and response to climate change and other external pressures, both short and long term;
- platforms for managing conflict over natural resources;
- create and intensify learning opportunities, to broaden the set of information and knowledge available to farmers and support local innovation: Livestock Field Schools are an example of how this can be done;
- support local innovation processes;
- help livestock keepers identify opportunities, to enrich the set of options they have when making livelihood choices: re-thinking how advisory services are provided, particularly to small-scale, relatively poor livestock keepers, is an important ingredient.

Decision-makers and all research and development partners are increasingly aware that "the heart of the rangeland sustainable management" is linked to institutional issue. Indeed, in the past the situation of rangelands was relatively better not only because population pressure and demand for meat were lower, but also because the management of rangelands was more strictly controlled by traditional institutions (*jmaas* in Morocco*, Myaad* in Tunisia) that enjoyed effective power. Numerous policy and institutional reforms have been carried out in several countries of

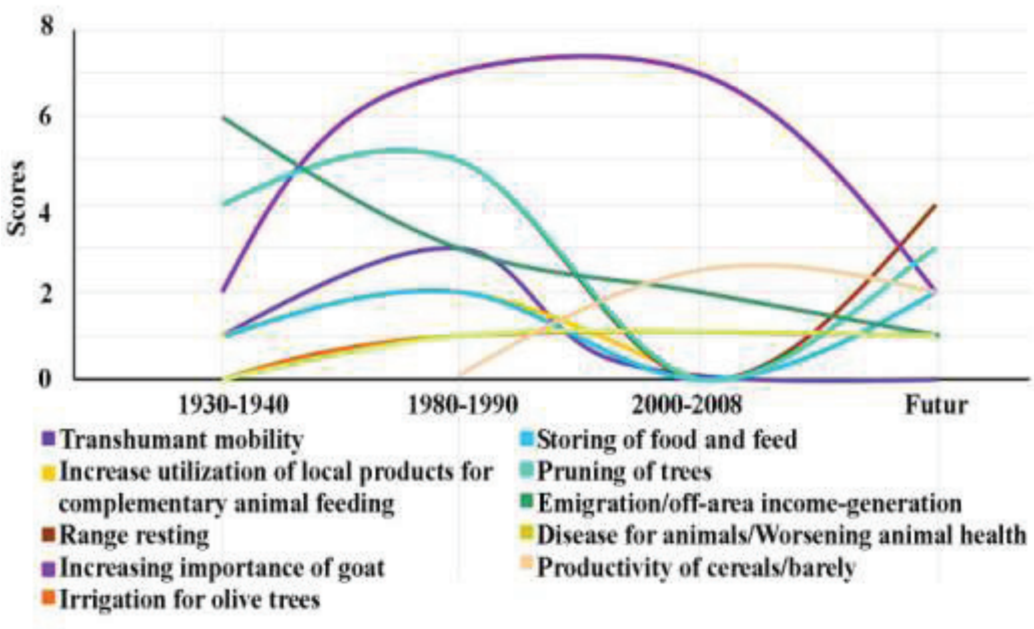

Figure 1. Tendencies of major drought strategies in Chénini agropastoral community, Southern Tunisia (Sghaier et al. 2008).

the WANA. In most cases, policy and institutional reforms weakened pastoral institutions. These institutional reforms can be classified into three main approaches: state appropriation of rangeland resources, strengthening customary tribal claims, and privatization with titling (Ngaido and McCarthy 2004).

Recent experience of communal rangeland management in South Tunisia (IFAD PRODESUD Project) is quite promising. The community-based organizations (GDAs) are built up on socio-territorial units that correspond to the traditional tribe boundaries. They are fully participating in the design and the implementation of their integrated local development. The approach used involves the real participation of agropastoral communities, in a new bottom-up mode, for the establishment of community development plan (CDP) that reflects the real issues and priority needs of the community. This is developed through the joint inputs of all stakeholders including community members, agricultural specialists, extension services, local administration and state representatives. Best-bet technologies for technical, institutional and policy issues are jointly identified for implementation, monitoring and evaluation. The community is represented by a formal community-based organization (CBO), directly elected by community members and fully recognized by government authorities as their equal partner for implementation of all actions set out in the jointly developed CDP. This includes such crucial issues as management of communal pasture and rangelands (20,000 ha of collective rangelands are put under rest and fully controlled by the communities), as well as the procurement of funds and necessary inputs and facilities, and the independent and transparent contact with all stakeholders and similar CBOs in the WANA region for exchange of relevant information and experiences (Nefzaoui et al. 2007).

3.3. Science and technology

Science and technology, including climatic adaptation and dissemination of new understandings in rangeland ecology and a holistic understanding of pastoral resource management, is still lacking. Successful adaptation will be about the quality of both scientific and local knowledge, local social capital and willingness to act. Communities should have key roles in determining what adaptation strategies they support if these have to succeed. The integration of new technologies into the research and technology transfer systems potentially offers many opportunities to further the development of climate change adaptation strategies. Tools such as geospatial information and spatial analysis, and other decision support tools will continuously play a crucial role in improving our understanding on how climate change will affect livelihoods of pastoral communities. Climate change also offers the opportunity to promote payment to pastoralists for environmental services, as in the case of some livestock keepers in Europe. These services could include watershed management, safeguarding biodiversity, landscape management and carbon sequestration (MacOpiyo et al. 2008). NARS in collaboration with ICARDA have been working to develop several options to cope with vulnerability and climate variability. Options include: managing water scarcity, livestock nutrition and health, rangeland management and monitoring, integration of crops and livestock, and diversifying feed resources.

Managing the production risk caused by the variability of feed availability is the central issue in the SR production system in the WANA region. Although solutions to major SR constraints resulted in some easing of the pressure caused by human needs for SR products, the consumption-production gap increases for most of the countries and imports are therefore increasing into the

WANA region both in terms of feed and animal products. This trend is becoming alarming with the recent surge of cereal prices, particularly barley. The future of SR production in the WANA region is uncertain. The WANA countries will witness an increasing budget load for small ruminant production and import. Most countries will have to face an increased pressure on rangelands which requires an innovative approach to their effective management and complementation with better use of local natural resources with an emphasis on water harvesting and better use of adapted indigenous plant species, such as cactus and fodder shrubs, and introduction of feed blocks using agricultural by-products and treated straw. More attention should be paid to devising efficient animal nutrition and health management. Better integration of cereals and livestock production should be pursued, with more attention to the value of straw and fallow replacement with adoption of adequate rotations and conservation agriculture techniques that would increase feed production while maintaining the natural resource base for sustainable development. (Nefzaoui et al. 2008)

3.4. Risk management to enhance system resilience

Several tools are available for managing risk management. Among these are:

i. Early warning and preparedness aim at improving regional capacities to monitor and analyze livestock related food and livelihood security information and to advocate for timely and appropriate responses.
ii. Adoption and dissemination of new understandings in rangeland ecology and pastoral economics, climate change and recognition of the capacity of pastoralism to sustainably produce valuable goods in marginal lands
iii. Focus on Need-Oriented-Technology and addressing the specific concerns raised by pastoral producers themselves
iv. Target human development to enhance the livelihoods of agropastoral communities.
v. Rangeland monitoring to adapt to climate change. This might include: rapid methods for rangelands quantification of carbon stocks/carbon sequestration & Payment for; environment Services (PES) inductive policy.; diversifying livestock & forage species for climate resilience; water harvesting and conservation techniques.
vi. Markets and economic integration and income diversification might bring positive benefits of spreading risk.
vii. Enabling pro-pastoral policies. Pastoral societies have a right to utilize local resources that sustains and protects their livestock. Enabling pastoralists to claim their rights and participate in decision-making at policy level is important because policies and institutions influence the ability of livestock owners to use their assets in support of their livelihoods. The principal governance issue has been, and continues to be, resource access and control. In most pastoral areas, community organizations and local non-governmental organizations are very important, especially where they are influential in advocating and influencing user rights to access of resources found in these communities (MacOpiyo et al. 2008).
viii. Most WANA governments view pastoral resources as state property, while the pastoral communities consider them as their territory. Poorly defined tenure rights often lead to conflicts and equity issues. Those who advocate devolution policies suggest that the success of range management depends on the extent to which pastoral communities are granted full control over access and use of the resources and on the assurance of benefiting from improvements (Ngaido and McCarthy 2004).
ix. Drought relief programs. The high cost of droughts and the increasing vulnerability of agropastoral societies

have led many governments in the region to intervene with various forms of drought assistance. However, many of these interventions are encouraging farming practices that could increase both the extent of future drought losses and the dependence of local people on government assistance. They are also costly to governments and use resources that could otherwise be spent for development purposes (Hazell 2007). This point of view is not shared with the recent results of an USAID program in East Africa. An analysis of supplementary livestock feeding programs in northern Kenya in 2001 assumed that feed was provided for 8000 sheep and goats for three months during drought. Each animal was fed 250g concentrate/day. The cost was compared with the cost of replacing these animals by restocking after the drought. Whereas the feed program cost US$ 82,353, the restocking would have cost US$ 258,065 – it was around three times more expensive to restock than to keep sheep and goats alive during the drought through feed supplementation. In Afar region restocking sheep and goats costs around 6.5 times more than supplementary feeding, restocking cattle costs 14 times more than feeding (Pastoralist Livelihoods Initiative / Policy Brief, Number 2 November 2007).

4. Looking ahead

Long-term vision action plan is needed to integrate research and development programs focusing on marginal areas. Wealth of knowledge is available today to build initiatives to help agropastoral communities to adapt and mitigate climate change impact; however, new research is needed with new paradigm. This work should revolve around the development of collaborative learning processes to support the adaptation of livestock systems to better cope with the impacts of climate change. Farmers already have a wealth of indigenous knowledge on how to deal with climate variability and risk, but well-targeted capacity building efforts area needed to help farmers deal with changes in their systems that go beyond what they have experienced in the past.

In sum, the livestock development issues raised by climate change are highly intertwined and complex; some of the possible impacts at broad scales are reasonably well-researched while others are not, and currently many of the agricultural and other impacts at local scales are simply not known. How these impacts may combine to affect household vulnerability, and how adaptive capacity may be most effectively increased, are critical issues that need considerable attention (Thornton and Herrero 2008). New science and tools will be based on:

- Biotechnology: Use of biotechnology tools in the development of species that are adapted to heat and drought stresses as well as to biotic stresses while maintaing higher productivity.
- Modeling at local level: Elaborate climate models which would allow better understanding of climate change impact at local level in order to improve forecasting climatic and metrological events, and to help communities to be better prepared.
- C sequestration is needed to increase the carbon stocks and sequestration by rangelands through increased vegetative plant cover; access the world carbon market (CDM clean development mechanisms) and investigate the institutionalization of payment for environment Services (PES).
- Insurance: Insuring against climatic risk is becoming a powerful tool for risk management that offers payback on indices on measurable objectives. The insurance would allow farmers to better manage risk and encourage to invest in agropastoral activities.

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5.5. Quantitative measurement of arid land condition and change at the local scale

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Abstract

Vegetation and soils of arid lands are changing across the face of the globe. These changes are the result of shifting managerial strategies, climatic parameters, and the expansion/contraction of plants and animal populations. Because changes in agro-ecosystems affect the livelihoods and development of rural communities, it is important that planners and policy makers be able to document land/ecosystem condition and trend in relation to managerial actions at specific locations. Quantification of ecosystem parameters that are used for condition and trend assessment has been difficult, time consuming, and expensive resulting in very few locations worldwide with detailed records. Tilled agricultural lands have been altered from their original conditions even more than either rangelands or natural plant communities, yet have largely been ignored because their change has been profound and establishment of reference points is difficult. We have developed monitoring technologies and protocols that can be used at local scales which speed the collection, processing, and storage of indicators of agro-ecosystem health. By coupling digital photography, differential global positioning systems technologies, information collected with accessory devices, and computer software applied in a strict monitoring protocol, we are able to rapidly sample and record the geographic position (latitude/longitude) of quadrats ($1m^2$ to $25m^2$) with the following vegetation, litter, and soil parameters: 1) green leaf cover of plants, 2) cover of litter, 3) percent bare ground, 4) soil pedestal/rill presence, 5) vegetative canopy gap, and 6) water flow pattern. If vegetative species are visually distinctive, plants can also be identified. Repeated measurements over time at the same locations provide information regarding environmental trend and rate of change. When we couple our local scale measurements with landscape scale remote sensing data such as satellite or high altitude aerial photography, we have a more complete picture of vegetation dynamics and system change which facilitates interpretation.

1. Introduction

Ecologists and natural resource managers are often called upon to evaluate the effects of their actions and thus are required to document changes in plant communities

(Greig-Smith 1983). They typically want to know whether communities are progressing towards a desired goal or regressing. Development of vegetation sampling protocol requires careful assessment of management goals in relation to benefits received from sampling efforts. Traditionally, ecologists have employed quadrats that are sampled for plant cover, aboveground biomass, and density (Barbour et al. 1987; Cox 1990; Hill et al. 2005). Also of importance is the cover of litter and percentage of bare ground exposed to the erosive impact of rain. Parameters that involve cover are typically recorded by field personnel using field sampling techniques that are based on visual estimates (Bureau of Land Management 1996; Magill 1989). The Daubenmire quadrat, for example, is painted in patterns that facilitates estimates of 5%, 25%, 50%, 75%, 95% and 100% coverage (Daubenmire 1959, 1970). However, proper documentation requires not only careful examination of individual quadrats (samples) but large numbers of samples, if the information is to be used in a statistical context.

Furthermore, traditional sampling techniques for monitoring changes in rangeland vegetation cover are subjective, time consuming, costly, and destructive. Attempts in using photography for measuring cover through film camera or automated digital image analysis are numerous (Booth et al. 2004). Louhaichi et al. (2001) mounted a 35-mm film camera on a lightweight platform of polyvinyl chloride (PVC) tubing to monitor forb dynamics in dry areas. The camera was pointed vertically downward 1.7 m above the ground. A 1-m^2 frame was central in the photograph, which provided an estimate of scale. In recent years, digital photography has become a common and affordable means for the scientific community to document and present images. High-resolution digital images are useful for several types of data gathering and have proven to be a quick and accurate means for vegetation classification (Bennett et al. 2000). Digital cameras, in conjunction with image analysis software, are being used to quantify vegetation canopy cover in rangelands (Louhaichi et al. 2006a). Recently, digital image analysis was used to map slick spot dynamics with increased precision over more traditional evaluation methods (Louhaichi et al. 2006b, 2007).

For several years we have been exploring ways to quantify vegetation using digital cameras, continuously recorded DGPS positions and computer analysis. Photographic records of plots or experimental sites can be a simple, rapid, and cost effective alternative to aerial photos. Photo points are obtained with a hand held camera from an elevated position (Hacker et al. 1990; Borman 1995). Digital cameras record the date and time when photographs are taken to the nearest second. DGPS receivers record the location of the antenna and time with great accuracy and if a continuously recording GPS is coupled with a digital camera, we know the time, position and camera settings of the photograph. The image can be rotated and geographically registered to make it a map and colors in the image can be interpreted by humans or a computer algorithm to make meaningful classes. With this registered digital image, measurements of objects in the photo can be quantified and information can be stored in digital format.

The current research builds-on on the preliminary work done by Borman et al. (2002) and Louhaichi et al. (2001) at the Department of Rangeland Ecology and Management at Oregon State University, OR, USA, who developed new methodology for assessing the impact of grazing on crops by integrating high spatial-temporal resolution remote sensing (platform photography) and GIS combined with a rigorous, repeated ground-truthing data collection. The overarching goal of this research is to enhance our understanding of and ability to quantitatively measure the condition and change of arid land at the local scale, in particular:

- Design and build a photographic staff that holds a digital camera, compass and level so RAW images can be obtained with the proper ancillary information.
- Develop software to position, rotate and register the images and save them in a global bitmap format.
- Design and program software to rapidly classify the images into green leaves, litter and soil or into other meaningful classes.

2. Materials and methods

2.1. Digital vegetation charting

A digital charting apparatus was assembled together as shown in Figure 1. It consists of a Bogen- Manfrotto 681B Professional Aluminum Monopod & B3025 3D Junior Head, camera capable of obtaining RAW format digital imagery and a platform fixed parallel to the image sensor containing a continuously recording Differential Global Positioning System (DGPS), compass and level. Both digital color and digital infrared cameras can be used. The GPS receiver's clock is extremely accurate since it synchronizes with the atomic clocks embedded within the satellites. Thus, camera's clock needs to be synchronized with the GPS clocks. The camera clock is usually set to local time and the GPS clock is set to universal time. The camera time offset from universal time is determined by photographing a computer screen showing the official Greenwich Mean Time. The official Greenwich Mean Time is found at http://wwp.greenwichmeantime.com/. If the offset from camera time is known then the position of the camera during the photo shoot can be determined. Depending on the canopy vegetation cover including herbaceous, low and tall shrubs, the monopod height above the ground can be adjusted. With shorter technicians we sometimes use remote triggering cable because the camera is too high to comfortably reach the shutter release. Taller vegetation requires higher camera position to reduce distortion in the image and we have used pole-mounted cameras that are triggered using radio-controlled servos. During field data collection, we routinely switch between oblique images (beginning transect line) and vertically downward images as shown in Fig. 2.

2.2. Image synchronization

Synchronization between image data and location information is accomplished using GeoAlbum® which is a software developed by Global Geomatic Solutions (Johnson et al. 2007). For each separate project or field assignment, it is best to store all the images and the GPS data in the same directory. DGPS data is loaded into the program as either comma delineated value (CSV) files with a text header in each column, a shapefile, or as native National Marine Electronics Association (NMEA) data string text files. In order to geo-position the images, several steps are involved in the process: 1) determination of the global position of the camera when the photograph was taken, 2) conversion of RAW images into a standard 24-bit BMP format, 3) rotation of the image so that north is to the top, 4) scale the image, 5) generation of projection and world files so the image can be viewed correctly in a GIS program, 6) tagging the image with important information in an associated information file, and 7) storage of the original image, processed image and associated information in digital format (Fig. 3).

Output from the program can either be a single database or associated information files with the same name as the photo but an inf file extension. The information files

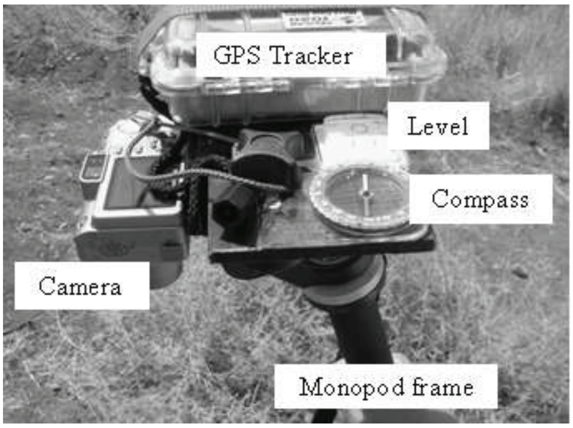

Figure 1. The camera-staff setup used to collect spatially explicit digital photographs of vegetation. It consists of a digital camera, GPS tracker, compass and level, all attached to a monopod.

Figure 2. Both oblique (left) and vertically downward (right) images can be taken in the field with the staff mounted digital cameras.

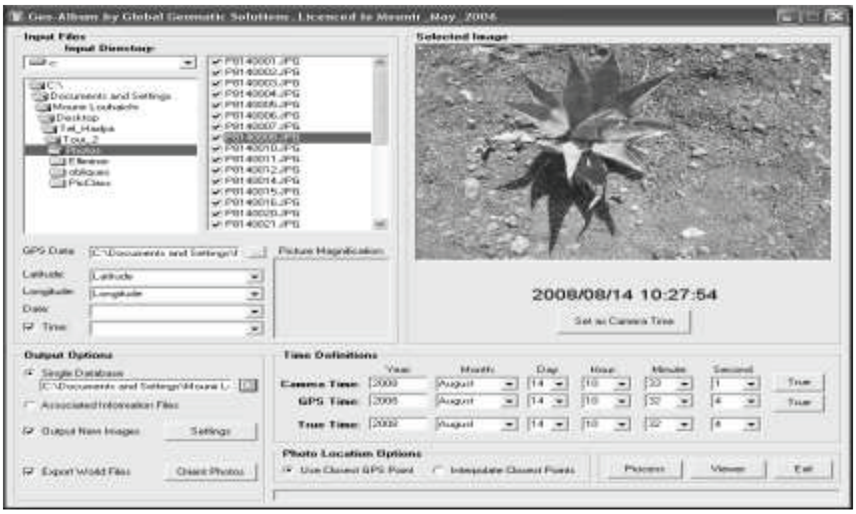

Figure 3. Images are imported into Geo-Album and linked to the GPS file. The camera clock is synchronized to the GPS clock and true time is specified. Photo locations can be assigned the closest point or position can be interpolated between the closest GPS points.

Figure 4. Collared image showing the date, local time and GMT of when the image was taken (top) and easting and northing coordinates of its exact location (bottom).

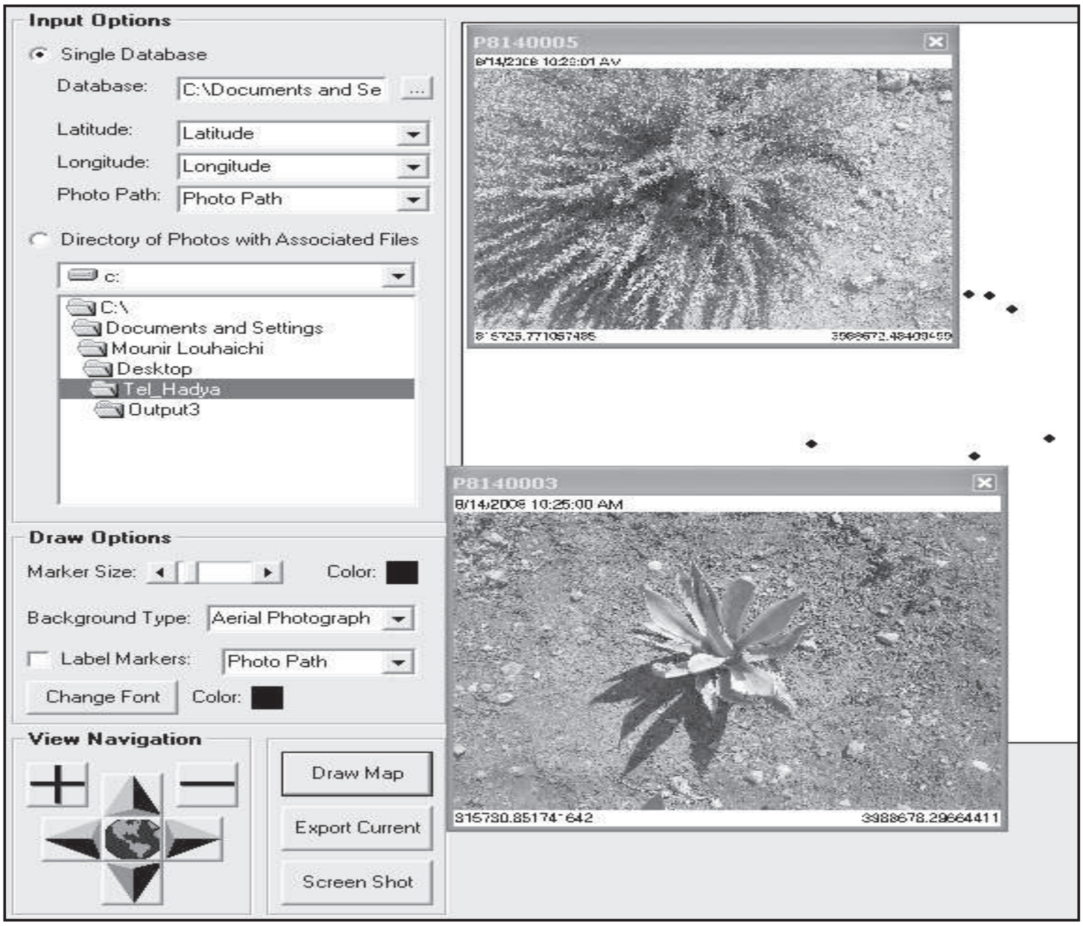

Figure 5. Position of each photograph can be plotted on the screen. If a point is selected by clicking it, the image will open in a new window.

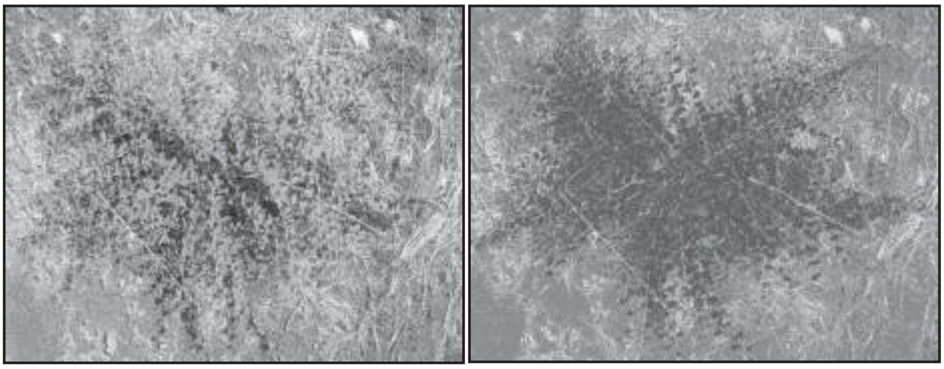

Figure 6. Original image of *Capparis spinosa* L. (left) taken using the digital vegetation charting apparatus. The image was imported into VegMeasure to be analyzed and interpreted for green leaves, litter, rocks and soil (right).

are in American Standard Code for Information Interchange (ASCII) text and contain latitude, longitude, elevation, date and time of the camera when the photo was taken. New images can also be output in a referenced global bitmap format. If desired, a collar can be created above and below the image with pertinent information such as project name, position, date, time, etc (Fig. 4). World files are not generated for oblique or landscape photos but they can still be accompanied with information files or positioned information burned into a collar. Output photographs with world and projection files can be opened in most GIS programs and maintain spatial fidelity.

Output from the program also includes a point map superimposed on a blank background, a digital orthophotographic quadrangle map or a USGS digital raster graphics map downloaded from the TerraServer website http://terraserver-usa.com. Images can be labeled with data from the information files, marker size adjusted and resulting images exported for use in other programs. The data viewer is useful for previewing images in relation to their position on the landscape and examining the distribution of the photographic samples (Fig. 5). Comparison of ground or vegetative condition is facilitated with the viewer.

2.3. Image processing

Johnson et al. (1998) and Louhaichi et al. (2001) have developed an algorithm based on the red, green, and blue bands of color photography. The information contained in a digital image includes the amount of red, green, and blue (RGB) light emitted for each pixel in the image. The digital numbers of each pixel were ratioed resulting is a Boolean image where green leaf is classified as cover and soil as nonliving. The algorithm was later automated and compiled into non-commercial software named VegMeasure® version 1.6 (Johnson et al. 2003). During the past decade, VegMeasure® has been widely used for rapid monitoring of both rangeland vegetation and monoculture crops such as wheat.

More recently a new version of VegMeasure® (version 2.0) is being developed. The beta version allows users to define meaningful categories for an image and select pixels on the screen that represent each classification (Fig. 5). As pixels are selected and added to the category, the color space of the class is defined. The user can also set the threshold distance from the defined colors in each class that will be assigned to that category. If the Digital Picture Info box is selected, the pixel under the cursor will be classified and the group and the distance to the color will be identified on the lower right side of the control panel. Once the Analyst is satisfied with the categories the image is classified. Classification parameters (settings) can be saved and applied to other images taken in similar vegetation under similar light conditions.

Output from the program consists of a classified digital bitmap image with colors assigned to each class by the Analyst. Also output is an ASCII raster classification map with class numbers as cell values, an information file with the number of pixels in each classification and, if desired, the settings used for the classification.

4. Conclusions

The components described in this paper can be efficiently used to gather spatially registered quantitative data on rangeland vegetation in the dry areas. Up to 60 photo quadrats can be taken per hour. Processing time to rotate and assign coordinates takes about 20 minutes and time for image classification is variable and dependent on the contrast between classes of interest. Without having to leave a permanent mark on the ground, this technique allows land managers to establish long term monitoring sites. Monitored areas can be revisited each season or year to assess the spatial and temporal effect of natural and human induced factors. We have used this protocol to document the effects of year-to-year variation in weather on native forbs, wild fires, grazing, weed invasions and managerial actions on both rangelands and agronomic croplands. We believe that these techniques hold promise for monitoring rangeland condition and trend, as well as evaluation of rangeland health

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5.6. Improving dry season feeding in smallholder dairy systems: a case study of testing maize crop-lablab intercropping technology with farmers in Uganda

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Abstract

Elephant grass (*Pennisetum purpureum*) is recommended as a basal forage for stall-fed improved dairy cows in Uganda. However, the low quantity and low crude protein (CP) (<12%) of elephant grass fodder during the dry season limit intake, digestion and utilization by cows thereby leading to drastic reduction in animal productivity. To alleviate this concern, a study on maize stover-lablab residues as a feed and food was done on 32 smallholder dairy farms. The objective of the study was to investigate on-farm effect of intercropping of *Lablab prupureus* (lablab) with maize on grain and stover production. The study also evaluated feed utilization and response of crossbred dairy cows fed forages originating from maize crop-lablab intercropping system supplemented with on-farm generated protein (*Calliandra calothyrsus* leaf hay) and homemade concentrate. The results showed that stover dry matter and maize grain yields and cob size were increased by 26, 7 and 6%, respectively when maize was intercropped with lablab compared to maize monocrops (4,373 kg/ha/yr; 2,912 kg/ha/yr; 134 g respectively). On average, the CP content of maize stover-lablab residues was 1.9 times higher (8.4%) in intercrops when compared to the monocrops. Cows fed maize stover-lablab residues in addition to elephant grass fodder and supplemented with 1 kg/cow/day of calliandra leaf hay and 4 kg/cow/day of homemade concentrate (16% CP) produced higher milk yield (12.9 liters/cow/day) than cows fed elephant grass-legume mixtures (9.7 liters/day) and sole elephant grass fodder (6.9 liters/cow/day). Maize crop-lablab intercropping technology is important to resource poor crop-livestock farmers as it improves the quality and quantity of fodder to fill the feed gap during the dry season while improving maize grain yield from the same piece of land; improves carrying capacity; and enhances milk yield, growth rate and reproductive performance of the animals.

1. Introduction

The livestock sector is a major component of Uganda's economy, contributing about 30% of the country's Agriculture Gross Domestic Product (AGDP) (MAAIF 2004). Smallholder livestock systems are especially important because they are a major source of milk, meat, direct daily cash income, family assets, manure, fuel and farm power for transport and cultivation. Cattle population in Uganda comprise of 7.5 million of which 1.3 million (17.3%) are exotic/crosses and 6.2 million (82.7%) indigenous (UBOS 2007). The national goat population is 8.1 million, of which 0.3 million (3.9%) are exotic. Cattle and goats have been identified as priorities by the Government of Uganda for poverty eradication through the Plan for Modernization of Agriculture (PMA) policy. Therefore, they are of strategic importance to Uganda in addressing the Comprehensive Africa Agriculture Development Program (CAADP) pillar 3 (increasing food supply and reducing hunger), and Millennium Development Goal 1 (eradicating extreme poverty and hunger).

Although dairy farming contributes 40-50% of the livestock GDP and 17-19% of the Agricultural GDP (Anon. 2006), improved dairy cattle production is constrained by inadequate feeds especially during the dry season. Previously, elephant grass fodder has been recommended as a basal feed resource because of its high biomass dry matter (DM) yield compared to other grasses, but some studies have shown that its quality and quantity declines during the dry season resulting in protein and energy deficits (Kabirizi 2006).

Maize crop is a major food and cash crop in Uganda. Maize stover is produced in large quantities during the dry season and could be an additional feed resource but its utilization is constrained by low (4%) crude protein (CP) content. The possibility of intercropping maize crop with *Lablab purpureus* (lablab) to improve fodder yield and quality during the dry season was therefore tested with farmers during the period of 2003-2004 (Kabirizi 2006). The major objective was to determine the effects of maize crop-lablab intercropping on maize grain, fodder and milk yield.

2. Methods and materials

2.1. Study area and selection of farmers

The study was carried out in Masaka district located between $0^0 15'$ and $0^0 43'$ South of the equator and between 31^0 and 32^0 East longitude. The annual average rainfall received is between 800-1200 mm with 100-110 rainy days and an average humidity of 61.2% (Anon 2007). The average minimum and maximum temperature is 15.8^0C and 30.3^0C. The soil texture varies from place to place ranging from red laterite, sandy loam and loam. The study was conducted in three villages where 10 households per village were selected based on their willingness to participate in the research and availability of land and labour to plant and manage the fodder fields.

2.2. Experimental details

Three fodder bank technologies (treatments) were tested: 1) Maize crop-lablab intercrop; 2) Elephant grass-*Desmodium intortum* (desmodium) mixtures; and 3) Sole elephant grass (farmer’s practice - control). The treatments were randomly assigned to the 30 participating farmers in a Randomized Complete Block Design with 10 replications.

2.2.1. Study 1

For this study, ten kg of maize (variety *Longe 1*) and 4 kg of lablab seed were supplied to each of the 10 farmers to plant 0.20 ha of maize crop-lablab intercrop (ML) and 0.2 ha of maize monocrop (MS). This was during the first cropping seasons of 2005- 2006. Maize was planted at 75 cm x 50 cm spacing. Within three weeks after germination of the maize, lablab was sown in between the rows at a spacing of 1m x 1m. Maize was harvested at physiological maturity, 120 days after germination, when the cobs were dry but the stover was still green.

Maize stover-lablab residues (ML), stover from maize monocrop (MS), cobs and maize grain yields were estimated on whole plant basis using 3 quadrates of 1 m x 1 m randomly selected from the middle of the fields from 8 randomly selected households. The mean weight of cobs, grain, lablab and stover yield from each quadrate was recorded. The ML and cobs from the quadrates were harvested and weighed separately. After harvesting the dry cobs, the above ground plant material from the intercrop (stover and lablab) were harvested, air-dried and later stored on well ventilated racks that were constructed by the farm owners. The feeds were offered to dairy cattle during the dry season.

Samples of about 0.3 kg of stover and lablab from ML and MS were taken, weighed and dried at 60^0C for 72 hours. The grain and stover yield from each household was recorded. The dried samples were analysed for crude protein content using methods described by A.O.A.C. (2001).

Maize grain yield; DM yield (ML, MS) and CP of the fodder were subjected to statistical analysis using a General Linear Model procedure for Randomized Complete Block Design using SAS (1999). The data collected were subjected to analysis of variance (ANOVA). The model used in the analysis was: $Y_{ij} = \mu + P_i + H_j + e_{ij}$, where Y_{ij} = fodder or grain yield or chemical composition,
μ= Overall mean; P=Effect of i^{th} Practice (P), 1-2 (monocrop; intercrop); $H^j = j^{th}$ Household/plot; e_{ij} =Random error.

Comparisons of means were considered significantly different at ($p<0.05$) using the Least Significant Difference (LSD).

2.2.2. Study 2

In this study the effect of feeding different forage combinations on the performance of crossbred cows was studied. The basal forages and supplements used in a feeding trials are shown in Table 1. Elephant grass-desmodium mixture and sole elephant grass were established and managed using methods described by Kabirizi (2006). The supplements [*Calliandra calothyrsus* (calliandra) leaf hay and *Lablab purpureus* (lablab) hay] were produced using methods described by Kabirizi (2006) and Mpairwe (1998), respectively. Animals used in this study were crossbreeds (indigenous cows x Holstein-Friesians), 26-28 weeks in-calf at the start of the feeding trials and had calved once. However, data collection started when the cows were 28 weeks in-calf. The farmers carried out all recommended animal health management measures. The feeding trials lasted 12 months, each cow covering 2 months *prepartum* and 10 months postpartum. Elephant grass-desmodium mixture and sole elephant grass fodder were harvested every morning. The fodder was chopped into pieces of about 5 cm before offering it to the cows.

Each farmer was supplied with a 100-kg spring balance to weigh the daily quantities of feeds offered to the animals. Intake was estimated as quantities of all feeds offered minus quantities refused on DM basis. Samples of feeds offered were taken once every month for chemical composition using procedures described in Study 1. The farmers recorded total daily milk produced. Data were subjected to the analysis of variance (ANOVA) procedure for Randomized Complete Block Design using the procedure in SAS (Statistical Analysis Systems) (1999). The model used in the analysis was: $Y_{ijk} = \mu + T_i + S_j + C_k + (TS)_{ij} + \epsilon_{ijk}$, where:

Y_{ijk} = Overall performance (k^{th} cow in the j^{th} season receiving the i^{th} Treatment);
μ = Overall mean; T_i = Effect of the i^{th} Treatment, i = 1, 2, 3, 4; S_j = the j^{th} Season, j = 1, 2 (wet and dry); $(TS)_{ij}$ = Interaction between the i^{th} Treatment and j^{th} Season;
ϵ_{ijk} = Random error.

3. Results and discussion

3.1. Effects of intercropping lablab with maize crop on stoverDM and grain yield

The effects of intercropping maize with lablab on maize stover dry matter (DM) and grain yields are presented in Table 2.

Table 1. Experimental treatments

Treatment	Basal forages	Supplements
1	EGD	2 kg/cow/day LH + 1 kg/cow/day CLH + 4 kg/cow/day HMC
2	EGML	1 kg/cow/day CLH + 4 kg/cow/day HMC
3	Sole EG	None (farmers' practice)

EGD=Elephant grass-desmodium mixture; EGML = elephant grass fed with maize stover-lablab residues; LH= lablab hay; CLH = calliandra leaf hay; HMC= homemade concentrate; Sole EG= Sole elephant grass fodder

Table 2. Effects of intercropping maize crop with lablab on grain and stover DM yield

Parameter	Cropping system		
	Intercrop	Monocrop	SEM
Lablab fodder DM yield (kg/ha/yr)	1321	-	-
Stover DM yield (kg/ha/yr)	4166	4373	200.6
Total fodder DM yield (kg/ha/yr)	5486[a]	4373[b]	174.7
Mean weight of cobs (g/cob)	142[a]	134[b]	4.2
Grain yield (kg/ha/yr)	3115[a]	2912[b]	136.1

SEM=Standard Error of the Mean

Intercropping maize crop with lablab increased ($p>0.05$) maize grain yield by about 7%, compared with the monocrops. Total fodder DM, grain yields and cob size were about 32%, 7% and 6% higher ($p<0.05$) in intercrops than in maize monocrop, respectively. There were no differences ($p>0.05$) in maize stover DM yield between the monocrops and the intercrops.

Improved total fodder DM yields could be attributed to higher proportion of lablab in the intercrop and efficient utilization of water resources and soil nutrients in ML intercrops. It could also be due to less competition to plants from weeds. Two months after introducing lablab into the maize crop, lablab plants provided a soil cover, thus reducing water loss from the soil by evaporation. It also controlled the weeds that could have competed with maize and lablab plants for soil nutrients and moisture. Because of the deep-rooted nature, lablab plants were able to tap water and nutrient resources deep in the soil profile. The relatively lower DM yield of maize stover in intercrops compared to monocrops could be due to the smothering effects of lablab vines on the maize stalks during the third month after planting the maize seed. During that period, lablab vines grew vigorously twining around the maize stalks and this could have lowered the yield of the maize stover.

A review of several studies by Kabirizi (2006) showed a depression of 7 to 24% in grain yield when cereals were simultaneously intercropped with lablab.

The improved grain yields obtained in this study could have been due to late planting of lablab in the maize crop. Due to labour constraints, farmers staggered the planting dates (21 to 35 days) of lablab into the maize crop and this could have minimized interspecies competition and ensured full utilization of available growth factors in a growing season. Thus delaying the planting of lablab enabled the earlier sown maize to grow without competition.

3.2. Effects of intercropping maize crop with lablab on chemical composition of maize stover

Table 3 shows results on the effect of intercropping maize with lablab on CP content, crude protein yield and mineral content of maize stover.

Intercropping maize with lablab increased ($p<0.05$) CP content and total crude protein yield (CPY) when compared to maize monocrop. Intercropping reduced ($p<0.05$) DM but increased ($p<0.05$) P and Ca contents compared to maize monocrops.

The improvement in CP and CPY in the intercrops could have been due to higher proportion (24%) of lablab in ML. While CP content of lablab was 18.6%, that of maize stover was only 4%. Improvement in the quality and quantity of ML is therefore the key factor in increasing the nutritional value of the stover for the dairy cows during the dry season. The higher Ca and P contents in the intercrops were attributed to presence of lablab legume which has been reported to have higher Ca and P contents compared to maize stover (Kabirizi 1996). Lablab had a higher CP content than maize stover. Although CP content of ML and EGD was improved through intercropping, the CP content was still below the minimum (10-16% CP) level required for effective microbial activity in the rumen for growth and lactation of dairy cattle (NRC 2001).

Based on the findings of this study, it is recommended that dairy cattle fed on forages from maize crop-lablab intercropping systems must be supplemented with other sources of protein and energy to meet the nutritional requirements of lactating cows.

3.3. Effect of feeding crossbred cows forages from maize crop-lablab intercrops supplemented with calliandra leaf hay and/or lablab hay and a homemade concentrate on dry matter intake and milk yield

The chemical composition and *in vitro* dry matter digestibility of the basal forages and supplements used in the study are given in Table 4.

Calliandra leaf hay, homemade concentrate (HMC) and lablab hay (LH) supplements had higher CP than elephant grass-desmodium mixture (EGD), sole elephant grass (EG) and maize stover- lablab (ML) forages. Crude protein content of EG was lower than 16%, the minimum level required for maintenance and production of dairy cattle (NRC 2001).

Mean dry matter intake (DMI), CP and metabolozable energy (ME) intake of the basal diets and supplements offered to the animals are shown in Table 5. Total DMI, CP and ME intake were higher ($p<0.05$) in supplemented than in unsupplemented cows (sole EG). Mean DMI of elephant grass fodder was 52% lower ($p<0.05$) in cows that were offered EGML diets than those that were offered sole EG. Total DMI, CP

Table 3.Effect of intercropping maize with lablab on chemical composition of maize stover

Parameter	MS from monocrop	ML stover	SEM
Dry matter (%)	49.8^{b}	47.2^{a}	1.83
CP (%)	4.0^{b}	7.7^{a}	0.22
CP yield (CPY) (kg/ha/year)	180^{b}	432.0^{a}	36.84
Calcium (%)	0.33^{b}	0.39^{a}	0.02
Phosphorus (%)	0.44 ^{b}	0.50^{a}	0.02

SEM=Standard Error of the Mean; MS: Maize monocrop; ML= Maize/lablab intercrop.

Table 4. Chemical composition (% DM) of the basal forages and supplements

Parameter	Basal forages			Supplements		
	EGD	EG	ML	CLH	HMC	LH
Dry matter	14.0	14.5	90.0	78.9	89.6	83.3
Neutral detergent fibre	61.8	64.8	61.1	51.2	19.0	54.8
Crude protein	9.7	7.2	6.2	22.5	16.7	15.8
In vitro Organic matter digestibility	63.7	58.1	62.9	60.1	77.7	59.7
#ME (MJ/kg DM)	9.6	8.7	9.2	9.0	11.7	9.0
Phosphorus	0.26	0.21	0.51	0.46	0.24	0.47
Calcium	0.26	0.25	0.37	1.65	0.47	0.46

EGD: Elephant grass-desmodium mixture; EG= Sole elephant grass fodder; ML= Maize stover-lablab residues; CLH= Calliandra leaf hay; HMC= Homemade concentrate; LH +Lablab hay; ME= Metabolizable energy.

Table 5. Intake of forages and supplements and milk yield of crossbred dairy cows

Parameter	**Diets**			
	EGD+LH+ CLH+ HMC (Diet 1)	EGML+ CLH+HMC (Diet 2)	Sole EG (Diet 3)	SEM
Total DMI (kg)	11.3^{b}	12.0^{a}	7.0^{c}	0.03
Total crude protein intake (g/cow/day)	1443^{a}	1269^{c}	503c	29.60
Total Metabolizable energy intake (MJ/kg DM)	114.3^{b}	116.3^{a}	60.7^{c}	0.30
Milk yield (l/cow/day)	9.7^{b}	10.9^{a}	6.9^{c}	0.04

Means within a row followed by different superscripts differ ($p<0.05$); SEM = Standard Error of the mean; DMI= dry matter intake; EGD = elephant grass-desmodium mixtures; EGML=Elephant grass fodder fed together with maize/lablab stover; LH = Lablab hay; HMC = Homemade concentrate; EG = sole elephant grass fodder.

and ME intake were highest ($p<0.05$) in cows that were offered EGML basal diet with CLH and HMC supplements.

3.4. Milk yield affected by feeding elephant grass-desmodium or maize crop-lablab forages with a calliandra leaf hay and/or lablab hay and a homemade concentrate

The effect of supplementing forages from maize crop or elephant grass-forage legume intercropping systems with a legume hay and homemade concentrate on mean daily milk yield of crossbred cows fed EGD or EGML basal forages is shown in Table 5. EGD+ CLH + LH + HMC yielded ($p<0.05$) about 7% more milk than cows fed on EGD + LH + HMC diet. Cows fed on EGML+ CLH + HMC produced higher milk yield throughout the study period. Increased total dry matter intake (TDMI) with supplementation could be due to increased CP intake (Table 4) that was deficient in control diet. Ebong et al. (1999) indicated that dry calliandra foliage increases the DM content and amount of protein passing the rumen as well as decreasing the content of anti-nutritional factors. The lower mean daily milk yield observed in control animals throughout the entire lactation period could be attributed to low intake of CP and ME observed in this diet (Table 4) and inadequate feed supply especially during the dry season.

The higher milk yield in cows offered EGML compared to cows that were offered EGD basal forages means that for a smallholder dairy farmer with limited land for food and fodder production, integration of lablab in maize cropping system is one way of improving feed quality and quantity and therefore improving milk yield during the dry season.

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5.7. Evaluation of sweet potato (*Ipomia batatas* L) tuber as an alternative animal feed

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Abstract

There is a critical shortage of animal feed in Eritrea. It has been also suggested that sweet potatoes could be an alterative source of protein and energy in the formulation of diets for animals. The purpose of this study was to determine the nutritive value of different cultivars of sweet potatoes introduced in the country and evaluate the potential to replace brown sorghum in poultry feed. In order to evaluate the composition of the introduced cultivars, sample of tubers from four cultivars and vines from two cultivars and from three different locations were analyzed. High protein (> 10 %) contents were found both in the tubers and vines. Dry matter content was high in the tuber harvested form Ala. This showed that there was variation in the nutrient content between cultivars and locations. In order to evaluate its potential as poultry feed replacing brown sorghum, one-week old White Leghorn layer chicks (n=280), were fed on five starter diets for five weeks. The starter diets contained 100%(T-1), 75%(T-2), 50%(T-3), 25%(T-4) and 0%(T-5) sun dried sweet potato as a replacement for brown sorghum. Variables evaluated were feed intake (TFI) to five weeks, live weight gain (LWG) to five weeks, feed conversion efficiency (FCE), mortality (M) and organ weights (OW). A significant difference was found only for TFI (1130.7, 1119.4, 929.1, 967.8 and 1033.9 g). No significant differences were found for LWG, FCE, M and OW. These results suggest that no detrimental effect resulted from the substitution of 100 % sweet potato for brown sorghum in the diets of starter white leghorn layer chicks.

1. Introduction

Livestock production is an extremely important sector of the Eritrean rural economy, especially in the more arid areas of the country. On an average a rural household has between three and five sheep and/or goats and a number of poultry. Most livestock are raised using an extensive system that relies on natural pasture and crop residues. As a result there is a marked annual fluctuation in stock condition, which reflects the availability of feed and fodder (Kayouli et al. 2002).

Like other agricultural products, shortage of animal feed is aggravated with the adverse effect of climatic changes (IAASTD 2008), which is causing an increase in the frequency of floods and droughts resulting in less reliable and less predictable water supply. In such situations the utilization of biodiversity including drought tolerant plants, along with developing water storage systems have been suggested as some of the coping mechanism with climate change (FAO 2008).

Sweet potato (*Ipomoea batata* L.) is one of the twelve principal plant species utilized as human food throughout the world (Paneque 1991). It is also one of the world's highest yielding crops with total food production per unit area exceeding that of cereals and also having a higher food value. The production potential of some the introduced cultivars in Eritrea under research reaches 74.3 t/ha of marketable tuber and 111.7 t/ha of vine (NARI 2005). Sweet potato is also tolerant to the impact of climate changes. John (2008), from his interview with farmers and animal herders in Uganda about the impacts of climate changes on their lives, reported that the only crop that currently does well is sweet potato.

Approximately one third of the sweet potato production in the developing countries goes to animal feed (Scott 1991). In some places like the slopes of Mount Kilimanjaro in Tanzania where standards of smallholder stock husbandry are relatively high, sweet potato is an important animal feed, especially for use during dry seasons (Jana 1982). Different studies have shown that sweet potato could be used as a replacement for cereals in the diets of animals to minimize the competition with humans. Early studies of Masher et al. (1948) showed that replacement of maize by dehydrated sweet potato in the food of dairy cows could give as much milk (91-100 %) as maize. Yeh (1982) also reported fresh sweet potato vines were palatable to cattle, and a cow of 400-500 kg weight could consume 50-70 kg daily and with increasing the proportion of fresh sweet potato vines more milk could be produced. Massey (1943), cited in FAO (1990), in a three-year trial found that substitution of corn with sweet potato led to more meat production in lambs. Lee and Young (1979) reported that chickens fed diets containing 24 % sweet potato in substitution of maize grew performed as well as those on the all-maize diet.

As a new crop to Eritrea, there is lack of information including the nutritive value of the introduced cultivars. There is also a paucity of information on the utilization of dried sweet potato replacing sorghum which is a stable food of Eritrean. This study therefore assesses sweet potato as an alternative animal feed resource by determining the nutritive value of selected cultivars and by assessing the performance of White Leghorn chicks fed sun dried sweet potato tuber as a replacement of brown sorghum.

2. Materials and methods

2.1. Study 1: Determination of nutritive value of different cultivars

The experiment was conducted in March, 2006 at The College of Agriculture, University of Asmara, North of Asmara. For nutritive value analysis of tubers , fresh tubers of similar growth period (6 months) from four cultivars (440024, 56638, 440131 and 440132) from different locations (Table 1 were used. For the nutritive value analysis of fresh vines, six months old vines of two cultivars (440131 and 440132) were used. A representative sample (1-1.5 kg) of tuber and vine from each cultivar was weighed and placed in a sealed plastic bag for dry matter determination and chemical analysis. The dry matter (DM), crude protein (CP), ash, crude fibre (CFr), crude fat (CFt) and nitrogen free extract (NFE) content of the samples were determined by using a standardized procedure (AOAC 1984).

2.2 Study2: Chicks feeding trial

The experiments were conducted from March to May, 2006 at the College of Agriculture, University of Asmara, North of Asmara. Twenty wire-mesh cages each with $1m^2$ area were constructed. In each pen sawdust was used as a bedding material. Each pen had a 100-watt bulb in a metal lampshade as a heater; additionally the 5 m x 6 m house was heated by two 3000-watt electric heaters for the first three weeks of the experimental period.

The sweet potatoes used in the experiment were cultivated and harvested at NARI, Ala (private farm), and at the University of Asmara, College of Agriculture farm. The growing period was approximately 6 months. Fresh sweet potatoes were collected from the farms. Equal proportions from each location were sliced and mixed using a hand operated chopping machine. The slices were sun-dried to about 10% moisture on the chicken wire frame. Drying was carried out during the day time. During night time it was collected and left unsacked indoors resulting in good quality product. The dried sweet potatoes were then bagged and stored in a dry place until they could be milled.

The ingredients used for diet formulations were brown-sorghum, cottonseed cake, sesame meal, fish meal, wheat middling, salt, mineral-vitamin premix, calcium-carbonate, dicalcium-phosphate and synthetic amino acids. The sun-dried sweet potato chips were milled into a flour using a Hippo1.5 hammer mill and then used as an ingredient. Using the nutritive value as reported in the literature for the ingredients and laboratory analysis of the proximate composition values for the sweet potatoes, five experimental diets were formulated using an Ultramix (1990) linear programme. The diets were formulated to replace sorghum grain in a starting chick diet at an inclusion rate of 100 %, 75 %, 50 %, 25 % and 0 % sweet potato (Table 2C). Samples of feed from each treatment were taken and proximate analysis of DM, CP, ash, CFr, CFt and NFE were determined by a standardized procedure (AOAC 1984). Feeding experiment was conducted using a day-old white leghorn layer chicks, with equal numbers of each sex, purchased from the Ministry of Agriculture Poultry Farm, Mendefera. After one week of adaptation, the chicks were weighed and allocated randomly to the experimental starter diets. The treatments were replicated four times with 14 birds per replicate and 56 birds per treatment (28 males and 28 females). The experiment lasted for five weeks. During the feeding trial the same management practice was adopted for the birds on all treatments. Based on the recommendations of Singh (1990) the temperature of the house was set at 33 ^{0}C at the start and gradually decreased to 22 ^{0}C by day 21. The space allocated per bird was 700 cm^2. Each pen had a drinker and feeder allowing each bird 4 cm and 2 cm of trough space, respectively.

In the study of growth performance, the birds were fed and watered *ad libitum*. Records of daily feed intake (feed intake was determined by deducting the leftovers from the total quantity supplied the previous day at a specified time) and weekly live weight, feed conversion efficiency and mortality were kept or calculated. At 6 weeks of age, 4 birds were selected at random from each treatment to be used for organ analysis. Birds to be studied were deprived of feed for 24 hours, killed by externally severing the carotid arteries and jugular veins and left to bleed. The carcasses were eviscerated and the guts washed out. They were then pluck dissected into component parts, comprising gizzard, crop and oesophagus, heart, intestines, liver, lungs, pancreas, proventriculus and spleen. Weight of each organ was recorded

The data were analyzed using a one-way ANOVA program by GenStat Software as a completely random design and presented as means of each group and least significant difference (LSD).

3. Results and discussion

3.1 Study 1: Determination of nutritive value of cultivars

The results of the analysis of the different varieties studied are shown in (Table 1).

The dry matter content showed differences within cultivar. Cultivar 400132 from Ala showed the highest dry matter content. The same cultivars harvested from Halhale had the next highest dry matter content. Cultivars 56638 had the lowest dry matter. The dry matter content of cultivars 400132 from Asmara and Halhale were comparable to that reported by Dominguez, (1991). The two cultivars used for the analysis of their vines had slight differences in the dry mater content, and the values were comparable to what was reported by Dominguez (1991). The variation in ash content (Table 1) was more related to varietal than location effects. The CP content (Table 1) ranged from 10.07 % to 12.69 %, which was higher than that reported by Huang (1982). A comparable crude protein content of 10 .9 % was reported from Trinidad (Dominguez 1991). Li (1982) suggested that it was possible to get sweet potatoes with high protein content from the existing wide genetic variation through selection and breeding. Ruiz (1982) also reported that differences in crude protein content could be expected between varieties. The highest CP content was recorded in variety 400132 harvested from Halhale. The protein content of vines showed the same trend as that of the tubers. As a starchy food sweet potato tuber has a low fat content. A relatively high fat content was observed in the vines (Table 1). The fat content of tubers ranged from 0.15 to 1.65 % and of the vines 1.03 and 1.8 %.

In general, the vines had higher fibre content than tubers (Table 1). The carbohydrate content (Table 1) of tubers for all cultivars ranged from 77.91 to 79.88 %. The carbohydrate content of the vines was 37.49 % and 38.0 %. Collins and Walter (1982) stated that vines had much lower carbohydrate content than tubers and this was in agreement with results found in this analysis. The analysis of gross energy content (Table 1) of tubers in this study showed a range from 15.2 to 15.7 MJ/kg DM. The gross energy content in vines was lower.

The nutritive value of a plant or feed is affected by many factors of which variation between varieties, growing conditions (soil type, climatic condition, water etc.) and harvesting time are the most well known factors. In this regard the variation in the nutritive values of sweet potato under the analysis was to be expected.

3.2 Study 2: Chicks feeding trial

3.2.1 Composition of diets

The proximate analysis of the diets (Table 3) showed similarity in crude protein and energy values between the experimental diets indicating the isocaloric and isonitrogenous nature of the diets. The protein content of all diets was approximately 18 % and this coincides with the recommended level of crude protein for starter white leghorn layer chicks given by NRC (1994). The metabolizable energy using an average efficiency of 80 % (Patrick and Schaible 1980) for T-1, T-2, T-3, T-4, T-5 was found to be 11.6, 11.6,11.7,11.8,11.9 MJ/kg DM of feed respectively, which is similar to the recommended level (NRC 1994) i.e. 12 MJ/Kg DM. There were slight differences in DM content; where the diets with the highest sweet potato content had higher DM.

3.2.2 Birds' performance

The response of the chickens to the diets is shown in (Table 4). There were no significant differences ($\rho > 0.05$) in live weight gain and feed conversion efficiency between the treatments. However, feed intake between the treatments differed significantly ($\rho < 0.05$).

There was a significant difference ($\rho < 0.05$) in feed intake between treatments T-1,

Table 1. Nutritive values of cultivars

Cultivars	440024	56638	440131		440132(China)			
Location harvested:	Halhale	Halhale	Halhale	Halhale	Asmara	Ala	Halhale	
Part	Tuber	Tuber	Tuber	Vine	Tuber	Tuber	Tuber	Vine
Dry matter (%)	27.17	21.32	20.38	13.63	28.12	34.39	29.11	15.28
Ash (%)	5.58	6.18	7.97	19.11	4.9	4.79	5.68	17.63
CP (%)	10.67	10.96	10.08	25.45	11.38	10.07	12.69	28.94
C fat (%)	0.69	0.61	0.72	1.18	1.62	1.65	0.15	1.03
C fibre (%)	3.82	3.62	1.53	16.26	4.19	3.62	3.01	14.92
Carbohydrate (%)	79.24	78.62	79.69	38	77.91	79.88	78.48	37.49
Gross energy (MJ/Kg DM)	15.3	15.2	15.3	11.1	15.6	15.7	15.3	11.5

Table 2. Composition of the starter feed

Starter ration per 100 kg					
Ingredients	100%(50% SP-0% S)	75%(37.5%SP 12.5% S)	50%(25% SP-25% S)	25%(12.5% SP-37.5 S)	0%(0%SP 50% S)
Sweet potato	50	37.5	25	12.5	0
Brown sorghum	0	12.5	25	37.5	50
Wheat middling	25	25	25	25	25
Sesame cake	18	17	16	15	14
Fish meal	3.2	3.1	3.1	3	2.9
Cotton seedcake	2	2.8	3.6	4.4	5.3
Methionine	0.07	0.06	0.05	0.04	0.03
Lysine	0.25	0.25	0.25	0.25	0.25
Min/Vit.	1	1	1	1	1
Dicalcium phos.	0.06	0.03	0	0	0
Limestone	0.47	0.73	0.99	1.22	1.45
Salt	0.12	0.11	0.1	0.09	0.09

(SP = Sweet potato and S = Sorghum % in the ration)

Table3. Nutritional composition of the diets in the treatments

Replacement of Sorghum (%) in Feeds >	100(T-1)	75(T-2)	50(T-3)	25(T-4)	0(T-5)
Moisture (%)	8.0	8.1	9.0	9.3	11.3
Ash (%)	9.7	9.2	8.7	8.8	7.6
CP (%)	18.1	18.4	18.2	18.4	18.1
C fat (%)	2.6	2.8	2.9	3.8	3.3
C fibre (%)	7.3	7.8	7.6	7.8	7.6
Carbohydrate (%)	62.8	62.8	62.6	61.2	63.5
Calculated Gross Energy (MJ/Kg DM)	14.5	14.5	14.6	14.8	14.9

Table 4. Performance of birds on the experimental diets

Treatments	T-1	T-2	T-3	T-4	T-5	LSD (ρ =0.05)
Initial Body Weight (g)	48	47.8	49.2	47.6	48.6	NS
Final Body Weight (g)	262.6	259.3	228.3	258.1	277.2	NS
Total Body Weight Gain (g)	214.7.	211.6	179.0.	210.5.	228.6.	NS
Total Feed Intake (g)	1130.7a	1119.4a	929.1b	967.8b	1033.9ab	122
Feed Conversion Efficiency	5.33	5.33	5.2	4.61	4.58	NS
Mortality/pen	0.5	0.5	0.75	0.25	0.5	NS

Means in the same row without common letter differ at ($\rho < 0.05$)

Table 5. Weight of different organs of the birds

Organs	T-1	T-2	T-3	T-4	T-5	LSD (ρ =0.05)
Gizzard (g)	12.35	10.6	10.53	11.05	13.58	NS
Crop and Oesophagus (g)	3.5	2.38	2.9	2.75	3.27	NS
Heart (g)	2.325	2.225	2.05	2.45	2.475	NS
Intestine (g)	27.4	25.6	21.9	24.5	28	NS
Liver (g)	10.8	11	9.55	11.1	10.82	NS
Lungs (g)	2.2	1.975	1.75	1.65	2.2	NS
Pancreas (g)	2.3	1.90	1.75	1.75	1.5	NS
Proventriculus(g)	2.725	2.55	2.35	2.3	2.65	NS
Spleen (g)	0.5	0.6	0.525	0.575	0.575	NS

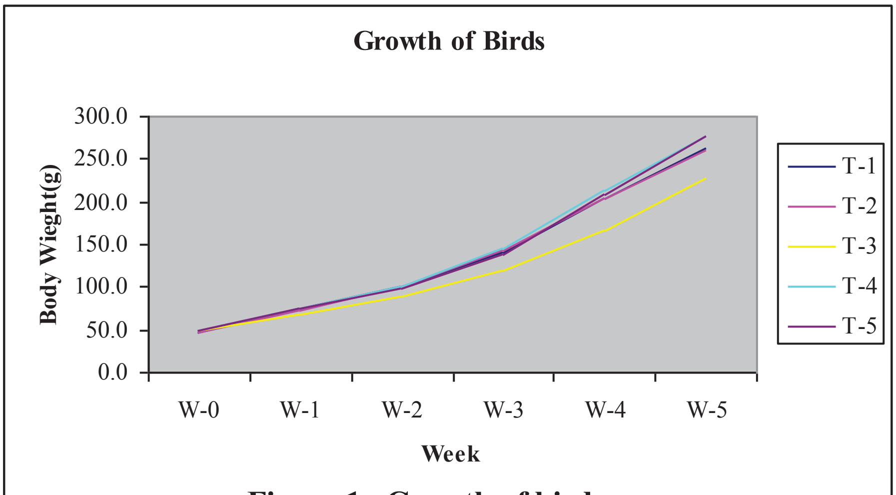

Figure 1. Growth of birds.

T-2 and T-3, T-4 while these four treatments had no significant difference ($\rho > 0.05$) from T-5. Similarly Vasco *et al.* (1997) found a significant difference of feed intake in Japanese quail fed a laying diet when substituting sweet potato for maize as an energy source. There were relatively high intakes in treatments T-1, T-2 and T-5. There is no obvious explanation for the decrease of feed intake at the intermediate levels of sweet potato and sorghum used. The lack of significant difference in the intake of the birds between 100 % and 0 % levels probably indicates that the levels of sweet potato were not the only factors that affected the intake. Ayuk (2004a) found that the inclusion of sweet potato meal in the rations did not decrease palatability and hence feed consumption.

Birds under the treatments showed no significant difference in body weight gain (Figure 2). However, these results showed that generally all birds performed less than what was reported for white leghorn layers at 6 weeks of age (NRC 1994). This could be attributed to several different factors including the environment where the birds were reared. In hot climates the gain is expected to be less (Daghir 1995) because of lower feed intakes. The similarity in weight gain in the treatments portrayed the isoprotein nature of the diets. The result was different from what has been reported in comparison with corn by Agwunobi (1999) and Vasco *et al.* (1997). All reports attributed the nutritional deficiencies encountered in sweet potato as a reason. With this reason, the similarity with the sorghum grain is justified by the fact that the sorghum (brown) used in this experiment had comparable nutrient deficiencies to that of sweet potato.

The feed conversion efficiency (FCE) of birds in different treatments was not significantly different ($\rho > 0.05$). However, the trend showed that birds in T-5 and T-4 had better FCE. It was also observed that the birds in the highest sweet potato diets had higher water consumption and continually passed wet drops. Such a laxative effect could possibly affect their feed conversion efficiency. Similar observations were reported by Agwunobi (1999). Feed conversion efficiency has also been reported to be affected by the variety differences of the sweet potato. Banser *et al.* (2000) reported that the feed conversion efficiency of broilers fed with two different varieties of cassava and sweet potato had better feed conversion efficiencies compared with those fed maize.

All deaths recorded in this study were considered to be due to non-nutritional factors, nevertheless there was no significant difference among the five treatments. Organs dissected out of the sample birds from all treatments were weighed and these values are given Table 5. Comparison of the organs showed that there were no significant ($\rho > 0.05$) differences between the weights of the organs under study. The lack of significant differences between the treatments further showed that the two ingredients were having a similar effect on the growth of the birds' organs. However a trend showed that birds fed high levels of sweet potato meal may have had higher pancreas weights. This could be due to the effect of the inhibitors that increased the secretions and so the size of pancreas. Such effects with sweet potatoes were reported by Birk (1989).

4. Conclusion

At a time where climate changes affects agricultural production systems; the introduction of sweet potato could play a major role in minimizing the current shortage of animal feed particularly the competition between human and animals for cereals. From this study it can be concluded that the already introduced sweet potato can replace sorghum up to 100 % in the diet of white leghorn layer chicks without any significant effect on body weight gain, feed conversion efficiency, organ development and mortality.

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5.8. Evaluation of spineless cactus (Opuntia ficus-indicus) as an alternative feed resource for ruminants in Eritrea

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Abstract

Animal feed resource in Eritrea is fluctuating and limited in supply. Therefore, searching for an alternative feed resource that can sustain animal production during the long dry season is essential. Cactus is drought tolerant and succulent feed resource available throughout the year in Eritrea. The study was done to evaluate the effect of increasing levels of spineless cactus (Opuntia ficus-indica) inclusion on feed and water intake, apparent digestibility and body weight change in sheep fed a base diet of urea-treated barley straw. For this purpose, twenty four fat tailed Highland male sheep with initial mean live weight of 21.1kg were randomly assigned into four treatments. Animals in T1 received ad libitum amount of urea-treated barley straw alone, while those in T2, T3 and T4 received ad libitum urea-treated barley straw supplemented with 175g, 350g and 525g of spineless cactus (DM basis), respectively. Spineless cactus cladodes were high in water content and ash, but low in crude protein, and crude fiber. With increasing level of cactus, there were significant increases in dry matter intake (DMI) and body weight performance while the water consumption deceased. The highest DMI was found in the last two treatments as compared to the first two treatments. Sheep in T1 consumed more water (2 liters/day) than the other treatments (0.85, 0.51, 0.15 liters per day for T2, T3 and T4, respectively). The highest body weight gain (51.9g/day) was found when sheep received 350g DM of cactus (T3), while the lowest was in the control diet (26.8g/day). The metabolism trial demonstrated that available energy intake was directly related to animal performance in the feeding trial. In conclusion, feeding cactus with urea treated barley straw can significantly increase animal performance and feed intake, and reduce water intake.

1. Introduction

Livestock plays a significant role in the Eritrean economy and food security of the rural population. However the livestock production system has low productivity mainly due to low feed quality and availability. The majority of ruminant feed resources come from grazing on rangeland pasture and crop residues. The quality and availability of these resources decrease soon after the rainy season, leaving the animal with limited supply of poor quality forage, characterized by low palatability (low intake), low protein content and low digestibility. Feed shortage being such a serious problem, utilization of multipurpose trees and shrubs such as spineless cactus (Opuntia-ficus-indica)) could provide standing feed resources during critical periods of shortage and prolonged drought and can serve as an alternative strategy to reduce the chronic feed shortage. Cactus possesses the most important characteristics for animal feed in drought-prone regions, namely high dry matter yields, drought tolerance/adaptability, nutritive value and palatability(Tegegne 2001; McIlroy 1972).

Spineless cactus is a xerophytic plant belonging to the family Cactaceae and the genus Opuntia (Sirohi et al. 1997). It has high water use efficiency due to its crassulacean acid metabolism (CAM) photosynthetic pathway (Noble 1995). This makes cactus an extremely important fodder in water-scarce semi-arid regions (Felker and Inglese 2003; Nefzaoui and Ben Salem 2001; Shoop et al. 1977). It is a naturalized plant in Eritrea and is locally called Beles. It is well adapted to marginal land with poor soil fertility and the low, erratic rainfall conditions in Eritrea (MAO 1998). It remains succulent during the long dry season when it can serve as a source of feed and water for the animals. Furthermore, it can be used as a human food, as fuel and in medicine and it provides good forage for bees. It is also one of the key elements in rangeland rehabilitation projects (Barbera et al. 1995). Cactus can prove lifesaving both for human and animals in the time of drought (MOA 1998).

In Eritrea, the use of cactus for animal feed is currently limited to grazing and during the dry season. 'Cut and carry' is practiced during drought periods, but it is not commonly used. The cactus-peel waste and surplus fruit contribute a substantial amount of feed to ruminates, especially to the peri urban dairy cattle. However, no research has so far been done in Eritrea concerning its nutritive value, its utilization as animal feed, and its role in animal performance. Farmers usually reported that their animals get diarrhea when fed high level of cactus during the dry season. The aim of this research was therefore to evaluate cactus as an alternative feed source and to investigate its effect on animal performance at different levels of feeding.

2. Materials and methods

The experiment was carried out at the College of Agriculture farm, University of Asmara (highlands of Eritrea), located at 15° 17´N, and 38° 55´E and at an altitude of 2300 m above sea level. It is characterized by a semi-arid climate with an average annual rainfall of about 500 mm. Twenty-four highland fat-tailed sheep, 5-7 months of age with an average initial live weight of 21.1± 0.15kg, were randomly allocated into one of the four treatments of the feeding trail. The treatments were:

T-1 : urea treated barley straw alone
T-2 : urea treated straw + 175g cactus
T-3 : urea treated straw + 350g cactus
T-4 : urea treated straw + 525g cactus

Prior to the start of actual data collection the animals were allowed to have a 21day adaptation period to get used to the experimental treatments. During the feeding trial, animals were housed separately in well-ventilated concert-floored indoor pens. Each treatment consisted of 6 animals and was divided into two replications with 3 animals in each replication (pen). The animals were checked to ensure that they were all healthy. All the sheep were given a prophylaxis treatment against internal and external parasites. At the end of the feeding trial, four of the sheep were transferred into metabolism cages and used in a digestibility trial for a further period of 10 days. Current-year (terminal) and two year old (sub-terminal) cladodes of Opuntia ficus-indica (spineless cactus) were harvested once every week from Arbereboee-Shegrinee naturalized cactus plantations. Cladodes were cut into small pieces using a manual chopper. The barley straw was treated with urea (5%) as stated by Chenost and Kayouli (1997).

All groups of animal were given a weighed amount of urea treated straw ad libtum and graded levels of cactus twice at 08:00 am and 05:00 pm daily after removal of the leftover feed. The amount of straw intake was adjusted to be about 20% in excess of the amount consumed on the previous day. Feeds were placed in group troughs for each treatment. Fresh and clean drinking water and a commercially produced mineral lick were available ad libitum. To calculate daily feed and water intake, amounts offered to and refused by each group of animal was recorded daily. The body weight of animals was recorded every two weeks before feeding and watering after overnight fasting. Sub-samples of feed offered and refused was dried, ground, and stored for laboratory analysis.

The sheep were blocked by weight and within each block randomly allocated to one of the four treatments, having 6 animals each. Each group of animal was randomly divided into two homogenous sub-groups (replicates) of 3 animals.

Four male sheep were caged in the metabolism cage for 10 day duration, involving quantitative collection of feeds, refusals and faeces. This was performed at the end of the feeding trail in order to assess the apparent digestible nutrient intake of animals. The sheep were adapted in the metabolism cages for 5 days prior to faecal collection. The daily faeces and urine produced were collected for each animal. Sample of feeds, refusals and faeces were prepared daily and dried for DM determination (Ben Salem et al. 2004).

The proximate analysis for dry matter (DM), crude fibre (CF), crude protein (CP), ether extract (EE), and ash was done as per AOCA (1984). Data on feed dry matter intake, growth rate and water intake were analyzed using standard analysis of variance (ANOVA) in a randomized block with GENSTAT statistical producer software. Where significant differences occurred, the least significant difference (LSD) test was used for mean separation.

3. Results and discussion

3.1. Chemical composition of feed

The proximate chemical composition of the spineless cactus and urea treated barley straw is presented in Table 1. The samples of spineless cactus were collected from the naturalized cactus plant in the Area - breabuee–Shgrinee area. The cladodes were high in water and ash, but low in crude protein and crude fiber content. In line with this finding, several authors reported that cladodes grown on poor fertility soils had similar low CP content (Tegegne et al. 2005a; Mustafa 2004; Nefzaoui and Ben Salem 2001; Flachowsky and Yami 1985). The crude protein content of cactus was below the general minimum of 7% CP required for normal microbial activity in the rumen (Preston and Leng 1987). Therefore, animals fed with cactus-based diets need appropriate protein supplementation. In semi-arid regions, where water is a very scare resource, the high water content of cactus can be considered as a benefit. Compared to the urea treated straw, cactus had 65% more gross energy.

3.2. Effect of supplementation on feed intake

The effect of increasing level of spineless cactus on feed intake is presented in Table 2.

The amount of cactus in this study was restricted; however, it was highly palatable feed and was eaten before the urea treated barley straw. Except for T2, there was a highly significant ($p<0.001$) increase in the total dry matter consumption with increasing spineless cactus levels in the diet, and as expected a comparable reduction in straw dry matter intake. The increased dry matter intake of sheep was in line with previous researchers (Tegegne et al. 2005a; Ben Salem et al. 2002c). The highest DM intake expressed on metabolic weight basis was found in sheep that received 350g spineless cactus and was highly significant ($p<0.001$) compared to the other treatments. In agreement with this result, Tegegne et al (2005a) found the total dry matter intake increase progressively from 77 to 100g/kg0.75/day when the cactus supplement increased from 0 to 60% in pasture hay based diet of sheep.

Voluntary dry matter intake is related to the intake potential of the feed and the nutrient demand of the animal (Coleman and Moore 2003). Cactus is a highly palatable feedstuff. As in other studies, higher total dry matter intake was associated with the higher consumption and digestibility of cactus (Tegenge et al. 2005a; Nefzaoui and Ben Salem 2001). The gradual decrease in dry matter intake of straw can be explained by the substitutive or associative effect of feed when replaced with a highly soluble source of carbohydrate (Preston 1985). Such an effect was also reported by Njwe and Olubajo (1989) when they supplemented West African Dwarf goats fed fresh Guatemala grass (*Tripsacum laxum)* with increasing levels of cassava flower and groundnut cake.

Increasing cactus level has a negative effect on fiber digestion. Research work on rumen fermentation (Misra et al. 2005; Ben Salem et al. 1996) has clearly showed that the rumen protozoa population increases significantly with increasing cactus level. Therefore, reduction in straw consumption can be attributed to the adverse effect of ciliated protozoa on the rumen fiber digesting bacteria affecting cellulolytic activity (Preston and Leng 1987). Ben Salem et al (1996) found an increase in ammonia concentration was associated with the increase of protozoa in the rumen, as protozoa could contribute to the dietary protein (Preston and Leng 1987). However, the reduction in straw intake was not associated with the decreases in rumen pH, because as several workers (Misra et al. 2005; Ben Salem et al. 1996) have shown, with an increase of spineless cactus the rumen pH remains within the recommended range (6.8 to 7.1) that allows cellulolysis (Mould et al. 1983).

In this study there was no digestive disturbance or any health effect observed even at the highest rate of cactus inclusion that substituted about 50% of the dry matter intake (DMI). In line with this finding, Ben Salem et al (1996) indicated that spineless cactus can be fed without any digestive disturbance up to 55% of the total DMI, as long as it is combined with a straw-based diet. Tegenge et al. (2005a) also reported the absence of any negative effect when cactus constituted up to 60% total DMI. The absence of a negative effect of cactus could be due to the higher digestibility and water content of cactus that facilitated the rapid disappearance of cactus from the rumen (Nefzaoui and Ben Salem 2001).

3.3. Effect of supplementation on water intake

Sheep water intake with increasing level of spineless cactus is shown in Table 3. The animal water consumption was significantly ($p<0.001$) reduced with increasing inclusion of cactus in the diet. This result is in good agreement with the pervious work (Tegenge et al. 2005a; Ben Salem et al. 1996; Tikabo et al. 2006). The water intake of sheep in T1 was in agreement with that reported by King (1983) for sheep in east Africa. Sheep in T2 drank of 50% less water per kilogram of feed intake, while sheep in T4 almost stopped water consumption. Ben Salem et al. (1996) indicated that sheep stopped drinking water when the cactus intake reached 600g/day. In the tropics, the dry season is characterized by higher temperatures, decreased supply of water and higher dry matter of herbage. Therefore, animals that are sustained on poor quality dry roughages are in need of plentiful amounts of water to facilitate digestion (Kahasay 1998).

Table 1. Chemical composition of experimental feeds

Nutrients (%)	Diets	
	Spineless cactus	Treated straw
Dry matter (DM)	12.9	69.4
Analysis on DM basis		
Crude protein (CP)	4.75	10.2
Ash	16.77	7.3
Crude Fiber (CF)	15.85	46.5
Ether extract (EE)	0.88	1.1
Nitrogen free extract (NFE)	61.6	34.8
Gross energy (mj/kg)	13.22	8.0

Table 2. The effect of increasing level of spineless cactus on feed intake of sheep fed urea treated barley straw

Feed intake	T1	T2	T3	T4	LSD
Cactus DMI (g/day)	0	175	350	525	
Straw DMI (g/day)	987.2a	730.1b	730.1b	537.2c	14.55
Straw DMI (g/ kg BW0.75/day)	94.35a	70.63b	68.81c	48.78d	2.388
Total DMI (g/day)	987.2c	905.2d	1080.1a	1062.2b	3.65
Total DMI (g/kg BW0.75/day)	94.35b	87.57c	101.81a	96.48b	3.418

Means with different letters in the same row differ significantly ($p<0.001$)
LSD=Least significance difference

Table 3. Water intake of sheep supplemented with different level of spineless cactus

Water intake	T1	T2	T3	T4	LSD
Water (l/day)	1.98a	0.78b	0.57c	0.18d	0.03
Water intake (l/kg DMI)	1.98a	0.85b	0.51c	0.15d	0.04
Water intake (l/kg BW0.75/day)	0.187a	0.074b	0.052c	0.017d	0.0077

Means with different letters in the same row differ significantly ($p<0.001$).
LSD=Least significance difference

Table 4. Live bodies weight change of sheep fed increasing level of spineless cactus

Body weight	T1	T2	T3	T4	LSD
Initial (kg)	21.25	21.25	21.08	21.25	NS
Final (kg)	23.67b	24.25b	25.67a	25.50a	0.832
Gain (g/day)	26.8b	33.3b	51.9a	47.2a	12.26

Means with different letters in the same row differ significantly ($p<0.01$)
LSD=Least significance difference

Animals travel long distances to reach water points, spending more energy and losing body weight. In East African countries, during the drought season the distance traveled increased by 43 to 52% for small ruminants (Ndikumana et al. 2002).
Several authors have showed that spineless cactus could supply considerable water to the animals (Sirohi et al. 1997; Le Houerou. 1996; De Kock. 1980). De Kock (1980) reported that sheep can survive from 400-500 days without drinking water when they were allowed to consume unrestricted amount of cactus. In Eritrea where water is a vital resource especially during the dry season, the high water content of cactus can play a significant role in mitigating drinking water shortage.

3. 4. Effect of supplementation on animal performance

There was a significant difference in body weight gain when urea treated barley straw was supplemented with spineless cactus (Table 4). The gain was significantly ($p<0.05$) higher for sheep on T3 and T4 than on the unsupplemented control diet. This result is in accordance with pervious works (Tegegne et al, 2005b).

Even though the total dry matter intake of the sheep in the control was higher than that of sheep in T2, sheep in the latter group performed better. This could be attributed to the lack of readily fermentable organic matter for sheep that were fed urea treated straw alone. The dry matter digestibility of the urea treated straw was higher when it was supplemented with cactus than when it was fed alone. Some 22% body weight improvement was achieved in this study, which is quite interesting as animals lose body weight normally during the dry season.

The results of this experiment support pervious work on the supplementation of cactus as a cheap source of energy for efficient utilization of non-protein nitrogen. Earlier Shoop et al (1977) had suggested that the high level of soluble carbohydrates of cactus could be combined with ammonia- or urea-treated straw, as it could provide a readily available source of energy necessary for the efficient utilization of the non-protein nitrogen in the rumen. Tegenge et al (2005b) have clearly showed that the cactus could substitute for wheat bran at 40%, as long as it is combined with the straw treated with urea.

3.5. Apparent digestible nutrient intake

A digestibility study was conducted, and apparent digestible nutrient intake was determined (Table 5). Increasing cactus proportion in the diet resulted in improvement of the energy density of the diet (higher %TDN). Therefore, supplementation of cactus results in increased total digestible nutrient intake (TDNI) or digestible organic intake (DOMI). Body weight gain as a measure of animal performance was highly correlated with dry mater intake and its energy concentration, and these results are consistent with those of other researchers (Moore et al. 1999; Solaiman et al. 1980). The higher performance of sheep in T3 and T4 as compared to the first two treatments may be because of increase in the available dietary energy (Fuentes 1997) and through an associative effect. In this associative effect, the addition of cactus improves the total digestibility of the diet, including the digestibility of the straw. Previously, Tegenge et al (2005b) reported an improvement in urea treated straw digestibility by 5% units when cactus was added to the diet.

Improvement in the performance of sheep in T2 was only slight and cactus supplementation at the lower level (175g DM) did not result in a significance difference as compared to the control diet. This might be because, although T2 shows an improvement in energy, there is both a decreased percent dietary protein and lower daily digestible protein intake. The crude protein intake of the animals was lower for this group (T2) than for either T1 or T3.

Table 5. The apparent digestible nutrient intake of sheep with increasing level of cactus in a urea treated barley straw based diet

Apparent Digestible Nutrient Intake				
Proportion of cactus in urea treated based straw diet	0%	18.60%	33.54%	51.95%
DOMI (g)	541.8	504.8	667.8	656.3
DCPI (g)	61.2	51.8	61.5	42.6
TDNI (g)	542.0	588.2	672.0	663.1

DOMI=digestible organic matter intake, DCPI=digestible crude protein intake, TDNI=total digestible nutrient intake

Table 6. The crude protein intake (CPI in g/d) of sheep (20-25 kg weight) in the study as compare to the estimated requirement for sheep from NRC (1985)

CPI in this study	Treatment	T1	T2	T3	T4
	Observed	97.80	82.79	98.28	68.08
CPI estimated from NRC (1985)	For 25g ADG	92.5	92.5	92.5	92.5
	For 50g ADG	100.5	100.5	100.5	100.5

ADG =average daily gain, CPI = crude protein intake

When the actual crude protein intake was compared to the estimated NRC (1985) requirements (see Table 6), these animals might have a lack of adequate protein intake. In this case, the higher energy may not properly be utilized for better growth, because protein becomes limiting to animal performance. Supplementation of 350g DM from cactus (T3) seems to be the optimum supplementation rate. At this level, the animals are able to maintain the protein the extra energy and optimizes growth. Therefore, animals in T3 had a higher TDNI as compared to the other groups. Inclusion of cactus at higher rate (T4) was still better than the first two treatments, indicating benefits from additional energy. However, the slightly lower performance of animals in this group could be due to the small laxative effect as a result of lower fiber intake and (or) possibility due to higher urine nitrogen loss. T4 had the highest urinary nitrogen loss observed in the metabolism trial. Previously, Sirohi et al. (1997) reported that higher urinary nitrogen loss was a cause for its lesser incorporation into body synthesis when cactus was fed at higher level (58·9 and 71·1% of total DMI).

4. Conclusions

Feeding cactus in combination with urea treated barley straw can significantly increased animal performance and feed intake, and significantly reduce water intake. For diets based on urea-treated straw, the optimal inclusion rate for cactus was about a third of the diet and (or) 350g/d of cactus DM for sheep. Below this level, cactus reduced the protein content of the diet, so only a slight improvement was seen over urea-treated straw alone. Above this level, cactus could cause a laxative effect, so that no further improvement was seen over the 350g/d level. Use of cactus as an animal-feed supplement can play a significant role in promoting sustainable livestock production by providing with an alternative feed as well as water source.

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5.9. Environmental effect on nitrogen metabolism and its effect on protein requirement of Egyptian oasis sheep

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Abstract

The effect of season on nitrogen metabolism and protein requirements for maintenance of Egyptian Oasis sheep was determined through two nitrogen metabolism trials carried out in summer and in winter using the same four Egyptian Frafra rams. They were fed isocaloric ration (72 TDN) to cover the maintenance energy requirement at the level of 2.0 % DM of live body weight, however with different crude protein content (6.13, 7.93, 9.70 and 15.07 % CP for R1, R2, R3 and R4 rations respectively). Temperature humidity index value (THI), plasma total protein (TP), albumin (ALB), urea (UR), cereatinine (CR) and plasma globulin (GLB) were determined. Nitrogen balance was calculated by the difference between nitrogen intake and nitrogen outgo in feces and urine. Crude protein and ether extract digestibility values were significantly higher in winter than in summer, while increasing dietary protein significantly improved the digestibility of CP and crude fiber (CF). Nitrogen balance was significantly higher in summer than in winter. Total water intake was significantly higher in summer and increasing dietary protein level increased total water intake. Season and level of dietary protein significantly insignificant affected blood nitrogen metabolites. The study showed that the protein requirement for maintenance of Egyptian Oasis sheep was higher during winter than in summer by 31.0 %. It was found to be 3.83 g CP/ kgW$^{0.75}$ during winter season, and 2.57 g CP/ kgW$^{0.75}$ during summer.

1. Intoduction

Protein is the most expensive nutrient in livestock feed. Therefore, it is a limiting factor of its productivity (Singh and Sengar 1970). Maintenance requirements of Egyptian native ruminants has not been intensively studied during the last 50 years, except for a few attempts done to determine the maintenance requirements of protein for some breeds of sheep (Ossimi, Rahmany and Barki). Different approaches were used, e.g. nitrogen balance on feeding low nitrogen diet (less than 5% CP) or protein supplemented diets (Abou-Raya et al. 1972).

Currently, in most of the developing countries, feeding standards are based on presumed energy and protein requirements of temperate breeds (ARC 1965; NRC 1985). However, nutritional requirements are supposed to differ between breeds and under different environmental conditions. Values for protein requirements for maintenance are influenced by age, species, breed, physiological status and activity of the animal, diet characteristics (energy-protein ratio, level of degradable protein and essential amino acid content), seasonal climatic conditions particularly ambient temperature and humidity, and methodology by which protein requirements are determined (El-Bedawy et al. 1998, 2004; El-Shafie et al. 2005).

The aim of this study was to evaluate the effect of season on nitrogen metabolism and its reflect on protein requirements of maintenance of Egyptian Oasis sheep.

2. Material and methods

The effect of season on nitrogen metabolism and protein requirements for maintenance of Egyptian Oasis sheep was determined through two nitrogen metabolism trials in 4 x 4 Latin squares design. The first one was carried out in summer (temperature humidity index, THI = 83.69) while the second one was carried out in winter (THI = 62.70). In each trial same four Egyptian Frafra Oasis rams were used. Frafra is one of the Egyptian Western Desert Oasis (27°N, 28°E). The rams were 30-36 months old, with an average body weight ranging from 40- 48 kg.

The rams were fed isocaloric ration (72 TDN) covering the maintenance energy requirement at the level of 2.0 % DM of live body weight. However, the crude protein (CP) content in the experimental rations was 6.13, 7.93, 9.70 and 15.07 % for rations R1, R2, R3 and R4, respectively. Ingredients and chemical compositions of the experimental rations are presented in Tables 1 and 2. The rams were fed individually in metabolic cages for 15 days in the preliminary period followed by seven days for total collection of feces and urine. Initial and final body weights were recorded in each experiment. Drinking water was made available in free choice and daily water consumption was recorded to determine water balance. Feeds were offered once a day at 09:30 h. Ambient temperature (AT) and relative humidity (RH%) were recorded simultaneously daily to calculate temperature humidity index value (THI).

Feces and urine were collected; a sample of 10 % of the collected feces was sprayed with solution of 10 % sulfuric acid and 10 % formaldehyde then oven dried at 60 ˚C for 24 hours. A composite sample of dry feces for each ram was ground and kept at room temperature for nitrogen determination. Urine was collected in clean stopper plastic bottles, each containing 50 ml of 10 % sulfuric acid and used for nitrogen determination.
Chemical composition was determined according to the standard methods of A.O.A.C. (1984).

Blood samples were collected from the jugular vein in heparnized tubes, and plasma total protein (TP), albumin (ALB), urea (UR) and cereatinine (CR) were determined by a colorimetric method using Stanbio kits USA. Plasma globulin (GLB) was calculated by the difference between TP and ALB. Nitrogen balance was calculated by the difference between nitrogen intake and nitrogen outgo in feces and urine.

Relationship between nitrogen intake and nitrogen balance was used (Singh and Mudgal 1991) to calculate the nitrogen requirements by regression of nitrogen intake (NI) on nitrogen balance (NB), NI as dependent variable and nitrogen balance (NB) as independent variable for the 16 observations in each season. The general regression formula is: NI = a + b (NB). At NB= zero (nitrogen equilibrium), the N requirement = the intercept value.

Factorial method was used to determine the nitrogen requirement for maintenance according to the following formula applied by Harris and Mitchell (1941) as suggested by Sengar (1980): N requirement = MFN + EUN / BV x TD , where is MFN Metabolic fecal nitrogen, EUN = endogenous urinary nitrogen, BV = biological value of protein, TD = true digestibility of protein. EUN was calculated by regression of urinary nitrogen (UN) on nitrogen intake (NI) by the regression equation UN = a + b (NI). When NI = zero,

Table 1. Ingredients percentage in the experimental rations

Ingredients	IFN	R1	R2	R3	R4
Yellow corn	4-02-931	50	45	40	25
Soybean meal	5-04-604	0	5	10	25
Rice straw	1-04-077	50	50	50	50

IFN = International feed number

Table 2. Calculated chemical composition of tested ration.

Chemical composition	Rations R1	R2	R3	R4
Dry matter (DM %)	90.50	90.34	90.18	89.70
Chemical composition on DM basis (%)				
Organic matter (OM)	91.10	90.80	90.51	89.62
Crude protein (CP)	6.13	7.93	9.70	15.07
Crude fiber (CF)	17.49	17.69	17.88	18.49
Ether extract (EE)	2.47	2.55	2.63	2.87
Nitrogen free extract (NFE)	65.01	62.63	60.30	52.19
Ash	8.90	9.20	9.49	10.38

then UN = EUN. Metabolic fecal nitrogen

Table 3. Mean effect of seasons and dietary protein levels on nutrient digestibilities % in Oasis sheep

Item	Dietary protein (%)					Season			
	6.13	7.93	9.70	15.07	SEM	Summer	Winter	SEM	**PxS**
DM	72.87	73.43	73.95	76.32	4.55	74.16	74.12	5.11	NS
OM	76.19	76.50	77.27	74.30	2.89	77.78	77.53	4.36	NS
CP	45.10[d]	56.27[c]	63.44[b]	77.48[a]	3.38	59.19[b]	61.87[a]	13.40	*
CF	55.45[b]	59.31[ab]	56.75[b]	63.96[a]	3.16	57.51	57.43	7.39	NS
EE	79.55	81.45	82.79	84.69	2.16	81.03[b]	83.04[a]	4.26	NS
NFE	84.73	85.17	85.72	85.12	3.35	85.02	85.39	4.80	NS

[a,b,c and d] *Means in the same row within each trait having different superscripts differ (p<0.05)*
NS = No significant interaction between season and dietary protein level.
* = Significant interaction

(MFN) was calculated by regression of fecal nitrogen (FN) on nitrogen intake (NI) by the regression equation FN = a + b (NI); when NI = zero, the FN = MFN. Biological value of protein (BV) was calculated according to the following equation (Mitchell 1924):

$$BV = [NI– (FN-MFN) - (UN-EUN)/NI- (FN- MFN)] \times 100$$

True digestibility of dietary protein (TD) was calculated according to the following equation (Mitchell 1924): $TD = [NI- (FN-MFN)/NI] \times 100$

Two factors factorial arrangement was used to test the effect of season, dietary protein and their interaction (P x S) using analysis of variance procedure. Duncan's multiple range tests was used to separate mean effects for season, dietary protein and their interaction (SAS 1999).

3. Results and discussion

3.1. Nutrient digestibility

The mean effects of season and dietary protein level on nutrient digestibility y are shown in Table 3. Increasing dietary protein significantly improved the digestibility of CP and CF. These results conform with those found by Woods et al. (1958) and Bunting et al. (1987). The digestibility of DM, OM, EE and NFE was not significantly affected by the level of dietary protein. These results are in agreement with findings of Ahmed and Abdellatif (1995). Crude protein and EE digestibility values were significantly higher in winter than in summer, while other nutrients were not affected by the season. Murad et al. (1994) suggested that the influence of ambient temperature on apparent digestibility of nutrients depended on diet composition. Denek et al. (2006) found that in Awassi rams CP digestibility during fall was much higher than during summer in Turkey. The interaction between season and dietary protein percentage had no significant effect

digestibility of all nutrients except CP as alsp observed by Goetsch and Johnson (1999).

3.2. Nitrogen intake

Increasing dietary protein level caused impulsive increase in nitrogen intake irrespective of non-significant change in feed intake. Increasing nitrogen intake from 7.54 to 17.94 g/h/day increased fecal nitrogen from 4.15 to 4.61 g/h/day, however this increase was not significant. While, increasing nitrogen intake significantly increased urinary nitrogen loss from 2.94 to 8.51 g/h/day (Table 4) as also observed by El-Bedawy et al. (1998). This result could suggest that fecal nitrogen loss is less affected by increasing nitrogen intake. Aarts et al. (1992) reported that the concentration of protein in the diet had greater impact on urinary excretion than fecal excretion of nitrogen.

Total nitrogen output ($P<0.05$) increased from with increasing nitrogen intake (Table 4) as also reported by several authors working on sheep and goats (Reuben 1992; El-Bedawy et al. 1998, 2004; Helal 2002). Increasing nitrogen intake significantly increased absorbed nitrogen and nitrogen balance (Table 4) as reported by other workers (El-Bedawy et al. 1994; El-Bedawy el. 1998, 2004; El-Shafie et al. 2007). Urinary nitrogen and total nitrogen output were significantly higher in winter than in summer, while, nitrogen balance was significantly higher in summer than in winter. El-Bedawy et al., (2004) found similar effect of temperature on nitrogen balance of goats.

3.3. Water intake

Increasing dietary protein level increased drinking water and total water intake, but the increase was not significant (Table 5).

Table 4. Mean effect of seasons and dietary protein levels on nitrogen metabolism in Oasis sheep

Item	Dietary protein %					Season			
	6.13	7.93	9.70	15.07	SEM	Summer	Winter	SEM	PxS
N intake	7.54[d]	9.90[c]	11.93[b]	17.94[a]	3.24	11.46	11.82	3.68	*
Fecal N	4.15	4.38	4.35	4.61	0.63	4.43	4.29	0.51	NS
Urinary N	2.94[c]	4.07[b]	5.24[b]	8.51[a]	1.47	5.53[b]	6.73[a]	1.68	**
Total output	7.09[b]	8.45[b]	9.59[ab]	13.12[a]	1.70	9.96[b]	11.02[a]	1.86	NS
N Absorbed	3.39[c]	5.52[b]	7.58[b]	13.33[a]	1.20	7.03	7.53	0.89	*
N Balance	0.45[c]	1.45[b]	2.34[b]	4.82[a]	0.89	1.50[a]	0.80[b]	1.15	NS

[a,b,c and d] *Means in the same row within each trait having different superscripts differ (p<0.05)*

NS = No significant interaction between season and dietary protein level.

* = Significant interaction ** = Highly significant interaction

Similar results were reported in sheep by Terill (1968) and in goats by Bahyan et al. (1997) and El-Shafie (2004).

The feed moisture was significantly higher in winter than in summer. While, drinking water and total water intakes were significantly higher in summer than in winter. Increase in water consumption was found by Gengler et al. (1970) in heat stressed cows and sheep. El-Shafie (2004) found that in Egyptian Nubian goats increasing environmental temperature from 25°C to 35°C increased the absolute values of drinking and total water intake by about 35 %. Increasing dietary protein intake did not significantly affect fecal water loss (Table 5), as also observed by Pfeiffer et al. (1995) and El-Shafie (2004). Feces water loss was significantly higher in winter than in summer. Ashour et al. (2002) and El-Shafie (2004) reported comparable decrease in fecal water loss in heat stressed sheep and goats. Urinary water loss as well as total water output increased as dietary protein level increased. Insensible water loss was not affected by dietary protein level, while it was significantly higher in summer than in winter. This may be attributed to high amount of water loss in panting during summer season. Murad et al. (1994), Ashour et al. (2002) and El-Shafie (2004) reported that insensible water loss was higher in heat stressed rams and bucks than under comfort temperature. The effect of interaction of season and dietary protein level was not significant oin water metabolism, which agrees with the observations of Higginbotham et al. (1989).

3.4. Blood parameters

The effect of season and level of dietary protein as well as their interaction on blood parameters (Table 6) was insignificant.

3.5. Assessment of maintenance nitrogen requirement

During the winter season the regression equation was NI (g/h/day) = 10.27 + 2.12 NB (g/h/day). At nitrogen equilibrium (NB = 0), nitrogen intake will represent nitrogen requirement for maintenance. Thus protein requirement for Oasis sheep during winter season was found to be 3.74 g CP/ kg$W^{0.75}$ or 2.31 g DCP/ kg$W^{0.75}$ based on protein digestibility of 61.87 % and body weight of 44.3 kg in average.

Table 5. Mean effect of seasons and dietary protein levels on water metabolism in Oasis sheep

Item	Dietary protein %					Season			
	6.13	7.93	9.70	15.07	MSE	Summer	Winter	MSE	P*S
Average body weight (kg)	42.5	43.5	42.6	41.4	0.43	41.1	44.3	1.1	
Intake, ml/h/d									
Feed	67.64	68.66	68.87	67.64	1.32	65.7[b]	70.69[a]	0.93	NS
Drinking	2532.7	2436.4	2424.2	2703.6	137.5	3129.3[a]	1919.7[b]	97.2	NS
Total	2600.4	2505.0	2494.1	2771.3	137.5	3195.0[a]	1990.4[b]	97.2	NS
Output, ml/h/day									
Fecal	285.6	310.2	268.3	277.9	29.5	268.3	302.6	20.8	NS
Urinary	581.1[b]	488.6[c]	590.7[b]	789.9[a]	71.0	661.8	563.4	50.2	NS
Total	866.75	798.8	859.0	1067.7	79.6	930.1	866.1	56.3	NS
Insensible water loss, ml/h/day	1733.6	1706.2	1635.2	1703.5	139.4	2264.9[a]	1124.3[b]	98.6	NS

[a,b,c and d] *Means in the same row within each trait having different superscripts differ ($p<0.05$)*
NS = No significant interaction between season and dietary protein level.

Table 6. Mean effect of seasons and dietary protein levels on nitrogen blood metabolites of Oasis sheep

Item	Dietary protein %				SEM	Season		SEM	P*S
	6.13	7.93	9.70	15.07		Summer	Winter		
TP (g/dl)	6.64	7.21	7.48	6.74	0.60	7.19	6.85	0.43	NS
ALB (g/dl)	4.12	4.77	4.94	3.90	0.59	4.73	4.16	0.55	NS
GLB (g/dl)	2.52	2.42	2.48	2.80	0.14	2.46	2.64	0.16	NS
UR (mg/dl)	30.67	25.89	28.01	24.98	1.13	26.63	28.35	0.88	NS
CR (mg/dl)	1.36	1.29	1.28	1.25	0.27	1.15	1.46	0.11	NS

NS = No significant interaction between season and dietary protein level.

During the summer season the regression equation was NI (g/h/day) = 6.99 + 1.21 NB (g/h/day). Thus protein requirement for Oasis sheep during summer season was found to be 2.70 g CP/ $kgW^{0.75}$ or 1.60 g DCP/ $kgW^{0.75}$ based on protein digestibility of 59.19 % and body weight of 41.1 kg in average.

Endogenous urinary nitrogen (EUN): During winter season the regression equation was found to be UN (mg/ $kgW^{0.75}$) = -170.0 + 0.818 NI. Therefore, at NI = zero the EUN would be equal to UN = 170.0 (mg/ $kgW^{0.75}$).While During summer season the regression equation was found to be UN (mg/ $kgW^{0.75}$) = -14.16 + 0.334 NI and EUN as 14.16 (mg/ $kgW^{0.75}$).

Metabolic fecal nitrogen (MFN): During the winter season the regression equation was FN (mg/ $kgW^{0.75}$) = 269.4 + 3.24 NI. At NI = zero the MFN was equal to FN = 269.4 (mg/ $kgW^{0.75}$). During the summer season the regression equation was UN (mg/ $kgW^{0.75}$) = 208.4 + 9.13 MFN was 208.4 (mg/ $kgW^{0.75}$).

The biological value of dietary protein by Oasis sheep during winter season averaged 71.41 % vs. 68.39 % during the summer season. On the other hand the true digestibility of dietary protein averaged 98.44 % during winter season vs. 90.72 % during summer season.

Protein requirement of Oasis sheep during the winter season calculated by factorial method was found to be 3.92 g CP/ $kgW^{0.75}$ or 2.43 g DCP/ $kgW^{0.75}$ based on average protein digestibility of 61.87 % and body weight of 44.3 kg. While during summer season it was found to be 2.43 g CP/ $kgW^{0.75}$ or 1.44 g DCP/ $kgW^{0.75}$ based on average protein digestibility of 59.19 % and body weight of 41.1 kg.

The nitrogen metabolism trial on feeding rations containing varying levels of protein content through winter and summer season indicated the following assessment of protein requirement for maintenance of Egyptian Oasis sheep as calculated by two methods. During winter season (THI = 62.70) the requirement was found to be 3.83 g CP/ $kgW^{0.75}$ or 2.37 g DCP/ $kgW^{0.75}$ based on protein digestibility of 61.87 % and body weight of 44.3 kg on average. While during summer season (THI = 83.69) it was found to be 2.57 g CP/ $kgW^{0.75}$ or 1.52 g DCP/ $kgW^{0.75}$ based on protein digestibility of 59.19 % and body weight of 41.1 kg on average. This estimate of protein requirement for maintenance of Egyptian Oasis sheep conforms with those found by El-Bedawy et al. (1998).

The present study showed that the protein requirement for maintenance of Egyptian Oasis sheep was higher during winter than in summer by 31.0 %, which is in agreement with the observations of Ames and Willms (1977), El-Bedawy et al. (2004) and El-Shafie et al. (2005). The reduction in the requirement in summer reflects the reduction in nitrogen outgo and urinary nitrogen during heat stress. This reduction could be a part integrated in general reduction in metabolic heat production in high ambient temperature.

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5.10. Evaluation of some pasture species grown under conditions of rock-phosphate fertilization and mycorrhizal inoculation on calcareous soil

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Abstract

The study was conducted at Maryout Agricultural Experimental Station of the Desert Research Center during summer season of 2006 and 2007 to evaluate the effect of rock-phosphate (15, 30, 45 kg P2O5 per feddan, 1 feddan = 0.42 ha) and inoculation with Vesicular Arbuscular Mycorrhizae (VAM) on growth, forage yield and quality of three legume species, Dolichos lablab L., Clitoria ternatea L., and Macroptilium atropurpureum. Increasing the rate of phosphate from 15 to 45 kg/feddan significantly increased growth, forage yield and chemical constituents in the tested legumes. Species differed from one another in all the parameters studied. The highest green fodder and dry yield was recorded in lablab followed by clitoria. The highest forage yield of different legume pasture species was obtained with mycorrhizal inoculation. The crude protein, crude fiber and nutritive values (DM%,TDN and SV) were best in lablab. The soil analysis after harvest of the three forage legumes revealed that inoculation with mycorrhiza and the application of rock-phosphate reduced the pH and Ec values and increased the organic matter and soil fertility as well as nutrients solubility and availability which increased nitrogen and phosphorus content in the crops.This improvement was more pronounced under lablab than the othertwo species.

1. Introduction

Many agriculture soils are infertile with low levels of essential plant nutrients, especially N and P. Phosphorus availability is a problem in calcareous soils due to its fixation and conversion into less available forms. Attention is being now devoted to reduce the rates of mineral fertilizer applications by using bio-fertilized farming system to enhance the availability of nutrients present in the medium. Many investigators have demonstrated that biofertilization with phosphate-dissolving microorganisms might be comparable to a treatment with chemical phosphate fertilizer. The use of rock phosphate for direct application has therefore gained attention worldwide because rock phosphate as a natural raw material is the only nutrient-rich P source for organic farming (Hart et al. 2004).

Conventional commercial P fertilizers are largely water-soluble and contain high and immediately available P. Their application to a calcium carbonate rich soil can lead to loss of availability. Use of other phosphate fertilizer sources, such as untreated rock phosphate may provide an economical and energy-efficient alternative to chemically processed fertilizers (Villanueva et al. 2006) if it could be combined with biofertilizers that may enhance P availability. Studies to isolate and select microorganisms with the ability to promote higher solubilisation of rockphospates have been carried out under tropical conditions, especially in interaction with micro-organisms involved in biological nitrogen fixation. Beneficial plant-microbe interaction in the rhizosphere are primary determinants of plant health and soil fertility. Arbuscular mycorrhizal (AM) are the most important microbial symbiont for the majority of plants and under conditions of P-limitation, to enhance nutrient uptake, water relations, and above–ground productivity (Jeffries et al. 2003). Bolandnazara et al. (2007) studied the effect of *Glomus versiforme, Glomus intraradices,* and *Glomus etunicatum* on onion and found *G. versiforme* produced higher yield and improved water use efficiency than other species. The abundance and type of AM fungi present in the rhizosphere show large varieations. Green gram [*Phaseolus aureus* Roxb. (*Vigna radiata* var. *radiate*) rhizosphere had *Glomus mosseae*, *Glomus microcarpum*, *Gigaspora margarita*, and *Scutellospora* sp. Although *Glomus mosseae* was the most frequent. The range of distribution varied from a single species of AM fungus to three species belonging to two genera in one sample (Valsalakumar et al. 2007).

Legume forage crops have a higher feeding value than non-legume due to higher content of protein, minerals and energy for animal feeding. New tropical legumes for pasture phase in subtropical cropping areas include butterfly pea (*Clitoria ternatea*), burgundy bean (*Macroptilium bracteatum*) and perennial lablab (*Lablab purpureus*). Duponnois et al. (2005) indicated that *G. intraradices*+ rock phosphate increased growth, biomass and P leaf mineral content of *Acacia* over the single treatment (inoculation or rock phosphate). Cullen and Hill (2006) found that lablab and butterfly pea grew well depending on the level of soil phosphorus. Saleh et al. (2008) reported that combination of mycorrhiza with rock phosphate gave the highest significant increase in plant biomass, nitrogen and phosphorus uptake in *Acacia.* Nayyar et al. (2008) studied the effect of mycorrhizal under three P rates (0, 20 and 40 kg P_2O_5 ha^{-1}) on alfalfa and found that biomass production was increased with inoculation by mycorrhizal combined with phosphorus fertilization. Similar results were reported by Hetrick et al. (1994)on *Andropogon gerardii* and *Festuca arundinacea*; Jacquot et al. (2000) on *Medicago truncatula*; Lesueu et al. (2001) on *Calliandra calothyrsus*; Pankhurst et al. (2005) on forage legume pasture; Plenchette and Duponnois (2008) on *Atriplex nummularia;* and Marques et al. (2008) on *Solanum nigrum.* Radwan (1997) reported that increasing P-fertilizer up to 60 Kg P_2O_5 and inoculation with *Glomus fasciculatum* significantly increased growth, dry weight, crude protein and phosphorus percentage in mungbean. Yinsuo et al(2004) showed that using mycorrhiza increased biomass, leaf area, P and N accumulation in *Vicia faba*.). Increasing phosphorus with biofertilizer increased yield of *Vicia faba* (Akande et al. 2006; Rizk et al. 2006).

The present study compares the performance of three new perennial tropical summer- legumes under three levels of rock phosphate application and two strains of VA- mycorrhizal inoculation. The effect of these treatments on some physical and chemical soil properties was also examined.

2. Materials and methods

Field experiments were conducted during the summer seasons of 2006 and 2007 at the Maryut Research Station of the Desert Research Center in the North Western Coast of Egypt.
The soil was sandy clay loam with a pH of 7.9, EC 6.9 dS/m, $CaCO_3$ content of 34%, OM content of 0.84%, available N 29.1g/kg, P 8.74g/kg and K 81.35g/kg soil. The cation concentrations were 15.2 meq/L Ca^{+2}, 9.2 meq/L Mg^{+2}, 21.8 meq/L Na^{+1} and 1.9 K^{+1} meq/L and the anion concentrations were 9.30 meq/L of HCO_3^{-1}, 27.8 meq/L Cl^{-1}, and 28.63 meq/L SO_4^{-2}. The irrigation water had a pH of 7.8, EC of 6.85 dS/m, and TDS of 3800 ppm.

Separate experiment was done on each the three legume forage crops, namely lablab (*Dolichos lablab L.*); butterfly pea (*Clitoria ternatea L.*); and ciratro (*Macroptilium atropurpureum* (Dc.) Urb.). Rock phosphate (26.4% P_2O_5) was applied at the rates of 0, 15, 30, 45 Kg P_2O_5 per feddan (1 feddan = 0.42 ha) and added during seedbed preparation. The inoculum of vasicular arbuscular mycorrhizal fungi, originating from the rhizosphere of maize, was multiplied in pot culture, containing peat : vermiculite : perlite mixture of 1:1:1 by volume, with maize. The inoculum material contained 756 spores and 10^3 propagules g^{-1} on oven dry bases. The uninoculated control was treated with the growth media without mycorrhizal inoculant. Mycorrhizal inoculation was done by planting the seed over a thin layer of mycorrhizal inoculum material at the time of sowing using two strains of VA-mycorrhizal fungi, *Glomus macrocarpum* (M1) and *Glomus fasciculatum* (M2).

The experimental design for each crop was a complete randomized block design with four replicates. Plot area was $10.5m^2$ (3x3.5m) with five ridges and the distance between plants was 30cm. Seed were sown at the rate of 3, 4 and 2 kg seeds/fad for lablab, clitoria and siratro respectively. One week after sowing, any gaps were filled and a week later plants were thinned to one plant per hill. Potassium fertilizer at the rate of 50 Kg/fad as potassium sulphate (48% K_2O) was added before sowing.

The crops were harvested by cutting plants 15 cm above the ground level. The first cut was taken after 70 days from sowing and the second one 45 days thereafter. Samples of ten guarded plants were chosen at random from each experimental unit to study the plant height and number of branches/plant. Fresh and dry forage yields were determined. Samples were dried at 70^oC until constant weight and then ground to a fine powder. The powdered samples were analyzed for total nitrogen by Kjeldal method (Peach and Tracey 1956), and crude protein was calculated by multiplying the total nitrogen percentage by 6.25. Crude fiber was determined according to A.O.A.C. (1990). Phosphorus content was determined colorimetrically. In order to estimate the feeding values, starch value (SV)and total digestible nutrients (TDN) the following formulae developed by Khafagi (1977) were used: $SV=0.435DMP+1.20$; $TDN=0.625DMP-0.15$, where DMP is the dry matter percentage. Soil samples were taken from treatments after harvesting to determine the chemical properties. The collected data were statically analyzed using computer program Co-Stat according to procedures outlined by Snedecor and Cochran (1980). For means comparison, Duncan's multiple range test was used (Duncan 1955).

3. Results and discussion

3.1. Growth response

There were significant increases in plant height and number of branches/plant with VA-mycorrhizal inoculation in all the three species and inoculation with *Glomus fasciculatum* (M2) showed superiority over *Glomus macrocarpum* (M1) in all studied traits (data not presented here). The improvement may be attributed to increased P availability and improved soil aggregation and reduction in soil salinity by absorbtion of salts by fungal hyphae. Crush (1974) studied the response of several legumes to inoculation with VA-mycorrhizal fungi in some phosphorus deficient soils and found that nodulation and growth of *Centrosema pubescence, Stylosanthes guyanesis, Trifolium repens* and *Lotus pedunculatus* were considerably increased when plants were inoculated with mycorrhizal.

Rock phosphate application, at increasing rate, increased plant height and number of branches of all the three investigated crops. The highest rate of rock phosphate (45 Kg

P_2O_5/ fad) increased plant height, for example, in the 1st cut of the 1st season by 97.7, 90.4 and 74.0 percent and the number of branches/plant by 9.8, 8.0 and 7.6 % for lablab, clitoria and siratro, respectively. Abusuwar and Abdella (2004) also found that increasing phosphorus fertilizer increased growth of clitoria.

The effect of the interaction between rock phosphate and mycorrhizal inoculation was significant on plant height and number of branches /plant for all the three investigated legume crops for the two cuts of each season. The treatment effects were higher in the 2nd cut for all crops in both seasons. The highest values were recorded in the 2nd cut of the first season with lablab, followed by clitoria and siratro. Lablab appeared to be better adapted to the local conditions.

3.2. Forage yield response

Data in Table 1 and 2 show the influence of mycorrhizal inoculation and phosphate fertilization on forage yield of three species in the first and second season respectively. The inoculation with *Glomus fasciculatum*(M2) was more effective in increasing fresh and dry forage yield than *Glomus macrocarpum* (M1).The fresh forage yield in the first cut in the first season increased with inoculation with M1 and M2, respectively, by 5.54% and 13.64 % in case of lablab, by 11.31% and 23.25% in case of clitoria and by 26.78 % and 42.29 % in siratro. Bittman et al. (2006) indicated that the beneficial effect of indigenous AM fungi is most important in stressed environments.

Increasing rate of P2O5 significantly increased both fresh and dry forage yields in both cuts in both season with all the three crops. The effect of the interaction between mycorrhizal inoculation and rock phosphate was also significant. For example, in case of the 1st cut in the 1st season with lablab crop, the increase in fresh forage yield with the combination of M2 and 45 Kg P_2O_5 amounted to 12% while it was about half of that (6%) with the combination of 45 Kg P_2O_5 with no inoculation. Medina and Sylvia (1988) found similar results with siratro.

3.3. Response of some forage quality traits

Results in Table3 and 4 showed that mycorrhizal inoculation increased to different extents crude protein %, crude fiber % and phosphorus % and the increases in the 1 st cut of 1st season were higher than that of the 2nd cut for the three legume crops. The lowest values of crude protein and crude fiber were obtained with lablab in both cuts for the two seasons. The mean values of *Glomus fasciculatum* treatment were relatively higher than those obtained with *Glomus macrocarpum.*

There was increase in the percentage of crude protein, crude fiber and phosphorus with increasing the rock phosphate rates. Also siratro recorded the highest crude fiber while lablab recorded the lowest values. These result agreed with Jingura et al. (2001). The interaction between the two factors was significant in all studied traits.

3.4. Forage nutritive value response

Table 5 and 6 showed that dry matter, starch values, and total digestible nutrients were significantly increased with the increase in the rate of rock-phosphate application and under inoculation with mycorrhizal fungi especially with *Glomus fasciculatum* in both cuts of both seasons in all species except the first cut in lablab. Abou-deya et al. (1999) also observed that nutritive values of *Vigna oblingifolia* and *Macroptilium lathyroids* increased by adding 100 Kg P_2O_5/fad. Lablab had relatively the highest nutritive values while siratro showed the lowest values. Results are in close agreement with Mero and Uden (1998) and Jingura et al. (2001)

Table 1. Response of forage yield of the three forage legumes to mycorrhizal inoculation and rate of rock-phosphate during 2006 growing season

Inoculationmycorrhizal	Rock-phosphate rate(KgP_2O_5/fad)	Lablab		Clitoria		Siratro	
		1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
		First season					
		Fresh forage yield(Ton/fad)					
Without	0.0	1.864f	6.277h	1.289f	5.116e	0.894g	4.520i
	15	2.175e	6.406g	1.508e	5.200e	0.990fg	4.580h
	30	2.404d	6.487f	1.726d	5.382d	1.166ef	4.640g
	45	2.590c	6.520ef	1.876c	5.599c	1.384d	4.690fg
Mean		2.258c	6.423c	1.600c	5.324c	1.109c	4.608c
M1	0.0	1.953f	6.521ef	1.526e	5.339d	1.024fg	4.700fg
	15	2.246e	6.559de	1.702d	5.594c	1.299de	4.740ef
	30	2.540c	6.597d	1.878c	5.762ab	1.588bc	4.792de
	45	2.788b	6.677c	2.016b	5.802ab	1.714b	4.843bcd
Mean		2.383b	6.589b	1.781b	5.624b	1.406b	4.769b
M2	0.0	2.165e	6.726bc	1.711d	5.722b	1.294de	4.821cd
	15	2.390d	6.753b	1.874c	5.798ab	1.428cd	4.869bc
	30	2.698b	6.817a	2.024b	5.852a	1.695b	4.898b
	45	3.012a	6.853a	2.279a	5.885a	1.894a	5.107a
Mean		2.566a	6.787a	1.972a	5.814a	1.578a	4.924a
Mean of rock-phosphate	0.0	1.994d	6.508d	1.509d	5.392d	1.071d	4.680d
	15	2.270c	6.573c	1.695c	5.531c	1.239c	4.730c
	30	2.547b	6.634b	1.876b	5.665b	1.483b	4.777b
	45	2.797a	6.683a	2.057a	5.762a	1.664a	4.880a
Dry forage yield(Ton/fad)							
Without	0.0	0.604e	2.166i	0.427g	1.724i	0.224i	1.540h
	15	0.665d	2.272h	0.469f	1.747h	0.241h	1.560g
	30	0.678d	2.338g	0.517e	1.769fg	0.259fg	1.570f
	45	0.688d	2.397f	0.544cde	1.803de	0.271ef	1.580f
Mean		0.659c	2.293c	0.489c	1.761c	0.249c	1.563c
M1	0.0	0.677d	2.436ef	0.460f	1.763gh	0.247gh	1.580f
	15	0.690d	2.470e	0.479f	1.785ef	0.268ef	1.620e
	30	0.706cd	2.580d	0.539de	1.822d	0.281de	1.640d
	45	0.732bc	2.599d	0.571bc	1.934b	0.302bc	1.670c
		0.699b	2.521b	0.512b	1.826b	0.275b	1.628b
M2	0.0	0.703cd	2.701c	0.541cde	1.822d	0.267ef	1.640d
	15	0.740bc	2.740bc	0.562bcd	1.882c	0.289cd	1.670c
	30	0.771ab	2.770ab	0.580ab	1.944b	0.307b	1.730b
	45	0.800a	2.795a	0.601a	1.980a	0.329a	1.760a
Mean		0.754a	2.752a	0.571a	1.907a	0.298a	1.700a
Mean of rock-phosphate	0.0	0.661c	2.434d	0.476d	1.770d	0.246d	1.587d
	15	0.698b	2.494c	0.503c	1.805c	0.266c	1.617c
	30	0.718ab	2.563b	0.545b	1.845b	0.282b	1.647b
	45	0.740a	2.597a	0.572a	1.906a	0.301a	1.670a

*M1:*Glomus macrocarpum* **M2: *Glomus fasciculatum*

Table 2. Response of forage yield of the three forage legumes to mycorrhizalinoculation and rate of rock-phosphate during 2007 growing season

Inoculation	Rock-phosphate rate(KgP_2O_5/fad)	Lablab		Clitoria		Siratro	
		1St cut	2nd cut	1St cut	2nd cut	1St cut	2nd cut
Second season							
Fresh forage yield(Ton/fad)							
Without	0.0	4.590b	5.227g	3.290d	4.672f	3.064h	3.515j
	15	4.640b	5.324f	3.340d	4.702ef	3.178fg	3.553ij
	30	4.690b	5.389ef	3.400cd	4.742de	3.206ef	3.595hi
	45	4.800ab	5.540bc	3.440cd	4.770d	3.240de	3.630h
Mean		4.680c	5.370b	3.368b	4.722c	3.172c	3.573c
M1	0.0	4.640b	5.340ef	3.690bcd	4.703ef	3.146g	3.698g
	15	4.680b	5.390ef	3.970abc	4.834c	3.237de	3.718fg
	30	4.740b	5.424de	4.290a	4.939b	3.280cd	3.766ef
	45	4.980a	5.504cd	4.370a	4.984b	3.320c	3.797de
Mean		4.760b	5.415b	4.080a	4.865b	3.240b	3.745b
M2	0.0	4.680b	5.549bc	4.300a	4.774d	3.294cd	3.842cd
	15	4.720b	5.622b	4.036ab	4.849c	3.378b	3.889bc
	30	4.770b	5.736a	4.437a	4.981b	3.404b	3.950ab
	45	5.011a	5.794a	4.483a	5.165a	3.472a	3.977a
Mean		4.795a	5.675a	4.314a	4.942a	3.387a	3.915a
Mean of rock-phosphate	0.0	4.637d	5.372d	3.760b	4.716d	3.168d	3.685c
	15	4.680c	5.445c	3.782ab	4.795c	3.264c	3.720b
	30	4.733b	5.516b	4.042ab	4.887b	3.297b	3.770a
	45	4.930a	5.613a	4.098a	4.973a	3.344a	3.801a
Dry forage yield(Ton/fad)							
Without	0.0	0.981g	1.847g	0.804f	1.422h	0.730h	1.236g
	15	1.074fg	1.878fg	0.827ef	1.463g	0.754g	1.255fg
	30	1.175ef	1.932ef	0.861ef	1.530e	0.780ef	1.301de
	45	1.215de	1.975de	0.878ef	1.549de	0.797de	1.372bc
Mean		1.111c	1.908c	0.843c	1.491c	0.765c	1.291b
M1	0.0	1.082fg	1.933ef	0.843ef	1.471g	0.762fg	1.270ef
	15	1.198def	2.043d	0.864ef	1.500f	0.777f	1.283ef
	30	1.351bc	2.181c	0.892de	1.558d	0.805cd	1.360c
	45	1.394abc	2.233c	0.964d	1.580c	0.823bc	1.396ab
Mean		1.256b	2.098b	0.891b	1.527b	0.792b	1.327ab
M2	0.0	1.309cd	1.981de	0.895de	1.500f	0.780ef	1.284ef
	15	1.377bc	2.186c	1.095c	1.550de	0.806cd	1.330d
	30	1.473ab	2.422b	1.225b	1.603b	0.838ab	1.383bc
	45	1.518a	2.568a	1.335a	1.631a	0.850a	1.426a
Mean		1.419a	2.289a	1.138a	1.571a	0.819a	1.356a
Mean of rock-phosphate	0.0	1.124c	1.920d	0.847d	1.464d	0.757d	1.263d
	15	1.216b	2.036c	0.929c	1.504c	0.779c	1.289c
	30	1.333a	2.178b	0.993b	1.564b	0.808b	1.348b
	45	1.376a	2.259a	1.059a	1.587a	0.823a	1.398a

Table 3. Response of crude protein and crude fiber of the three forage legumes to mycorrhizal inoculation and rate of rock-phosphate during 2006 growing season

Inoculation	Rock-phosphate rate(KgP_2O_5/fad)	Lablab		Clitoria		Siratro	
		1St cut	2nd cut	1St cut	2nd cut	1St cut	2nd cut
First season							
Crude protein %							
Without	0.0	12.65h	11.20f	18.15h	15.05i	18.40h	15.40h
	15	12.80g	11.45e	18.40g	15.25h	18.65g	15.75g
	30	12.90fg	11.65de	18.55fg	15.45fg	18.90ef	16.10f
	45	12.95ef	11.80cd	18.70ef	15.60de	19.15cd	16.6cd
Mean		12.83c	11.53c	18.45c	15.34c	18.78c	15.96c
M1	0.0	12.85fg	11.70d	18.65f	15.35gh	18.65g	15.85g
	15	12.90fg	11.85cd	18.85de	15.50ef	18.85f	16.40de
	30	13.05de	12.00c	19.20c	15.65d	19.05de	16.70c
	45	13.25bc	12.35b	19.55b	15.80c	19.35b	17.05b
Mean		13.01b	11.98b	19.06b	15.58b	18.98b	16.50b
M2	0.0	13.15cd	12.00c	18.95d	15.65d	18.85f	16.20ef
	15	13.30b	12.35b	19.25c	15.85c	19.05de	16.70c
	30	13.35b	12.65a	19.55b	16.15b	19.25bc	17.10b
	45	13.55a	12.85a	19.75a	16.35a	19.55a	17.70a
Mean		13.34a	12.46a	19.38a	16.00a	19.18a	16.93a
Mean of rock-phosphate	0.0	12.88d	11.63d	18.58d	15.35d	18.63d	15.82d
	15	13.00c	11.88c	18.83c	15.53c	18.85c	16.28c
	30	13.10b	12.10b	19.10b	15.76b	19.07b	16.63b
	45	13.25a	12.33a	19.33a	15.92a	19.35a	17.12a
Crude fiber %							
Without	0.0	20.20g	23.25a	23.20g	26.20g	27.20g	32.25h
	15	20.70f	23.45a	23.50f	26.70f	27.60ef	32.55g
	30	20.90e	23.75a	23.60ef	27.55de	27.85d	32.80f
	45	21.35d	24.05a	23.80de	27.85cd	28.05bc	33.20d
Mean		20.79c	23.63a	23.53c	27.08c	27.68c	32.70c
M1	0.0	20.70f	23.70a	23.55f	26.85f	27.55f	32.75f
	15	20.85e	24.20a	23.70def	27.45e	27.75de	33.05e
	30	21.35d	24.70a	23.85cd	28.10c	27.90cd	33.50c
	45	21.65c	20.05a	23.90cd	28.65b	28.15b	33.75b
Mean		21.14b	23.16a	23.75b	27.76b	27.84b	33.26b
M2	0.0	21.35d	23.85a	23.80de	27.60de	27.75de	33.00e
	15	21.60c	24.20a	24.05c	28.10c	27.90cd	33.50c
	30	21.85b	24.70a	24.35b	28.85b	28.20b	33.75b
	45	22.35a	25.05a	24.60a	29.35a	28.45a	34.00a
Mean		21.79a	24.45a	24.20a	28.48a	28.08a	33.56a
Mean of rock-phosphate	0.0	20.75d	23.60a	23.52d	26.88d	27.50d	32.67d
	15	21.05c	23.95a	23.75c	27.42c	27.75c	33.03c
	30	21.37b	24.38a	23.93b	28.17b	27.98b	33.35b
	45	21.78a	23.05a	24.10a	28.62a	28.22a	33.65a
		Phosphorus %					
Without	0.0	2.10g	2.80g	1.75i	2.00h	1.60g	1.85i
	15	2.35f	3.00fg	1.90hi	2.40fg	1.80fg	2.00hi
	30	2.55ef	3.50e	2.15fg	2.50efg	1.85ef	2.20fg
	45	2.65de	3.85cd	2.35def	2.65de	2.05de	2.35ef
Mean		2.41c	3.29c	2.04c	2.39c	1.83c	2.10c
M1	0.0	2.45ef	3.20f	2.00gh	2.35g	1.85ef	2.05gh
	15	2.65de	3.55e	2.25ef	2.50efg	2.05de	2.25f
	30	2.80cd	3.85cd	2.45cde	2.65de	2.20cd	2.45e
	45	3.00c	3.95c	2.55cd	2.75cd	2.35c	2.65d
Mean		2.73b	3.64b	2.31b	2.56b	2.11b	2.35b
M2	0.0	3.00c	3.60de	2.35def	2.55ef	2.25cd	2.35ef
	15	3.50b	3.85cd	2.65c	2.85c	2.70b	2.85c
	30	3.85a	4.20b	3.00b	3.05b	2.85ab	3.15b
	45	4.05a	4.55a	3.25a	3.30a	3.05a	3.35a
Mean		3.60a	4.05a	2.81a	2.94a	2.71a	2.93a
Mean of rock-phosphate	0.0	2.52d	3.20d	2.03d	2.30d	1.90d	2.08d
	15	2.83c	3.47c	2.27c	2.58c	2.18c	2.37c
	30	3.07b	3.85b	2.53b	2.73b	2.30b	2.60b
	45	3.23a	4.12a	2.72a	2.90a	2.48a	2.45a

Table 4. Response of crude protein and crude fiber of the three forage legumes to mycorrhizal inoculation and rate of rock-phosphate during 2007 growing season

In-oculation	Rock-phosphate rate(KgP_2O_5/fad)	Lablab 1st cut	Lablab 2nd cut	Clitoria 1st cut	Clitoria 2nd cut	Siratro 1st cut	Siratro 2nd cut
Second season							
Crude protein %							
Without	0.0	11.35g	10.85f	14.05g	13.25g	14.40f	12.15e
	15	11.55g	11.00f	14.25fg	13.45fg	14.65e	12.40de
	30	11.85de	11.25e	14.50de	13.85de	14.85d	12.70cd
	45	12.05d	11.35de	14.60cde	14.05d	15.15c	12.85cd
Mean		11.70c	11.11c	14.35c	13.65c	14.76c	12.53b
M1	0.0	11.70ef	11.20e	14.25fg	13.70ef	14.70e	12.40de
	15	11.85de	11.45d	14.55cde	14.00d	14.85d	12.80cd
	30	12.35c	11.65c	14.75c	14.40c	15.25c	13.10bc
	45	12.55bc	11.85b	15.00b	14.75b	15.65b	13.60a
Mean		12.11b	11.54b	14.64b	14.21b	15.11b	12.98ab
M2	0.0	12.00d	11.50cd	14.45ef	14.05d	14.85d	12.80cd
	15	12.35c	11.65c	14.70cd	14.50bc	15.20c	13.55a
	30	12.70b	11.85b	15.00b	14.75b	15.70b	13.50ab
	45	13.00a	12.05a	15.40a	15.05a	15.90a	13.85a
Mean		12.51a	11.76a	14.89a	14.59a	15.41a	13.43a
Mean of rock-phosphate	0.0	11.68d	11.18d	14.25d	13.67d	14.65d	12.45c
	15	11.91c	11.37c	14.50c	13.98c	14.90c	12.92b
	30	12.30b	11.58b	14.75b	14.33b	15.27b	13.10b
	45	12.53a	11.75a	15.00a	14.62a	15.57a	13.43a
Crude fiber %							
Without	0.0	28.45g	32.40g	33.50h	35.20g	35.35g	37.25h
	15	28.85f	32.75f	33.70g	35.45f	35.65f	37.55g
	30	29.20e	33.00e	33.85g	35.65de	35.85e	37.85ef
	45	29.55d	33.30d	34.15f	35.80cd	36.20d	38.20cd
Mean		29.01c	32.86c	33.80c	35.53c	35.76c	37.70b
M1	0.0	28.85f	32.80f	33.85g	35.55ef	35.85e	37.55g
	15	29.30e	33.00e	34.35e	35.75cd	36.25d	37.75fg
	30	29.60cd	33.35d	34.70d	35.85c	36.50c	38.05de
	45	29.80bc	33.60c	34.90c	36.25b	36.75b	38.35c
Mean		29.39b	33.19b	34.45b	35.85b	36.34b	37.93b
M2	0.0	29.25e	33.25d	34.45e	35.85c	36.30d	38.30cd
	15	29.65bcd	33.55c	34.85cd	36.30b	36.60c	38.65b
	30	29.85b	33.85b	35.20b	36.75a	36.85b	39.00a
	45	30.20a	34.20a	35.50a	36.85a	37.00a	39.20a
Mean		29.74a	33.71a	35.00a	36.44a	36.69a	38.79a
Mean of rock-phosphate	0.0	28.85d	32.82d	33.93d	35.53d	35.83d	37.70d
	15	29.27c	33.10c	34.30c	35.83c	36.17c	37.98c
	30	29.55b	33.40b	34.58b	36.08b	36.40b	38.30b
	45	29.85a	33.70a	34.85a	36.30a	36.65a	38.58a
		Phosphorus %					
Without	0.0	1.55h	1.85d	1.35g	1.50i	1.25g	1.60g
	15	1.75gh	2.00d	1.50f	1.70h	1.45f	1.75f
	30	1.95efg	2.25c	1.70e	1.95fg	1.65e	1.95de
	45	2.20de	2.35c	1.95d	2.15de	1.85d	2.10c
Mean		1.86c	2.11c	1.63c	1.83c	1.55c	1.85c
M1	0.0	1.85fg	2.00d	1.60ef	1.90g	1.55ef	1.85ef
	15	2.25cd	2.35c	1.70e	2.10ef	1.65e	2.05cd
	30	2.50b	2.60b	1.90d	2.30cd	1.85d	2.25b
	45	2.75ab	3.00a	2.05cd	2.55ab	2.05bc	2.45a
Mean		2.34b	2.49b	1.81b	2.21b	1.78b	2.15b
M2	0.0	2.05	2.35c	1.95d	2.15de	1.85d	2.05cd
	15	2.50bc	2.65b	2.15c	2.45bc	1.95cd	2.25b
	30	2.85a	3.05a	2.45b	2.60ab	2.20b	2.50a
	45	3.00a	3.15a	2.60a	2.65a	2.45a	2.55a
Mean		2.60a	2.80a	2.29a	2.46a	2.11a	2.34a
Mean of rock-phosphate	0.0	1.82d	2.07d	1.63d	1.85d	1.55d	1.83d
	15	2.17c	2.33c	1.78c	2.08c	1.68c	2.02c
	30	2.43b	2.63b	2.02b	2.28b	1.90b	2.23b
	45	2.62a	2.83a	2.20a	2.45a	2.12a	2.37a

Table 5. Response of nutritive values of the three forage legumes to mycorrhizal inoculation and rate of rock-phosphate during 2006 growing season

Inoculation	Rock-phosphate rate(KgP_2O_5/fad)	Lablab		Clitoria		Siratro	
		1[St] cut	2[nd] cut	1[St] cut	2[nd] cut	1[St] cut	2[nd] cut
First season							
Dry matter %							
Without	0.0	34.76a	34.50h	33.17a	33.70a	25.02a	34.07bcd
	15	30.59c	35.46g	31.17abc	33.60a	24.36a	34.08bcd
	30	28.21d	36.04f	29.96bcd	32.88abc	22.27ab	33.92bcd
	45	26.55e	36.74e	29.00bcd	32.20cd	19.62bcd	33.74cd
Mean		30.03a	35.69c	30.83a	33.10a	22.82a	33.95b
M1	0.0	34.66a	37.35d	30.12bcd	33.04abc	24.18a	33.62d
	15	30.72c	37.66d	28.15de	31.92d	20.99bc	34.12bcd
	30	27.78d	39.15c	28.71cde	31.62d	17.70cd	34.29bc
	45	26.26e	38.93c	28.36de	33.34a	17.66cd	34.50b
		29.86a	38.27b	28.84b	32.48ab	20.13b	34.13b
M2	0.0	32.46b	40.15b	31.63ab	31.84d	20.67bcd	33.95bcd
	15	30.97c	40.58ab	29.97bcd	32.45bcd	20.30bcd	34.40b
	30	28.55d	40.63ab	28.71cde	33.22ab	18.12cd	35.23a
	45	26.58e	40.77a	26.35e	33.65a	17.37d	34.49b
Mean		29.64a	40.53a	29.17b	32.79b	19.12b	34.52a
Mean of rock-phosphate	0.0	33.96a	37.33c	31.64a	32.86a	23.29a	33.88b
	15	30.76b	37.90b	29.76b	32.66a	21.88a	34.20a
	30	28.18c	38.61a	29.13bc	32.57a	19.36b	34.48a
	45	26.46d	38.81a	27.90c	33.06a	18.21b	34.24a
Starch value							
Without	0.0	16.32a	16.21h	15.62a	15.86a	12.08a	16.02bcd
	15	14.51c	16.63g	14.76abc	15.82a	11.81a	16.03bcd
	30	13.47d	16.88f	14.24bcd	15.51abc	10.89ab	15.96bcd
	45	12.75e	17.18e	13.82bcd	15.21cd	9.74bcd	15.88cd
Mean		14.26a	16.73c	14.61a	15.60a	11.13a	15.97b
M1	0.0	16.28a	17.45d	14.30bcd	15.57a	11.72a	15.82d
	15	14.56c	17.58d	13.44de	15.08d	10.33bc	16.04bcd
	30	13.29d	18.23c	13.68cde	14.96d	8.90cd	16.12bc
	45	12.62e	18.11c	13.54de	15.70a	8.88cd	16.21b
Mean		14.19a	17.84b	13.74b	15.33b	9.96b	16.05b
M2	0.0	15.32b	18.67b	14.96ab	15.05d	10.19bcd	15.97bcd
	15	14.67c	18.85ab	14.23bcd	15.27bcd	10.03bcd	16.16b
	30	13.62d	18.87ab	13.69cde	15.66ab	9.08cd	16.53a
	45	12.76e	18.94a	12.66e	15.84a	8.76d	16.20b
Mean		14.09a	18.83a	13.89b	15.46ab	9.52b	16.22a
Mean of rock-phosphate	0.0	15.97a	17.44c	14.96a	15.49a	11.33a	15.94b
	15	14.58b	17.69b	14.14b	15.18a	10.72a	16.08a
	30	13.12c	17.99a	13.87bc	15.38a	9.62b	16.20a
	45	12.71d	18.08a	13.34c	15.58a	9.13b	16.10a
Total digestible nutrients							
Without	0.0	21.57a	21.41h	20.58a	20.92a	15.49a	21.14bc
	15	18.97c	22.01g	19.33ab	20.85a	15.08a	21.15bc
	30	17.48d	22.38f	18.58abc	20.40ab	13.77ab	21.05bc
	45	16.44e	22.81e	17.98bc	19.98cd	12.12cde	20.94c
Mean		18.62a	22.15c	19.12a	20.54a	14.12a	21.07b
M1	0.0	21.51a	23.20d	18.68abc	20.50abc	14.96ab	20.86c
	15	19.05c	23.38d	17.44bc	19.80d	12.97bcd	21.52ab
	30	17.32d	24.32c	17.79bc	19.61d	10.91de	21.28bc
	45	16.26e	24.19c	17.58bc	20.69a	10.89de	21.42abc
Mean		18.54a	23.77b	17.87b	20.15b	12.43b	21.27ab
M2	0.0	20.14b	24.95b	19.62ab	19.75d	12.77cde	21.07bc
	15	19.21c	25.21ab	18.58a	20.13bcd	12.54cde	21.35abc
	30	17.69d	25.24ab	17.79bc	20.62ab	11.18de	21.87a
	45	16.48e	25.34a	16.32c	20.88a	10.71e	21.41abc
Mean		18.38a	25.19a	18.08b	20.35ab	11.80b	21.43a
Mean of rock-phosphate	0.0	21.07a	23.19c	19.63a	20.39a	14.41a	21.02b
	15	19.08b	23.53b	18.45b	20.26a	13.53a	21.34a
	30	17.50c	23.98a	18.05bc	20.21a	11.95b	21.40a
	45	16.39d	24.11a	17.29c	20.52a	11.24b	21.26ab

Table 6. Response of nutritive values of the three forage legumes to mycorrhizal and rate of rock-phosphate during 2007 growing season

Inoculation	Rock-phosphate rate(KgP_2O_5/fad)	Lablab		Clitoria		Siratro	
		1^{St} cut	2^{nd} cut	1^{St} cut	2^{nd} cut	1^{St} cut	2^{nd} cut
Second season							
Dry matter %							
Without	0.0	21.36f	35.33f	24.45cd	30.45g	23.83bcd	35.17cde
	15	23.14ef	35.29f	24.78cd	31.12ef	23.73cd	35.31cde
	30	25.02def	35.85f	25.32c	32.26a	24.33abcd	36.18bc
	45	25.31cde	35.65f	25.50c	32.47a	24.62ab	37.80a
Mean		23.70c	35.53c	25.01b	31.58ab	24.13a	36.12a
M1	0.0	23.29ef	36.19f	22.78ef	31.27def	24.23abcd	34.33ef
	15	25.61cde	37.90e	21.81fg	31.02f	24.01abcd	34.52def
	30	26.51bcde	40.21cd	20.81g	31.54cde	24.56abc	36.11bc
	45	27.98abcd	40.57c	22.04fg	31.69bcd	24.77a	36.77ab
Mean		25.85b	38.49b	21.86c	31.38b	24.39a	35.43a
M2	0.0	27.98abcd	35.70f	23.54de	31.43def	23.68d	33.44f
	15	29.14abc	38.88de	27.10b	31.97abc	23.86bcd	34.19ef
	30	30.85a	42.22b	27.61b	32.17ab	24.63ab	35.02cde
	45	30.33a	44.32a	29.78a	31.57cde	24.48abcd	35.86bcd
Mean		29.58a	40.28a	27.01a	31.79a	24.16a	34.63a
Mean of rock-phosphate	0.0	24.21b	35.74c	23.59c	31.05c	23.91b	34.31c
	15	25.96ab	37.36b	24.56b	31.37b	23.87b	34.67c
	30	27.46a	39.43a	24.58b	31.99a	24.51a	35.77b
	45	27.87a	40.18a	25.77a	31.91a	24.62a	36.81a
Starch value							
Without	0.0	10.50f	16.57f	11.84cd	14.45g	11.57bcd	16.50cde
	15	11.27ef	16.55f	11.98cd	14.74ef	11.53cd	16.57cde
	30	12.09cdef	16.80f	12.22c	15.24a	11.78abcd	16.94bc
	45	12.74abcde	16.71f	12.29c	15.33a	11.91ab	17.64a
Mean		11.65b	16.66c	12.08b	14.94b	11.70a	16.91a
M1	0.0	11.33def	16.94f	11.11ef	14.80def	11.74abcd	16.14ef
	15	12.34bcdef	17.69e	10.69fg	14.70f	11.64abcd	16.22def
	30	12.73abcde	18.69cd	10.25g	14.92cde	11.88abc	16.91bc
	45	13.37abcd	18.85c	10.78fg	14.99bcd	11.97a	17.20ab
Mean		12.44b	18.04b	10.71c	14.85b	11.81a	16.62a
M2	0.0	12.77abcde	16.73f	11.44de	14.87def	11.51d	15.74f
	15	13.87abc	18.11de	12.99b	15.11abc	11.57bcd	16.07ef
	30	14.62a	19.57b	13.21b	15.19ab	11.92ab	16.43cde
	45	14.39ab	20.48a	14.15a	14.94cde	11.85abcd	16.79bcd
Mean		13.91a	18.72a	12.95a	15.03a	11.71a	16.26a
Mean of rock-phosphate	0.0	11.53b	16.75c	11.46c	14.71c	11.61b	16.13c
	15	12.49ab	17.45b	11.89b	14.85b	11.58b	16.29c
	30	13.15a	18.35a	11.89b	15.12a	11.86a	16.76b
	45	13.50a	18.68a	12.41a	15.09a	11.91a	17.21a
Total digestible nutrients							
Without	0.0	13.20f	21.93f	15.13cd	18.88g	14.75bcd	21.83cde
	15	14.32ef	21.91f	15.33cd	19.29ef	14.68cd	21.92cde
	30	15.49def	22.26f	15.68c	20.01a	15.06abcd	22.46bc
	45	15.67cde	22.14f	15.84c	20.15a	15.24ab	23.48a
Mean		14.67c	22.06c	15.50b	19.58ab	14.93a	22.42a
M1	0.0	14.41ef	22.47f	14.09ef	19.39def	14.99abcd	21.31ef
	15	15.85cde	23.54e	13.48fg	19.24f	14.85abcd	21.43def
	30	16.42bcde	24.99cd	12.86g	19.57cde	15.20abc	22.42bc
	45	17.34abcd	25.21c	13.62fg	19.66bcd	15.33a	22.84ab
Mean		16.01b	24.05b	13.51c	19.47b	15.09a	22.00a
M2	0.0	17.34abcd	22.16f	14.56de	19.49def	14.65d	20.75f
	15	18.06abc	24.14de	16.79b	19.83abc	14.70bcd	21.22ef
	30	19.14a	26.24b	17.11b	19.96ab	15.25ab	21.74cde
	45	18.81ab	27.55a	18.46a	19.59cde	15.15abcd	22.26bcd
Mean		18.34a	25.02a	16.73c	19.72a	14.94a	21.49a
Mean of rock-phosphate	0.0	14.98b	22.19c	14.59c	19.25c	14.80b	21.30c
	15	16.08ab	23.20b	15.20b	19.45b	14.74b	21.52c
	30	17.02a	24.50a	15.22b	19.85a	15.17a	22.21b
	45	17.27a	24.97a	15.97a	19.80a	15.24a	22.86a

Table 7. Effect of forage legumes, mycorrhizal inoculation and rate of rock-phosphate on some chemical properties of soil after harvest

In-oculation	Rock-phosphate rate (KgP_2O_5/fad)	Lablab					Clitoria					Siratro				
		pH 1:2.5	Ec ds/m	OM %	Available nutrients (mg/Kg)		pH 1:2.5	Ec ds/m	OM %	Available nutrients (mg/Kg)		pH 1:2.5	Ec ds/m	OM %	Available nutrients (mg/Kg)	
					nN	PP				nN	PP				nN	PP
Without	**0.0**	7.80	6.19	1.02	42.2	9.0	7.85	6.44	0.94	32.1	8.82	7.88	6.37	0.90	30.1	8.80
	15	7.79	6.05	1.1	52.3	12.3	7.82	6.38	0.98	38.9	10.1	7.86	6.30	0.94	32.2	10.2
	30	7.74	6.03	1.13	55.6	14.3	7.80	6.34	1.00	40.2	11.6	7.84	6.28	0.96	33.4	11.4
	45	7.72	6.01	1.17	58.7	15.6	7.78	6.32	1.02	44.6	12.3	7.83	6.24	0.98	36.2	12.1
M1	**0.0**	7.61	5.84	1.22	64.2	16.8	7.74	6.22	1.08	49.1	14.3	7.79	6.12	1.0	36.8	13.8
	15	7.60	5.82	1.31	68.3	17.9	7.71	6.19	1.09	53.4	15.6	7.77	6.09	1.06	39.1	14.3
	30	7.58	5.80	1.48	71.2	18.6	7.70	6.15	1.12	58.1	16.1	7.75	6.02	1.09	44.3	15.6
	45	7.55	5.78	1.50	73.9	19.6	7.69	6.11	1.22	60.2	17.3	7.73	5.94	1.1	48.2	16.8
M2	**0.0**	7.32	5.68	1.61	76.3	20.6	7.52	6.01	1.28	64.3	17.3	7.68	5.90	1.14	50.2	17.6
	15	7.30	5.54	1.64	77.4	21.3	7.50	5.98	1.31	66.3	18.2	7.64	5.84	1.16	52.3	18.0
	30	7.22	5.50	1.69	78.1	22.6	7.49	5.92	1.34	68.2	19.6	7.61	5.80	1.18	54.6	18.7
	45	7.18	5.48	1.70	80.2	23.6	7.46	5.84	1.38	69.2	20.4	7.58	5.78	1.24	55.9	19.4

3.5. Effect of treatments on some soil chemical properties after harvest

Data in Table 7 revealed that the forage legume species, mycorrhizal inoculation and rates of rock-phosphate affected to different extents all the studied chemical properties. The pH and EC values were decreased which must have increased the availability of phosphorus especially when appling rock phosphate at high rates and inoculation with *Glomus fasciculatum*. Lablab was more effective than other species. These results were in agreement with Stamford et al. (2006) who found that available P increased when rock phosphate and biofertilizer were applied. Whitbread et al. (2006) found that soil nitrate-N content was increased more by lablab than clitoria. Singh and Kapoor (1999) and Nour-El-Dein and Salama (2006) stated that N_2-fixing and phosphate dissolving microorganisms increased levels of nitrogen and phosphorus in soil and plants, which increased soil fertility and productivity.

4. Conclusion

The results presented in this study indicate that lablab has great potential, mainly because of its high biomass production. Where seed and availability are not limiting, its production is recommended. Clitoria and siratro are good perennials, but their relatively low yields mean that they require large areas of land to produce adequate quantities needed to last a dry season of about 5 months. The legumes are recommended for use in a 'cut-and-carry' system, and should be grown in the wet season, harvested and conserved to be fed as supplements in the dry season because it is during the dry season that natural pasture is inadequate and of poor quality. The legumes would offer a relatively cheap source of supplementary feeding. Also, mycorrhizal fungi played an important role in the release of phosphorus in both rock phosphate and in soil under calcareous conditions.

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5.11. Managing populations of leaf-cutting bees and their effect on alfalfa seed production in newly reclaimed area in Egypt

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Abstract

Alfalfa (*Medicago sativa*) is a high quality forage and green manure crop that originated in the Middle East. Currently, alfalfa is planted on nearly 120,000 ha of land in Egypt, and the area is rising each year, especially in the newly reclaimed lands. The leaf-cutting bees are very important pollinator of alfalfa and the seed production is dependent on them. These bees are under high risk because of the fast replacement of mud houses, which contain the natural nests, by concrete houses in the production areas. For increasing their population in the field, artificial nests were prepared by using polystyrene foam and transferred to experimental field. The experimental field was divided into three main parts 20, 30, and 40 meters away from the artificial nests. The maximum production of alfalfa seeds occurred in the plots that were close to the nest. The seed production declined as the distance from artificial nests increased. The method is simple and can be easily adopted by seed producers of alfalfa.

1. Introduction

Agriculture development in Egypt has been a national goal during the last decades. This development has involved several approaches, e.g. expansion of cultivated land, and maximization of land production and animal production .One of the major problems that facing the most of the newly reclaimed areas is the relatively low production of crops due to the lack of insect pollinators .The same problem is found also in the certain areas of the old lands due to the wide use of pesticides. The mechanization of agriculture has adversely affected the wild pollinators as well as the honeybee industry. Also, the concrete houses have quickly replaced the old mud houses in the villages, which used to be sites for nests of the pollinators.

Alfalfa (*Medicago sativa* L.) is a high quality forage and green manure crop that originated in the Middle East. Varieties are available and are being bred that are well-adapted to the reclaimed agricultural lands in Egypt. Solitary bees and bumble bees are most efficient pollinators of alfalfa. Honey bee efficiency, on the other hand, is low: after opening alfalfa flowers several times, honey bee “learns” to collect nectar without tripping them, owing to the specific structure of alfalfa flower. For this reason, despite the abundance of honey bee in alfalfa fields, seed yield per hectare may be very poor when solitary bees and bumble bees are not present. For instance, low alfalfa seed yields were recorded after the second world war in the most agriculturally developed countries, which were the first to apply pesticides and the first to destroy the natural habitats of native solitary bees by introducing monocultures over vast areas. This soon resulted in thinning the fauna of native pollinators and caused a drastic reduction in alfalfa seed yields. The problem was successfully overcome for the first time in the USA and Canada with the domestication and utilization of the solitary bee *Megachile rotundata* (Fabricius 1793; Hobbs 1965).

Alfalfa flowers require visiting bees to trip the sexual column, thereby providing pollination and subsequent pod and seed set. Tripping done by a specialized group of bees which enter the flowers and press the keel by their own weight releases the male and female organs to distribute pollen and effect cross-pollination (Abrol 1993).

Alfalfa seed weight and number of seeds per pod are the characteristics, which determine seed yield and quality. The position of the seed in the pod influences seed weight. The largest seed is at the base of the pod. Both seed and pollen parents influence seed weight and number of seeds per pod (Katepa – Mupondwa et al. 1996).Open flowers decrease more rapidly over time than total bracts in commercial alfalfa fields, indicating that the decline in open flowers was not strictly due to a decline in available flowers. Some of the decline in open flowers was apparently due to rapid turnover as flowers were pollinated by bees (Strickler 1997). The present study aimed to study appropriate placement of the artificial nests for leaf-cutting bees (*Megachile minutissima* Radoszkowski) to maximize seed production of alfalfa.

2. Materials and methods

2.1. Artificial nesting

Artificial bee nests were prepared in March 2006 and transformed to natural nest sites in Tel El Kebir, about 50 kilometers west of Ismailia on the Delta of River Nile (Kamel et al. 2007). The natural nests were transferred to the experimental field by the end of July and August for over-wintering period. The artificial nests were protected from all damage or attack by ants or any other pests during the whole period. The artificial nests used were made from foam. Each nest piece was 50 cm in length, 12 cm width and 2 cm thickness. In each piece 26 holes of 10 cm depth and 6 mm diameter were dug. After sticking the foam pieces above each other holes were created in this block and the shelter was developed. Straws were made out of paper tubes 10 cm in length and 5.2 mm internal diameter. One tube was put in each hole. All foam nests were painted with black color for imitation of the natural nests. The artificial nests were transferred to the natural nesting sites in different villages of Tel El Kebir in April till the end of July 2006 (Fig. 1 and 2). The total numbers of nests were 20 and the total number of emerged bees were 1495.

2.2. Experimental field preparation

In the beginning of October 2007, the experimental field of bees research unit, Suez Canal University, Ismailia was prepared for alfalfa seed cultivation. The variety used was Ismailia 1 produced by Agricultural Experimental Station in Ismailia. The distance between plants was 30cm and the total number of plant in the field was 1200. The experimental field was divided into three parts: 20 m, 30 m and 40 m away from the nest. To study the seasonal blooming of alfalfa, 36 of plants were labeled, 12 plants for each location. Each plant was observed for the number of total flowers, number of total pods, number of seeds in 100 pods, weight of 100 seeds and average seed production per plant. The blooming season started in mid March and ended in May when seed was formed. The blooming season was synchronized with the leaf-cutting bees emergence, which started at the end of March and ended by the end of May. The crop in the whole field was harvested in end of June (Fig. 3). The data were analyzed by using CoStat statistical method analysis.

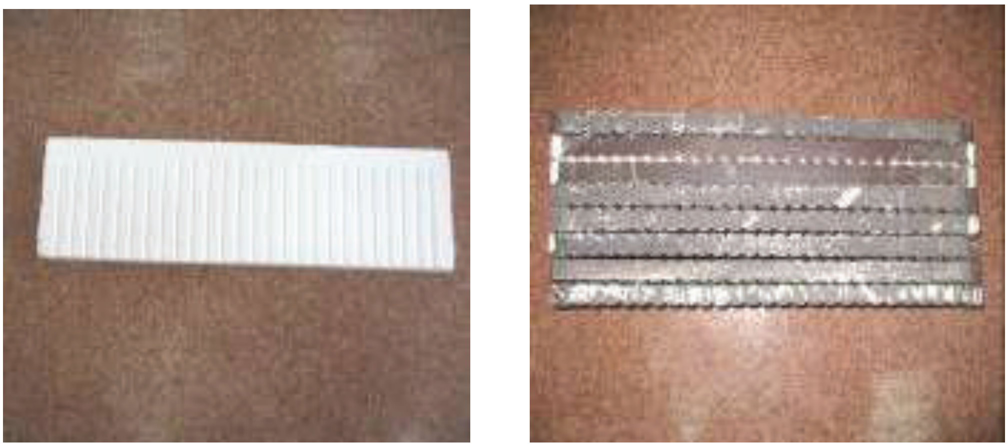

Figure 1. Foam pieces used for artificial nesting of leaf-cutting bees.

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Figure 2. Completed artificial nest of leaf-cutting bees.

Figure 3. The alfalfa experimental field with the shelters.

Table 1. The number of flowers and pods per inflorescence per plant, seeds /100 pods, weight of 100 seeds, and seed yield per plant in relation to the distance from the artificial nests in 2007

Distance from nest	Number of flowers	Number of pods	Number of seeds /100 pods	Dry weight of 100 seeds g	Seed yield g / plant
20 m	22.7 a	17.2 a	288.5 a	0.25 a	5.42 a
30 m	21.5 a	15.7 a	238.2 a	0.22 a	4.20 b
40 m	20.7 a	10 b	249.5 a	0.17 b	1.75 c
L.S.D (5%)	2.4	2.2	74	0.03	0.94

3. Results

Alfalfa seed production data as affected by the distance from nests are shown in Table 1. There were no significant differences between the three treatments for average number of flowers per inflorescence per plant. However, the numbers of pods per inflorescence decreased as the distance from nests increased. There were no significant differences between the treatments for the average number of seed per 100 pods. However, there were significant treatment differences for the dry weights of 100 seeds. The seed yield per plant was significantly decreased as the distance from the nests increased.

Leaf-cutting bees are considered as one of the most important pollinators of leaf-cutting bees worldwide. The emergence of leaf-cutting bees from artificial nests synchronized with the alfalfa blooming seasons in Ismailia, Egypt. The bee activity varied at different times of the day but the maximum activity was at 1 pm. The number of bees decreased as the distance from the artificial nests increased. So if the farmers use artificial nests for alfalfa leaf-cutting bees it is recommended to place the nests to cover the whole field instead of putting them in one side of the field (Shebl et al. 2008).

4. Discussion

The data showed that the foraging activity of leaf-cutting bees and the distance of their nest have a big influence on the alfalfa seed production. The flower abundance and pollinator movement have an impact on seed or fruit yield and may have implications for crop pollinator management. Alfalfa may yield less seed when flowers are abundant, suggesting that early introduction of bees into alfalfa may be desirable to maintain a low count of flower in the crop stand (Strickler 1999). Composite pattern of floral resource availability demonstrated an initial burst of bloom, followed by a linear decline in total flower per raceme and an exponential decline in number of racemes with open flowers over the season. Number of open flowers and nectar availability declined more rapidly close to bee shelters than at a distance from them (Strickler and Freitas 1999). Environmental influence and pod position effects on seed weight and number of seeds per pod were small when compared with genetic effects in alfalfa. Selection for seed characteristics in seed and pollen parents could improve alfalfa seed production and seed quality (Katepa – Mupondwa et al. 1996).

Leaf-cutting bee *Megachile rotundata* appears to move with a 56% probability of leaving a given raceme and a given plant; this foraging behavior results in a few flowers visited per plant (Strickler and Vinson 2000).

The more rapid decline in open flowers per raceme close to bee shelters was consistent with this interpretation. The model of alfalfa pollination predicts a similar decline in the number of open flowers. An exponential decline in open flowers provides an explanation for the advantage of using large numbers of bees to pollinate alfalfa rapidly (Strickler 1997). To reach the maximum production of seed yields, the shelters of bees should be repeated every 20-30 meters. More research has to be carried out to find the the numbers of bees to reach the maximum production per plant of alfalfa.

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Theme 6. Stress physiology: drought, heat, cold and salinity

6.1. Effect of salt stress on growth, leaf gas exchanges, transpiration efficiency and Na accumulation and partitioning of twenty pearl millet inbred lines

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Abstract

Salinity is an ever increasing problem in many parts of the world and understanding the mechanisms of plant tolerance to salt stress is a critical step to develop crop varieties that can tolerate soil salinity. Pearl millet genotypes showing contrast in their tolerance to salinity, based on previous yield assessment, were tested for the response to salt treatment of leaf gas exchange, transpiration efficiency (TE), biomass accumulation, apparent Na xylem concentration and sodium distribution in different plant parts. Lines were tested twice in hydroponics under glasshouse conditions. A salt treatment of 75 mM sodium chloride was applied in the nutrient solution at the late vegetative growth stage and treatment was maintained for 20 days. Substantial variation across genotypes was observed in TE, DW and Na^+ accumulation response to NaCl treatment. The transpiration decreased in most genotypes upon salt treatment, but several maintained almost as high a value as non-salinity treated plant (e.g. tolerant 841B-P3, PRLT 2/89-33), whereas the transpiration of other genotypes decreased 25-40% (e.g. sensitive 863B-P2, H77/833-2-P5). The difference between TE under salt stress and TE under non-saline conditions was significantly and positively correlated to the amount of DW accumulated (0.58), showing that genotypes capable of maintaining biomass accumulation under stress were those capable of increasing TE under stress. There was large variation in the apparent Na concentration in the xylem (total Na accumulated in shoot / total transpiration water), and also in the Na concentration in stem and leaves across genotypes. Tolerant lines stored a larger proportion of Na in the stem. So, increase in TE, maintenance of a high transpiration rate, storage of Na in the stem and tissue tolerance to high Na concentration are possible mechanisms for salt tolerance in pearl millet. More data on salt compartmentation in the cells would be needed to better assess the latter hypothesis.**

1. Introduction

Salinity severely reduces crops yield in an estimated 100 million hectares of arable lands (FAO 2008) across the world, mostly arid and semi-arid regions. According to FAO (2008), due to progressing climate change and inadequate water management the salt accumulation in soil is likely to steadily increase by 1-2% per annum. Even if a change in agronomic management could probably take care of most of that drift, such a change in practices is not always affordable because it would require major investments that small holder farmers are not keen to make. Therefore, to maintain global food security, there is an increasing need to develop crop varieties with tolerance to salinity. This would however necessitate a better understanding of the mechanisms by which plant can tolerate salt stress.

Plant adaptations to salinity are of three distinct types: osmotic stress tolerance, Na^+ or Cl^- exclusion from vital organs, and tolerance of tissue to accumulated Na^+ or Cl^- (Munns and Tester 2008). The osmotic effect of a high salt concentration lowers the soil water potential and limits water uptake. As a consequence, plants suffer with water deficit. Therefore, maintaining water uptake to maintain plant growth under salt stress is of primary importance for plant productivity. In particular, it is important to understand how leaf gas exchange is affected by salt treatment, whether there is genotypic difference in the response, and whether this response relates to tolerance. To our knowledge, there is virtually no published work on these aspects in pearl millet.

The maintenance of high transpiration rates under salt stress may lead to dragging some salt in the transpiration stream, especially in the apoplastic pathway, in case the Casparian band is not properly developed in the endodermis (Steudle 2001). Therefore, the plant must reconcile the need to sustain the transpiration stream to sustain growth, and to avoid salt loading in the xylem stream. So, a low transpiration stream to avoid salt drag might also be a strategy to cope with salt stress, provided it is compensated by a high transpiration efficiency (TE), i.e. biomass/water transpired (g kg^{-1}). Therefore, it may be worthwhile testing whether salt tolerance can be related to TE under salt stress, and/or whether tolerance can relate to genotypic differences in TE in pearl millet.

Under salt stress condition, low sodium accumulation has often been used as a proxy for tolerance. This is the case in wheat, where genotypes absorbing less Na in their shoot are more tolerant (Munns and James 2003). Previous work on rice (Yeo and Flowers 1986) also indicates that genotypes with low xylem Na concentration were tolerant to salinity. Do these relationships work in pearl millet? In the case of pearl millet, Na accumulates in pearl millet shoot, and there seems to be a relationship between shoot sodium concentrations and shoot biomass under salt stress (Krishnamurthy et al. 2007). However, there was no attempt to relate this to possible differences in the xylem Na concentration that could results from differences in the loading of Na in the xylem across genotypes. This knowledge is important as it would help identify in which part of the plant the efforts towards improved tolerance must be devoted.

A critical aspect of cellular and organism metabolism is about controlling and integrating Na^+ absorption and allocation in plants parts (Cheeseman 1988). So, salt distribution in different plant parts also plays an important role in salt tolerance. A negative correlation between salinity tolerance and Na accumulation in leaves is often seen when comparing different genotypes within species (Munns 2002; Tester & Davenport 2003). However, it has been shown that tolerant sorghum lines were capable of compartmenting salt in the stem (Netondo et al. 2004). This information is not available in pearl millet.

Pearl millet is an under studied crop despite being the 6th most important crop worldwide (5th in Asia) and therefore reports on salinity tolerance mechanisms in this crop are rare. Pearl millet was classified as a moderately tolerant species (Mass 1993) to increased salinity with wide intra-specific variation providing the base-ground for research on understanding the mechanisms influencing salinity tolerance of this species and for breeding purposes. Therefore, the overall goal of the present study was to gain more insight on the possible salt tolerance mechanisms in pearl millet. The specific objectives were (i) to test the plants transpiration response to salt stress treatment, (ii) assess changes in TE upon salt stress and possible genotypic differences, (iii) compare genotypes for the Na concentration in the xylem stream, and (iv) compare salt distribution in the plant parts. Each of these parameters was then related to an index of tolerance, which was calculated as a "salt susceptibility index" based on biomass reduction in saline conditions.

2. Material and methods

Germplasm: Twenty pearl millet pure inbred lines developed by the Pearl Millet Breeding Group of ICRISAT were tested along with four inbred testers. These inbred lines were used because they are the parents of RIL mapping populations and previous assessment has shown some variation for seed yield under salt stress conditions between them (our unpublished data). Experiment 1 was started on 07 May 2006 under glasshouse conditions. Plants were grown in hydroponics. Each genotype was grown under normal growth condition until the application of two treatments, i.e. non-saline (control) and saline, with four replications. Experiment 2 was a repeat of Experiment 1, but started on 02 July 2006 under same conditions.

Growth conditions and experimental set-up: Experiments were carried out in a glasshouse, with day/night temperature of 28/22 ºC, humidity 70%. *Firstly* seed were sown in 4" x 6" size sealed bottom tray filled with 3-4 kg of pure sterilized sand. Approximately 50 seed were grown in each tray. Around a liter of nutrient solution was applied after sowing to wet the sand and ensure proper germination. Re-wetting of the sand was done using tap water. *Secondly,* 7-10 days old seedlings were transferred in 12"x 6"x3" size tray filled with 20 liters of nutrient solution, covered with a perforated thermocol sheet fitting 30-40 seedlings in each tray. Through the holes, seedling's roots were hanged in nutrient solution with the help of hydrophobic cotton wool wrapped around the plant's collar to prevent the stem to slip through the hole. Compressed air was supplied to each tray through 7-8 thin pipes, at an approximate rate of 500 mL min^{-1} in each pipe, distributed equally to all parts of the tray to facilitate proper aeration to the roots. The pH was maintained in the range 6-7 by adding calcium carbonate in the tray. Nutrient solution was replaced every five days. *Thirdly,* plants were transferred in to 250 ml flask between 15-20 days after sowing (DAS). Glass flasks were wrapped with aluminum foil to ensure darkness in the rooting medium and prevent the algae growth. Bottle mouths were fixed with thick rubber cork having a hole in the centre, and were slit open to allow the insertion of the plant collar through the hole. Plant roots were soaking in the nutrient solution and cottonwood wrapped around the plant's collar. Compressed air was provided to the roots through an individual thin pipe fitted through the central hole of the rubber stopper, and delivering air at the bottom of the flask at a rate of 500 mL min^{-1}. Deionized water was added to compensate water losses and the nutrient solution in the flasks was replaced every 3-4 days for each genotype, three sets of plants were grown, with five replications per genotype in each set. The genotypes were randomized within each set. One set was used to assess the plant biomass at the time of imposing the treatment. The other two sets where those used to assess the transpiration response, one being exposed to salt treatment whereas the other one was kept as the non-saline control.

Nutrient composition: A balanced nutrient composition and concentration of the solution was used: $MgSo_4$ (2.05mM), K_2SO_4 (1.25mM), $CaCl_2$ (3.3mM), KH_2PO_4 (0.5 mM), Fe-EDTA (40µM), Urea (5mM), H_3BO_3 (4µM), $MnSO_4$ (6.6µM), $ZnSO_4$ (1.55µM), $CuSO_4$ (1.55µM), $CoSO_4$ (0.12µM) and Na_2MoO_4 (0.12µM) (Kalia and Drevon 1985; Vadez and Sinclair 2001).

***Salt treatment*:** A salt treatment of 50 mM NaCl in both experiments was applied at 30DAS, i.e. two weeks after transferring plants to the flasks, and increased to 75 mM next day (Munns et al., 2002). Another set was kept under control (non-saline) conditions. Nutrient solution was replaced every fourth day. Nutrient solution volume was adjusted every day after weighing the flasks, targeting the flask weight right after changing the nutrient solution. Plants were harvested at 18 and 17 days after salt application in Experiment 1 and 2 respectively, and kept for oven drying at 60^0C for two days, after separating the plant into different parts i.e. leaf, stem, panicle and roots.

Measurements: All the parameters were calculated on the basis of mean values of the two experiments. Transpiration was measured gravimetrically by regular weighing of the flasks. We previously measured whether the air bubbling through the flask could be a significant cause for water evaporation from the flask and found that only minor and negligible loss occurred. Loss in flask weight due to transpiration was compensated by water addition with simple de-ionized water. This allowed maintaining the concentration of the salt treatment close to the applied values. Total transpiration was then the sum of daily transpiration rates. The biomass of plants at the time of imposing the treatments was measured by harvesting one set of plants. This biomass was then used to estimate the biomass increase during the treatment imposition periods, which were 18 and 17 days in Experiment 1 and 2.
Transpiration efficiency (TE) was calculated as:
TE = Biomass increase between period of treatment to harvest / total transpired water in this period

The leaf area of plants was measured immediately after harvest with Li-Cor model 3100c Area Meter.

To assess salinity tolerance, the percent relative reduction under saline conditions compared to control (RR %) was computed as:
RR% = 1 – (biomass under salinity/biomass under control)*100
And then the salinity susceptibility index (SSI) was computed as:
SSI= (1-YSS/YNS)/ (1-XSS/XNS)

where YSS and YNS are the mean biomass of a given accession in saline and non-saline and XSS and XNS, are the means of all accessions under salinity stressed and non-stressed environments respectively (Fisher and Maurer 1978).

Na^+ concentration in leaf, stem and root tissues was determined, using 150mg of finely ground sample, digested in 4 ml of concentrated H_2SO_4 with 0.5% of selenium powder at 360^0C for 4500 s on a block digester. The digest was diluted to 75 ml using distilled water. This was used to estimate Na^+ (Sahrawat et al. 2002) using an atomic absorption spectrophotometer (Varion model 1200, Australia).

3. Results

***Dry matter accumulation*:** There was a large variation in biomass accumulation under salinity (Table 1). On an average across the genotypes, there was a 20% decrease in total dry matter under salinity. However, the genotypes varied largely and the percentage decrease in shoot varied from less than 10% in three genotypes, including PRLT 2/89-33, to above 40% in others such as LGD1-B-1-10 (Fig. 1).

Table 1: Mean values across all genotypes (and SD, standard deviation in brackets) of total dry weight, transpiration, leaf area and TE under non-saline (control) and saline treatments

Parameter	Control (SD)	Saline (SD)
Total dry weight (g plant^{-1})	8.025 (1.92)	6.341 (1.72)
Transpiration (g plant^{-1})	1124.75 (194.79)	856.06 (139.57)
Leaf area (cm^2 plant^{-1})	457.97 (147.4)	414.55 (137.39)
TE (g biomass kg^{-1} water transpired)	6.48 (1.21)	6.69 (1.49)

Transpiration: On average, transpiration dropped around 24% (Table 1) across all the genotypes upon salt treatment. However, there was again a wide range of variation across the genotypes, from 8% to 40% (Fig. 2). Seven inbred had less than a 15% decrease, and these include PRLT 2/89-33, 841B-P3, ICMP-451-P8, W504-1-P1. By contrast, three genotypes had a decrease above 30%, including H77/833-2-Bulk that had a 40% drop in

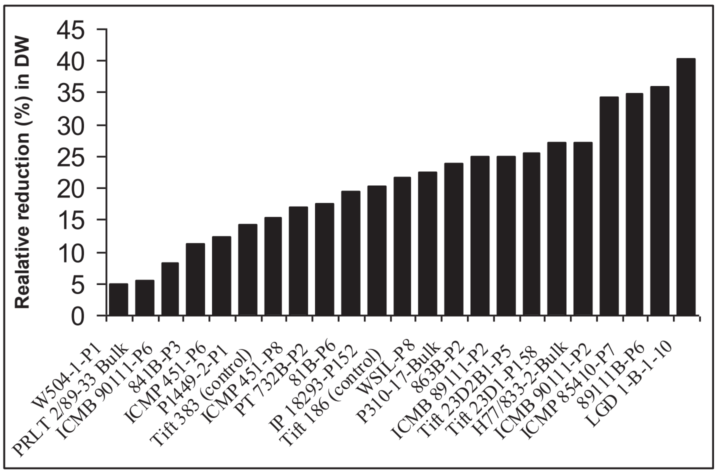

Figure 1. Relative reduction percentage ([1 – (DW salt / DW control)] ×100) in dry matter under salinity treated plants compared to their respective control.

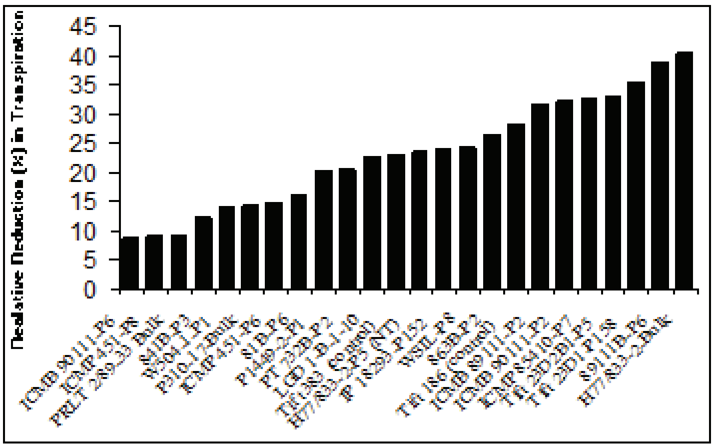

Figure 2. Relative reduction percentage ([1 – (transpiration salt / transpiration control)] × 100) in dry matter content under salinity treated plants compared to their respective control.

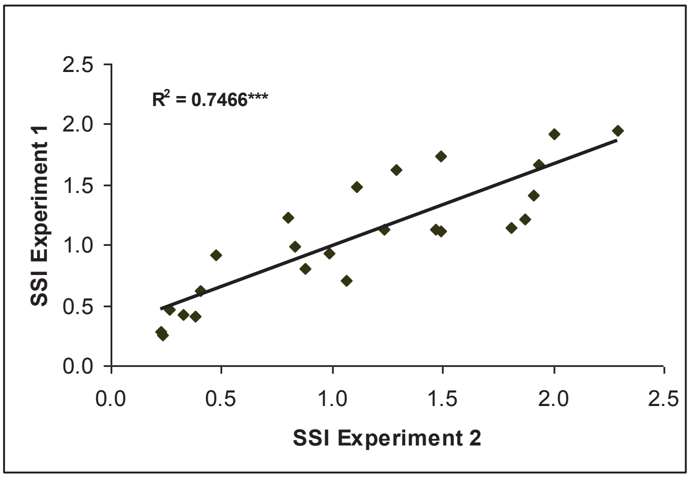

Figure 3. Relationship between the dry weight ratio (DW salt/DW control) and the transpiration ratio (transpiration salt/transpiration control). (*significant at P= 0.001)**

transpiration upon salt treatment. The dry weight ratio (saline/control) showed a high significant linear relationship with the transpiration ratio (Fig. 3; r^2= 0.6114; P = <0.001), indicating that genotypes able to maintain high biomass under salt stress were able to maintain high transpiration.

Salinity susceptibility index (SSI): The salinity susceptibility index was calculated for both the experiments and the values of the two experiments were highly correlated (R^2=0.747; P= <0.001) with each other (Fig 4). Hence, the mean SSI over the two experiments was taken to categorize the genotypes as tolerant, moderately tolerant and susceptible (Table 2). Five Genotypes (W504-1-P1, PRLT 2/89-33, 841B-P3, ICMP-451-P6 and ICMB90111-P6) had low SSI values (below 0.5) which indicated their tolerance to salinity. Another five having SSI varying between 0.5-0.9 were considered as moderately tolerant. The remaining genotypes, with SSI values above 0.9, were categorized as susceptible.

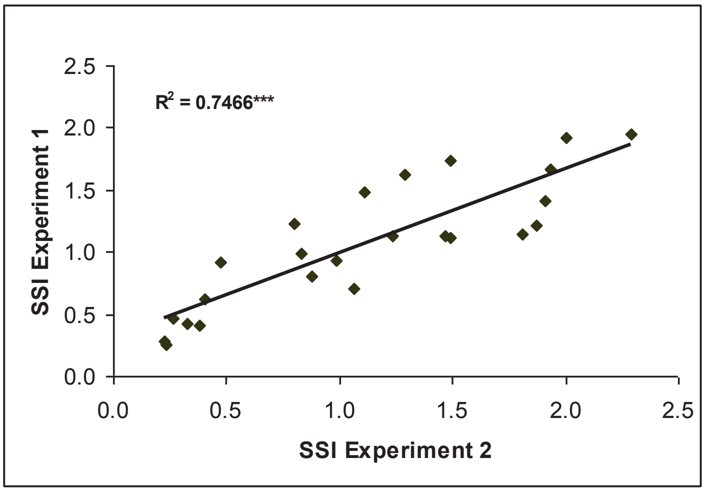

Figure 4. Linear relationship between the salinity susceptibility indices (SSI) of experiment 1 with experiment 2. (*significant at P= 0.001)**

Table 2: Salinity susceptibility index (SSI) of 24 genotypes based on the average biomass of experiment 1 & 2

Genotypes	Average SSI	Tolerance group
W504-1-P1	0.24	Tolerant
PRLT 2/89-33 Bulk	0.25	
ICMB 90111-P6	0.37	
ICMP 451-P6	0.38	
841B-P3	0.39	
P1449-2-P1	0.51	Moderately tolerant
Tift 383 (control)	0.70	
ICMP 451-P8	0.85	
PT 732B-P2	0.89	
H77/833-2-Bulk	0.91	
81B-P6	0.96	Susceptible
Tift 186 (control)	1.02	
P310-17-Bulk	1.18	
H77/833-2-P5 (NT)	1.29	
Tift 23D2B1-P5	1.30	
863B-P2	1.30	
ICMB 89111-P2	1.46	
Tift 23D1-P158	1.48	
WSIL-P8	1.54	
ICMB 90111-P2	1.62	
IP 18293-P152	1.66	
89111B-P6	1.80	
ICMP 85410-P7	1.96	
LGD 1-B-1-10	2.12	

Transpiration efficiency: The transpiration efficiency under non-saline control conditions was 6.48±1.21across all the genotypes, whereas it was 6.69±1.49 under saline conditions (Table 1), indicating that overall, TE was not significantly altered under salt stress. However, the mean TE in the highly tolerant group tended to increase under salt stress whereas the mean TE in the sensitive group was unchanged under salt stress (data not shown). In fact, a significant negative relationship was found between the SSI and TE under salt stress conditions (Fig: 5; r^2=0.498; P=0.05), indicating that genotypes having high SSI value (sensitive) had low TE values.

Sodium accumulation: Genotypes showed large variation in sodium accumulation (Fig 6). Three of inbreds (W504-1-P1, 841B-P3 and P1449-2-P1) and a tester (89111B-P6) had very high sodium accumulation compared to H77/833-2-Bulk, ICMP-451-P8 and ICMP-451-P6 which accumulated very small amount of Na.

***Apparent xylem sodium concentration*:** The apparent xylem Na concentration appeared to vary a lot across genotypes, from as low as 2-3 mg L^{-1} up to 25 mg L^{-1}. However, there appeared to be no trend linking this trait to the SSI (Fig. 7). Genotypes like W504-1-P1, 841B-P3, PT732B-P2, ICMB90111-P2, Tift23D1, Tift23D2, 863B-P2 had high concentration, whereas genotypes ICMP451-P6, H77/833-2- bulk and ICMP 85410-P7 had very low concentration.

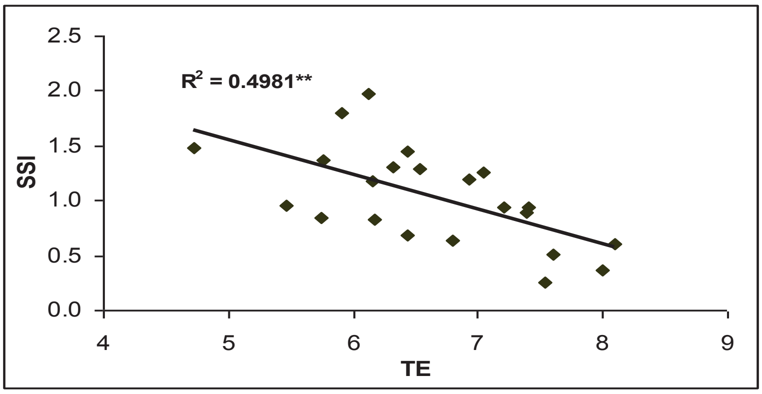

Figure 5. Linear relationship between salinity susceptibility index and transpiration efficiency under salt stress (significant at P= 0.005)**

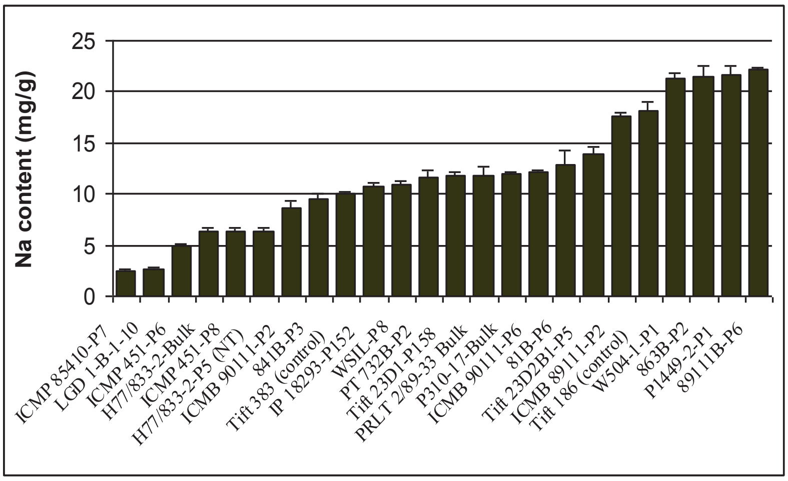

Figure 6. Sodium concentration (mg Na g^{-1} biomass) in the whole plant of salt treated genotypes of experiment 1. Data are the means (bar indicate SE) of 4 replications.

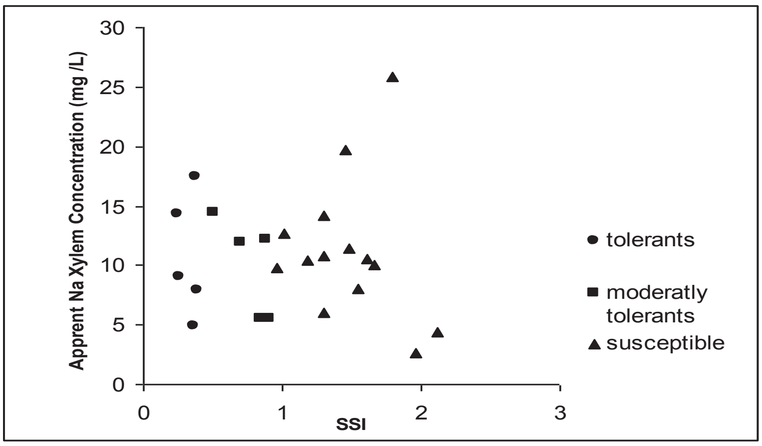

Figure 7. Relationship between the apparent sodium xylem concentration (mg Na L^{-1} transpired water) and the SSI in tolerant (closed circle), moderately tolerant (closed squares) and susceptible (closed triangles) genotypes.

Sodium distribution in plant parts: The tolerant lines accumulated larger proportion of Na in stem (49%) and roots (41%) than in leaves (10%) in vegetative stage (Fig 8a). In moderately tolerant genotypes (Fig 8b) there was also a major accumulation in stem and roots (39% and 44%) compared to leaves (16%). By contrast, in susceptible lines it was much larger in the leaves, reaching 24% of the total (Fig. 8c). Sensitive group had a small proportion of the total Na in the panicle, whereas there was no such observation in the case of tolerant lines.

4. Discussion

Our data showed that the response to salt treatment in pearl millet genotypes varied for: (i) the degree of transpiration decrease, (ii) transpiration efficiency, (iii) the amount of Na accumulated, (iv) the Na concentration in the xylem, and (v) the distribution of Na in shoot parts. The SSI was well related to the ratio of transpiration and to TE, showing that both the maintenance of a high transpiration rate, along with a high TE under salt stress led to the maintenance of a large biomass under salt stress. While the Na concentration in the xylem had no significant relationship with the SSI, it appeared that tolerant genotypes were capable of storing large proportions of Na in the stem compared to sensitive lines (high SSI), while the latter had higher proportion of Na in the leaves.

Growth of pearl millet genotypes was reduced in response to salinity as showed by lower mean values of dry weight under salinity compared to control. Genotypes also showed large variation in transpiration response to salinity (Fig 2) and a significant drop as compared to control plants (Table 1). The transpiration response was well correlated with biomass accumulation (Fig 3; $r^2 = 0.61$). We interpret that the reduction in transpiration might have led to increased metabolic energy cost and reduced carbon gain (Richardson and McCree 1985; Netondo et al. 2004), hence reduced biomass accumulation, therefore it may indicate that the primary response of plants to salinity is reduction in transpiration. The cause for the transpiration decline is not clear but could be due to the osmotic effect of salt causing a water stress on plants, as reported in maize (Cramer et al. 1994, Fortmeier & Schubert 1995) and in wheat (Munns 2002).

Transpiration efficiency showed a negative relationship with SSI, with tolerant genotypes having higher TE compared to susceptible lines (Fig 5). In addition, an increase in TE under salt stress was found in tolerant and moderately tolerant genotypes in stress plants compared to sensitive lines where TE was lower than in tolerant and where TE remained similar under stress. These data indicate that the maintenance of a high biomass under salt stress was in part due to an overall higher TE of tolerant lines and the capacity to raise TE under salt stress. To our knowledge, there has not been such approach to salt stress tolerance research and the comparison to other work is difficult. However, evidences that TE, a trait normally related to drought stress has also some involvement in salt tolerance appeals for further investigation.

There was a large range in sodium concentration among the genotypes (Fig 6), however, this did not relate significantly with differences in SSI. These results contrast to previous report showing that low Na accumulation relates to more tolerance (Krishnamurthy et al. 2007). Genotypes also varied a lot in their apparent xylem sodium concentration but we also did not find any relationship between this trait and SSI (Fig 8). These data indicate that tolerant genotypes can also have high Na in the xylem and high Na accumulation, and suggest that salt tolerance in pearl millet could be related to tissue tolerance.

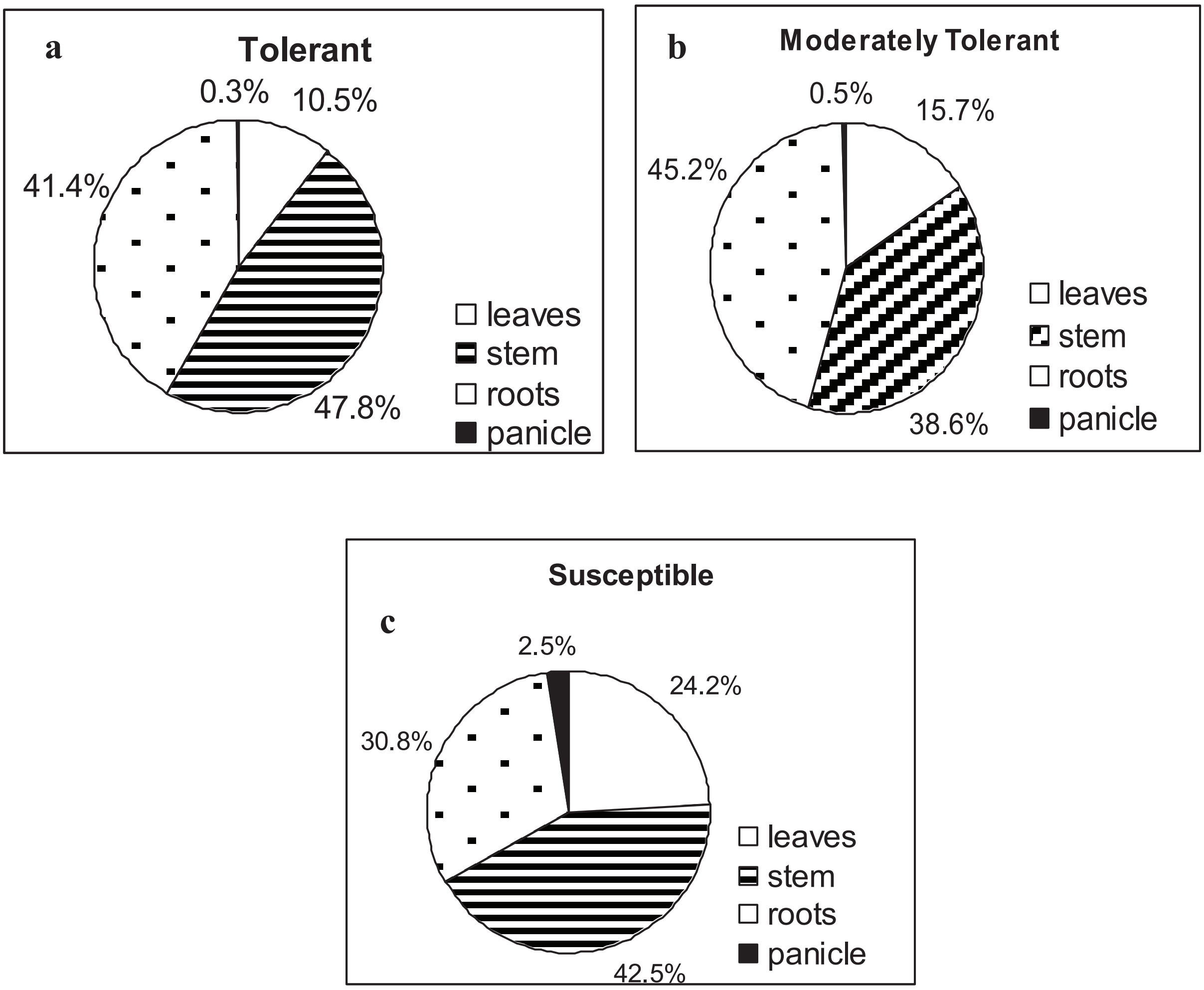

Figure 8. Percentage distribution of sodium in different plant parts in (a, n = 5) tolerant genotypes, (b, n = 5) moderately tolerant genotypes, and (c, n = 14) susceptible genotypes.

Sodium was found as major cation that accumulated in roots and stem in response to salinity. Similar observations have been made in tolerant lines of sorghum (Netondo et al. 2004). The major deposition in roots may indicate that salt entry into the xylem is restricted at the root level, as a consequence of an increase in the efflux from the root to avoid/diminish the Na loading into the xylem (Cheeseman 1982) or by restricting the entry of Na towards the root cylinder because of the strong barriers like casparian band (Renault et al. 2001). One very interesting trend was shown in Fig 8 where Na accumulation in the leaves was clearly higher in the sensitive genotypes, whereas tolerant lines stored most of the sodium in roots and stems. A negative correlation between salinity tolerance and Na accumulation in leaves is often seen when comparing different genotypes within species (Munns 2002; Tester & Davenport 2003). It also reflects salt impact on tissue (Greenway and Munns 1980), reduction in photosynthetic rates (McCree 1986; Netondo et al. 2004), and attainment of maximum salt concentration tolerated by the fully expanded leaves (Munns and Termaat 1986).

5. Conclusion

Plant salt tolerance in pearl millet appears to be complex and likely related to various traits having different characteristics. It appeared to be related both to the maintenance of a large transpiration stream and to having a high and increased TE under salt stress in tolerant lines. In addition, Na accumulation did not always result in susceptibility, and this was probably related to the potential of tolerant line to store Na in the stem and the roots.

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6.2. Physiological and growth responses of two cool-season turfgrass species to NaCl stress

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Abstract

Physiological behavior and growth responses to NaCl stress were studied in Kentucky bluegrass (*Poa pratensis* L., a salt-sensitive species) and Tall fescue (*Festuca arundinacea* Schreb, a moderately-salt tolerant species). The plant growth of both species decreased when NaCl concentrations increased. The decreases in root length and root dry weight were more significant in Kentucky bluegrass than in Tall fescue. Kentucky bluegrass accumulated the higher amount of Na^+ and Cl^- under salt stress than in Tall fescue. The salinity induced mineral nutrition imbalance for Kentucky bluegrass, because K^+, Ca^{2+}, Mg^{2+}, NO_3^- and Cl^- concentrations significantly declined. However, this condition did not happen in Tall fescue. The increase in malondialdehyde (MDA) was higher in Kentucky bluegrass than in Tall fescue. The superoxide dismutase (SOD), catalase (CAT) and glutathione reductase (GR) activities of Tall fescue were higher than those of Kentucky bluegrass under increasing salinity. Whereas in the root the ascorbate peroxide (APX) activity was lower in Tall fescue than in Kentucky bluegrass. These results indicate that Tall fescue exhibited a better protection mechanism under salinity conditions by inhibiting the accumulation of Na^+ and Cl^- to keep ion balance and maintaining higher antioxidant enzymes activities against oxidative damage than Kentucky bluegrass.

1. Introduction

Salinity is one of the most significant factors limiting crop productivity. About 20% of the world's cultivated land and nearly half of all irrigated lands are affected by salinity (Zhu 2001). Critical water shortages are occurring with the expanding population growth and urbanization development, resulting in restrictions on the use of potable water for turfgrass irrigation. Therefore, turfgrasses are increasing being subjected to salinity stress, due to accelerated salinization of irrigated agricultural lands, and the need to use of effluent or other marginal quality, often saline, water sources for turfgrasses irrigation (Marcum 1999). The use of saline water for turfgrass irrigation has the potential to save fresh water. There are increasing concerns about the need for managing turfgrass in salt affected soils, and increasing need for salt tolerant turfgrasses.

Salt can have detrimental effects on turfgrasses in various ways. Direct effects include osmotic stress, ion toxicity, nutrient imbalance, membrane dysfunction and inhibition of general metabolic processes such as photosynthesis and respiration (Orcutt and Nilsen 2000). As a consequence of ion imbalance and hyperosmotic stress, secondary stresses such as oxidative stress may happy by increasing reactive oxygen species (ROS), for example, superoxide radicals, hydrogen peroxide and hydroxyl radicals (Sudhakar et al. 2001), which are highly reactive in the absence of any protective mechanism, and can affect normal metabolism through oxidative damage to lipid, nucleic acids and proteins.

Specific effects of salt stress on plant metabolism, especially on leaf senescence, have been related to the accumulation of toxic ions (Na^+ and Cl^-) or to K^+ and Ca^{2+} depletion (Demiral and Türkan 2005). Salinity tolerance has been associated with ion regulation in many plants. To mitigate ion injury, many plants can maintain a low Na^+ concentration in shoot by accumulating Na^+ in root and preventing Na^+ translocation to the shoot (Yamanouchi et al. 1997). In addition, the maintenance of a high cytosolic K^+/Na^+ ratio is also considered to be important (Song et al. 2006).

To scavenge ROS, plants have evolved specific molecular defence tactics involving both enzymatic and non-enzymatic antioxidant mechanisms. Several enzymes are involved in scavenging ROS including superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), peroxidase (POD) and glutathione reductase (GR) (Cavalcanti 2004). The activities of the antioxidative enzymes increase under salt stress in plants and appear to present an important stress-tolerance capacity. A close correlation between the antioxidant capacity and salinity tolerance has been demonstrated in many plants. Malondialdehyde (MDA) amount, which is the decomposition product of polyunsaturated fatty acid oxidation, is widely used to measure the extent of lipid peroxidation as indicator of oxidative stress (Gossett et al.1994).

Kentucky bluegrass (*Poa pratensis* L.; KBG) is a cool-season grass, which is considered to be a premier lawn grass that can form an attractive, durable, persistent turf (Meyer and Funk 1989). Tall fescue (*Festuca arundinacea* Schreb.; TF) is an open-pollinated, perennial, cool-season turf and forage grass species that can serve as a utility turfgrass for soil solidification and as a feed for the livestock (Dong et al. 2007). As turfgrasses, both species are widely used for turf lawns in public and private parks, golf courses, fairways, playgrounds, and athletic fields.

Research activities on turfgrass salinity tolerance are quite diverse. However, limited information is available on physiological and growth responses of Kentucky bluegrass and Tall fescue in hydroponics growing system under salinity. Understanding the physiological and biochemical responses of salinity adaptation could help us to choose turfgrass for saline water irrigation, and to breed salt tolerant species.

The aim of this study was to investigate the effect of NaCl on the growth parameters, ionic content, lipid peroxidation level in terms of MDA content and antioxidant enzyme activities of two cool season turfgrass species. The investigation also attempts to gain understanding of salinity tolerance mechanisms and to provide information for breeding salt resistant turfgrass species.

2. Materials and methods

The experiment was conducted at the Faculty of Agriculture, Tottori University from May to June 2006 and the study was repeated again from September to October 2006. Seeds of Kentucky bluegrass (*Poa pratensis* L.) cv.'Blue star' and Tall fescue (*Festuca arundinacea* Schreb) cv. 'Little Hero' were sterilized in 0.5% (w/v) sodium hypochlorite on a magnetic stirrer for 10 min (Torello and Symington 1984), thoroughly rinsed with distilled water and

germinated on solid soil amendment medium in the growth room. The temperature of the growth room was maintained at 24±2°C, and humidity was 60%.
Three-week-old grass seedlings, uniform in size and development, were transplanted to 4L plastic pots (5 plants per pot) filled with a nutrient solution in a naturally lighted glasshouse. Mean air temperatures of glasshouse ranged from 20-32°C during the experiment. Relatively humidity was between 60-70%. The nutrient solution composition contains macronutrients (mol m^{-3}): 2.0 N (NH_4NO_3), 0.4 P (NaH_2PO_4), 2.0 K (KCl), 1.0 Ca ($CaCl_2 \cdot 2H_2O$), 2.0 Mg ($MgSO_4 \cdot 7H_2O$), and micronutrients (g m^{-3}) as: 2.0 Fe ($FeSO_4 \cdot 7H_2O$), 0.5 Mn ($MnSO_4 \cdot 5H_2O$), 0.2 B (H_3BO_3), 0.1 Zn ($ZnSO_4 \cdot 7H_2O$), 0.01 Cu ($CuSO_4 \cdot 7H_2O$) and 0.05 Mo $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$. The nutrient solution was adjusted to pH 6.5 by adding H_2SO_4 or NaOH, aerated constantly with air during the experiment period, and replaced twice a week.

Seedlings were allowed to growth under non-saline conditions for 15 days to achieve full establishment before starting salt treatment. The plants were arranged in a randomized complete block design and separated in five groups (replicates) for each cultivars irrigated with a nutrient solution supplemented with different concentrations of NaCl (0, 50,100,150 and 200mM). To avoid osmotic shock, salt concentrations were gradually increased by 50 mM every 24 h until reaching the maximum salinity level of 200mM NaCl. Salinity treatments were continued for a period of 40 days and plants were harvested for various determinations.

During the experiment, the plant growth parameters (shoot height, root length, dry weight of shoot and root) were determined. Turf quality and leaf firing, the criteria commonly used to evaluate physiological health and appearance, were visually estimated weekly (Alshammary et al. 2004). The Na^+, K^+, Ca^{2+} and Mg^{2+} concentrations were analyzed using atomic absorption spectrophotometry (Z-6100 Polarized Zeeman Atomic absorption spectrophotometer; HITACHI, Japan). Cl^- and NO_3^- were determined using an ion chromatography system (Shimadzu LC-VP; Kyoto, Japan).

For protein and enzymes extractions, shoot and root frozen material (0.15 and 0.2g) were ground into a fine powder in liquid nitrogen with a chilled mortar and pestle and homogenized with 50mM potassium-phosphate buffer (PH 7.8), containing 0.1mM EDTA and 2% (w/v) polyyinylpolypyrrolidone (PVPP). The whole extraction procedure was carried out at 4℃. Homogenates were centrifuged at 13,000g for 40 min at 4℃ and supernatants were used for determination of enzyme activity and protein content. SOD activity was determined by the method of Tanaka and Sugahara (1980). CAT activity was determined by the method of Aebi (1984) with a slight modification. APX activity was determined by the method of Nakano and Asada (1981). GR activity was calculated by measuring the GSSG-dependent oxidation of NADPH monitored as described by Tanaka et al. (1988). The enzyme activities were expressed on the basis of per unit protein weight. Total soluble protein content was determined by using bovine serum albumin as a standard (Bradford 1976). MDA content was determined by the thiobarbituric acid (TBA) method as described by Heath and Packer (1968).

All data were evaluated by one-way analysis of variance (ANOVA) using SPSS 10.0 statistical program. Mean values were compared by the Duncan test when significant difference occurred at 5% level of probability.

Table 1. Effects of salt stress on plant growth parameters in Kentucky bluegrass (KBG) and Tall fescue (TF)

NaCl	Shoot length (cm)	Root length (cm)	Shoot DW (g)	Root DW (g)	Turf quality	Leaf firing (%)
KBG						
0 mM	32.20±1.05a	31.59±0.65a	2.49±0.13a	0.76±0.04a	8.62±0.08a	13.52±0.11a
50mM	27.42±0.49b	24.90±0.64b	1.65±0.09b	0.65±0.03b	6.25±0.16b	32.87±1.19b
100 mM	22.40±0.41c	22.61±0.61c	1.25±0.09c	0.46±0.02c	3.88±0.08c	56.71±1.65c
150 mM	20.70±0.46c	19.57±0.33d	0.96±0.04d	0.29±0.004d	2.70±0.12d	74.32±1.95d
200 mM	18.03±0.66d	14.86±0.52e	0.57±0.03e	0.15±0.014e	2.27±0.11e	84.24±1.74e
TF						
0 mM	40.84±0.69a	34.37±0.78a	2.83±0.10a	0.69±0.01a	8.80±0.10a	9.33±0.15a
50mM	36.26±0.29b	33.90±1.51a	2.20±0.36b	0.67±0.04a	8.13±0.08b	15.51±0.69b
100 mM	30.39±0.83c	39.48±2.63b	1.32±0.07c	0.59±0.01b	6.69±0.26c	29.54±1.38c
150 mM	25.75±1.09d	29.99±0.93a	1.36±0.10c	0.54±0.01b	5.68±0.15d	56.13±1.16d
200 mM	22.88±0.81e	29.47±1.14a	1.14±0.05c	0.51±0.04b	4.32±0.10e	70.28±0.55e

Each value is the mean of five replicates ± S.E. Means with common letters are not significantly difference at $p<0.05$.

3. Results and discussion

Salinity significantly reduced shoot height of KBG and TF (Table 1). Likewise, the root length decreased significantly with increasing salinity for KBG, but nosignificant change occurred in TF. Shoot and root dry weights of the two species decreased significantly as salinity increased. However, the difference between the both species was apparent. The reduction in KBG was more significant than that in TF. For example, in comparison to the control, Root dry weights of KBG grown in 100, 150 and 200 mM NaCl were reduced by 39.5, 61.8 and 80.3% respectively. However, the root dry weights of TF were reduced by 14.5, 21.7 and 26.1%.Turf quality declined as salinity concentration increased for both species (Table 1). TF had higher turf quality than KBG. Turf quality was significantly decreased for KBG with increasing salinity and dropped to 3.88 at 100 mM. However, TF maintained a minimal acceptable quality (5.68) even at 150mM NaCl. Leaf firing percentage of both species increased with increasing salinity, reaching 52% for KBG and 28% for TF at 100mM NaCl (Table 1). Leaf firing for KBG was dramatically higher than that for TF at the same salinity concentrations.

Growth parameters, such as shoot growth, root mass and root length and turfgrass quality have been reported to be excellent criteria to determine salinity tolerance among turfgrass (Alshammary et al 2004). In our study, increasing salinity levels had little effect on root length and root dry weight of TF. The extensive system of TF may be an adaptive mechanism enabling the plant to increase water uptake under salt stress. The shoot growth of KBG was inhibited more severely than that of TF. The shoot growth reduction may result in reduced photosynthetic surface area and eventually in limited supply of assimilates. Once the rate of leaf death equaled the rate of new leaf expansion, continued growth would cease ((Munns and Termaat 1986). Therefore, KBG exhibited the worse turf quality and higher leaf firing percentage than TF. Based on the data on growth parameters, TF exhibited the better salinity tolerance than KBG.

The ionic content of the two species is shown in Table 2 and 3. In both species, the content of Na^+ in the shoot and root increased significantly with increasing concentrations of NaCl. KBG accumulated significantly higher Na^+ levels in the shoot and root than TF. And Na^+ content in both species was higher in roots than in the shoot. The different effect of salinity on the K^+ content between the species was apparent. The K^+ content decreased linearly in shoot and root of KBG under salinity, whereas there was no significant difference in the shoot and root of TF. Compared with control, the Ca^{2+} and Mg^{2+} content in the shoot of both species and in the root of KBG decreased with the increase in salinity concentration. However, Ca^{2+} content in the root of TF remained approximately constant and Mg^{2+} content slightly increased with increase in salinity. Cl^- content in the shoot and root of KBG increased significantly with increasing salinity concentration. However, TF accumulated less Cl^- than KBG under saline condition. Salinity decreased the NO_3^- content in shoot and root

Table 2. Effects of salt stress on ionic content (mg/g DW) in Kentucky bluegrass (KBG) and Tall fescue (TF)

NaCl	Shoot Na^+	Shoot K^+	Shoot Ca^{2+}	Shoot Mg^{2+}	Shoot Cl^-	Shoot NO_3^-
KBG						
0 mM	0.85±0.17a	33.30±0.90a	5.59±0.13a	4.06±0.33a	19.65±0.82a	2.74±0.11a
50mM	8.62±0.91b	26.53±0.51b	4.74±0.06b	3.71±0.09a	23.38±0.76a	2.27±0.28ab
100 mM	17.56±0.41c	24.41±0.54c	4.23±1.00c	2.96±0.11b	39.05±0.82b	1.69±0.27bc
150 mM	24.00±0.85d	18.45±0.75d	4.13±0.16c	3.19±0.17b	45.35±3.04c	1.42±0.12c
200 mM	34.24±1.14e	17.64±0.43d	3.62±0.21d	3.04±0.07b	46.89±2.90c	1.56±0.06c
TF						
0 mM	0.70±0.14a	3.86±2.61a	5.97±0.33a	4.32±0.10a	14.82±0.74a	1.68±0.33a
50 mM	5.21±1.72b	42.14±3.15ab	4.90±0.2abc	3.34±0.26b	35.30±0.39b	1.63±0.49a
100 mM	13.55±1.68c	32.59±0.16c	5.38±0.82ab	4.00±0.32a	37.36±0.39b	1.75±0.53a
150 mM	14.22±0.65c	36.95±1.40bc	4.10±0.16bc	3.31±0.10b	38.89±2.47b	2.72±0.43ab
200 mM	15.40±0.85c	40.15±2.01ab	3.63±0.05c	2.83±0.13b	36.80±1.57b	3.65±0.27b

Each value is the mean of six replicates ± S.E. Means with common letters are not significantly difference at $p<0.05$.

Table 3. Effects of salt stress on ionic content (mg/g DW) in Kentucky bluegrass (KBG) and Tall fescue (TF)

NaCl	Root Na^+	Root K^+	Root Ca^{2+}	Root Mg^{2+}	Root Cl^-	Root NO_3^-
KBG						
0 mM	1.31±0.15a	34.42±1.70a	2.76±0.19ab	1.80±0.15a	18.87 ±0.35a	1.87±0.09a
50mM	22.12±0.91b	22.23±0.57b	2.92±0.09a	1.52±0.09ab	41.04 ±1.25b	1.63±0.58a
100 mM	29.63±1.26c	24.03±1.11b	2.53±0.48ab	1.61±0.10ab	50.51 ± 3.22c	1.94±0.24a
150 mM	32.56±0.96c	21.31±1.14b	2.45±0.47ab	1.42±0.07bc	54.95 ± 2.91c	1.09±0.26a
200 mM	39.87±2.12d	14.03±0.26c	1.84±0.05b	1.19±0.02c	52.36 ± 0.97c	1.34±0.12a
TF						
0 mM	5.51±0.17a	38.87±2.06a	2.65±0.04a	1.07±0.07a	22.71 ±0.29a	2.23 ±0.31a
50mM	16.27±0.65b	35.85±0.88a	3.14±0.16a	1.07±0.11a	33.70±0.58ab	2.90 ±0.59a
100 mM	28.08±0.59d	29.69±0.72b	2.58±0.33a	1.39±0.08b	31.50 ±1.03a	2.46 ±0.35a
150 mM	21.28±1.19c	30.14±0.36b	2.58±0.06a	1.17±0.07ab	45.14 ±5.48b	2.66 ±0.58a
200 mM	18.61±1.41bc	31.85±0.88b	2.61±0.42a	1.27±0.12ab	44.80 ± 6.82b	3.10 ±0.59a

Each value is the mean of six replicates ± S.E. Means with common letters are not significantly difference at $p<0.05$.

of KBG, and a significant reduction in shoot was observed. However, the NO_3^- content in the shoot and root of TF increased with increasing salinity.

KBG accumulated a larger amount of Na^+ and Cl^- ions in shoot and root than TF which resulted in a remarkable reduction of K^+, Ca^{2+}, Mg^{2+} and NO_3^- in KBG. In both species Na^+ and Cl^- accumulation were greater in root than in shoot which indicated that both species had the ability to prevent Na^+ entry to the shoot. However, the process was more efficient in TF than in KBG according to the ratio of Na^+ concentrations in the shoot and root. The significantly decrease of K^+ content resulted in an increase in the Na^+/K^+ ratio for both shoot and root of KBG. Tester and Davenport (2003) pointed out that high Na^+/K^+ ratio could disrupt protein synthesis in the cell. Under saline conditions, Cl^- competes with anions, such as NO_3^-, and depresss NO_3^- uptake, which may cause ion imbalance (Hu et al. 2005). Form our result, the Na^+ and Cl^- caused toxicity and the nutrient imbalance in KBG was more

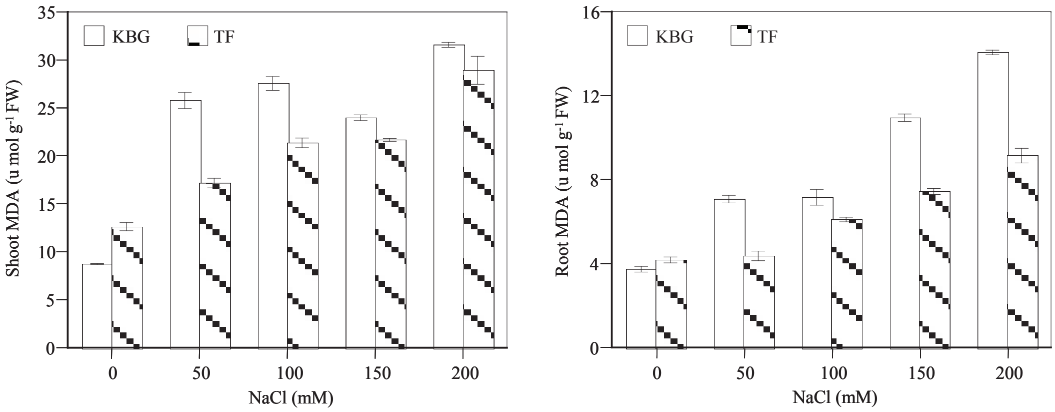

Figure 1. Effects of NaCl concentration on malonyldialdehyde (MDA) concentrations (umol g^{-1}FW) in the shoot and root of Kentucky bluegrass (KBG) and Tall fescue (TF). Values are the mean±standard error (n=3).

significant than that in TF. Regulation of transport and distribution of ions in various plant parts and within cells is an important feature of mechanism of salt tolerance (Greenway and Munns 1980). Therefore, TF had the better ability to maintain the nutrition balance than that of KBG under salt condition.

Lipid peroxidation levels in both turfgrass species, measured as the content of MDA, are given in Fig. 1. The MDA content of the two cool-season turfgrass increased significantly with increasing concentrations of NaCl. However, The MDA accumulation of shoot and root in KBG was higher than that in TF under salinity treatment. On the other hand, MDA accumulation in the shoot of both species was significantly higher than that found in root. The content of MDA, a product of lipid peroxidation, is considered as a reliable indicator of the oxidative stress resulting from several abiotic constraints (Hernandez et al. 2001). The significant increase in MDA concentration in KBG with increasing NaCl concentration, compared to the lower MDA concentration in TF under the same conditions suggests that the latter is better protected against oxidative damage under salt stress. The improved protection in TF may reflect a more efficient antioxidative system as evidenced by a higher activity of antioxidant enzymes (Fig. 2 and Fig. 3).

SOD and CAT activities in the shoot of both species declined dramatically to below the control level with increasing concentrations of NaCl (Fig. 2). SOD and CAT activities in the root of KBG plants was not affected by salt treatment. However, the SOD and CAT activities in the root of TF increased with increasing NaCl concentration. The SOD and CAT activities of TF were higher than that of KBG. The GR activities of KBG and TF exhibited similar trend as SOD and CAT (Fig. 3). TF maintained the higher APX activity level than KBG. On the contrary, the APX activity in the root of KBG was significantly higher than that of TF at the same salinity treatment even through the activity decreased with increasing salinity. Recent studies showed that salt tolerance is closely related to the efficiency of antioxidant enzymes (Muscolo et al. 2003 and Shalata et al. 2001). Besides the GR activity in the shoot of KBG at the higher NaCl concentrations and the APX activity in the root of KBG, our results showed that TF exhibited higher antioxidant enzyme activities than KBG under salt stress. Significant increase in MDA level in shoot of both species appeared to be correlated with a decrease in activities of antioxidant enzymes. However, the higher antioxidant enzyme system in the root of TF might have important role in imparting tolerance in salt stress conditions. These results are in good agreement with those of Shalata et al. (2001) who found that SOD and CAT activities decreased in roots of salt-sensitive plants but increased in roots of salt-tolerant plants under salt stress.

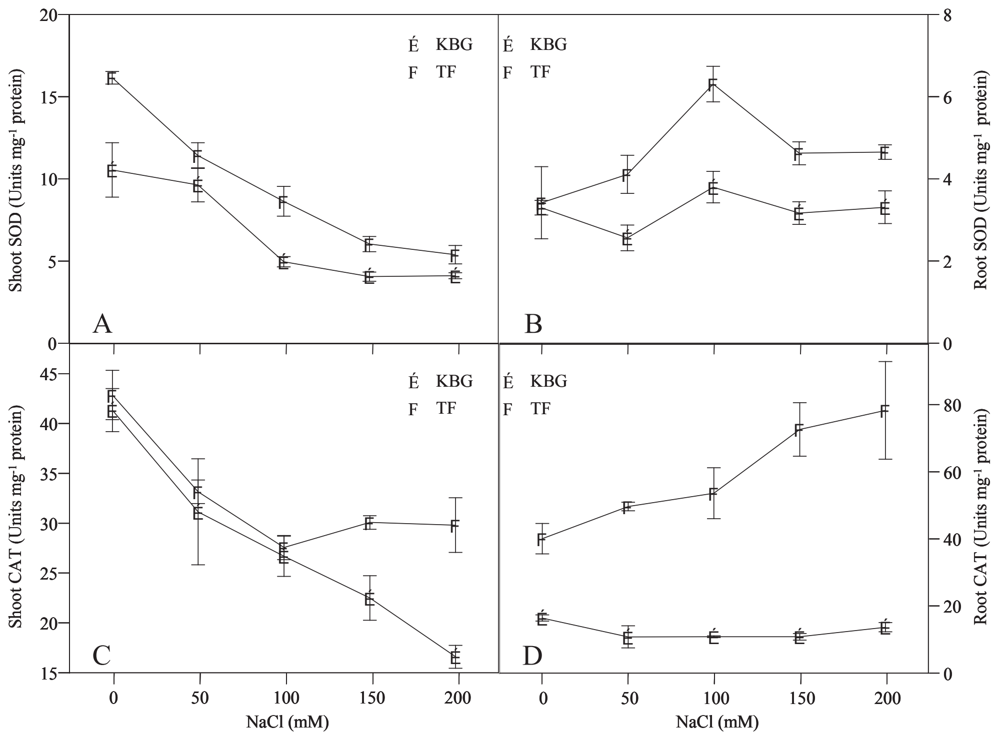

Figure 2. Effect of NaCl concentration on (A) shoot SOD, (B) root SOD, (C) shoot CAT and (D) root CAT activities of Kentucky bluegrass (KBG) and Tall fescue (TF). Values are the mean±standard error (n=3).

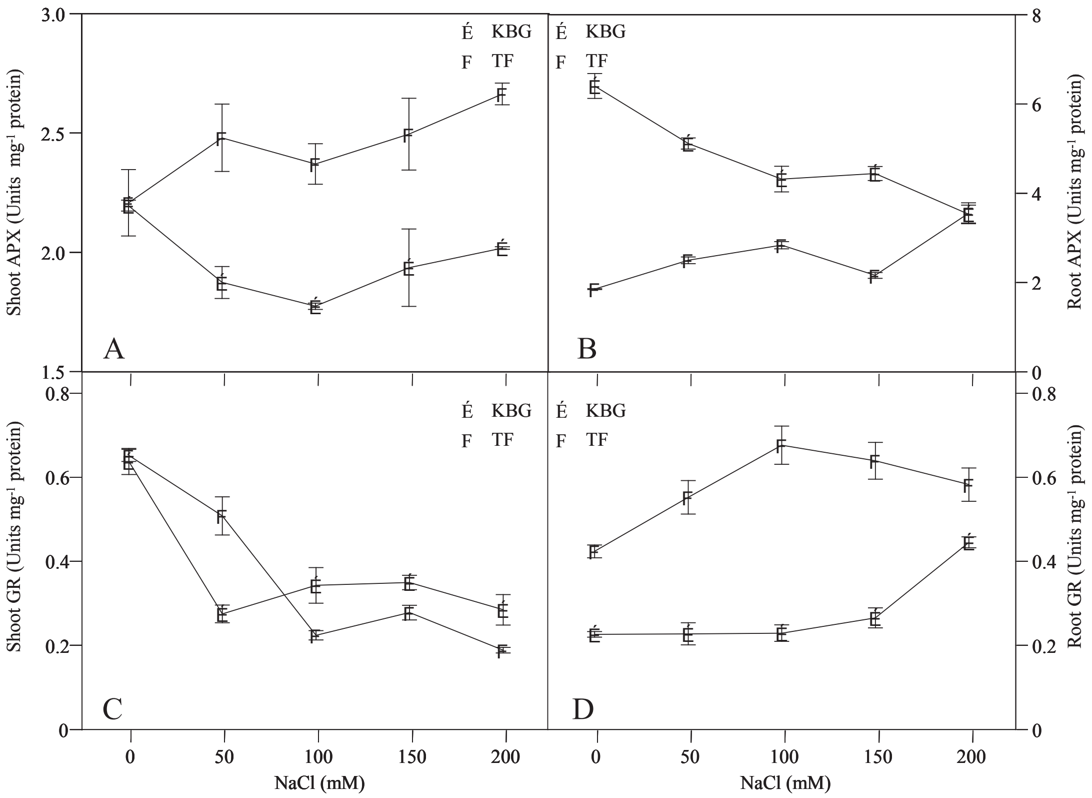

Figure 3. Effect of NaCl concentration on (A) shoot APX, (B) root APX, (C) shoot GR and (D) root GR activities of Kentucky bluegrass (KBG) and Tall fescue (TF). Values are the mean ± standard error (n=3).

In conclusion, the results from the present study showed that the physiological and growth responses could account for the different salt tolerant ability of both turfgrass species. Tall fescue, a moderately-salt tolerant species, exhibits a better salt-tolerant ability by inhibiting the accumulation of Na^+ and Cl^- to keep ion balance, maintaining higher antioxidant enzymes activities against oxidative damage, than Kentucky bluegrass, a salt-sensitive species.

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6.3. Nitrogen metabolism in halophytes: Study on Swiss chard

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Abstract

In this study on Swiss chard (*Beta vulgaris* var. cicla) the effects of NaCl on nitrate reductase (NR) and glutamine dehydrogenase (GS) activity, which are related to nitrogen metabolism and photosynthesis, were investigated. Three NaCl concentrations (0, 10, 100 mM) and three nitrogen forms (NO_3-N, NH_4NO_3-N, and NH_4-N) were combined and Swiss chard was grown under 9 treatment combinations. Seedlings were transplanted to nutrient solution and were cultivated for 15 days. Treatments were then started and lasted for 6 days. Activities of NR and GS and photosynthetic rate were measured at 1, 6 hours and 1, 6 days after the start of treatments. Swiss chard showed good growth with NO_3-N and NH_4NO_3 under salinity conditions. Nitrogen absorption was also higher with NO_3-N and NH_4NO_3 under salinity conditions. Photosynthetic rate was low at 2-6 hour in NaCl 100mM + NO_3-N but it recovered at 1 day. At 6 days, photosynthetic rate was significantly lower with NH_4-N under both NaCl and NaCl free conditions. NR activity and GS activity tended to be high under NaCl conditions. These results suggest that NaCl stimulates the activity of nitrogen assimilation enzymes. Consequently, the growth of Swiss chard was enhanced under salinity condition. As Swiss chard showed good growth under salinity condition, it can be classified as a halophyte.

1. Introduction

Most of glycophytes utilize NO_3-N as nitrogen source. However, under saline conditions N absorption is inhibited because of antagonism between Cl^- and NO_3^- ions. Consequently, plant growth suffers. Inhibition of NO_3^- uptake by Cl^- has been reported in many plant species: barley (Helal et al. 1975; Aslam et al. 1984; Ward et al. 1986; Klobus et al. 1988), cotton (Silberbush and Ben-Asher 1987), tomato (Kafkafi et al. 1982), melon (Feigin et al. 1987) and wheat (Torres and Bingham 1973; Balasubramanian and Sarin 1975). On the other hand, the halophytes grow healthily in coastal marshes under high salt environments.

Swiss chard (*Beta vulgaris*) is a plant that showed good growth under moderate salt condition in our former experiment. Therefore, we proposed a hypothesis that its good growth under saline conditions is closely related to the activated nitrogen metabolism. We studied the effect of NaCl and different forms of nitrogen in the medium on activity of nitrate reductase (NR) and glutamine dehydrogenase (GS), which are involved in the primary stage of nitrogen assimilation in the plants.

2. Materials and methods

2.1. Cultivation and treatments

Seeds of Swiss chard (*Beta vulgaris* var. cicla) were germinated with distilled water in a container filled with vermiculite in a greenhouse. Seedlings were irrigated with tap water everyday. When the fourth leaf appeared, they were transplanted to 4 L plastic pots (4 plants per pot) and cultivated hydroponically with nutrient solution for 2 weeks. The nutrient solution consisted of 2 mM KCl, 1 mM $CaCl_2 \cdot 2H_2O$, 2 mM $MgSO_4 \cdot 7H_2O$, 0.4 mM $NaH_2PO_4 \cdot 2H_2O$, 1 mM NH_4NO_3, 0.5 ppm $MnSO_4 \cdot 5H_2O$, 0.005 ppm $(NH_4)_5Mo_7O_{24} \cdot 4H_2O$, 0.2 ppm H_3BO_3, 0.1 ppm $ZnSO_4 \cdot 7H_2O$, 0.01 ppm $CuSO_4 \cdot 5H_2O$ and 0.015 ppm Fe-EDTA. Five days before starting the differential treatments, NaCl 10 mM was added to every pot to get the plants acclimated to salt. Three levels of NaCl concentration (0, 10, 100 mM) and three forms of N (NO_3-N, NH_4 &NO_3, NH_4-N) were combined and Swiss chard was grown under 9 treatment combinations (Table 1). Treatment exposure lasted for 6 days.

Table 1. The outline of treatments

N-source		Na (mM)								
		0			10			100		
NO_3	(mM)	0	2	4	0	2	4	0	2	4
NH_4		4	2	0	4	2	0	4	2	0
Treatment No.		1	2	3	4	5	6	7	8	9

2.2. Growth measurement and chemical analysis

The plants were harvested 6 day after treatments, divided into shoots and roots, then rinsed with deionized water. After fresh weight (FW) was recorded, samples were dried at 70^0 C for 48 h in an oven and their dry weight (DW) was recorded. Dried material was finely ground and digested by sulfuric acid and hydrogen peroxide to allow measurement of minerals and nitrogen. Content of Na and K was measured by flame photometry and that of Ca and Mg was measured by atomic absorption spectrophotometry (Hitachi Z6100 Polarization Zeeman Atomic Absorption Spectrophotometer). N content was measured by Nessler's method (Han and. Golterman 2004) using a spectrophotometer.

2.3. Activities of enzymes

The youngest and fully expanded leaves were harvested at 2h, 6h, 1d and 6day after treatments and instantly frozen in liquid N for 1 min, then stored at -30^0 C for enzyme activity assay. About 0.5 g sample of leaves was homogenized with 3 mL of 50 mM potassium phosphate, pH 7.8, containing 5 mM EDTA and 5 mM L-cysteine. After the homogenate was centrifuged at 18000 *g* for 20 min, the supernatants were used to determine the activities of enzymes (Cruz et al. 1970; Alvim et al. 2001; Xu and Zhou 2006). The activity of nitrate reductase (NR, EC 1.6.6.1) was determined according to the procedure of Baki et al. (2000) and Xu and Zhou (2006). The activity of glutamine dehydrogenase (GS, EC 6.3.1.2) was determined according to the procedure of Rhodes (1975).

2.4. Photosynthetic rate

The net photosynthetic rate was measured using a portable photosynthesis system (LI-6400P, Li-Cor, Inc., Lincoln, NE, USA) under ambient temperature and 1000 µmol m^{-2} s^{-1} quantum flux. Readings were terminated after 30 s.

3. Results and discussion

The N source and NaCl concentration in medium affected the plant growth. Shoot dry weight (DW) of plants fed NO_3-N under 10 mM NaCl was the highest, and that of plants fed NO_3-N were better in growth than those fed other N source, independent of NaCl concentration in mediums (Fig. 1). These results indicate that Swiss chard requires moderate NaCl to stimulate growth and nitrate is appropriate source for it.

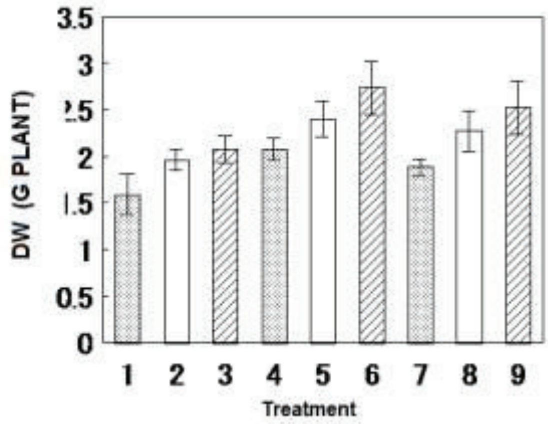

Figure 1. Shoot dry weight (DW) of Swiss chard. Dotted bars (1, 4, 7), White bars (2, 5, 8) and hatched bars (3, 6, 9) respectively indicate NO_3, NH_4NO_3 and NH_4 as nitrogen treatments.

Under NaCl free condition, the content of cations (except Na) was highest with NO_3 and lowest with NH_4 (Table 2). These trends are similar to those for the DW under NaCl free conditions. Total nitrogen content under NaCl-free condition also showed similar trend. There was a significant correlation between DW and total nitrogen content under NaCl-free condition (treatment 1-3) ($r=0.997$, $p<0.05$). Total nitrogen content (Fig. 2) tended to be

Table 2. The concentration of elements in the shoot of Swiss chard. The unit for measurement was mg g^{-1} DW.

		Treatment	K		Na		Ca		Mg	
Na (mM)	0	1	44.48	bc	12.50	d	2.06	d	6.45	b
		2	58.12	b	13.45	d	3.69	b	8.00	b
		3	71.48	a	17.95	d	4.98	a	10.33	a
	10	4	49.87	bc	23.11	cd	2.25	d	8.06	b
		5	58.78	b	24.99	cd	3.22	bc	7.82	b
		6	49.86	bc	31.88	c	3.37	b	8.16	b
	100	7	34.35	c	67.49	a	2.52	cd	7.10	b
		8	45.48	bc	49.33	b	1.98	d	7.11	b
		9	44.74	bc	63.13	a	1.74	d	6.48	b

higher in NH_4NO_3 site in the presence of NaCl. There was no significant correlation between DW and total nitrogen in the presence of NaCl (treatment 4-9). These results indicate that nitrogen absorption was a limiting factor for growth under NaCl-free condition, while it could be presumed that something other than nutrient absorption may be responsible for DW increment in presence of NaCl.

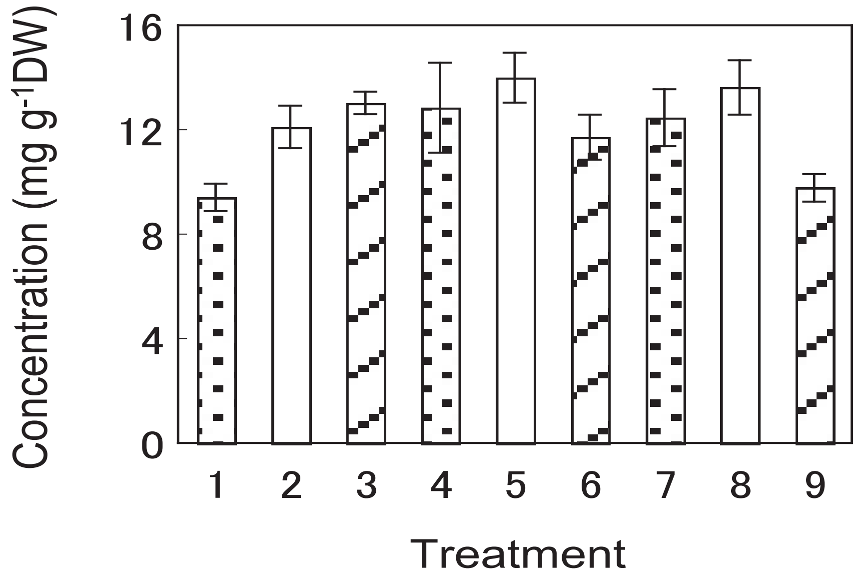

Figure 2. Total nitrogen concentration in the shoot of Swiss chard. Dotted bars (1, 4, 7), White bars (2, 5, 8) and shaded bars (3, 6, 9) respectively indicate NO_3, NH_4NO_3 and NH_4 as nitrogen treatments.

The activity of nitrate reductase (NR), the first enzyme in the NO_3^- reduction and assimilation pathway, has shown contradictory behaviour in different plant species in response to salt stress (Bourgeais-Chailou et al. 1992; Crarmer and Lips 1995; Ehlting 2007). However, there are few reports about relationship between nitrogen assimilation and salt in halophytes. Swiss chard was used in this study because of its short growth period and
because it showed good growth in the presence of moderate salt in former study. NR activity

Different letters indicate the significant differences ($P < 0.05$) among treatments.

showed higher level at 10 mM NaCl irrespective of the form of nitrogen available to the plant (Fig. 3). NR activity deteriorated temporarily at 0 and 100 mM NaCl levels, 2h after treatment. The temporal deterioration was restored by 6h after treatment. Glutamine dehydrogenase (GS) activity showed higher level at 0 mM NaCl just after treatment and in the presence of NaCl after 6h of treatment (Fig. 4).

The photosynthesis rate from just after the treatment to 1d tended to remain at lower level in the presence of NaCl, except when NH_4 was the source of N (Fig. 5). There after, photosynthesis rate in NO_3 and NH_4NO_3 treatments showed higher level in presence of NaCl at 1 to 6d after treatment. Photosynthesis rate decreased temporarily, especially in 100 mM NaCl treatment, at 6h after treatment. This might be because of the deterioration of NR.

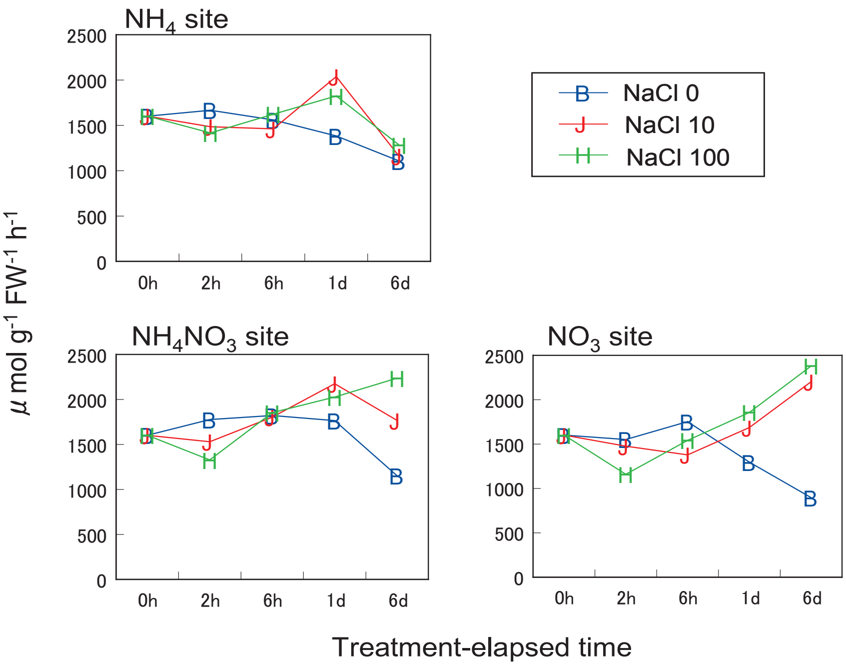

Figure 3. Temporal changes of nitrate reductase activity. Blue, red and green respectively indicate 0, 10 and 100 mM NaCl in the medium.

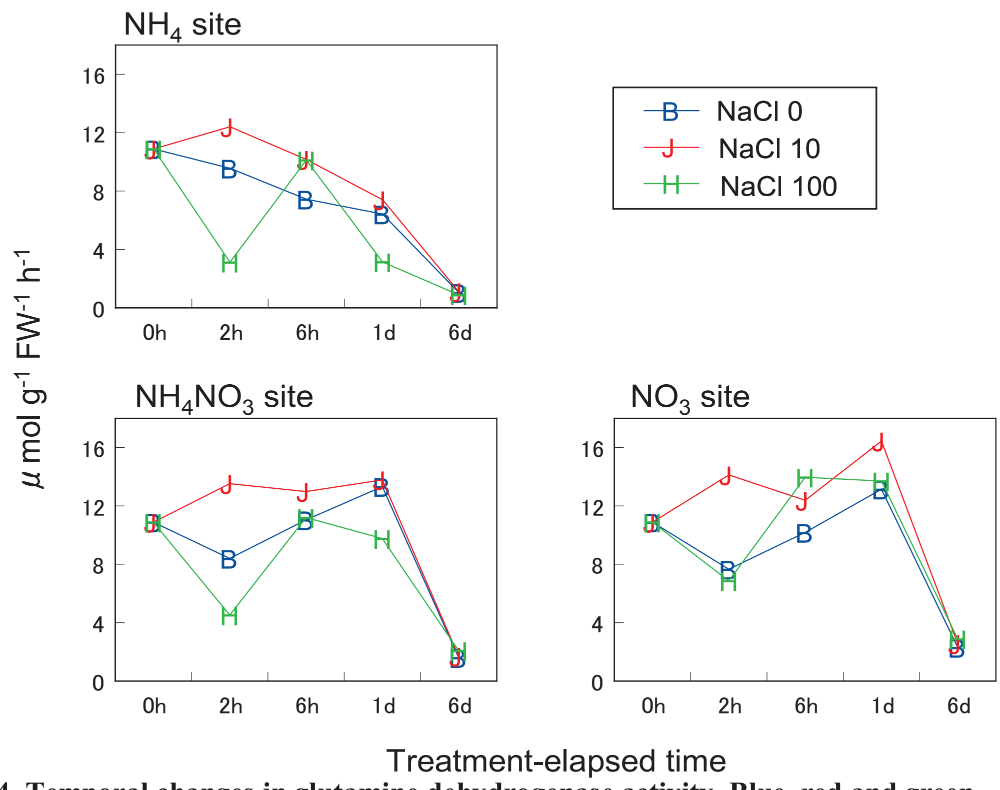

Figure 4. Temporal changes in glutamine dehydrogenase activity. Blue, red and green respectively i ndicate 0, 10 and 100 mM NaCl in the medium

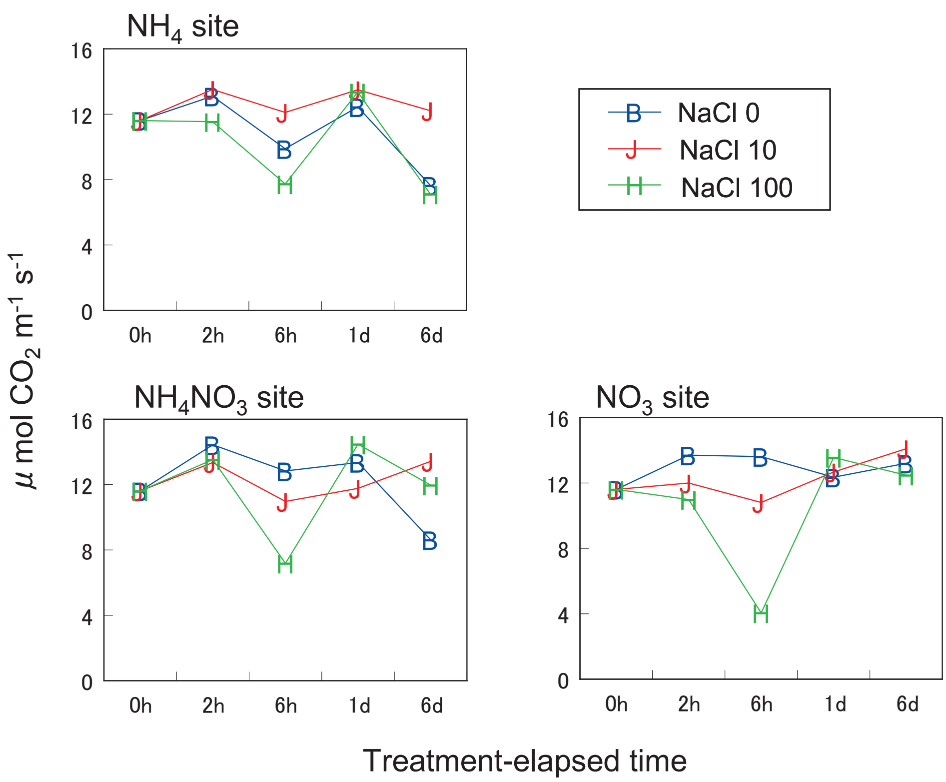

Figure 5. Temporal changes in photosynthesis rate. Blue, red and green respectively indicate 0, 10 and 100 mM NaCl in the medium

In summary, when Swiss chard was grown without salt, plant fed NO_3 showed the best growth and NH_4 nutrition was not appropriate. Growth was limited mainly by nitrogen absorption because of significant correlationip between N and DW. Absorption of cations also affected DW because of correlation between cations and DW. When Swiss chard was grown with salt, it showed the best growth with NO_3 treatment with 10 mM NaCl and the growth was greater than that in NaCl-free condition. The good growth in the presence of NaCl is not related to the absorption of N and cations, but to N assimilation. Nitrogen assimilation enzymes (e.g. NR and GS) are stimulated by NaCl and they affected photosynthesis.

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6.4. Identification of silicon regulated genes under drought or salt stress

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Abstract

Silicon (Si) is the second most abundant element on the surface of the earth and in soils. The beneficial effects of Si on enhancing plant ability to tolerate and overcome multiple environmental stresses are generally recognized. To clarify the role of Si on plants tolerance to environmental stresses, we used Suppression Subtractive Hybridization (SSH) approach to identify candidate genes regulated by Si under salt or drought stress from cucumber (*Cucumis sativus* L.). A subtracted cDNA library was constructed using mRNA isolated from roots and leaves of plants grown with or without added Si under drought or salt stress. Differentially expressed clones due to added Si were further confirmed by differential screening using forward and reverse subtracted probes. A new aquaporin belonging to the plasma membrane intrinsic protein (PIP) subgroup and a calcium binding protein genes were among twenty clones found to be regulated by Si addition under drought or salt stress. These results suggest that the beneficial effect of silicon on enhancing plant stress tolerance might be due to the involvement of Si in inducing these genes under stressing environments.

1. Introduction

Silicon (Si) is the second only to oxygen in abundance as a soil constituent. The direct source of Si in soil solution that plant roots draw upon is H_4SiO_4 over the physiological range of pH values, at concentration normally ranging from 0.1 mM to 0.6 mM (Epstein 1999). After uptake by plants Si accumulates on the epidermis of various tissues mainly as a polymer of hydrated amorphous silica (Ma 2004). Silicon content in plant tissues varies considerably with species, ranging from 0.1 to 10% on a dry weight basis (Ma 2004; Ma and Takeshi 2002).

Silicon is extensively reported to have beneficial effects on plant growth. These beneficial effects include increased photosynthesis activity, correction of nutrient imbalance, increased insect and disease resistance (Ma 2004), increased drought tolerance (Agarie et al. 1998; Ma et al. 2001; Hattori et al. 2001, 2005; Gong et al. 2003), reduced mineral toxicity (Williams and Vlamis 1957*a,b*; Horiguchi and Morita 1987) and salinity stress (Liang et al. 1996, 2007; Yeo et al. 1999). Silicon beneficial effects vary according to plants species, usually more clear in plants with higher capacities to accumulate Si (Si accumulators), and expressed more clearly when plants are subjected to biotic or abiotic stresses (Ma 2004). Si application is known to affect the activities of several enzymes including H^+-ATPase and superoxide dismutase in barley (*Hordeum vulgare* L.) (Liang 1999), ascorbate peroxidase, dehydroascorbate reductase and glutathione reductase in cucumber (*Cucumis sativus* L.) (Zhu et al. 2004). The beneficial effects of Si on alleviating salt stress in a number of plant species including rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), barley, cucumber and tomato (*Lycopersicum esculentum* L.) have been demonstrated (Liang et al. 2007). Sodium concentration in shoots of rice (Yeo et al. 1999) and barley (Liang et al. 1996, 1999) was decreased by addition of Si which was attributed to Si-induced reduction in transpiration rate (Matoh et al. 1986) and to the partial blockage of the transpirational bypass flow (Yeo et al. 1999). Furthermore, the increased uptake and transport of K^+ and decreased uptake and transport of Na^+ from roots to shoots in barley was thought to be attributable to Si-induced stimulation of the root plasma membrane H^+-ATPase under salt stress (Liang et al. 2007).

Cereal crops supplied with Si retain a higher leaf water potential under water stress conditions than non-supplied crops (Hattori et al. 2005). Gong et al. (2005) reported that Si alleviates oxidative damage of wheat plants in pots under drought. Silicon could decrease the transpiration rate and membrane permeability of rice under water deficit induced by polyethylene glycol (Agarie et al. 1998). In sorghum (*Sorghum bicolor* Moench), plants grown in pots applied with silicon had higher relative water content and dry materials (Hattori et al. 2001). Wheat plants applied with silicon could maintained better water status and higher content of dry materials compared with non-silicon treatment under drought (Gong et al. 2003). Alleviation of heavy metal toxicity by Si addition is well reported. Si alleviated Mn toxicity in barley, cucumber (Liang et al. 2007) and rice (Ma and Takahashi 2002). Alleviation of Al toxicity by Si in sorghum, barley, teosinte (*Zea mays* L. ssp. Mexicana), tomato and soybean (*Glycine max* L.) has been reported (Hodson and Evans 1995; Liang et al. 2007). Many reports have showed that Si alleviated physical stress caused by radiation, low and high temperatures, wind, waterlogging and low and high lightintensity (Ma 2004).

Despite the apparent beneficial role of Si in plant growth, health and development, the role of Si in plant biology has been poorly understood (Epsteine 1994; Lewin and Reimann 1969). Although Si is suggested to be actively involved in the metabolic and/or physiological activities, especially in plants subjected to multiple stresses (Liang et al. 2007), attempts to relate Si with plant metabolic or physiological activities under stress environments remain inconclusive. In this study we attempted to identify genes induced by Si under stressing conditions which might directly be involved in plant stress tolerance.

2. Material and methods

2.1. Plant materials

Seeds of cucumber (*Cucumis sativus* L.) were rinsed thoroughly with distilled water, and germinated on moist filter paper in an incubator at 28 °C for 20 hours in the dark then placed between sheets of moist filter paper to allow roots to elongate vertically under the same conditions. Seedlings were transplanted into plastic containers for hydroponic culture in a growth chamber under natural light conditions at 25-28 °C and 50-60 % humidity. The hydroponic culture consisted of a continuously aerated ¼ strength Hoagland nutrient solution. The pH of the nutrient solution was adjusted to 6.0 daily using 0.1 M KOH and/or H_2SO_4. The nutrient solution was renewed every two days.

2.2. Stress treatments

Sodium chloride (NaCl) was used to create two salt-stress treatments with 100 ppm silicon added to the first (+Si and 50 mM NaCl) but not the second (-Si and 50 mM NaCl). Polyethylene glycol (PEG) was used to create two drought stress treatments with 100 ppm silicon added to the first (+Si and PEG 13% w/v) but not to the second (-Si and PEG 13% w/v). Si was added as potassium silicate (K_2SiO_3) to the nutrient solution. The additional K due to K_2SiO_3 was subtracted from KNO_3 and the loss in the nitrate concentration was supplemented with a diluted nitric acid. The pH was re-adjusted to 6.0 using H_2SO_4.

2.3. Construction of subtracted cDNA library

Leaf tissues (0.1g) from of cucumber plants from each treatment were used to isolate total RNA using TRIzol (Invitrogen) according to manufacturer's instructions. Poly $(A)^+$ RNA was purified from the total RNA by the Oligotex^{TM}-dT 30 super kit (Roche) according to manufacturer's instructions. Suppression subtractive hybridization (SSH) (Diatchenko et al. 1996) was performed with PCR-Select cDNA Subtraction kit (Clontech) to identify genes that are differentially expressed due to silicon addition under salt or drought stress. The mRNA purified from Si-applied stress treatments (+Si) was used to prepare the tester cDNA while mRNA purified from control stress treatment (-Si) was used to prepare the driver cDNA according to manufacturer's instructions. Both cDNAs were digested with *Rsa* I then the tester cDNA was divided into two portions, and each was ligated to a different cDNA adaptor (adaptor 1 or 2R) provided by the manufacturer. A portion of *Rsa* I-digested driver cDNA was hybridized to each adaptor-ligated tester cDNA and a second hybridization was carried to allow single strand cDNAs from the first hybridization to form new hybrid molecules which consisted of the differentially expressed sequences. Enrichment of the differentially expressed sequences was carried by a primary PCR using Go Taq® Green Master Mix (Promega) and PCR Primer 1 (5'-CTAATACGACTCACTATAGGGC-3') while the background was reduced by a secondary PCR using Nested PCR primer 1 (5'-TCGAGCGGCCGCCCGGGCAGGT-3') and Nested PCR primer 2R (5'-AGCGTGGTCGCGGCCGAGGT-3') supplied by the manufacturer.

2.4. Cloning Secondary PCR into T/A cloning vector

The secondary PCR product was cloned into pCR 2.1-Topo T/A cloning vector (TOPO TA Cloning®, Invitrogen) according to manufacturer's instructions. Positive colonies were picked randomly for plasmid extraction.

2.5. Confirmation of differentially expressed sequences

The PCR-Select Differential Screening Kit (Clontech) was used to further confirm the differential expression of positive clones and to eliminate sequences common to both the tester (+Si) and driver (-Si) according to manufacture instructions with some modifications. cDNAs of the positive clones from the forward subtraction were amplified by PCR using Nested primers, denatured and blotted into nylon membranes (Hybond TM-N^+, Amersham, UK). Forward-subtracted and reverse-subtracted probes were prepared using PCR DIG Probe Synthesis Kit (Roche, Applied science). Membranes were hybridized using hybridization buffer (DIG Easy Hyb, Roche, Applied science, Germany). Detection of hybridized DIG labeled probe to target hybrids was conducted using DIG Luminescent Detection kit (Roche, Applied science, Germany) according to manufacturer's instructions. The membranes were exposed to X-Ray film to develop the hybridization signals.

2.6. Sequencing differentially expressed sequences

Plasmid DNA was isolated from positive clones which were confirmed to be differentially expressed. M13 Forward or M13 Reverse universal primers supplied by the manufacturer along with TOPO TA Cloning® kit (Invitrogen) were used to sequence the inserts using Big Dye Terminator Cycle Sequencing kit (Applied Biosystems). The NCBI/BLAST online program (http://www.ncbi.nlm.nih.gov) was used to search the nucleotide sequence homology.

3. Results

3.1. Identification of differentially expressed sequences by SSH

Suppression subtractive hybridization which is based on suppressive PCR that selectively amplifies differentially expressed cDNAs and suppresses amplification of non-target cDNAs (Diatchenko et al 1996) was used to identify genes induced by Si in cucumber plants under drought or salt stresses in contrast to plants subjected to same stresses but without added Si. The subtracted PCR product (Fig. 1) was cloned into Topo cloning vector and inserts were amplified by PCR from positive clones.

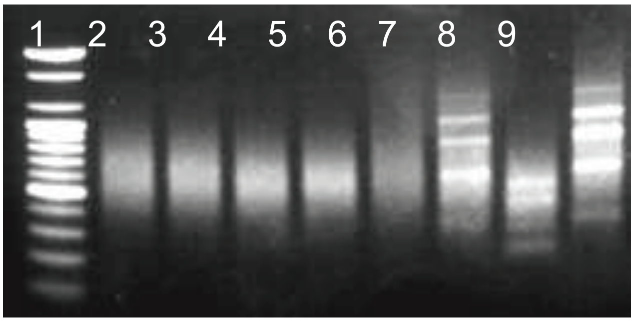

Figure 1. Secondary PCR product. Lane 1: Marker; lane 2, forward subtracted experimental cDNA; 3, unsubtracted tester control; 4, reverse subtracted experimental cDNA; 5, unsubtracted tester control for the reverse subtraction; 6, unsubtracted tester control for the control subtraction; 7, subtracted control skeletal muscle cDNA; 8, unsubtracted skeletal muscle; 9, PCR control subtracted cDNA.

3.2. Confirmation of differential expression of identified clones

Since the subtracted cDNA library might still contain some cDNAs that are common to both the tester and driver samples, differential screening for the cDNA library using forward-subtracted probe and reverse-subtracted probe was performed. Twenty positive colony harbored inserts are shown to be differentially expressed (Fig.2).

3.3. Sequences and homology

Part of the differentially expressed fragments was sequenced and a homology search was carried in to identify these fragments (Table 1). Of the differentially expressed sequences, a cucumber aquaporin and calcium binding protein were identified.

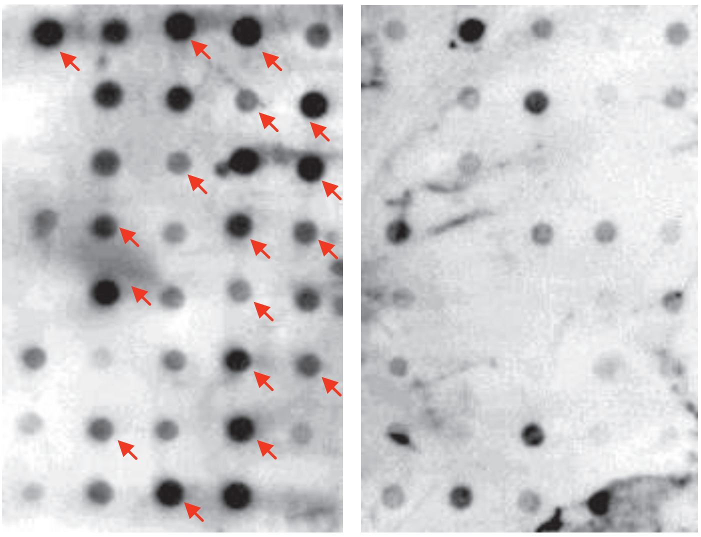

Figure 2. Differential screening of the subtracted fragments. Dot blots of the positive clones were hybridized with cDNA probes made from forward-subtracted cDNA and reverse-subtracted cDNA.

Table 1. Homology search results of the sequenced positive clones. NCBI/BLAST online program was used to search the nucleotide sequence homology

No.	Homology	%
A01	*Nicotiana tabacum* heat shock protein 90 (hsp90)	85
A03	unknown	
B01	*Beta vulgaris* mRNA for Calreticulin (calcium binding protein)	76
B04	unknown	
D02	*Citrullus lanatus* CLMT2 mRNA for type-2 metallothionein	86
D08	*R .communis* mRNA for enolase	82
E03	*Ricinus communis* ATP: pyruvate phosphotransferase	83
L17	*Cucumis sativus* aquaporin mRNA	86
L29	*Cucumis sativus* basic leucine zipper transcription factor CAT103 mRNA	99
L51	*Gossypium hirsutum* beta-tubulin 5 mRNA	85
R15	*Medicago truncatula* pyridoxine biosynthesis protein	82
R49	*Arabidopsis thaliana* GTP-binding protein	83
R111	*Cicer arietinum* mRNA for cytosolic fructose-1,6-bisphosphate aldolase	81
R119	*Lycopersicon esculentum* GDP-mannose pyrophosphorylase	81
S18	*N. tabacum* LHC-I mRNA for photosystem I (light-harvesting chlorophyll a/b-binding protein	77

4. Discussion

To clarify the role of Si on plants ability to tolerate and overcome environmental stresses we used SSH approach to identify stress tolerance candidate genes induced by silicon under salt or drought stress in cucumber (*Cucumis sativus* L.). SSH analysis revealed the presence of twenty putative clones whose expression was affected by Si addition under stressed conditions. Further analysis by differential screening of these clones confirmed their differential expression due to Si applications (Fig. 2). Part of the identified fragments was sequenced and shown to be induced by Si application (Table 1). An aquaporin and a calcium binding protein were identified among twenty clones shown to be differentially expressed due to addition of silicon under drought or salt stress.

Aquaporins, known as water channel proteins, form a large family of membrane channels that facilitate the diffusion of water and small neutral solutes across the cellular membranes of most living organisms (Agre et al. 1998). In plants, aquaporins occur as multiple isoforms and can be subdivided in four subgroups, the tonoplast intrinsic proteins (TIP), plasma membrane intrinsic proteins (PIP), Nodulin26-like intrinsic membrane proteins (NIP) and the small basic intrinsic proteins (SIP). TIP and PIP correspond to aquaporins that are abundantly expressed in the vacuolar and plasma membranes, respectively (Luu and Marurel 2005). Microarray studies in *Arabidopsis*, barley and rice have confirmed that transcription of aquaporin genes shows a remarkable responsiveness to multiple stresses such as cold, drought, high salinity, anoxia, or mineral starvation (Luu and Marurel 2005).

The aquaporin gene isolated in this study (partial sequence) showed 86% similarity to the cucumber aquaporin gene (accession no. EF202176), 74% similarity to *Gossypium hirsutum* PIP1 protein (EF079900) and 74% similarity to *Arabidopsis thaliana* PIP1B (At2g45960). This gene is shown to be differentially expressed in cucumber plants grown under stress conditions with applied Si in comparison to plants grown without added Si, and the homology search predicted that it is a new cucumber PIP isoform. A different up-regulation or down-regulation of aquaporin gene expression has been observed on rice cultivars (Kawasaki et al. 2001) and *Arabidopsis* (Maathuis et al. 2003). Moreover, Jang et al. (2004) observed that Arabidopsis PIP1;1, PIP1;2, and PIP2;3 were up-regulated by salt treatment, whereas PIP1;5 and PIP2;6 were down-regulated and accordingly suggested that differential aquaporin gene expression during salt stress may play role in limiting initial water loss during the salt stress. On the other hand, Si application has been demonstrated to alleviate salt stress in a number of plant species including rice, mesquite, wheat, barley, cucumber and tomato (Liang et al. 2007). Since our gene is showed to be enriched and differentially expressed due to Si application, we suggest that this gene might be induced by Si application under salt or drought stress. Further expression analysis by northern blots and RT-PCR is needed to determine the accurate time course expression of this gene.

Calcium plays a vital role in maintaining membrane stability and permeability (Mengel and Kirkby 1987). Greater Ca^{2+} concentrations in plant tissues might improve crop survival and plant growth under stress conditions (Cachorro et al. 1994). Knight et al. (1997) suggested that osmotic stress can mediate rapid elevations in cytosolic free calcium in *Arabidopsis* seedlings, and that these changes in Ca^{2+} levels may mediate an increase in the expression of drought-induced genes which have protective functions. In this study, we identified a new calcium binding protein gene (partial sequence) from cucumber by the use of SSH. This gene has 78% similarity to *Beta vulgaris* calcium binding protein (AJ002057) and 77% similarity to the *Arabidopsis thaliana* (Calreticulin CRT1). Addition of Si is reported to increase both leaf and root Ca^{2+} and maintain membrane permeability in salt-stressed wheat plants (Tuna et al. 2007). Since the isolated calcium binding gene in this study is shown to be enriched in cucumber plants grown with applied Si under salt or drought stress, we suggest that this gene might be induced by Si application and improved plants' ability to survive these stresses.

Further analysis is needed to determine the accurate time course expression of this gene. The diversity of the genes identified in this study reflect an important finding about the induction effect of silicon on various genes related to plant tolerance to environmental stresses.

Acknowledgment

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6.5. Pathological study on the pulmonary toxicity induced by the intra-tracheally instilled yellow dusts in mice

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Abstract

With global climate change, frequency and volume of yellow dusts (sand), which originates from Gobi desert, are increasing in Japan, resulting in one of the air pollution related threats to both human and animal health. There are, however, few reports on the pathological study of the pulmonary toxicity induced by yellow dusts. In this study, we examined inflammatory changes in the bronchoalveolar lavage fluids (BALF) and lung tissues of mice intra-tracheally instilled with yellow dusts. Distilled water (0.05ml) containing 200µg, 800µg and 3.0 mg of yellow dusts (CJ-1, General Science Corporation, Japan) was intra-tracheally instilled to ICR female mice. Number of white blood cell counts in BALF taken at 2hrs after instillation was elevated, but BALF taken at 24hrs after instillation did not show any increases. Increase of neutrophils and lymphocytes and total protein was observed in BALF taken at 2hrs and 24hrs after instillation. Histopathology demonstrated signs of acute inflammation with mild hemorrhage; macrophages and neutrophils were the major inflammatory cells at 2 hrs and at 24 hrs after instillation, respectively. In addition, TUNEL positive findings and 8-OHdG immunoreactivity were observed in the alveolar epithelial cells and macrophages, respectively. These results suggest that yellow dusts may induce acute pulmonary inflammatory changes; the inflammation may be associated with DNA damage by reactive oxygen species released from yellow dust particles.

1. Intoduction

Asian yellow dust (sand) aerosol (Kosa) originates from arid and semi-arid areas of China and transported from East Asia to the Pacific region including South Korea (Chung and Yoon 1996), Japan (Mori et al. 1999), and the United States (Uematu et al. 1983; Tratt et al. 2001). The frequency and scale of dust events giving rise to yellow dust aerosols have increased rapidly in the east Asian region since 2000 (Mori et al. 2003) and this seem to be due to environmental changes, such as desertification and climate change in middle and northwestern China (Ichinose et al. 2005).

The chemical studies of yellow dust in China and Japan have been carried out by many researchers. Mineralogical compositions of yellow sand are mainly quartz and feldspar and mica (Ishizaka 1991). In industrialized areas of eastern China, sulfur oxides and nitrogen oxides are produced and these gases are absorbed onto the mineral particles in the yellow dust (Mori et al. 2003). Fungal spores and walls (β-glucan) and lypopolysaccharide (LPS) of gram-negative bacteria from atmosphere are also absorbed onto particles of yellow dust (Ichinose et al. 2005), resulting in the increase in concern in the eastern Asia region about possible adverse respiratory effects.

Epidemiological studies showed that ambient yellow dust particles are associated with an increase in pulmonary and cardiovascular morbidity and mortality in Korea (Kwon et al. 2002) and Taiwan (Chen et al. 2004). A pathologic study showed yellow dust in the atmosphere caused bronchitis and alveolitis and increase of inflammatory cells and cytokine in bronchoalveolar lavage fluid (BALF). The degrees of the inflammation depended on the amounts of absorbed toxic material including pollutants in the air (Ichinose et al. 2005). Yellow sand itself, free from ambient pollutants, may also exhibit cytotoxicity to the alveolar epithelial cells *in vitro* (Kim et al. 2003).

To the best of our knowledge, there is no report on the pathological study of the lung toxicity induced by yellow sand particles free from chemical and biological materials. In this study, we show findings of acute pulmonary inflammation in BALF and the lung tissue induced by yellow sand particle itself.

2. Materials and methods

The yellow sand particles were collected in the loess layer in Gunsu Province of China. Mean particle diameters were about 0.03 ± 0.01mm. Particles were suspended in a saline solution. Four doses (50, 200, 800 and 3000 μg) of particle samples were chosen to determine dose effects on lung toxicity in mice. The solutions were autoclaved before use. Morphological examination of yellow sand particles was performed with scanning electron microscope (Model X-650, Hitachi, Tokyo, Japan).

Female ICR mice (10 weeks old) were used in the study. All animal experiments were performed according to the National Institute for Environmental Studies guidelines for animal welfare. Mice were anesthethized by an intraperitoneal injection of xylazine (3mg / kg) and ketamin (75 mg / kg). A volume of 0.05 ml of the yellow sand solution was instilled with an intratracheal cannula to mice. Similar volume of a saline solution was instilled to control mice. At 2 hrs and 24 hrs following single exposure, the animals were sacrificed under diethylether anesthesia. Four mice from each group were used for examination of BALF. Total protein was analyzed with a BCA™ Protein Assay Kit (PIERCE, USA) according to manufacturer's protocol. Three mice from each group were used for pathologic examination. The lungs were fixed by immersion in 10% neutral buffered formalin. Formalin fixed tissues of lungs were routinely processed, embedded in paraffin for histopathological and immunohistochemical examination.Transmission electron microscopy (TEM) was performed on formalin-fixed lung tissues of mice sacrificed 24 hrs after instillation of 3000 μg yellow sand.

All data were expressed as mean ± SE. Statistical significance was determined by Student's t-test for two group comparison. Differences were considered to be statistically significant when $P < 0.05$.

3. Results

3.1. Morphology of the yellow sand particles

As shown in Figure 1, yellow sand particles used were pleomorphic and varied in size. Some of particles were smaller than 10 μm.

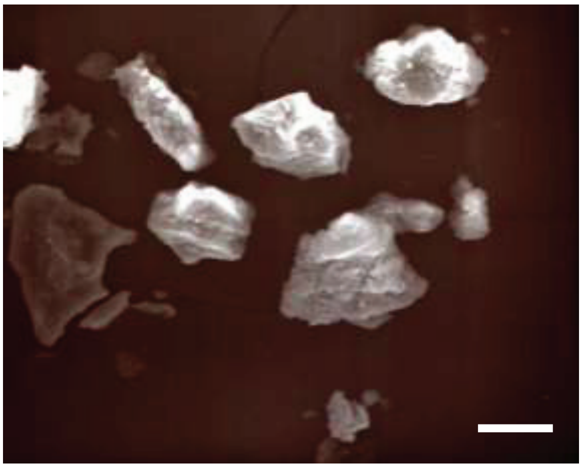

Figure 1. Scanning electron microscopic image of yellow sand particles showing pleomorphism and varied size. SEM. Bar = 10 µm.

3.2. Cytology and total protein analysis of BALF

Cellular and biochemical parameters in BALF of each group are shown in Table 1. Significant increase in the percentage of neutrophils was observed in the BALF taken at 24 hrs after instillation of 800 and 3000 µg of yellow sand particles. Reduced cell viability was shown in the BALF taken at 24 hrs after instillation of 50, 200 and 800 µg of yellow sand particles. Total protein concentrations were significantly increased in the BALF taken at 2 hrs after instillation of 50 and 3000 µg of yellow sand particles.

Table 1. Cellular and biochemical parameters in BALF

2 hrs	Control	1.51 ± 0.35	0.4 ± 0.2	89.1 ± 2.5	209.1 ± 10.0
	50	2.90 ± 0.44*	0.5 ± 0.2	83.1 ± 4.0	261.7 ± 18.2
	200	2.56 ± 1.18	0.3 ± 0.3	91.6 ± 3.2	255.2 ± 24.3
	800	2.46 ± 0.49	2.3 ± 1.2	92.1 ± 1.8	262.1 ± 44.2
	3000	3.19 ± 1.27	5.5 ± 3.9	83.7 ± 3.0	310.6 ± 32.4*
24 hrs	Control	2.09 ± 0.36	0.1 ± 0.1	95.2 ± 1.3	219.5 ± 16.6
	50	3.28 ± 0.85	0.2 ± 0.1	82.2 ± 6.0	285.4 ± 50.0
	200	1.19 ± 0.77	0.7 ± 0.7	85.7 ± 2.1*	257.9 ± 15.0
	800	0.49 ± 0.17	24.0 ± 6.7	77.5 ± 4.9*	257.9 ± 15.0
	3000	1.27 ± 0.46	34.5 ± 10.8*	86.4 ± 2.3*	716.8 ± 287.7

Values are the mean ± SE of 4 mice. *Significantly different from the control group P<0.05.

Increased number of neutrophils and activated alveolar macrophages (AMs) were observed in BALF (Fig. 2). Yellow sand particles were occasionally seen in the cytoplasm of the activated AMs.

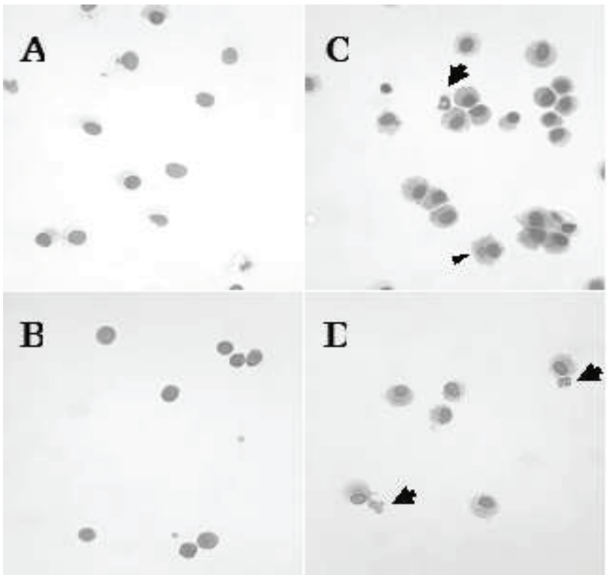

Figure 2. Cells in BALF from control mice 2 hrs (A) and 24 hrs (B) after instillation of saline. Cells in BALF from mice 2 hrs (C) and 24 hrs (D) after instillation of 800 µg of yellow sand particles. Neutrophils (arrows) and activated AMs characterized by increased volume of cytoplasm and occasional activated AMs (an arrow head) containing yellow sand particles in the cytoplasm are observed in the BALF from the treated mice (C, D). BALF, Diff Quick stain, × 400.

3.3. Histopathology of the lung

Histological sections of the lung treated with intra-tracheally instilled yellow sand particles showed acute inflammation in the lung (Fig. 3). The intensity of the inflammation increased with the amount of the particles instilled ($50 < 200 < 800 < 3000$ µg). Inflammation was more progressed at 24 hrs than at 2 hrs after instillation. Large size particles were observed within alveolar spaces and bronchiolar spaces. Small size particles, less than 5 µm, were occasionally shown in the cytoplasm of AMs. Degenerated alveolar epithelial cells around particles were observed in the lesion. Desquamated epithelial cells were observed in the lumina of the bronchioli. Diffuse mild to marked infiltration of AMs and neutrophils, focal mild hemorrhage and exudation of the serum protein to the alveolar space were also observed (Fig. 3E and 3F).

3.4. Immunohistochemistry of the lung (Laminin)

Laminin immunoreactivity in the inflammatory lesions was weak compared to the control tissue (Fig. 4).

3.5. Transmission electron microscopy of the lung

Aggregates of small size particles of the yellow sand were shown in the alveolar space; some of the particles were attached to the surface of the degenerated type Ⅰ alveolar epithelial cell (Fig. 5).

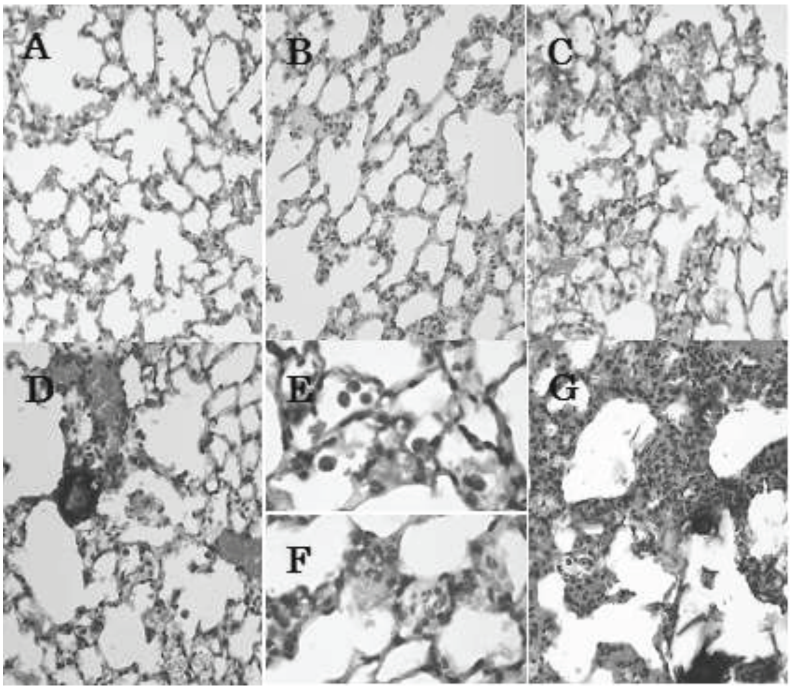

Figure 3. Lung sections from mice 24 hrs after intratracheal instillation of saline (A) and 50 µg (B), 200 µg (C), 800 µg (D, E ,F), 3000 µg (G) of yellow sand particles. Particles were seen in the alveolar spaces (D, G). Diffuse inflammatory cell infiltration in the alveolar walls and alveolar spaces (B~F). Alveolar macrophages and neutrophils were dominant in the inflammatory lesions (E, F). Lung, haematoxylin-eosin, × 260 (A, B, C, D G), × 540 (E, F).

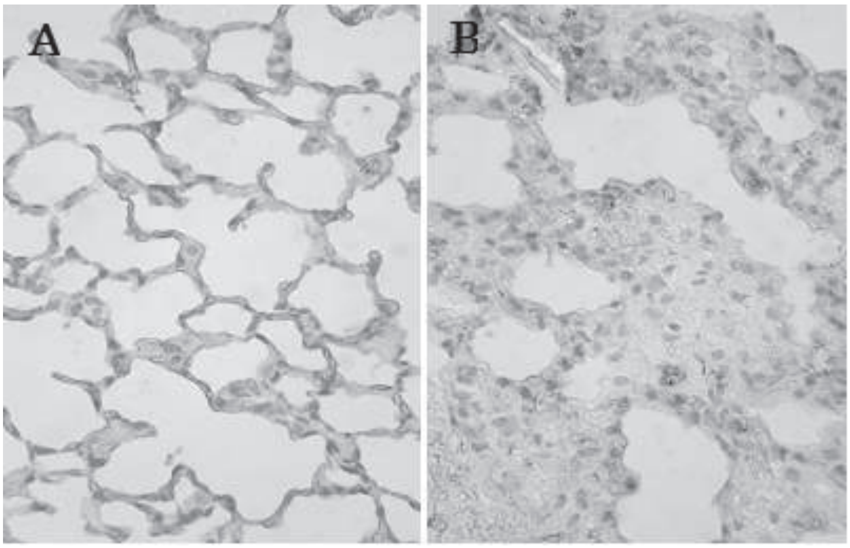

Figure 4. Lung sections from mice 24 hrs after intra-tracheal instillation of saline (A) and 3000 µg of yellow sand particles (B). Positive immune-histochemical expression for laminin was weak in the inflammatory lesion (B) compared to the control lung tissue (A). Lung, Haematoxylin counterstain, × 795.

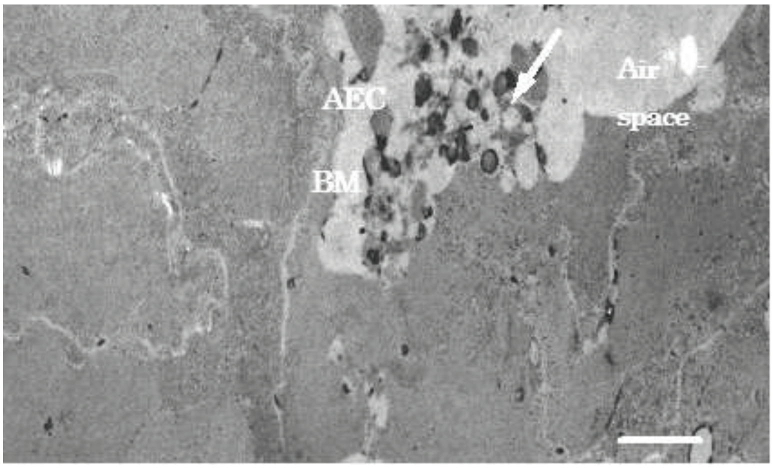

Figure 5. Alveolar structure of mice 24 hrs after intra-tracheal instillation of 3000 µg of yellow sand particles. Aggregated small size particles (arrow) were shown in the alveolar space; some of the particles were attached on the surface of the degenerated type I alveolar epithelial cell. AEC: type I alveolar epithelial cell, BM: basement membrane. TEM. Bar = 1 µm.

4. Discussion

Yellow sand particles mainly consist of quartz, feldspar and mica (Isizaka 1991). Becher *et al*. demonstrated feldspar and quartz induced inflammatory responses in the lung both *in vivo* and *in vitro*. Mica induced various biochemical markers of BALF (Bajpaei et al. 1992) and fibrosis in the lung (Zinman et al. 2002). Each mineral component of yellow sand particles may have potency in the cytotoxicity to the lung cells and inducing lung inflammation. Yellow sand particles induced decrease of cell viability, increase of intracellular calcium level, generation of H_2O_2, nitrate formation and, and Fenton activity *in vitro* (Kim et al. 2003). In this study, we showed that mineral component of yellow sand particles, free from chemical and biological materials, induced acute pulmonary toxicity *in vivo*.

In our study, yellow sand particles caused acute inflammatory changes; major inflammatory cells were alveolar macrophage and neutophils in both BALF and lung tissue. These inflammatory changes may be due to both primary cytotoxicity of yellow sand particles, which have been reported to generate reactive oxygen species *in vitro*, and secondary cytotoxicity by proinflammatory cytokine released from cells including activated macrophages and neutrophils. It is generally accepted that alveolar macrophages play a key role in starting the cascade of adverse reaction to toxic particles. Neutrophils perform an important defensive role against microbacterial infection, but when macrophages increase in number and become activated in response to particles deposition, macrophages can release chemotactic factors (Donaldson et al. 1992). These activated macrophages and neutrophils can release a variety of cytokines, toxic oxygen metabolites and proteinase that can damage the lung parenchyma and also stimulate fibroblast proliferation (Davis 1986).

Asian yellow dust particles, to which various chemicals and biological materials floating in the natural atmosphere were absorbed, induced bronchitis and alveolitis (Ichinose et al. 2005). The major inflammatory cells in BALF were neutrophils, lymphocytes and eosinophils; in the pathological study, neutrophil infiltration in alveolar spaces around the yellow dust particles was observed. The authors suggested that SO_4^{2-} and β-glucan attached to the particles, may be responsible for the inflammatory changes. Our study with yellow sand particles free from chemical and biological materials showed occurrence of acute pulmonary inflammation; eosinophil and lymphocyte infiltration was not obvious. These findings indicate that the quality and quantity of the pulmonary toxicity by yellow dust particles (Kosa) may depend on the physiological, chemical and biological factors in the inhaled particles.

Chest radiographs of residents in a wind-sand area showed signs of silicosis. The histological findings of lungs from a camel living in a wind-sand area for 20 years also showed silicosis (Xu et al. 1993). Mica induced fibrosis in the lung (Zinman et al. 2002). Slight granulonmatous changes were reported in the lungs 4 weeks after treatment with yellow dust particles (Ichinose et al. 2005). Thus, some mineralogical components of yellow sand appear to cause fibrogenesis. We examined histopathology of the lung 2 hrs and 24 hrs after instillation of yellow sand particles in the present study. Accumulation of neutrophils and alveolar macrophages in the alveolar walls and alveolar lumina around the yellow sand particles were observed. One of the key factors responsible for the genesis of pulmonary fibrosis induced by the inhalated sand particles may be various inflammatory mediators released by alveolar macrophages (Bignon et al. 1983; Olbück ey al. 1998). It is not certain whether the yellow sand particles instilled are cleared by alveolar macrophages. Retained particles may induce fibrosis associated with macrophage activation in the chronic stage of inflammation.

Pulmonary fibrosis may occur resulting from disturbance of the equilibrium between synthesis and degradation of the pulmonary extracellular matrix (ECM) (Dunsmore et al. 1996). Basement membranes at the air-blood barrier contain ECM including laminin (Hernandez 1988). Present study showed weakened laminin immunopositivity in the inflammatory pulmonary lesions, suggesting accelerated degradation of the ECM in the induced acute inflammation. It is likely that the observed early ECM changes may turn to fibrosis in the chronic stage.

In conclusion, this study demonstrated that mineralogical components of yellow sand particles, free from chemical and biological pollutants in the atmosphere, can cause acute inflammatory changes in the lung tissue and BALF *in vivo*.

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Theme 7. Improvement of stress resistance in dry area crops, shrubs and tree species through conventional breeding and application of biotechnology

7.1. Adaptation to climate change: Challenges for the breeders

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Abstract

Climate change is now indisputable, particularly in terms of increasing temperature, increasing CO_2 concentration, widespread melting of snow and ice, and rising global average sea level, while the increase in the frequency of drought is very likely but not as certain. Climate changes are not new and some of them have had a dramatic impact such as the birth of Agriculture due to the end of the last ice age about 11,000 years ago and the collapse of civilizations due to the late Holocene droughts between 5 and 1,000 years ago. The climate change occurring now will have – and is already having – an adverse effect on food production and food quality with the poorest countries most at risk. The adverse effect is the consequence of both the expected increase in frequency of some abiotic stresses such as heat and drought and the change in the spectrum of biotic stresses. Climate change is also expected to cause losses of biodiversity, mainly in more marginal environments. Plant breeding has always addressed both abiotic and biotic stresses and strategies of adaptation to climate change may include a more accurate matching of phenology to moisture availability using photoperiod-temperature response, increase access to a suite of varieties with different phenology to escape or avoid predictable occurrences of stress at critical periods in crop life cycles, improve water use efficiency, and re-emphasize population breeding to provide a buffer against increased unpredictability. These measures must go hand in hand with breeding for resistance to biotic stresses, and with an efficient system of variety delivery to farmers. Barley has been always considered the most resilient amongst the winter cereals with a range of possible uses still largely unexplored. Therefore, barley is an ideal crop that farmers in a number of countries are already using as a response to climate changes. The paper aims at discussing the contribution of barley breeding to the adaptation of crops to the future climate change.

1. Introduction

Today nobody questions whether climate changes are occurring or not, and the discussion has shifted from whether they are happening to what to do about them. The most recent evidence from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007) indicates that the warming of the climate system is unequivocal, as it is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. Some of the points raised by the report are:

- Eleven of the twelve years in the period 1995-2006 rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850);
- The temperature increase is widespread over the globe, and is greater at higher northern latitudes. Land regions have warmed faster than the oceans;
- Rising sea level is consistent with warming. Global average sea level has risen since 1961 at an average rate of 1.8 mm/yr and since 1993 at 3.1 mm/yr, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets;
- Observed decreases in snow and ice extent are also consistent with warming. Satellite data since 1978 show that annual average Arctic sea ice extent has shrunk by 2.7% per decade, with larger decreases in summer of 7.4% per decade. Mountain glaciers and snow cover on average have declined in both hemispheres.

It is also very likely that over the past 50 years cold days, cold nights and frosts have become less frequent over most land areas, and hot days and hot nights have become more frequent, and it is likely that heat waves have become more frequent over most land areas, the frequency of heavy precipitation events has increased over most areas, and since 1975 the incidence of extreme high sea level has increased worldwide.

Changes in snow, ice and frozen ground have with high confidence increased the number and size of glacial lakes, increased ground instability in mountain and other permafrost regions, and led to changes in some Arctic and Antarctic ecosystems (Walker 2007).

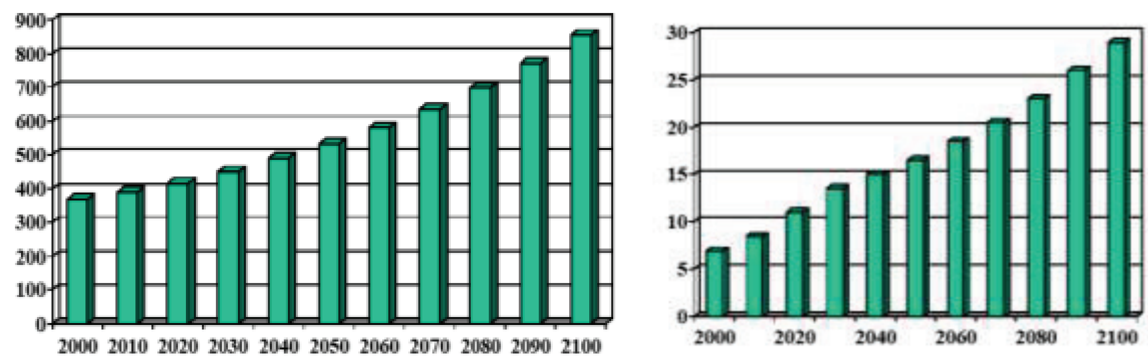

Figure 1. Projected CO_2 emission in billion tons carbon equivalent (left) and atmospheric CO_2 concentration in parts per million (right).

The projections to year 2100 indicate that CO_2 emission is expected to increase by 400% and CO_2 atmospheric concentration is expected to increase by 100% (Fig. 1). Some studies have predicted severe future impacts with potentially high extinction rates in natural systems around the world (Williams et al. 2003; Thomas et al. 2005).

2. Climatic changes in history

Even though climate changes are one of the major current global concerns, they are not new. Several climate changes occurred before, with dramatic consequences. Among these are:

- The decrease in CO_2 content which took place 350 million years ago and which is considered to be responsible for the appearance of leaves – the first plants were leafless and it took about 40-50 million years for the leaves to appear (Beerling et al. 2001);
- The one induced by perhaps the most massive volcanic eruptions in Earth history which took place in Siberia when up to 4 million cubic kilometers of lava erupted onto the Earth's surface that caused a worldwide depletion of the ozone layer with consequent burst of ultraviolet radiation, and the mass extinction that wiped out 95% of all species;
- The end of the Ice Age (between 15 and 13,500 BP) with the main consequence that much of the Earth became subject to long dry seasons. This created favorable conditions for annual plants which can survive the dry seasons either as dormant seeds or as tubers and led to the beginning of agriculture started in the area of the Near East known as the Fertile Crescent, around 11,000 BP;
- The Holocene flooding about 9,000 years ago believed to be associated with the final collapse of the Ice Sheet resulting in a global sea level rise by up to 1.4 m (Turney and Brown 2007). Land lost from rising sea levels drove mass migration to the North West and this could explain how domesticated plants and animals, which by then had already reached modern Greece, start moving towards the Balkans and eventually into Europe.

During the last 5,000 years drought, or more generally limited water availability, has been the main factor limiting crop production. Water availability has been associated with the rise of multiple civilizations while drought has caused the collapse of empires and societies, such as the Akkadian Empire (Mesopotamia, ca. 4200 calendar yr BP), the Classic Maya (Yucatan Peninsula, ca. 1200 calendar yr BP), the Moche IV–V Transformation (coastal Peru, ca. 1500 calendar yr BP) (de Menocal 2001) and the early bronze society in the southern part of the Fertile Crescent (Rosen 1990).

3. How do people respond to climatic changes?

Although the debate about climate changes is relatively recent, people, for example in Africa have been adapting to climate changes for thousands of years. In general, people seem to have adapted best when working as a community rather than as individuals. The four main strategies of adaptation have been a) changes in agricultural practices, b) formation of social networks, c) embarking in commercial projects, such as investing in livestock, and d) seeking work in distant areas: the first three of these strategies rely on people working together to improve their community (Giles 2007).

In coping continuously with extreme weather events and climatic variability, farmers living in harsh environments in Africa, Asia and Latin America have developed and/or inherited complex farming systems that have the potential to bring solutions to many uncertainties humanity is facing in an era of climate change (Altieri and Koohafkan 2003). These systems have been managed in ingenious ways, allowing small farming families to meet their subsistence needs in the midst of environmental variability without depending much on modern agricultural technologies (Denevan 1995). They can still be found throughout the world on some 5 million hectares, are of global importance to food and agriculture, and are based on the cultivation of a diversity of crops and varieties in time and space that have allowed traditional farmers to avert risks and maximize harvest security in uncertain and marginal environments, under low levels of technology and with limited environmental impact (Altieri and Koohafkan 2003). One of the salient features of the traditional farming systems is their high degree of biodiversity, in particular the plant diversity in the form of poly-cultures and/or agro-forestry patterns. This strategy of minimizing risk by planting several species and varieties of crops is more adaptable to weather events, climate variability and change and resistant to adverse effects of pests and diseases, and at the same time stabilizes yields over the long term, promotes diet diversity and maximizes returns even with low levels of technology and limited resources (Altieri and Koohafkan 2003).

The term autonomous adaptation is used to define responses that will be implemented by individual farmers, rural communities and/or farmers' organizations, depending on perceived or real climate change and without intervention and/or co-ordination by regional and national governments and international agreements. Pressure to cultivate marginal land, or to adopt unsustainable cultivation practices, may increase land degradation and endanger the biodiversity of both wild and domestic species, possibly jeopardizing future ability to respond to future climate risk. One of the options for autonomous adaptation includes the adoption of varieties/species with increased resistance to heat shock and drought (Bates et al. 2008).

4. Climatic changes, food and agriculture

Using the results from formal economic models, it is estimated (Stern 2005) that in the absence of effective counteraction, the overall costs and risks of climate change will be equivalent to losing at least 5 percent of global gross domestic product (GDP) each year. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20 percent of GDP or more, with a disproportionate burden and increased risk of famine on the poorest countries (Altieri and Koohafkan 2003). The majority of the world's rural poor, about 370 million of the poorest, live in areas that are resource-poor, highly heterogeneous and risk-prone. The worst poverty is often located in arid or semiarid zones, and in mountains and hills that are ecologically vulnerable (Conway 1997). In many countries, more people, particularly those at lower income levels, are now forced to live in marginal areas putting them at risk from the negative impacts of climate variability and change.

Climatic changes are predicted to have adverse impacts on food production, food quality and food security. One of the most recent predictions (Tubiello and Fischer 2007) is that by the year 2080 the number of undernourished people will increase by 1.5 times in the Middle East and North Africa and by 3 times in Sub-Saharan Africa compared to 1990. Agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Changes in precipitation patterns increase the likelihood of short-run crop failures and long-run production declines. Although there will be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative, threatening global food security (Nelson et al. 2009).

Food insecurity is likely to increase under climate change, unless early warning systems and development programs are used more effectively (Brown and Funk 2008). Today, millions of hungry people subsist on what they produce. If climate change reduced production while populations increase, there is likely to be more hunger. Lobell et al. (2008) showed that increasing temperatures and declining precipitation over semiarid regions are likely to reduce yields for corn, wheat, rice, and other primary crops in the next two decades. These changes could have a substantial negative impact on global food security. Climate change increases child malnutrition and reduces calorie consumption dramatically.

5. How do crops respond to climatic changes?

Adapting crops to climatic changes has become an urgent challenge which requires some knowledge on how crops respond to those changes. In fact plants have responded to increasing CO_2 concentration from pre-industrial to modern times by decreasing stomatal density as shown by the analysis of specimens collected from herbaria over the past 200 years (Woodward 1987). In *Arabidopsis thaliana* the gene *HIC* (High Carbon Dioxide) prevents changes in the number of stomata in response to increasing CO_2 concentration (Gray et al. 2000); mutant *hic* plants exhibit up to 42% increase in stomatal density in response to a doubling of CO_2. The implication is that the response of the stomatal density to increasing CO_2 concentration in many plant species is now close to saturation (Serna and Fenoll 2000). Stomatal density varies widely within species: for example in barley stomatal density varies from 39 to 98 stomata/mm^2 (Miskin and Rasmusson, 1970) suggesting that the crop has a fairly good possibility of adaptation.

It is now fairly well known how plants respond to increase CO_2 concentration which has both direct and indirect effects on crops. Direct effects, known as CO_2-fertilisation effects, are those affecting the crops by the presence of CO_2 in ambient air, which is currently sub-optimal for C3 type plants like barley and wheat. In C3 plants, mesophyll cells containing ribulose-1,5-bisphosphate carboxylase-oxygenase (RuBisCO) are in direct contact with the intercellular air space that is connected to the atmosphere via stomatal pores in the epidermis. Hence, in C3 crops, rising CO_2 increases net photosynthetic CO_2 uptake because RuBisCO is not CO_2-saturated in today's atmosphere and because CO_2 inhibits the competing oxygenation reaction leading to photorespiration. CO_2-fertilisation effects include increase of photosynthetic rate, reduction of transpiration rate through decreased stomatal conductance, higher water use efficiency, and lower probability of water stress occurrence. As a consequence crop growth and biomass production should increase up to 30% for C3 plants at doubled ambient CO_2 – other experiments show 10–20% biomass increase under double CO_2 conditions (Long et al. 2006). However, the estimates of the CO_2-fertilisation have been derived from enclosure studies conducted in the 1980s (Kimball, 1983; Cure and Acock, 1986; Allen et al. 1987), and today they appear to be overestimated (Long et al. 2006).

Indirect effects (also known as the weather effects) are the effects of solar radiation, precipitation and air temperature and, keeping management the same, cereals yields typically decrease with increasing temperatures and increase with increased solar radiation. If water is limiting, yields eventually decrease because of higher evapotranspiration. Precipitation will obviously have a positive effect by reducing water stress but can also have a negative effect such as, for example, causing water logging.

Therefore, the most likely scenario for plant breeding is the following:

- Higher temperatures, which will reduce crop productivity, are certain;
- Increase in CO_2 concentration is certain with both direct and indirect effects;
- Increase frequency of drought is highly probable;
- Increase in the areas affected by salinity is highly probable;
- Increase frequency of biotic stress is also highly probable.

Given this scenario conventional breeding and biotechnology may help developing new cultivars with enhanced traits better suited to adapt to climate change conditions. These include drought and temperature stress resistance; resistance to pests and disease, salinity and water logging. Additional opportunities for new cultivars include changes in phenology or enhanced responses to elevated CO_2. With respect to water, a number of studies have documented genetic modifications to major crop species (e.g., maize and soybeans) that increased their water-deficit tolerance (Drennen et al. 1993; Kishor et al. 1995; Pilon-Smits et al. 1995; Cheikh et al. 2000), although this may not extend to a wide range of crops. In general, too little is currently known about how the desired traits achieved by genetic modification perform in real farming and forestry applications (Sinclair and Purcell 2005).

Thermal tolerances of many organisms have been shown to be proportional to the magnitude of temperature variation they experience: lower thermal limits differ more among species than upper thermal limits (Addo-Bediako et al. 2000). Therefore a crop like barley which has colonized a huge diversity of thermal climates may harbor enough genetic diversity for thermal tolerance.

Soil moisture reduction due to precipitation changes could affect natural systems in several ways. There are projections of significant extinctions in both plant and animals species. Over 5,000 plant species could be impacted by climate change, mainly due to the loss of suitable habitats. By 2050, the Fynbos Biome (Ericaceae-dominated ecosystem of South Africa, which is a 'hotspot'of the International Union for the Conservation of Nature and Natural Resources) is projected to lose 51–61% of its extent due to decreased winter precipitation. The succulent Karoo Biome, which includes 2,800 plant species at increased risk of extinction, is projected to expand south-eastwards, and about 2% of the family Proteaceae is projected to become extinct. These plants are closely associated with birds that have specialized on feeding on them. Some mammal species, such as the zebra and nyala, which have been shown to be vulnerable to drought induced changes in food availability, are widely projected to suffer losses. In some wildlife management areas, such as the Kruger and Hwange National Parks, wildlife populations are already dependant on water supplies supplemented by borehole water (Bates et al. 2008).

With the gradual reduction in rainfall during the growing season for grass, aridity in central and west Asia has increased in recent years, reducing the growth of grasslands and increasing the bareness of the ground surface (Bou-Zeid and El-Fadel 2002). Increasing bareness has led to increased reflection of solar radiation, such that more soil moisture evaporates and the ground becomes increasingly drier in a feedback process, thus adding to the acceleration of grassland degradation (Zhang et al. 2003). Recently it has been reported that the Yangtze river basin has become hotter and is expected that the temperature will increase by up to $2^{o}C$ by 2050 relative to 1950 (Ming 2009). This increase will reduce rice production by up to 41% by the end of the century and corn production by up to 50% by 2080.

The negative impact of climatic changes on agriculture and therefore on food production is aggravated by the greater uniformity that exists now compared to 150-200 years ago. The decline in agricultural biodiversity can be quantified as follows: while it is estimated that there are approximately 250,000 plant species, of which about 50,000 are edible, we actually use no more than 250 – out of which 15 give 90% of the calories in the human diet, and 3 of them, namely wheat, rice and maize account for 60%. In these three crops, modern plant breeding has been particularly successful in selecting and releasing high yielding varieties, and the process towards genetic uniformity has been rapid – the most widely grown varieties of these three crops are closely related and genetically uniform (pure lines in wheat and rice and hybrids in maize). The major consequence is that our main sources of food are more genetically vulnerable than ever before, i.e. food security is potentially in danger. The danger has become real with the rapid spreading of diseases such as UG99 of stem rust, but applies equally well to climatic changes as the predominant uniformity does not allow the crops to evolve and adapt to the new environmental conditions. The expected increase of biofuel monoculture production may lead to increased loss of biodiversity with consequent genetic erosion.

6. Combining breeding and evolution: participatory- evolutionary plant breeding

One of the fundamental breeding strategies to cope with the challenge posed by the climate changes is to improve adaptation to a likely shorter crop season length by matching phenology to moisture availability. This should not pose major problems as photoperiod-temperature response is highly heritable. Other strategies include increase access to a suite of varieties with different duration to escape or avoid predictable occurrences of stress at critical periods in crop life cycles, shifting temperature optima for crop growth and re-emphasize population breeding.

In all cases the emphasis will be on identifying and using sources of genetic variation for tolerance/resistance to a higher level of abiotic stresses and the two most obvious sources of novel genetic variation are the gene banks (ICARDA has one of the largest gene banks with more than 100,000 accessions of several species including important food and feed crops such as barley, wheat, lentil, chickpea, vetch etc.) and/or the farmers' fields. Currently there are several international projects aiming at the identification of genes associated with superior adaptation to higher temperatures and drought; at ICARDA, but also elsewhere, it has been found that landraces, and is of immediate use in breeding for drought and high temperature resistance. The major difference between the two sources of genetic variation is that the first is static, in the sense that it represents the genetic variation available in the collection sites at the time the collection was made, and the second is dynamic, because landraces and wild relatives are heterogeneous populations and as such they evolve and can generate continuously novel genetic variation.

Adaptive capacity in its broadest sense includes both evolutionary changes and plastic ecological responses; in the climate change literature, it also refers to the capacity of humans to manage, adapt, and minimize impacts (Williams et al. 2008). All organisms are expected to have some intrinsic capacity to adapt to changing conditions; this may be via ecological (i.e., physiological and/or behavioral plasticity) or evolutionary adaptation (i.e., through natural selection acting on quantitative traits). There is now evidence in the scientific literature that evolutionary adaptation has occurred in a variety of species in response to climate change both in the long term as seen earlier in the case of stomata (Woodward 1987) or over relatively short time, e.g., five to 30 years (Bradshaw and Holzapfel 2006). However, this is unlikely to be the case for the majority of species and, additionally, the capacity for evolutionary adaptation is probably the most difficult trait to quantify across many species (Williams et al. 2008).

Recently Morran et al. (2009) have used experimental evolution to test the hypothesis that outcrossing populations are able to adapt more rapidly to environmental changes than self-fertilizing organisms as suggested by Stebbins (1957), Maynard Smith (1978) and Crow (1992) explaining why the majority of plants and animals reproduce by outcrossing as opposed to selfing. The advantage of outcrossing is to provide a more effective means of recombination and thereby generating the genetic variation necessary to adapt to a novel environment (Crow 1992). The experiment of Morran et al. (2009) suggest that even outcrossing rates lower than 5%, therefore comparable with those observed in self pollinated crops such as barley, wheat and rice, allowed adaptation to a stress environments as indicated by a greater fitness accompanied by an increase in the outcrossing rates.

Evolutionary plant breeding is an old concept introduced by Suneson more than 50 years ago working with barley (Suneson 1956), and its 'core features are a broadly diversified germplasm, and a prolonged subjection of the mass of the progeny to competitive natural selection in the area of contemplated use'. The results showed that traits relating to reproductive capacity, such as higher seed yields, larger numbers of seeds/plant and greater spike weight, increase in populations due to natural selection over time. The evolutionary breeding that ICARDA is initiating in Syria, Jordan and Algeria aims at increasing the probability of recombination within a population which is deliberately constituted to harbor a very large amount of genetic variation. Such a population may consist of a large mixture of hundreds of F_2 and is planted in a number of locations where it is left evolving under the pressure of the changing climatic conditions. The breeder and the farmers can also superimpose some selection criteria. While the population is evolving, lines can be derived and tested as pure lines, or a sub-sample of the population can be used for cultivation. The key aspect of the method is that the population is left evolving for an indefinite amount of time thus becoming a unique source of continuously better adapted genetic material.

The concept of evolutionary plant breeding is not new, but we will implement it in those communities which have been already practicing participatory plant breeding and therefore have the skills to make the best use of the genetic variation.

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7.2. Enhanced tolerance to abiotic stresses in transgenic plants over-expressing vitamin C recycling enzymes

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Abstract

Ascorbate (vitamin C) is a potent antioxidant and free-radical scavenger protecting plants against oxidative damage imposed by environmental stresses such as drought, salinity and ozone. Dehydroascorbate reductase (DHAR; EC 1.8.5.1) and monodehydroascorbate reductase (MDAR; EC 1.6.5.4) are crucial for ascorbate (AsA) regeneration and essential for maintaining a reduced pool of AsA. To examine whether an overexpressed levels of these enzymes could minimize the deleterious effects of environmental stresses, we developed transgenic tobacco plants over-expressing either *Arabidopsis thaliana* DHAR (*AtDHAR2*) or MDAR gene (*AtMDAR1*) in the cytosol. Incorporation of the transgenes in the genome of tobacco plants was confirmed by PCR and Southern-blot analysis and its expression was confirmed by Northern- and Western-blot analyses. DHAR transgenic plants exhibited up to 3.1 folds higher DHAR activity and 2.1 folds higher level of reduced AsA compared with non-transformed control plants, whereas MDAR transgenic plants exhibited up to 2.1 folds higher MDAR activity and 2.2 folds higher level of reduced AsA. Both types of transgenic plants showed maintained redox status of AsA and enhanced stress tolerance in term of significantly higher net photosynthesis rates under ozone, salt and drought stresses. Furthermore, MDAR transgenic plants exhibited significantly greater PSII effective quantum yield under ozone and salt stresses and lower hydrogen peroxide level when tested under salt stress. These results demonstrate that an over-expressed level of either DHAR or MDAR properly confers enhanced tolerance against ozone, salt and drought stress.

1. Introduction

Abiotic stresses, including those of salt, drought and ozone, are known to accelerate the accumulation of reactive oxygen species (ROS) such as singlet oxygen (O_2^1), superoxide radical (O_2^-), hydrogen peroxide (H_2O_2) and hydroxyl radical (OH•) in plant cells. ROS are capable of unrestricted oxidation of many cellular components and can lead to oxidative destruction of the cell (Mittler 2002). Main cellular components such as lipids, proteins, carbohydrates and nucleic acids are candidates to be oxidatively damaged. Detoxification of ROS in plant cells is accomplished by enzymatic and non-enzymatic scavenging systems. Plants detoxify ROS by a combination of antioxidants such as ascorbate (AsA) and glutathione (GSH), and antioxidative enzymes such as superoxide dismutase (SOD), ascorbate peroxidase (APX) and catalase (CAT). Antioxidative enzymes involved in the ascorbate-glutathione (AsA-GSH) cycle, mainly monodehydroascorbate reductase (MDAR), dehydroascorbate reductase (DHAR) and glutathione reductase (GR) are crucial for plant defense against oxidative stress (Mittler 2002).

AsA is a major redox buffer in plants, a cofactor of many enzymes, a regulator of cell division and growth and a molecule for signal transduction in plants (Pignocchi and Foyer 2003*a*). As a major antioxidant, AsA can directly scavenge free radicals and is considered to be of paramount importance as an electron donor for H_2O_2 detoxifications via APX in plant cells (Noctor and Foyer 1998). APX uses two molecules of AsA to reduce H_2O_2 to water with two molecules of monodehydroascorbate (MDHA) being generated in this reaction. In turn, MDAR uses NAD(P)H as electron donor to reduce MDHA enzymatically to AsA (Hossain et al. 1984). Being an unstable radical due to its short lifetime, MDHA spontaneously disproportionates to AsA and dehydroascorbate (DHA) if not rapidly reduced to AsA (Noctor and Foyer 1998). DHAR catalyzes the reduction of DHA to AsA using reduced glutathione (GSH). Since DHA is also an unstable molecule, if not rapidly reduced to AsA, it undergoes spontaneous and irreversible hydrolysis to 2,3-diketogulonic acid (Deutsch 2000). With their ability to regenerate AsA, MDAR plays an important role in maintaining reduced pool of AsA.

Transgenic plants with manipulated expression levels of antioxidants enzymes provided a significant tool to study the defense mechanism against oxidative stress, and have provided new insights into the role of antioxidant enzymes in scavenging active oxygen species (Foyer et al. 1994, Allen et al. 1997). Although many reports have investigated the role of different antioxidant enzymes in plant stress tolerance (Allen et al. 1997), overexpression of either MDAR or DHAR in cytosol remains an attractive area to investigate its significance in regenerating AsA and in protecting plants against oxidative stress. In this study we report the development of transgenic tobacco plants with overexpressed levels of either DHAR in cytosol and its physiological importance in protecting plants against various stresses such as ozone, drought and salt stresses, and polyethylene glycol (PEG) induced stress.

2. Materials and methods

2.1. Construction of plant expression vector and tobacco transformation

The cDNAs encoding *A. thaliana* MDAR (AtMDAR1; At3g52880) and DHAR (accession number AY140019) were amplified by reverse transcription polymerase chain reaction (RT-PCR) from the total RNA of *A. thaliana* (ecotype Columbia). The ends of the MDAR cDNA were modified by PCR to introduce *Sma*I sites using SmMDSe primer (5′-CGCCCGGGCTCCACCATGGCTATGGCGGAGAAGAGCTTA-3′) and SmMDAn primer (5′-ACGGGCCCGTCAGATCTTAGCTGCGAA-3′) to facilitate cloning in the corresponding site of pBI121 plant expression vector down stream of CaMV35S (cauliflower mosaic virus promoter) and upstream of *nos* (nopaline synthase) terminator.

For the construction of the plant expression vector harboring DHAR gene, the ends of DHAR cDNA were modified by PCR to introduce *Sma*I and *Sac*I sites using AtDHSm primer (5′-CGTCTAGACTCCACCCGGGCTATGGCTCTAGATATCTG-3′) and AtDHSc primers (5′-ACGAGCTCGTCACGCATTCACC3′) to facilitate cloning in the corresponding sites of pBE2113-GUS plant high-expression vector (Mitsuhara et al. 1996) down stream of CaMV35S and upstream of *nos* terminator. The constructs pBI-MDAR and pBE-DHAR were introduced separately into *Agrobacterium tumefaciens* strain C58C1 by electroporation and used for A*grobacterium*-mediated gene transfer to generate two types of transgenic plants overexpressing MDAR or DHAR, respectively. A*grobacterium*-mediated gene transfer was carried using sterile leaf discs from *Nicotiana tabacum* (SR-1) as described by Badawi et al. (2004). Genomic DNA was isolated from transgenic and non-transformed (SR-1) control plants leaves using ISOPLANT II kit (Nippon gene, Co., Ltd., Toyama, Japan) and used to verify the presence of transgenes in the genome of transgenic plants by PCR using the genes designated primers.

2.2. Southern- and northern- blot analyses

Southern blot and northern blot analysis were conducted to further confirm the incorporation and expression level of transgenes, respectively. For southern analysis, 10 μg DNA from transgenic plants and SR-1 control plants were digested with *Eco*RI restriction enzyme and transferred to nylon membrane (Hybond ^{TM}-N+, Amersham, UK). For northern analysis, total RNA (20 μg) was separated in formaldehyde gel and transferred to nylon membrane. Hybridizations for both southern and northern analyses were carried out following standard procedures (Sambrook et al. 1989). The labeled probes for MDAR and DHAR cDNA were prepared by PCR using PCR DIG Probe Synthesis Kit (Roche, Applied science, Germany) and the detection of hybridized DIG labelled probe was conducted using DIG Luminescent Detection kit (Roche Applied science, Germany) according to manufacture instructions.

2.3. Western blot analysis

The full length MDAR and DHAR cDNA was cloned down stream of 6xHis-tag sequence of the pQE-32 vector (Qiagen). Expression and purification of the His-tagged recombinant proteins was conducted using Ni-NTA agrose system (QIAexpress®, Qiagen). Antibodies against the purified recombinant proteins were raised by injection into guinea pigs. Proteins were extracted from transgenic and SR-1 control plants using TRIzol (Invitrogen). Protein samples (25 μg) were separated in 15% SDS-PAGE and transferred to Hybond ECL Nitrocellulose membrane (Amersham Biosciences) by ATTO semi-dry transfer cell (ATTO Corporation, Japan). Immunodetection was performed using diluted (1:20000) guinea pig antibodies against His-tagged recombinant protein as the first antibody and a diluted (1:5000) horseradish peroxidase conjugated anti-guinea pig IgG (SIGMA) as the second antibody.

2.4. Monodehydroascorbate reductase activity and levels of reduced and oxidized AsA

MDAR activity was assayed sepctrophotometrically according to the method of Hossain and Asada (1984) with slight modification. Plant leaf samples (0.2 g) were homogenized with 2 ml extraction buffer (1 mM ascorbate in 50 mM potassium phosphate buffer pH 7.8). The assay was performed at 25 ℃ with a reaction mixture containing 0.1 M Tris-HCl pH 7.2, 0.2 mM NADH, 2 mM ascorbic acid, 1 unit ascorbate oxidase and crude extract. The decrease in absorbance at 340 nm due to ascorbate was monitored and the activity was calculated using absorbance coefficient of 6.2 $mM^{-1}cm^{-1}$. Total protein was determined according to Bradford (1976).

2.5. DHAR activity assay

DHAR activity was assayed sepctrophotometrically according to the method of Nakano and Asada (1981) with slight modification. Plant leaf tissues (0.2 g) were homogenized with 2 ml of 0.1 M Tris-HCl (pH 7.8). The assay was performed at 25 ℃ with a reaction mixture contained 50 mM MES-NaOH (pH 6.3), 2 mM dehydroascorbate, 5 mM GSH and crude extract. The increase in absorbance at 290 nm due to ascorbate was monitored and the activity was calculated using absorbance coefficient of 2.8 $mM^{-1}cm^{-1}$.

2.6. Determination of reduced and oxidized ascorbate levels

Plant leaf tissues (0.2 g) were homogenized in 2 ml of an ice-cold 5% metaphosphoric acid, centrifuged (14,000 rpm, 4℃) for 20 min and 0.1 ml of the supernatant was added to 0.9 ml 5% metaphosphoric acid then filtered through 0.45μm MILLEX-®HV filter unit (MILLIPORE). Ten μl sample was used for determination of reduced ascorbate (AsA) on CAPCELL PAK C18 120 (Shiseido Co. Ltd., Japan) column, with 80% acetonitrile and 20% of 0.01M potassium phosphate (pH 3.0) as the mobile phase at rate of 0.5 ml min^{-1}. Ascorbate was detected in TOSOH UV-8010 absorbance detector (Tosoh Co., Tokyo, Japan) set at 248 nm. Calibrations were linear in the range of 50 - 300 ng ascorbic acid. DHA was reduced to AsA by neutralizing metaphosphoric acid in samples with 5M KOH and adding dithiothreitol DTT to final concentration of 10 mM then incubated for 30 min at room temperature. DHA was calculated as the difference between the total ascorbate (reduced plus oxidized) and reduced ascorbate.

2.7. Plant growth condition

The transgenic progeny (T_1) from the self-pollinated primary transformed lines (T_0) were germinated on kanamycin-containing MS medium (Murashige and Skoog 1962), whereas SR-1 seeds were germinated on antibiotic free MS medium and maintained in a growth chamber for 6 weeks at 12 h light cycle, 25℃ and 23% RH. Seedlings were transplanted in vermiculite and maintained in controlled conditions (25℃, 45-55% RH and 14 h light cycle). Unless mentioned elsewhere, three replications of 8–10 week old plants that were uniform in height and number of leaves were used in all stress evaluation experiments.

2.8. Determination of hydrogen peroxide

Hydrogen peroxide contents were determined by peroxidase-coupled assay using 4-aminoantipyrine and phenol as donor substrate (Frew et al. 1983) with slight modifications. Leaf samples (0.2 g) from MDAR transgenic and SR-1 control plants were homogenized in 2 ml of 5% (w/v) trichloroacetic acid (TCA), centrifuged (15,000 *g*, 4℃) for 20 min and the supernatant (50 μl) was added to 1 ml reaction mixture containing 2 mM phenol, 1.5 mM 4-aminoantipyrine, 0.1 M Tris-HCl buffer (pH 7.0) and 2 units peroxidase. Quinone-imine formation was measured at 505 nm. Absorbance resulted from any interfering substances was measured and subtracted in a separate 1 ml reaction containing 7 μl of 1 M tricine in 6 M KOH to neutralize the extract, 2 mM phenol, 1.5 mM 4-aminoantipyrine, 0.1 M Tris-HCl buffer (pH 7.0), 0.2 units catalase, incubated for 10 min at room temperature and finally 2 units peroxidase were added. Calibrations were carried using H_2O_2 standard curve.

2.9. Applying ozone, salt, drought and polyethylene glycol (PEG) stresses

Ozone stress was applied by fumigation with 0.2 ppm ozone generated using OES-10A ozone generator (DYLEC, Inc., Osaka, Japan), and the accurate fumigation level was continuously monitored by ozone monitor (OZONE MONITOR, model 1200, DYLEC, Inc., Osaka, Japan). Salt stress was applied by irrigating plants with 0.3 M NaCl solution supplied with 1 ml l^{-1} Hyponex nutrient solution, renewed every day for eight days. Drought stress was applied by withholding water from the plants. PEG stress was applied by irrigating plants with 10% (w/v) PEG solution supplied with 1 ml l^{-1} Hyponex nutrient solution.

2.10. Net photosynthesis and chlorophyll fluorescence measurements

A portable photosynthesis system (LI-6400; Li-Cor Inc., Lincoln, NE, USA) was used to measure net photosynthesis (μmol CO_2 m^{-2} s^{-1}) starting from zero time immediately before applying stress and continued for a designated time. Chlorophyll fluorescence measurements were performed with a portable PAM-2100 fluorometer (Heinz Walz, Effeltrich, Germany) as instructed by manufacture. Effective quantum yield of PSII (Y) was calculated as: $Y = \Delta F/Fm' = (Fm' - Ft)/Fm'$, where *Ft* is the fluorescence yield at any given time (steady state) and F_m' is the maximum fluorescence yield reached in a pulse saturating light during illumination.

2.11. Data analysis

Data points represent the mean of three replications. Data were analyzed using Student's t-test at 95% confidence limit.

3. Results

3.1. Generation of transgenic plants overexpressing either MDAR or DHAR

Transgenic plants overexpressing either MDAR or DHAR were generated by *Agrobacterium*-mediated gene transfer of *N. tabacum* cv. SR-1. PCR analysis using genomic confirmed the presence of MDAR transgene in five MDAR transgenic lines (Fig. 1a) and DHAR transgene in eight DHAR transgenic lines (Fig. 2a). Southern blots analysis confirmed the incorporation of MDAR transgene in the genome of MDAR transgenic plants (Fig. 1b) and DHAR transgene in the genome of DHAR transgenic plants (Fig. 2b). Northern blot analysis indicated that the transgenic plants had expressed the transgenes (Fig. 1c and Fig. 2c). Western blot analysis using antibodies raised against MDAR detected high levels of MDAR protein (47 kDa) derived from MDAR transgene in the extracts prepared from MDAR transgenic plants but not from SR-1 control plants (Fig. 3a), in contrast high levels of DHAR protein (23.4 kDa) derived from DHAR transgene was detected in DHAR transgenic plants using antibodies raised against DHAR (Fig. 3b).

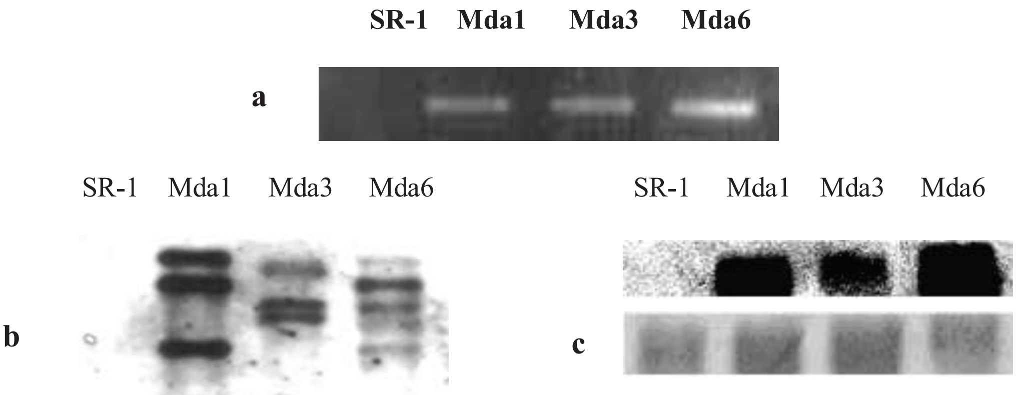

Figure 1. (a) PCR Detection of MDAR transgene in MDAR transgenic plants. (b) Southern blot analysis for MDAR transgenic plants .(c) Northern blot analysis MDAR transgenic plants. SR-1, control plant; MDAR transgenic lines are represented by Mda1, Mda3, Mda4, Mda6 and Mda9.

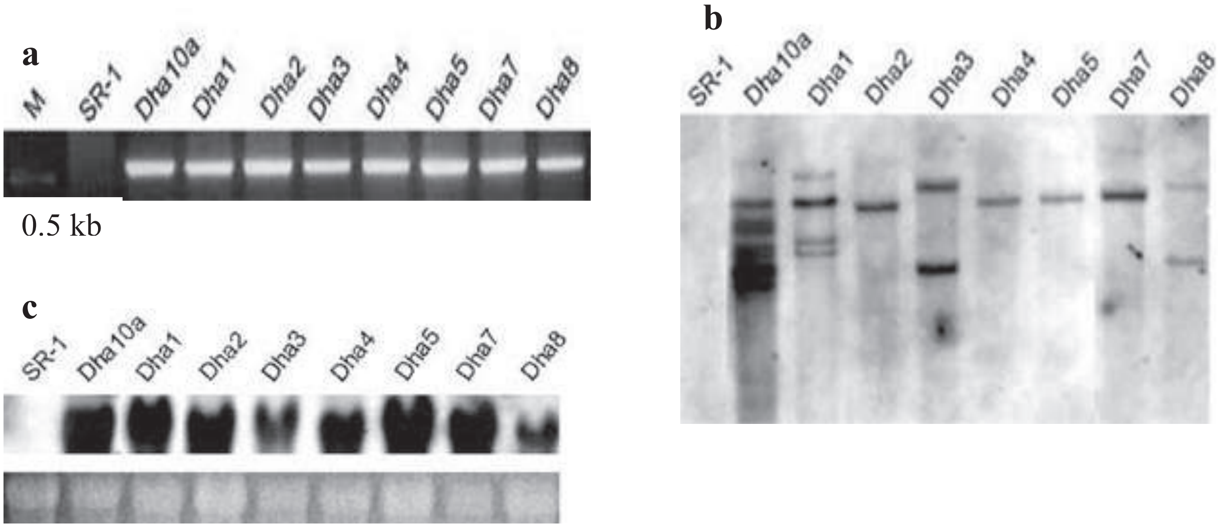

Figure 2. (a) PCR Detection of DHAR transgene in DHAR transgenic plants. (b) Southern blot analysis for DHAR transgenic plants. (c) Northern blot analysis for DHAR transgenic plants. SR-1, control plant; DHAR transgenic lines are represented by Dh10a, Dha1, Dha2, Dha3, Dha4, Dha5, Dha7 and Dha8.

Figure 3. (a) Immunoblotting of proteins from MDAR transgenic plants. (b) Immunoblotting of proteins from DHAR transgenic plants. SR-1, control plants; MDAR, MDAR His-tagged recombinant protein; DHAR, DHAR His-tagged recombinant protein.

3.2. Higher MDAR activity and increased AsA levels in MDAR transgenic plants

Compared to SR-1 control plants, Mda1, Mda3, and Mda6 transgenic lines exhibited increased MDAR activity to 1.5, 2.1 and 1.6 fold, respectively (Fig. 4a). The level of AsA in Mda1, Mda3 and Mda6 transgenic lines increased to 2.0, 2.2 and 2.2 folds, respectively (Fig. 4b), while the level of DHA decreased by 24.1, 26.2 and 23.1%, respectively. The redox status of ascorbate (AsA:DHA) increased from a ratio of 1.7 in SR-1 control plants to 3.8, 5.1 and 3.9 in Mda1, Mda3 and Mda6 transgenic lines, respectively.

3.3. Higher DHAR activity and increased AsA levels in DHAR transgenic plants

Compared to SR-1 control plants, DHAR transgenic lines Dha3, Dha4 and Dha7 exhibited increased DHAR activity up to 2.4, 3.1 and 2.3 fold, respectively (Fig. 5a).The level of AsA in DHAR transgenic lines Dha3, Dha4 and Dha7 increased to 1.9, 2.1 and 1.9 folds, respectively (Fig. 5b), while the level of DHA decreased by 23.3, 16.4 and 20.4%, respectively. The redox status of ascorbate (AsA:DHA) increased from a ratio of 1.9 in SR-1 control plants to 4.8, 4.9 and 4.5 in transgenic lines Dha3, Dha4 and Dha7, respectively.

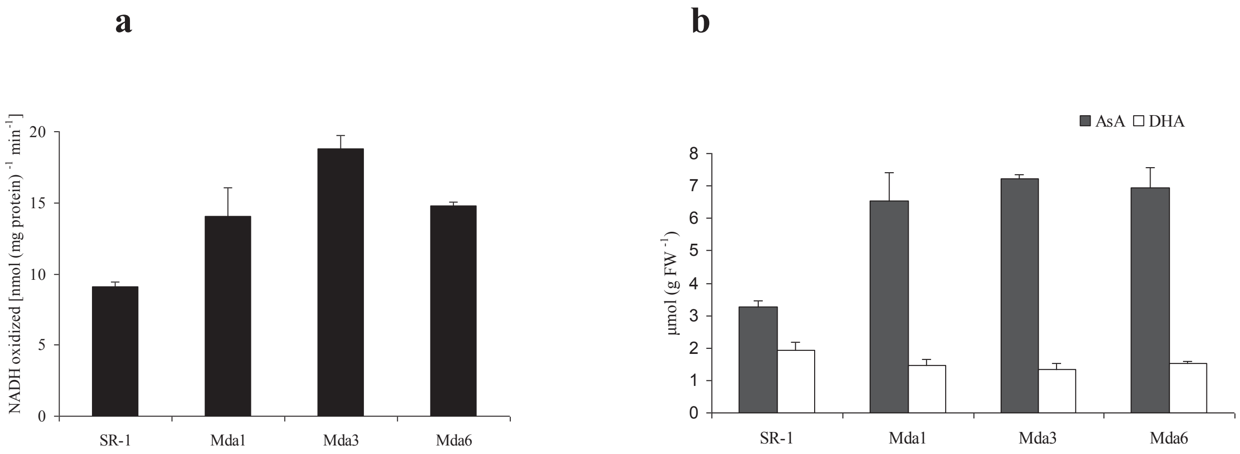

Figure 4. (a) MDAR activity and (b) Levels of reduced ascorbate (AsA) and dehydroascorbate (DHA) in MDAR transgenic and SR-1 control plants. The vertical bars represent the SE of the mean from triplicate determinations.

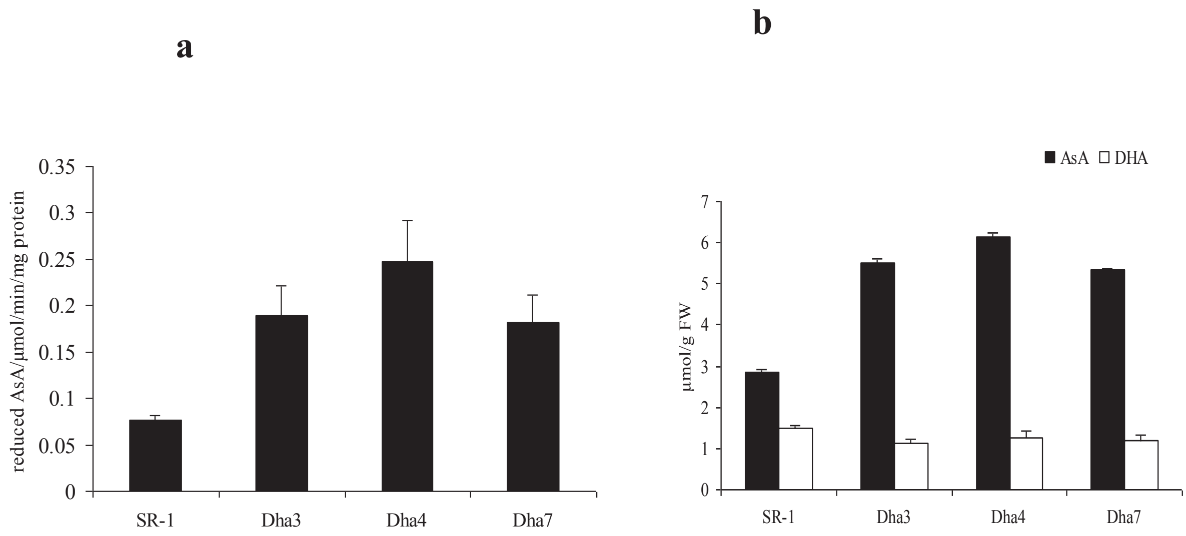

Figure 5. (a) DHAR enzyme activity and (b) levels of reduced ascorbate (AsA) and dehydroascorbate (DHA) in DHAR transgenic and SR-1 control plants. Vertical bars represent the SE of the mean from triplicate determinations.

3.4. Enhanced tolerance to ozone stress in transgenic plants

Exposure to ozone can inhibit photosynthesis (Chen and Gallie 2003). Fumigation of transgenic and SR-1 control plants with 0.2 ppm ozone resulted in a steady decrease in their net photosynthetic rate. MDAR transgenic plants showed significantly ($p < 0.05$) higher net photosynthesis rates compared to SR-1 control plants (Fig. 6a). Ozone fumigation is reported to cause a depression of the quantum yield of photosynthesis (Barnes et al. 1990), and reduction on photosynthesis activity revealed by changes in chlorophyll fluorescence characteristics (Agrawal et al. 1993). As estimated by (*ΔF/Fm'*), MDAR transgenic plants maintained significantly higher effective PSII yield during the entire period of stress (Fig. 6b). Similarly, DHAR transgenic plants showed significantly higher net photosynthesis rates under ozone stress compared to SR-1 control plants (Fig. 6c).

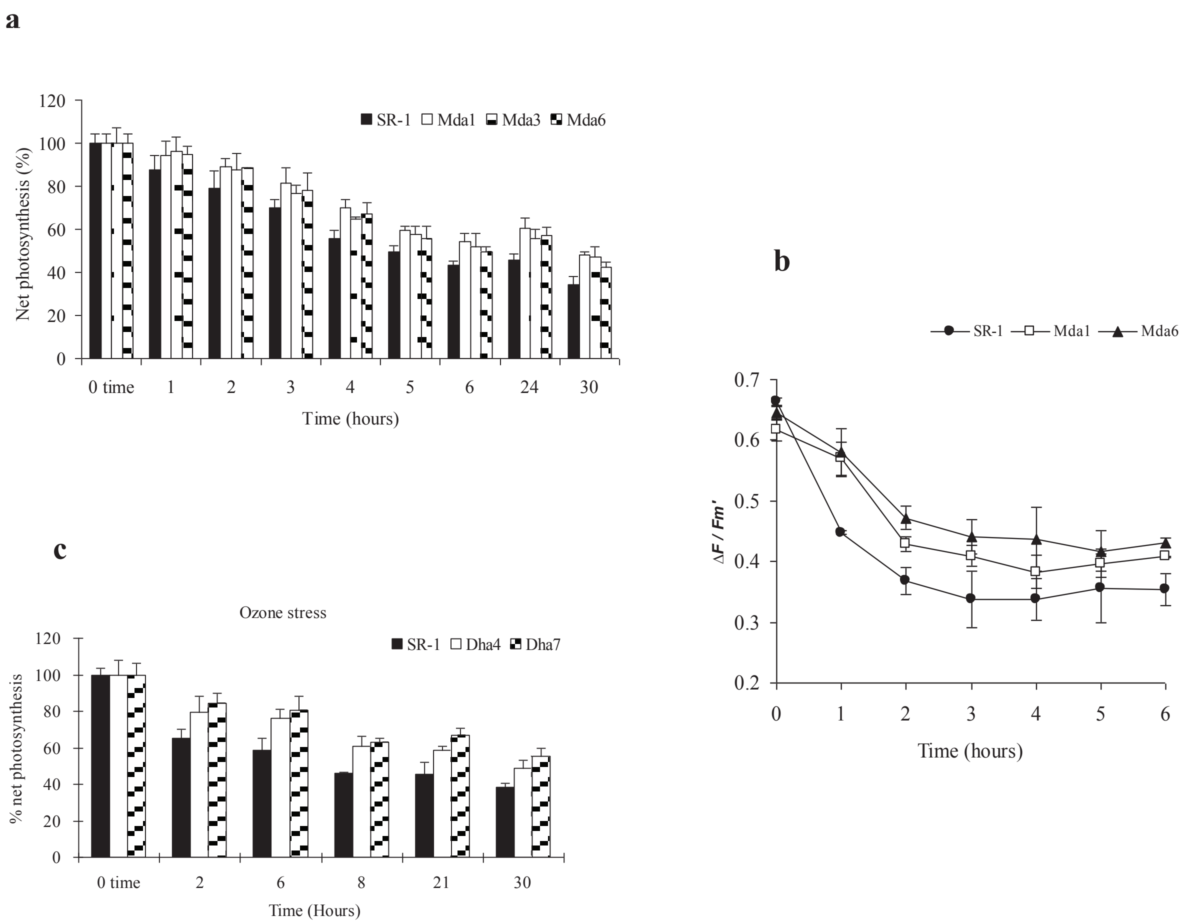

Figure 6. Net photosynthesis (%) and PSII effective quantum yield (*ΔF/Fm'*) during ozone stress. (a) The 100% net photosynthesis (µmol CO_2 m^{-2} s^{-1}) for MDAR transgenic and SR-1 control plants.(b) Effective PSII photon yield estimated by the fluorescence parameter *ΔF/Fm'* during ozone stress imposed on MDAR transgenic and SR-1control plants. (c) The 100% net photosynthesis for DHAR transgenic and SR-1 control plants. The vertical bars represent the SE of the mean from triplicate determinations.

3.5. Enhanced tolerance to salt stress

We investigated the effect of salt stress on net photosynthesis and photochemical efficiency (effective PSII photon yield *ΔF/Fm'*) of transgenic and SR-1control plants during eight days. Although these parameters were decreased in all plants, MDAR transgenic plants maintained significantly ($p < 0.05$) higher net photosynthetic (Fig. 7a) and photochemical efficiency (Fig. 7b) compared to control plants. DHAR transgenic plants performed similarly under salt stress in terms of higher net photosynthesis during the entire period of the stress (Fig. 7c).

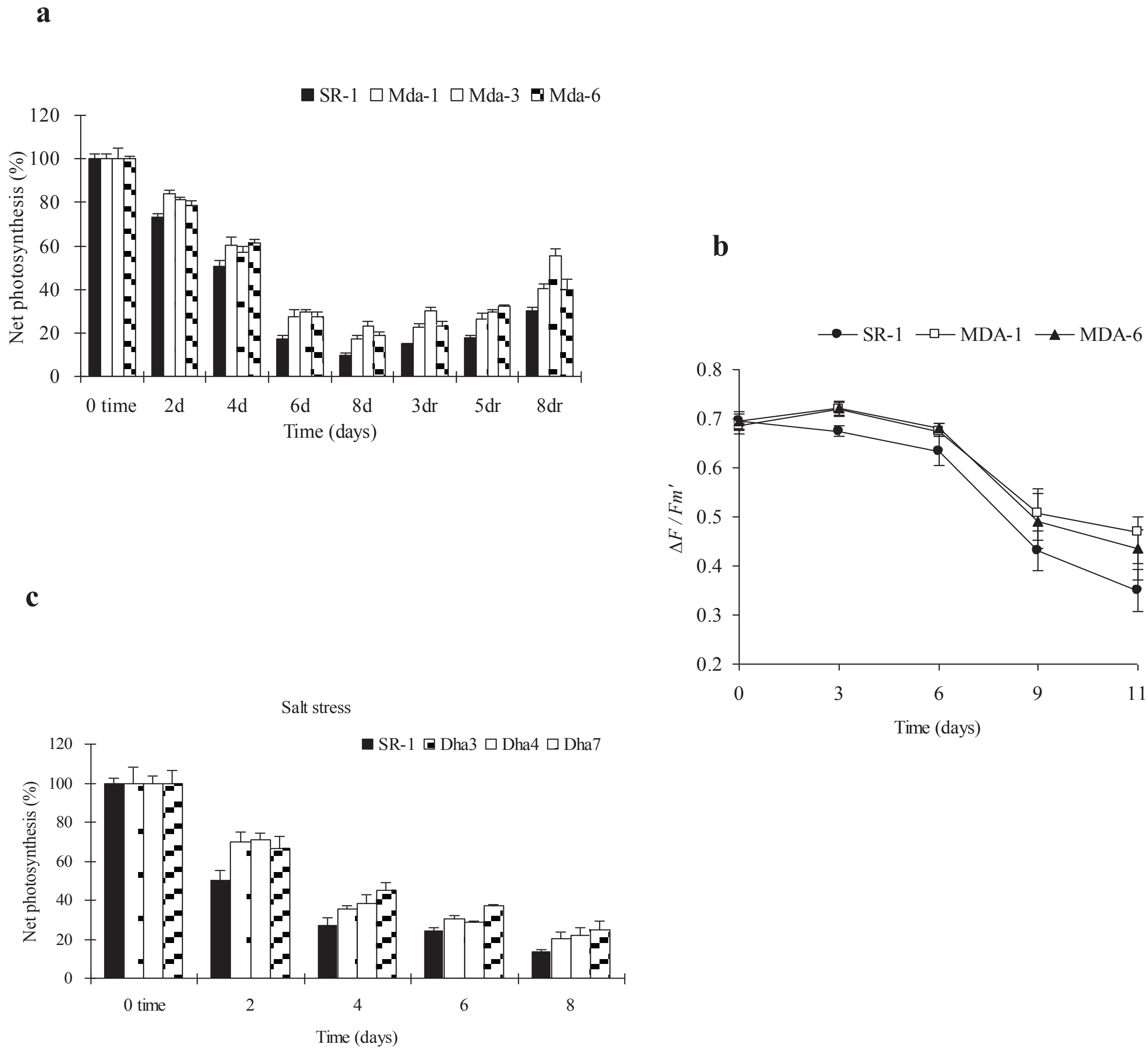

Figure 7. Net photosynthesis (%) and PSII effective quantum yield (*ΔF/Fm'*) during salt stress. (a) The 100% net photosynthesis (μmol CO_2 m $^{-2}$ s^{-1}) for MDAR transgenic and SR-1 control plants. 2d, 4d, 6d and 8d are 2, 4, 6 and 8 days of salt stress, respectively; 3dr, 5dr and 8dr are 3,5, and 8 days of recovery, respectively. (b) Effective PSII photon yield estimated by the fluorescence parameter *ΔF/Fm'* during salt stress imposed on MDAR overexpressing transgenic and SR-1control plants. (c) The 100% net photosynthesis for DHAR transgenic and SR-1 control plants under salt stress. The vertical bars represent the SE of the mean from triplicate determinations

3.6. Hydrogen peroxide contents under salt stress

Since high salinity is reported to induce oxidative stress (Hernández et al. 1993), the levels of H_2O_2 in both MDAR transgenic and SR-1 control plants were measured before and after salt stress treatments. Prior to the treatment, the level of H_2O_2 in all plants was low, with level of H_2O_2 significantly ($p < 0.05$) lower in MDAR transgenic plants than SR-1 control plants. After 4 days of salt stress, the level of H_2O_2 substantially increased to approximately 4 folds in all plants, but remains significantly ($p < 0.05$) lower in all MDAR transgenic plants compared to SR-1 control plants (Fig. 8).

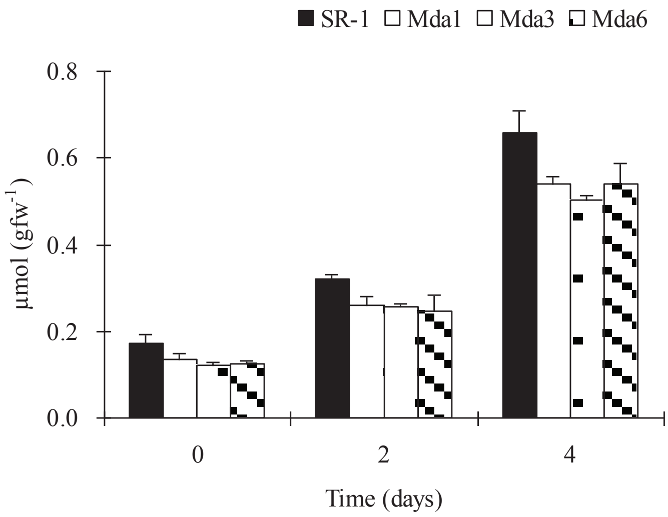

Figure 8. The levels of H_2O_2 in leaves of MDAR overexpressing transgenic and control plants (SR-1) before and during salt stress. The vertical bars represent the SE of the mean from triplicate determinations

3.7. Enhanced tolerance to drought stress

Compared to salt stress, the decrease in net photosynthesis of plants caused by 10% (w/v) PEG induced stress was relatively lower. Significantly ($p < 0.05$) higher net photosynthesis rates were observed in MDAR transgenic (Fig. 9a) and DHAR transgenic plants (Fig. 9b) compared to control plants. Moreover, under drought stress induce by withholding water, DHAR transgenic plants maintained significantly greater rates of their original photosynthesis compared to SR-1control plants (Fig. 9c).

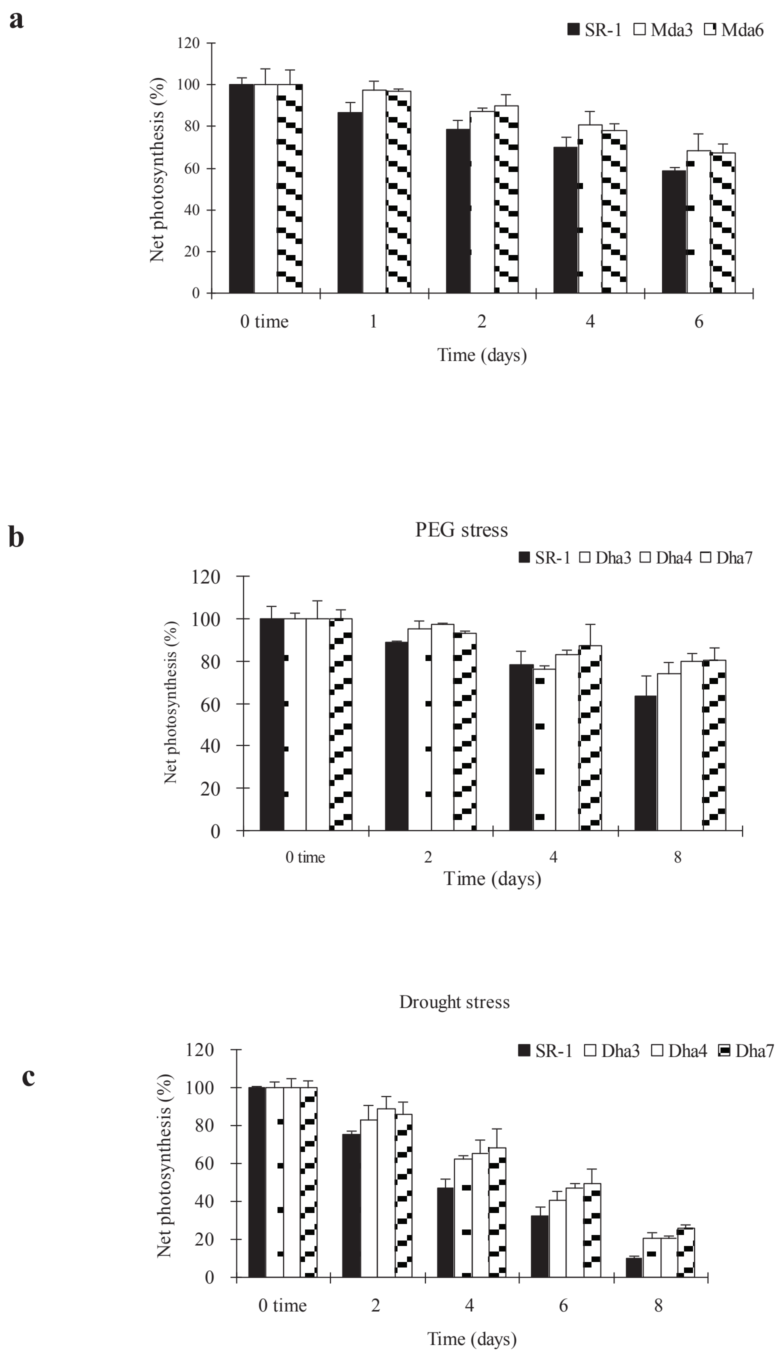

Figure 9. Net photosynthesis (%) during drought stress. (a) 100% net photosynthesis (μmol CO_2 m^{-2} s^{-1}) for MDAR and SR-1 control plants under drought induced by PEG. (b) 100% net photosynthesis for DHAR and SR-1 control plants under drought induced by PEG. (c) 100% net photosynthesis for DHAR transgenic and SR-1 control plants under drought induced by withholding water. The vertical bars represent the SE of the mean from triplicate determinations

4. Discussion

In plant cells, regeneration of AsA occurs via two ways; Mehler ascorbate peroxidase reaction which mainly reduces MDHA to AsA, and Halliwell-Foyer-Asada cycle which is found in several compartments of plant cells and mainly reduces DHA to AsA (Horemans et al. 2000*b*). To efficiently regenerate AsA, we developed transgenic tobacco plants overexpressing either MDAR or DHAR. Due to the introduced MDAR transgene, MDAR transgenic plants showed a significant increase in MDAR activity (Fig. 4a) and the level of AsA and its redox state were markedly increased in MDAR transgenic plants compared to SR-1 control plants (Fig. 4b). This increase could be attributed to that transgenic plants were more efficient in converting MDHA to AsA before being disproportionated into the fully oxidized DHA form. Efficient cycling between reduced and oxidized forms of AsA minimizes DHA degradation (Horemans et al. 2000). Therefore, the increase in AsA level and the decrease in DHA coupled with the improved redox state of AsA in transgenic plants could be understood through the enhanced recycling capacity resulted from the enhanced MDAR activity.

DHAR transgenic plants showed significant increase in DHAR activity compared to SR-1 control plants (Fig. 5a). Similar increase in DHAR activity was obtained on transgenic tobacco plants overexpressing human DHAR targeted to chloroplast (Kwon et al. 2001). Consequently, the level of AsA was markedly increased in DHAR transgenic plants (Fig. 5b) which could be attributed to that DHAR transgenic plants were more efficient in converting DHA to AsA before being hydrolyzed into 2,3-diketogulonic acid. The importance of cytosolic DHAR in reducing DHA diffused from other cell compartments was reported (Horemans et al. 2000*b*). A poplastic DHA has to be returned to cytosol for reduction to AsA (Pignocchi et al. 2003*b*). Therefore, the significant increase in AsA level in leaves of DHAR transgenic plants coupled with improved redox status of ascorbate could be mainly due to the enhanced activity of the cytosolic DHAR in reducing the oxidized DHA diffused from apoplast, chloroplast and other compartments of the cell into cytosol. Similar increase in AsA due to an increased expression of DHAR was reported by Chen et al. (2003).

Upon exposure to high concentrations of ozone, plants respond by triggering various defense systems including the antioxidative mechanisms (Sharma and Davis 1997). Ozone sensitivity is generally correlated with AsA status of the leaf tissues (Conklin and Barth 2004). The enhanced tolerance to ozone in MDAR transgenic plants (Fig. 6a) and DHAR transgenic plants (Fig. 6c) could be due to the elevated levels of AsA which mainly resulted from the enhanced activity of MDAR or DHAR, respectively. Higher activities of scavenger antioxidant enzymes may protect from oxidative stress (Pasqualini et al. 2001). The higher redox state of ascorbate in our transgenic tobacco plants could also explain the enhanced tolerance to ozone stress, which is consistent with the results reported by Sanmartin et al. (2003) that a decreased AsA/DHA ratio increased ozone sensitivity in transgenic tobacco plants overexpressing cucumber ascorbate oxidase gene. Furthermore, apoplastic AsA represents the first line of defense against potentially damaging external oxidants such as ozone, SO_2, and NO_2 (Plöchl et al. 2000; Barnes et al. 2002). Overexpressing of either MDAR or DHAR in cytosol might have maintained continuous flux of reduced AsA towards apoplast and consequently provided better protection against ozone. These results are in agreement with the report of Tanaka et al. (1985) indicating the importance of AsA in providing resistance against oxidative stress imposed by ozone.

AsA is important in photo-protection and the regulation of photosynthesis (Noctor and Foyer 1998), and probably plays an important role in providing resistance to oxidative stress imposed by ozone exposure (Sharma and Davis 1997). The effective PSII photon yield decreased more rapidly in SR-1 control plants than in MDAR transgenic plants under ozone stress (Fig.6b). Therefore, the greater protection of PSII photochemical activity in MDAR transgenic plants might be conferred by efficient supply of the regenerated AsA maintained by MDAR overexpressed levels.

The enhanced tolerance to salt stress in term of higher net photosynthesis in MDAR transgenic plants (Fig. 7a) and DHAR transgenic plants (Fig. 7c) could be understood through the higher levels of AsA and its maintained redox status. These results are in good agreement with Yamamoto et al. (2005) who reported that transgenic tobacco plants expressing ascorbate oxidase gene in antisense orientation exhibited higher AsA/DHA ratio, higher photosynthetic activity and lower H_2O_2 contents. Under salt stress, AsA is important in protecting and restoring the photochemical activity of PSII as demonstrated using the ascorbate-deficient *Arabidopsis* mutant (Huang et al. 2005). MDAR transgenic plants maintained greater PSII photon yield under salt stress compared to SR-1 control plants (Fig. 7b) which could be attributed to the increased level of AsA and the redox state.

AsA regeneration is necessary for the reductive detoxification of H_2O_2 (Hossain et al 1984), as well as its biosynthesis (Wheeler et al. 1998). Excess accumulation of H_2O_2 is one of the mechanisms by which plants are damaged under salt and drought stresses (Mittler 2002). H_2O_2 is able to pass through cell membranes and reach cell locations remote from its site of formation (Foyer et al. 1997). MDAR transgenic plants showed significantly lower levels of H_2O_2 (Fig. 8) and higher photosynthetic activity (Fig.7a) under salt stress compared to SR-1 control plants which could be mainly due to a fast removal of H_2O_2 during stress resulting from the elevated levels of AsA. Moreover, under salinity conditions AsA is reported to be mainly regenerated from MDHA (Mittova et al. 2000). Therefore, the enhanced tolerance to salt stress in MDAR transgenic plants could also be attributed to the overexpressed levels of MDAR that efficiently regenerated protective levels of AsA. These are consistent with the results reported by Huang et al. (2005) that H_2O_2 increased more dramatically in an ascorbate-deficient *Arabidopsis* mutant than in wild type plant under salt stress.

The higher photosynthetic rates drought stress in MDAR transgenic (Fig. 9a) and DHAR transgenic plants (Fig. 9b,c) under could be attributed directly to the higher levels of AsA in these transgenic plants. Adriano et al. (2005) reported that the level of total AsA that could limit cellular damage caused by ROS is an important attribute linked to drought tolerance in four interspecific *Prunus* hybrids. The reduction on net photosynthesis in both transgenic and controlled plants with the advancement of the stresses might be mainly due to the accumulation of ROS including H_2O_2, which exceeds ROS scavenging capacity of antioxidant enzymes functioning on its removal.

In conclusion, our results suggest that elevating AsA levels through overexpression of of either MDAR or DHAR could significantly contribute in enhancing plants tolerance to oxidative stress. Further studies in the consequences of the overexpression of these enzymes on the redox state of glutathione and on the activation status of other antioxidant enzymes are needed and will be very valuable in answering any questions that might remain.

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7.3. Participatory selection assisted by DNA markers for enhanced drought resistance and productivity in rice (*Oryza sativa* L.)

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Abstract

Lowland rice requires nealy 5000 litres of water for one kg grain yield required. At the same time, it contributes to about 20 to 25 per cent of methane gase emitted into the atmosphere. The intensive use of aerobic rice variety with drought resistance can prevent the release of greenhouse gases like methane and nitrous oxide. Identification of molecular markers associated with genes controlling drought resistance in rice is necessary step to improve breeding efficiency for this complex trait. In this study, the F_2 population derived from a cross between deep-rooted variety 'Moroberekan' with shallow-rooted variety 'IR20' was used to identify and validate SSR markers associated with root morphological traits. The F_2 lines were divided into two groups. In the first group 152 seedling having a minimum of 4 tillers were chosen and separated into 4 plantlets to plant them in PVC pipes measuring 1 meter in length and 20 cm diameter for root study under well-watered condition with four replications. Root sampling was done at maturity stage. The lines were genotyped using SSR markers. QTLs for MRL and root dry weight showed co-segregation with RM472, RM7 and RM201. The same material was forwarded to next generation (F_3) to validate the linked markers under both well-watered (WW) and low-moisture stress (LMS) conditions. These three markers were associated consistently with maximum root length (MRL) across generations whereas RM472, RM7 and RM242 were associated consistently with root dry weight in F_2 and F_3 generations. Only one marker, RM201 showed co-segregation consistently with root volume across generations. In the second group, 1224 F_2 plants were forwarded to F_6 using single seed dissent (SSD) breeding method to test the effectiveness of the marker-assisted selection (MAS) for drought resistant. A total of 126 SSD lines selected based on the five markers (RM7, RM472, RM257, RM242 and RM201) were grown under well watered (WW) and limited moisture supply (LMS) conditions in field and pipes. The high performing genotypic group was significantly superior to low performing group for MRL, grain yield, root volume, root dry weight and root number at 30 cm under LMS condition. Clearly, marker-assisted selection was effective for root morphological traits under LMS condition and ineffective under WW condition. Comparing MAS with conventional selection (farmers and breeders) in F_6 generation, the results showed that MAS group means were significantly different from farmer group means for MRL, root volume, root dry weight and root number at 30 cm, whereas MAS group means were significantly different from breeder group means for MRL and root dry weight. Thus, the identification of stable QTL for root morphological traits under well-watered and LMS conditions can aid in (MAS) and to introduce them into varieties with good yield potential. The long roots of aerobic rice help better absorption of water and facilitates better air circulation.

1. Introduction

Rice is the staple food for 2.5 billion people (Anon. 2004) and growing rice is the largest single use of land for producing food, covering 9 % of the earth's arable land (Anon. 2002). About half the total world rice area is rainfed, where drought is a major production constraint. Breeding for drought tolerance in rice remains a major challenge (Fukai, *et al*. 1999). Drought frequently causes loss of yield in rice. Grain yield can be drastically reduced if drought stress occurs during tillering or flowering stages. Hence, developing drought resistant cultivars, especially with good performance under late season drought stress is one of the major objectives in rice breeding programs (Boonjung and Fukai 1996; Pantuwan *et al*. 2002). In breeding programs to design drought tolerance of a crop, it is first necessary to gain an understanding of how the crop reacts to drought. It is also necessary to identify the characters associated with drought tolerance. This is best done under field conditions in the areas where the crop is grown since the seasonal timing of drought stress varies from one location to another.

Resistance or tolerance to water stress in crop plants is the combined result of many interacting morphological and physiological characters. Selection and breeding for desirable root characteristics associated with drought tolerance have been practiced in rice and the differential response of rice genotypes to drought has been related to root system characters (Steele et al. 2006). Among the root morphological traits, maximum root length, root dry weight, root volume and root to shoot weight and length ratios are associated with drought tolerance in upland conditions (O'Toole and Soematono 1981; Yoshida and Hasegawa 1982). Phenotypic selection for root morphological traits contributing drought tolerance is difficult, expensive and labour intensive. Recent developments in the molecular marker technology facilitate indirect selection of these complex traits through tightly linked markers. Identification of stable QTLs for root morphological traits across environments can aid in marker-assisted selection (MAS) and to introduce them into varieties with good yield potential (Lafitte and Courtois 1999; Hemamalini et al. 2000; Kanbar et al., 2002). Most of the earlier studies focusing on single marker or two flanked markers associated with a particular trait which means ignoring the different types of interaction between the markers located in the same region (Steele et al. 2006).

Conventional breeding has tended to focus heavily on "broad adaptability" the capacity of a plant to produce a high average yield over a range of growing environments and years. Unfortunately, candidate genetic material that produces very good yields in one growing zone, but poor yields in another, tends to be quickly eliminated from the breeder's gene pool. Yet, this may be exactly what small farmers in some areas need (Ceccarelli et al. 1996). Professional breeders, often working in relative isolation from farmers, have sometimes been unaware of the multitude of preferences — beyond yield, and resistance to drought — of their target farmers. Participation of farmers in the very initial stages of breeding, when the large genetic variability created by the breeders is virtually untapped, is expected to exploit fully the potential gains from breeding for specific adaptation through decentralized selection by adding farmer's perception of their own needs and farmers' knowledge of the crop (Ceccarelli *et al*. 1997). Thakur (1995) has screened material in farmer's fields at the F_2 stage, but subsequent generations have been grown by researchers. Conventional selection procedures take long time for developing lines with suitable genes. In this study, MAS and participatory techniques were combined together to develop drought-tolerant rice varieties exploiting more efficiently specific adaptation, and therefore to mach more precisely crops to their environment, particularly in the case of marginal, and stressful environments.

2. Material and methods

2.1. Plant material

The F_2, F_3, F_4, F_5, and F_6 materials derived from crossing divergent parents *viz.,* 'Moroberekan' and 'IR20' (Plate 1) were used in experiments. While, the female parent Moroberekan was an African *japonica* having a deep and thick root system and tolerance to drought but relatively low yield, the male parent was IR20, an *indica* type, having short stature, a shallow root system and high yield but susceptible to drought.
Field experiments were conducted during 2003-2005 at the Hebbal Research Campus, University of Agricultural Sciences, Bangalore and farmer's field at the *Shettigere* village 20 km North of Bangalore. The laboratory experiment was carried out in the Marker-Assisted Selection Laboratory, Department of Genetics and Plant Breeding, University of Agricultural Sciences, GKVK, Bangalore. The city of Bangalore is located in the heart of the South - the Deccan Plateau, with an average elevation of 900 m above sea level, with temperature ranging from around 24°C in winter to 35°C during summer, despite being between the very tropical latitudes of 12° 39' N and 13° N, longitude being 77 37' East. The F_2 seeds were divided into two sub-populations for evaluating root and yield morphological traits simultaneously (Fig. 1).

Plate 1. Variation among the parents (Moroberekan and IR20) for root system

2.2. Identification and validation of SSR markers associated with root morphological traits

In first sub-population, the entries were planted in nursery with 5 cm spacing between plants to produce more number of tillers at early stage of growth. Out of 272 seedlings having minimum of four tillers were chosen, 152 plants were separated into four plantlets to plant them in four replications (RCBD design) in PVC pipes. Ninety-two F_2 plants were selected randomly from the 152 vegetatively replicated lines and advanced to next generation.

Phenotypic evaluation of 92 $F_{2:3}$ families were conducted in PVC pipes condition under two moisture regimes (well-watered, WW, and low-moisture stress, LMS conditions). The experiment was laid out in an RCBD design separately for WW and LMS conditions in four replications each. Plants were watered daily throughout the cropping period in WW treatment and irrigation was stopped from 70 days after sowing up to 85 DAS in LMS treatment. Observation consisted of maximum root length (MRL) in cm, root number at 15 cm (RN15) and 30 cm (RN30), root volume (RV) in cc, root dry weight (RDW) in g and grain yield/plant (GY) in g. DNA was isolated from the same lines for laboratory experiment. The technique for root morphological study and DNA isolation was as described by Kanbar et al. (2004). Based on earlier investigation, twenty polymorphic SSR markers selected from four hot spots chromosomal regions on chromosomes 1, 3, 7 and 9 associated with QTL for drought resistance were used to screen the entries (Temnykh et al. 2001). RM302, RM212, RM265, RM315 and RM472 located on chromosome 1; RM7, RM218, RM251, RM563 and RM282 on chromosome 3; RM182, RM455, RM234, RM248 and RM420 on chromosome 7; and RM434, RM257, RM242, RM278 and RM201 (Fig. 1). The band corresponding to Moroberekan was scored as 1, the one corresponding to IR20 was scored as 3 and heterozygote was given a score of 2.

2.3. Comparative study between MAS and participatory plant selection

In the second sub-population, the single-seed descent (SSD) and participatory plant selection methods were used to advance the material for the study in the farmer's field at *Shettigere* village. The details of the material developed by the breeding procedure are depicted in Fig. 1. In SSD breeding method, one seed was taken from each of 1240 F_2 plants to forward to F_3 generation. These seeds were sown in plots of 3 x 3 meter size at low density (25 cm between rows and 15 cm between plants in each row). At harvest, one seed was taken from each plant, the seeds bulked and then used to raise the next generation of plants, 650 plants survived and produced grains. The same procedure was repeated in F_4 generation. In F_5 generation, 480 plant-to-row progenies of the SSD F_4 plants were grown with low-density (25 cm between rows and 15 cm between plants in each row). At maturity, 112 families were chosen at random to represent the whole population and the seed from each of these families harvested separately from that of every other to produce a mapping population comprising 112 RI lines. This population was screened using the five selected SSR markers to see the effectiveness of MAS. Twenty-two lines were selected in F_5 based on five associated markers data and divided equally into two groups based on the banding pattern of the markers (allele type). While, in first group, the genotypes lacked the Moroberekan alleles in all the markers, the second group of genotypes possessed the Moroberekan banding patterns in most of loci. These selected lines were advanced to next generation for comparative study (Table 4).

The material of participatory plant selection involved the F_3, F_4, F_5 and F_6 generations. In F_2, F_3, and F_4 generations, around 45 farmers and 15 breeders visited our field when more than 90% of the plant families were already mature. Every participant was given a plastic label with code number to tie to the selected plant. Visual selection was performed by the farmers and breeders. The best plants of farmer's and breeder's selection were advanced to F_5 generation. In F_5 generation, twenty and eighteen heterogeneous inbred families (HIFs) of farmer's and breeder's selection were used, respectively, as a material for Marker-assisted selection (MAS) (Fig. 1).

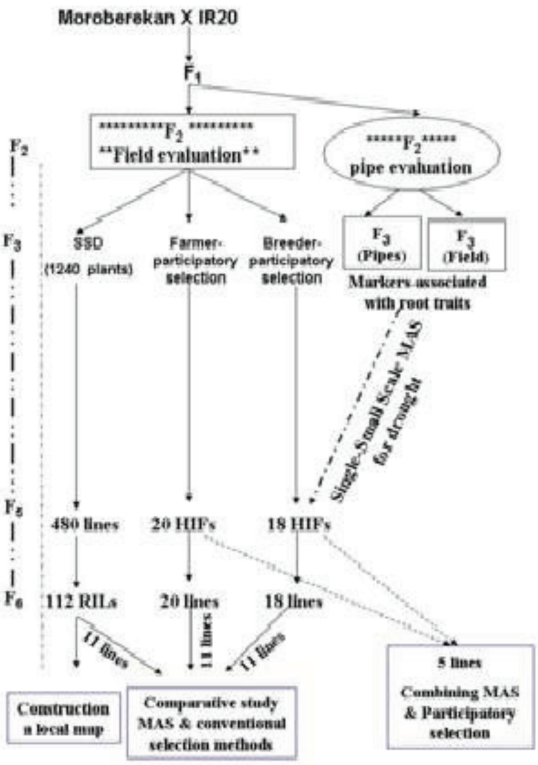

Figure 1 Diagrammatic representation of plan of work.

Twenty-two genotypes, selected based on marker data, were evaluated along with lines selected by farmers and breeders for yield and root evaluation in F_6 generation. These lines were evaluated under WW and LMS conditions in RCBD design of four replications for each at *Shettigere* village (farmer host land) for yield study. At 50 DAS, low-moisture stress was imposed by irrigating the plants once each twelve days up to 90 DAS. In WW condition, irrigation was given once every five days.

Root evaluation was performed under WW and LMS conditions using PVC pipes. The experiment was laid out in CRD design with four replications for each WW and LMS conditions at Hebbal Campus, UAS, Bangalore, during summer season of 2005. The LMS was induced in four replications by with-holding irrigation and providing rainout shelter between 70 to 85 DAS during tillering stage. After that water was given daily as in case of well-watered condition. Combining MAS with participatory selection under the target environment, five lines were selected and advanced to F_7 for developing varieties of rice tolerant to drought and accepted by the farmer.

2.4. Statistical analysis

The data of individuals was subjected to ANOVA to partite the variance using SAS statistical program (SAS Institute, Inc. 1996), and Duncan test was employed to classify mean values of different treatments when F-values were significant ($P<0.05$). QTLs linked to markers for different phenotypic traits were determined using single-marker analysis (Tanksley et al. 1982) and the results were tested using one-way analysis of variance (ANOVA). Association between the RM markers and the phenotypic performance of individuals for various traits were also established using step-wise regression analysis. All SSR markers from each chromosome were treated as independent variables (X_i) in a multiple regression analysis and different traits were treated as dependent variable (Y) (root length, root volume and root dry weight). These analyses were performed on data from each environment and the combined analysis using the GLM procedure in SAS. The t-test tests the hypothesis that the true means of two groups (MAS-farmer, MAS-breeder, and farmer-breeder-) of observations are the same. This analysis can be considered a special case of a one-way analysis of variance with two levels of classification. PROC TTEST computes the t statistic using the procedure of Gosset (1908).

3. Results and discussion

The experiment was conducted to identify a stable QTLs for root morphological traits across environments and generations in Moroberekan / IR20 cross and to combine MAS with participatory selection under the target environment for developing varieties of rice tolerant to drought and accepted by the farmer.

3.1. Identification and validation of SSR markers associated with root–related traits

Making use of the single-tiller approach, replicated PVC pipe trial was being able to perform in an F_2 population with four replications. Theoretically, data collected from this sort of field experiment best serve the purpose of estimation of genetic parameters and QTLs analysis; because the F_2 is genetically the most informative population that enables a direct estimation of all genetic components, and replicated field trial can provide estimates and also reduce the experimental errors. The results of the analysis of variance revealed significant differences for all the traits (data not shown) in F_2 and $F_{2:3}$. A wide variability was observed for all root-related traits and Duncan test revealed significant differences between the two moisture regimes (WW and LMS) in $F_{2:3}$ (Table 1).

Table 1. Descriptive statistics for root morphological traits studied under WW and LMS conditions in Moroberekan/IR20 F_2 and $F_{2:3}$ populations using PVC pipes

Traits	Generation	Condition	Mean	SE±	Min.	Max.	Range	Moro-berekan	IR20
Maximum root length	F_2	WW	66.96	0.77	15.00	131.00	116.00	65.00	39.40
	F_3	WW	61.65 a	0.80	29.00	114.00	85.00	55.75	27.50
		LMS	75.69 b	0.60	53.00	120.00	67.00	67.25	28.00
Root volume	F_2	WW	40.51	1.31	1.00	215.00	214.00	67.20	54.00
	F_3	WW	68.69 a	2.11	4.00	300.00	296.00	55.00	20.25
		LMS	58.46 b	1.62	10.00	218.00	208.00	38.50	21.00
Root dry weight	F_2	WW	4.84	0.13	0.30	18.00	17.70	6.50	5.32
	F_3	WW	8.88 a	0.32	1.23	41.80	40.57	8.50	5.25
		LMS	7.78 b	0.28	0.40	33.60	33.20	8.70	3.45
Root number (15 cm)	F_2	WW	91.26	2.12	10.00	350.00	340.00	93.20	114.40
	F_3	WW	126.07 a	3.09	7.00	386.00	379.00	108.50	103.50
		LMS	108.36 b	2.56	30.00	360.00	330.00	76.50	57.25
Root number (30 cm)	F_2	WW	35.99	1.18	1.00	180.00	179.00	28.80	20.00
	F_3	WW	37.40 a	1.23	1.00	140.00	139.00	41.75	---
		LMS	23.44 b	0.83	3.00	110.00	107.00	20.50	---
Root number (60 cm)	F_2	WW	12.74	0.45	1.00	20.00	19.00	6.67	---
	F_3	WW	2.11 a	0.38	1.00	16.00	15.00	---	---
		LMS	2.44 b	0.11	1.00	18.00	17.00	2.75	---

In this study, root sampling was done at maturity stage under both WW and LMS conditions. Therefore, the QTLs identified for root-related characters are active at the end of the life cycle of rice. In F_2 population, QTLs for MRL and RDW showed co-segregation with RM472, RM7 and RM201. Root volume was found to be associated with RM422 and RM201 (Table 2). Courtois *et al*. (2000) identified a QTL for MRL using doubled haploid lines of IR64 / Azucena. One QTL was strongly associated with RZ12 on chromosome 9 which is very close to RM201 and RM242 markers. RM472, RM7 and RM201 were associated consistently with MRL across generations. At the same time, RM472 and RM7 were linked consistently to RDW in F_2 and F_3 generations. Only one marker, RM201 showed co-segregation consistently with root volume across generations (Plate 2). Yadav *et al*. (1997) also reported a common QTL on chromosome 9 co-segregating with RZ12-RG667 in IR64/Azucena and RZ12 in CO39/Moroberekan mapping populations. Shen *et al*. (2001) have replaced RZ228 and RZ12 by RM201 and RM242 for the target region of chromosome 9 to use this region in MAS for deep rooted lines in IR64/Azucena backcross population. They also selected RM234, CDO418, RZ978, CDO38, and RM248 for the target region of chromosome 7 for the same purpose. Several other scientists reported the strong association of RM201 and RM7 with MRL across populations (Shashidhar et al. 2001; Kanbar et al. 2002, 2004; Steele et al. 2006). A low statistical threshold was used in this study to avoid false-negative and due to the relatively small size of the mapping population used for genotyping, as it is difficult to detect QTLs using a high threshold in a smaller population. Price et al. (2000) found that 89% of the QTLs detected by composite interval mapping concurred with those detected by single-marker analysis.

Markers within each group were analyzed as a multiple regression against data from individual generation, conditions and the combined data from both conditions (mean environment in F_3) to determine if a region of the genome could better explain the variation for root length, root volume and root dry weight performance (Table 3). Of the four marker groups, three showed significant association with all the traits in at least one environment.

The marker group on chromosome one was not showing any association with any of these three traits. Based on the result of SMA, such interaction was expected. No marker showed association with MRL, RDW and RV in F_3 population under LMS condition and the linkage of markers to QTLs associated with root morphological traits was significantly low.

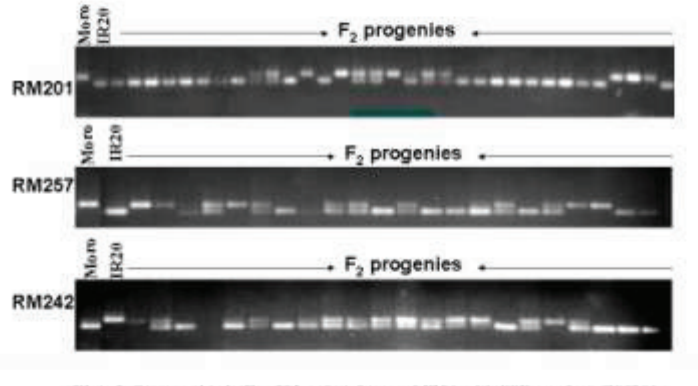

Plate 2: Segregation in F_2 of Moroberekan and IR20 with SSR markers RM201, RM257 and RM242.

Table 2. Microsatelitte markers linked to QTLs controlling root morphological traits in Moroberekan / IR20 F_2 and $F_{2:3}$ populations under WW and LMS conditions through single-marker analysis (n=92)

Marker	Chr.	F_2 population (WW)			F_3 population (WW)			F_3 population (LMS)		
		Trait	R^2	Pr > F	Trait	R^2	Pr > F	Trait	R^2	Pr > F
RM315	1				RN30	5.18	0.04	RN15	9.86	0.006
					RN60	5.68	0.038	RN30	9.87	0.006
RM212	1							RN15	8.33	0.005
								RN30	8.53	0.005
RM472	1	MRL	6.91	0.01	MRL	4.08	0.05			
		RN15	4.45	0.04	RN15	7.41	0.01			
		RV	5.17	0.03						
		RDW	4.08	0.05	RDW	4.08	0.05			
		RN60	5.11	0.03						
RM282	3				RN60	7.32	0.04			
RM7	3	MRL	6.15	0.01	MRL	5.78	0.02	MRL	17.04	0.0001
		RDW	5.95	0.01				RDW	6.43	0.01
								RV	5.12	0.03
								RN15	6.14	0.01
								RN60	3.83	0.05
RM234	7							MRL	10.33	0.008
								RN15	6.97	0.04
								RV	8.94	0.01
RM248	7	RN15	6.8	0.05						
RM201	9	MRL	16.62	0.0003	MRL	12.13	0.003			
		RN30	11.11	0.005						
		RV	9.58	0.01				RV	6.12	0.05
		RDW	10.27	0.008						
RM242	9	MRL	10.57	0.006						
					RV	8.86	0.016			
					RDW	10.89	0.006			
RM257	9				RV	5.89	0.043			
					RN60	7.49	0.039			

The markers group 9 was significantly associated with MRL across generations and conditions, but was not significantly linked to root volume. The MRL locus co-segregating with RM201 and RM242 at probability of 0.001 (LOD=3), which makes this region more specific to root-related traits. Marker group 7 was significantly associated with MRL under WW in F_3 and with root volume and root dry weight under LMS condition. Our findings suggest that root length-dominancy loci in chromosome regions may interact to influence extreme root length under a particular regime. The identification of gene–gene interactions may prove crucial to understanding the contributions of genes, which, by themselves, have relatively small effects on root length (deep and shallow).

In the present study, the marker groups on chromosome 3, 7 and 9 were associated with the mean environment of MRL in F_3 generation, while the marker group 7 and 3 showed association with mean environment of root dry weight and root volume, respectively. Knapp *et al*. (1990) believed that mean environment would be the most efficient condition for identification of QTLs because of the reduced standard error of trait values.

Table 3. Coefficients of determination (R^2) and significance of F-tests from multiple regression analyses performed between marker groups and MRL, RDW and RV in F_2 and F_3 populations under WW and LMS conditions and their environmental mean (* = Significant at 5% and ** = Significant at 1%).

Traits		Maximum root length				Root volume				Root dry weight			
Generation		F_2	F_3			F_2	F_3			F_2	F_3		
Condition		WW	WW	LMS	Env. mean	WW	WW	LMS	Env. mean	WW	WW	LMS	Env. mean
Chromosome number	Chr. 1												
	Chr. 3			0.16**	0.15**			0.06*		0.07*		0.07*	0.07*
	Chr. 7		0.11**		0.09*			0.11**	0.09*			0.08*	
	Chr. 9	0.15**	0.10**	0.08*	0.13**					0.11**			

3.2. Participatory selection assisted by DNA markers

3.2.1. Efficiency of MAS in F_6 generation

Identification of stable QTL for root morphological traits under WW and LMS conditions can aid in MAS. This would facilitate introducing them into varieties with good yield potential (Lafitte and Courtois 1999; Shen et al. 2001; Steele et al. 2006). The approach of single large-scale MAS (SLS-MAS) has been described (Ribaut and Betrán 1999). This interactively combines the use of DNA markers and conventional breeding. Hence, the MAS was applied in a single and small population without flanking markers, the modified SLS-MAS has been named as single small-scale participatory-selection assisted by DNA marker in this study. In contrast to the conventional SLS-MAS, Steele et al. (2006) did not use flanking markers to reduce costs and the time required and they only attempted to identify lines with one root QTL.

Under WW condition, t-test results showed that there were no significant differences between the two performing genotypic groups for all the traits except grain yield (Table 5). However, the mean values of high performing genotypic (HPG) group were higher than those of corresponding low performing genotypic (LPG) group for MRL, GY/plant, RN15 and RN30. Under LMS condition, the HPG group was significantly superior to the genotypes identified as LPG group for MRL, GY, RV, RDW and RN30. However, the mean values of LPG group were numerically higher than those of corresponding HPG group for root number at 30 cm. Clearly, MAS was effective for root morphological traits under LMS condition and ineffective under WW condition. As quantitative genetic theory suggests the effectiveness of MAS is inversely proportional to the heritability of given trait (Lande and Thompson 1990; Paterson et al. 1991). The results from this study are consistent with this statement. The heritability for root morphological traits under WW was higher than the heritability under LMS condition in F_6 generation (data not shown). The effectiveness of Moroberekan alleles on root-related traits was more than the IR20 alleles in LMS condition where the genotypes express themselves to their fullest potential under stress condition.

Table 4: Means for high and low performing genotypic groups for root-related traits and grain yield under stress and nonstress condition in F_6 generation

Genotypes	Markers					Well-watered condition						Low-moisture stress condition					
	RM7	RM472	RM257	RM242	RM201	MRL	GY#	RV	RDW	RN15	RN30	MRL	GY	RV	RDW	RN15	RN30
MI-3	3	3	3	3	3	49.0	17.4	88.0	8.2	162.5	6.5	46.5	9.0	31.0	3.1	148.0	10.0
MI-6	3	3	3	3	3	49.5	24.5	25.5	5.1	122.5	5.5	42.0	12.0	58.0	4.1	197.5	2.0
MI-7	3	3	3	3	3	24.5	14.9	19.0	1.1	77.5	5.5	41.0	8.6	34.5	3.9	106.5	2.0
MI-11	3	3	3	3	3	33.0	14.5	79.0	7.0	237.5	9.0	43.0	9.0	58.0	3.6	98.0	3.5
MI-13	3	2	3	3	3	39.5	14.3	52.5	4.5	157.0	19.0	42.0	5.0	23.5	4.4	91.0	4.5
MI-82	3	3	3	3	3	39.5	7.8	52.5	7.6	157.5	3.5	45.0	3.0	40.0	4.4	93.0	3.0
MI-93	3	3	3	3	3	55.5	7.0	147.5	14.8	255.5	19.5	45.5	5.5	16.0	2.2	72.5	3.5
MI-104	3	3	3	3	3	44.5	5.0	48.0	5.3	137.5	14.0	46.0	4.6	33.5	3.1	106.0	9.0
MI-109	3	3	3	3	3	36.5	11.7	87.0	9.9	154.0	1.5	47.0	3.1	43.5	6.2	117.5	4.5
MI-110	3	3	3	3	3	40.0	7.0	59.0	6.3	122.5	4.5	38.5	5.9	6.5	1.1	49.0	4.5
MI-111	3	3	3	3	3	37.5	5.0	77.5	7.0	234.5	5.0	47.5	3.1	54.0	4.5	122.5	4.5
MI-5	1	3	1	1	1	48.5	21.7	67.5	6.1	157.5	6.5	55.0	8.0	29.5	7.0	100.0	4.5
MI-25	1	1	1	1	1	45.0	27.5	105.0	12.5	244.5	19.0	63.0	8.0	49.0	7.3	157.5	5.5
MI-26	3	3	1	1	1	48.0	18.0	41.0	5.4	138.0	9.0	55.0	15.0	47.5	7.0	107.5	9.0
MI-27	3	1	1	1	1	36.5	29.5	67.5	6.3	172.5	4.5	62.0	9.4	59.0	14.0	187.5	14.0
MI-33	2	1	3	1	1	31.5	19.0	48.0	5.3	158.0	1.0	55.0	11.9	42.0	7.0	121.5	9.4
MI-34	3	1	1	1	1	49.0	22.3	31.0	3.7	92.5	4.5	59.0	12.0	43.5	7.1	187.5	4.0
MI-37	1	3	1	1	1	36.5	14.9	49.0	3.8	157.0	3.5	62.0	11.2	55.0	12.0	138.0	6.0
MI-85	1	1	1	1	1	49.0	10.4	59.0	4.9	177.5	9.0	59.0	10.0	58.0	7.0	127.5	14.0
MI-91	1	1	1	1	1	41.5	6.8	48.0	4.1	117.5	2.5	73.5	9.0	118.5	16.8	127.5	24.0
MI-94	1	3	1	1	1	41.5	17.9	58.0	8.2	117.5	6.5	56.0	8.0	29.0	7.0	88.5	3.5
MI-102	1	3	1	1	1	51.0	9.5	148.5	9.8	352.5	29.0	59.0	7.0	62.5	9.2	194.5	9.0

: Grain yield has been measured under field condition in farmer's land

Table 5. Grand mean and means for high and low performing genotypic groups, coefficient of variation for traits resulting from analysis of variance for WW and LMS conditions in Moroberekan / IR20 F_6 generation

Statistical paramaters	Well-watered	Low-moisture stress
	Maximum root length	
Grand mean	42.13	51.93
Mean low-performing genotypic group	40.81	44.00
Mean high-performing genotypic group	43.45	59.86
Difference	2.64^{ns}	15.86****
CV %	17.97	8.34
LSD %	6.74	3.86
	Grain yield#	
Grand mean	14.84	8.10
Mean low-performing genotypic group	11.73	6.25
Mean high-performing genotypic group	17.93	9.95
Difference	6.20*	3.70***
CV %	44.96	33.27
LSD %	5.93	2.39
	Root volume	
Grand mean	66.27	45.09
Mean low-performing genotypic group	66.86	36.23
Mean high-performing genotypic group	65.68	53.95
Difference	-1.17^{ns}	17.72*
CV %	51.91	46.10
LSD %	30.60	17.70
	Root dry weight	
Grand mean	6.67	6.45
Mean low-performing genotypic group	6.98	3.69
Mean high-performing genotypic group	6.37	9.22
Difference	-0.61^{ns}	5.53****
CV %	46.76	40.79
LSD %	2.77	2.34
	Root number at 15 cm	
Grand mean	168.34	124.50
Mean low-performing genotypic group	165.32	109.23
Mean high-performing genotypic group	171.36	139.77
Difference	6.04^{ns}	30.54^{ns}
CV %	38.14	30.59
LSD %	57.11	33.88
	Root number at 30 cm	
Grand mean	8.56	6.99
Mean low-performing genotypic group	8.50	4.64
Mean high-performing genotypic group	8.63	9.36
Difference	0.13^{ns}	4.72*
CV %	85.52	66.86
LSD %	6.51	4.16

Although currently MAS is used less in forward crossing than in backcrossing programs, forward MAS should become more common after novel alleles have been introgressed from exotic germplasm or wild relatives into elite genetic backgrounds. Selection for root traits by MAS could help drought tolerance breeding in upland rice (Price and Courtois 1999; Hemamalini et al. 2000; Steele et al. 2006). Steele et al. (2006) have transferred five QTLs for root morphological traits from 'Azucena' in to 'KalingaIII' using MAS.

3.2.2. Efficiency of MAS compared with conventional selection

Under WW condition, MAS group means were significantly different from farmer group means for MRL, RN15 and RN30 (Table 6), whereas MAS group means were numerically higher than breeder's group means for MRL, RV, RDW, RN15 and RN30 (Table 7). Under LMS condition, MAS group means were significantly different from farmer group means for MRL, RV, RDW and RN30. Where as, MAS group means were significantly different from breeder group means for MRL and RDW. There is a substantial improvement for MRL and RDW, which suggests that MAS is more effective than conventional selection for drought tolerance in this rice population. The high efficiency of MAS for these traits (MRL and RDW) could be due to the strong association of the target regions with these two traits compared with other root-related traits. Additionally the genetic variation was much greater in stress treatment than non-stress condition.

Participatory plant breeding (PPB), like conventional breeding, is predicted to give a low response to selection for traits with low heritability. These include many traits that farmers consider desirable, such as drought tolerance. The technology of MAS can be used to make selection for traits with low heritability more effective (Schneider *et al*. 1997). Compared with conventional selection (farmer and breeder), MAS was not effective in improving yield above the experimental means under stress and non stress conditions. This result is not surprising, because the five SSR markers are very specific for root morphological characters and the MAS was done at later stages where most of the families were stable.

3.2.3. Combining MAS and PPS

Combining MAS with participatory plant breeding selection could help the breeders to develop varieties resistant to drought and accepted by the farmers. Based on the five SSR markers data, five lines have been selected from the farmer and breeder F_6 lines. These lines were deeper rooting and higher yielding than the twp parents under both WW and LMS regimes in F_7 generations (Table 8) (Shashidhar, personal communication). Primary yield trials with three or more replications have to be conducted to evaluate these lines for yield, disease, maturity time and quality etc.

Table 6. Grand mean and means for MAS and farmer groups, coefficient of variation (CV) for the traits resulting from analysis of variance for WW and LMS conditions in Moroberekan/ IR20 F_6 generation

Statistical paramaters	Well-watered	Low-moisture stress
	Maximum root length	
Grand mean	41.27	51.87
MAS group	43.45	59.86
Farmer group	37.90	43.40
Difference	5.55*	16.46****
CV %	15.04	11.06
LSD %	5.83	5.39
	Grain yield#	
Grand mean	19.64	10.77
MAS group	17.93	9.95
Farmer group	21.44	11.79
Difference	-3.51^{ns}	-1.84^{ns}
CV %	59.06	42.44
LSD %	10.90	4.29
	Root volume	
Grand mean	59.07	42.64
MAS group	65.68	53.95
Farmer group	50.70	31.18
Difference	14.98^{ns}	22.77*
CV %	55.69	53.73
LSD %	30.91	21.53
	Root dry weight	
Grand mean	6.21	6.35
MAS group	6.37	9.22
Farmer group	5.93	3.27
Difference	0.44^{ns}	5.95****
CV %	40.58	41.17
LSD %	2.36	2.45
	Root number at 15 cm	
Grand mean	139.90	132.45
MAS group	171.36	139.77
Farmer group	107.10	123.30
Difference	64.26*	16.47^{ns}
CV %	40.22	31.24
LSD %	52.86	38.89
	Root number at 30 cm	
Grand mean	6.60	6.57
MAS group	8.63	9.36
Farmer group	3.80	3.80
Difference	4.83*	5.56*
CV %	90.87	4.61
LSD %	5.64	74.69

Table 7. Grand mean and means for MAS and breeder groups, coefficient of variation (CV) for the traits resulting from analysis of variance for WW and LMS conditions in Moroberekan / IR20 F_6 generation

Statistical paramaters	Well-watered	Low-moisture stress
	Maximum root length	
Grand mean	44.61	54.34
MAS group	43.45	59.86
Breeder group	44.56	48.33
Difference	-1.11^{ns}	11.53***
CV %	10.95	13.17
LSD %	4.58	6.72
	Grain yield#	
Grand mean	18.84	11.35
MAS group	17.93	9.95
Breeder group	19.84	12.95
Difference	-1.91^{ns}	-3.00^{ns}
CV %	50.46	67.37
LSD %	8.93	7.18
	Root volume	
Grand mean	67.06	52.21
MAS group	65.68	53.95
Breeder group	66.67	50.33
Difference	-0.99^{ns}	3.62^{ns}
CV %	48.02	48.12
LSD %	30.25	23.61
	Root dry weight	
Grand mean	7.03	7.36
MAS group	6.37	9.22
Breeder group	6.48	5.28
Difference	-0.11^{ns}	3.94***
CV %	39.99	41.56
LSD %	2.64	2.87
	Root number at 15 cm	
Grand mean	154.07	144.52
MAS group	171.36	139.77
Breeder group	135.44	147.44
Difference	35.92^{ns}	-7.67^{ns}
CV %	38.54	26.35
LSD %	55.80	35.79
	Root number at 30 cm	
Grand mean	7.53	7.95
MAS group	8.63	9.36
Breeder group	5.67	6.56
Difference	2.96^{ns}	2.80^{ns}
CV %	80.96	65.5
LSD %	5.73	4.89

: Grain yield has been measured under field condition in farmer's land

Table 8: Mean values of five MAS - participatory selected F_6 lines along with parents under WW and LMS conditions.

Genotypes	Markers					MRL		RN15		RN30		RV		RDW		GY/plant (pipes)		GY/plant (field)	
	RM7	RM472	RM257	RM242	RM201	WW	LMS	WW	LMS	WW	LMS	WW	LMS	WW	LMS	WW	LMS	WW	LMS
MIP-25-6-2	1	1	1	1	1	48.0	56.0	138.0	88.0	9.0	7.0	41.0	30.5	5.4	4.2	10.0	8.5	18.0	16.5
MIP-221-19-7	1	1	1	1	1	42.0	51.5	152.5	140.0	15.5	8.5	50.0	49.0	5.3	4.5	7.1	5.6	23.5	17.5
MIP-302-15-25	1	3	1	1	1	40.0	47.0	158.0	99.0	3.0	5.6	19.0	20.5	4.4	4.4	10.6	7.5	23.0	12.4
MIP-128-26-2	1	1	1	1	1	46.0	54.0	182.5	118.5	13.5	14.0	92.5	48.0	12.0	5.1	9.1	6.1	30.0	11.5
MIP-452-20-21	1	1	1	1	1	44.5	52.0	137.5	102.5	6.5	4.0	34.5	29.0	4.1	5.0	8.3	5.7	39.5	16.0
Moroberekan	1	1	1	1	1	36.0	46.0	122.0	92.0	3.5	7.5	39.0	31.0	3.7	3.5	7.1	5.6	20.5	12.0
IR20	3	3	3	3	3	22.0	25.0	137.0	109.0	-----	-----	33.0	29.0	3.8	3.1	6.2	4.4	13.0	7.5

4. Conclusions

The data obtained from this study of MAS is encouraging. Significant gains in the MAS compared with farmer and breeder selection were obtained from selection based on DNA markers linked to QTL controlling root-related traits. These results are of particular importance since the population sizes used was relatively small indicating that one may not need a large population size to achieve progress from MAS. In most cases, MAS provided simultaneous improvements for multiple traits (root length, root dry weight and root volume). The identification of rice selections with deep root system has been difficult because root evaluation is tedious, time consuming, relatively labor intensive and not well suited for mass screening. Marker-assisted selection can economically compete with PPS and the gains result from the reduced size and duration of breeding programs. Therefore, incorporating DNA markers into traditional breeding programs can reduce the time and money needed to achieve breeding goals.

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7.4. Improving barley drought tolerance through selection criteria and molecular markers

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Abstract

Thirtythree barley genotypes (two local Egyptian varieties, one local new line bred by Desert Research Center, two newly released ACSAD varieties and 26 exotic lines selected from 110 ICARDA barley germplasm lines) were grown under rainfed conditions in Maryout, north-western Coast for two seasons. Based on seed yield, two genotypes ('No. 22' and 'No. 23') proved drought sensitive while the two lines as tolerant (Egyptian newly bred line ' Su12303' and the exotic Line 'No. 13'). Grain yield/plant was positively correlated with spikes/plant, grains/spike and biological yield/plant. The main source (as total contribution) of plant grain yield variation was number of spikes/plant followed by number of grains/spike and 1000-grain weight. ISSR-PCR for five primers scored three positive markers which appeared in two drought tolerant lines (Su 12330 and Line 13) and absent in the two sensitive lines. Such markers could be detected by primers; 7899A, 7899B, 7898B and HB 2 at molecular sizes of 730, 560, 660 and 820 bp, respectively. A total of 8 unique bands for different genotypes were identified out of the polymorphic among the primers under study. Based on ISSR marker polymorphisms, similarity matrix showed that the closer relationship was scored between the two different genotypes A1028 and Line 13 followed by the two different genotypes Line 22 and A1028 and between Rihane-3 and A410 (similarity of 0.862, 0.860 and 0.825, respectively).

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the most important crops because it has great adaptive potential to various habitats, particularly those prone to drought. Identifying and understanding mechanisms of drought tolerance is crucial to the development of tolerant commercial cultivars.

The efficiency of a breeding program can be increased by selecting for traits associated with performance under stress, which are less prone to show significant genotype×environment interactions. Phenological and agronomic characteristics are generally attractive to breeders because they are easy and cheap to measure. Adapting crop phenology to water availability has been the main route by which yield has been improved when water is the limiting factor for growth (Annicchiarico and Pecetti 1995; Turner 1997). Under terminal water stress conditions, the yield of barley is comparatively greater than that of other cereal crops, a characteristic linked to its greater precocity (L´opez-Casta˜neda and Richards 1994; Mitchell et al. 1996). Genotype×environment interactions are therefore important in determining grain yield. These interactions can occur as a consequence of differential responses by genotypes to yearly variation in the quantity of rainfall or its distribution (Van Ginkel et al. 1998).Understanding the selection process requires: (i) identifying the main evolutionary forces of an environment where a species lives; and (ii) analyzing the effects of these forces on individual plant's fitness through the changes in plant architecture. The responses of plants to various stresses have for decades been the focus of physiological studies (Levitt 1980) and of molecular genetics studies (Grover et al. 1999; Forster et al. 2000).

There is considerable interest at present in using the emerging technologies of genomics as a means to identify key loci controlling stress tolerance and as a tool to screening for allelic variation in the wild and land race gene pools. Identification of domestication genes in crops revealed that most of the drastic changes during domestication are the result of functional impairments in transcription factor genes, and creation of new functions is rare (Pourkheirandish and Komatsuda 2007).

By classical plant breeding supported by new biotechnological methods, new varietiesfor hot and dry regions can be bred (Diab et al. 2004). These drought and heat-tolerant varieties can produce increased yields, not only in semiarid zones, but also in temperate areas with temporary drought and heat occurrence. Extensive efforts have been devoted to the characterization of genes induced or upregulated by drought (Close et al. 1989, 1993). Correlative evidence suggests a possible role for a number of these drought-induced genes in protecting cells from the harmful effects of dehydration (Bray 1997; Close 1997).

The ISSR molecular markers are semi-arbitrary, single forward primers by means of which high level of polymorphism could be realized. They have been successfully used for estimating genetic diversity in crops such as barley (Brantestam et al. 2004; Hou et al. 2005), wheat (Sofalian et al. 2008) and fababean (Afiah et al. 2008).

The present investigation was designed to study the performance of 33 barley genotypes under rainfed conditions at Maryout (North Western Coast of Egypt to identify genotypes tolerant to drought stress condition and to propose parameters for selection criteria under target conditions. The aim was also to obtain reliable molecular genetic marker for drought tolerance that can be used in breeding programs for yield improvement under drought stress conditions.

2. Materials and methods

Field experiments were conducted at Maryout (North Western Coast of Egypt), for two consecutive growing seasons (2006/07 and 2007/08) under rainfed conditions to evaluate the response of thirty three genotypes of barley that included twenty-eight lines from ICARDA, two from ACSAD, a new released line from Desert Research Center (Su 12330) and the two improved check cvs. (Giza 126 and Giza 2000). Names, sources and pedigree/or selection history of barley genotypes tested are presented in Table 1.

The rainfall reached 223.02 and 195.10 mm in the first and the second season, respectivley. Soil of the site was loamy clay and calcareous ($CaCo_3$ 34%). The experimental design was a randomized complete block with three replications. The plot area was of 3.0 x 3.5 m. In both seasons; the preceding crop was Sorghum. Grains were sown in rows, 30 cm apart. The other agricultural practices recommended for growing barely were followed.

Table 1. Name and / or Cross, pedigree and origin of all barley genotypes tested under rainfed conditions in 2006/07 and 2007/08 seasons

No.	Name/ cross	Origin
Giza 126	Baladi Bahteem/"SD729-Por1276/BC"	EGYPT
L1	Mari/Aths*2//Avt/Attiki/3/Aths/Lignee686/4/Alanda-01 ICB97-0958-0AP-1AP-0AP-2AP-0AP	ICARDA*
L2	Mari/Aths*2//Avt/Attiki/3/Aths/Lignee686/4/Alanda-01 ICB97-0958-0AP-1AP-0AP-9AP-0AP	ICARDA
L3	Mari/Aths*2//Avt/Attiki/3/Aths/Lignee686/4/Alanda-01 ICB97-0958-0AP-2AP-0AP-9AP-0AP	ICARDA
L4	Mari/Aths*2//Avt/Attiki/3/Aths/Lignee686/4/Alanda-01 ICB97-0958-0AP-9AP-0AP-7AP-0AP	ICARDA
L5	Schooner/Sara ICB97-0132-0AP-65AP-9TR-1AP-0AP	ICARDA
L6	Schooner/Sara ICB97-0132-0AP-65AP-9TR-2AP-0AP	ICARDA
L7	Schooner/Sara ICB97-0132-0AP-65AP-9TR-7AP-0AP	ICARDA
L8	Barque//Moroc9-75/Hml-02 ICB00-0017-0AP-46AP-0AP	ICARDA
L9	Avt/Attiki//M-Att-73-337-1/3/Aths/Lignee686/4/Rhn/Lignee527/3/Arar//Hr/Nopal ICB00-0575-0AP-6AP-0AP	ICARDA
L10	U.Sask.1766/Api//Cel/3/Weeah/4/Arar/5/Rhn/Lignee527/3/Arar//Hr/Nopal ICB00-0582-0AP-8AP-0AP	ICARDA
L11	Arbayan-01//M6/Robur-35-6-3/3/Libya ICB00-0591-0AP-5AP-0AP	ICARDA
L12	W12291/4/7028/2759/3/69-82//Ds/Apro/5/Zanbaka/3/ER/Apm//Lignee131 ICB94-0590-0AP-7AP-0AP-0AP-6AP-0AP	ICARDA
L13	Roho//Alger/Ceres362-1-1/3/Kantara/4/ Zanbaka/3/ER/Apm//Lignee131 ICB94-0604-0AP-7AP-0AP-0AP-17AP-0AP	ICARDA
L14	Lignee527/Arar ICB92-0755-22AP-0AP-6AP-0AP-0AP-1AP-0AP	ICARDA
L15	Arar/Lignee527//Arar/Rhn-03 ICB93-0345-0AP-2AP-0AP-0AP-14AP-0AP	ICARDA
L16	Arar/Lignee527//Arar/Rhn-03 ICB93-0345-0AP-2AP-0AP-0AP-19AP-0AP	ICARDA
L17	Eldorado//Alanda/Zafraa ICB94-0184-0AP-5AP-0AP-0AP-5AP-0AP	ICARDA
L18	Eldorado//Alanda/Zafraa ICB94-0184-0AP-5AP-0AP-0AP-11AP-0AP	ICARDA
L19	M126/CM67//As/Pro/3/Alanda/6/UC76252/Agrig88/5/Hml/4/Lth/3/Nopal//Pro/11012-2 ICB00-1360-0AP-2AP-0AP	ICARDA
L20	ArabiAbiad/Arar/3/Arar/19-3//W12291 ICB94-0681-0AP-5A-0AP-0AP-8AP-0AP-1TR-0AP	ICARDA
L21	Hml/Galleon ICB93-1096-0AP-12AP-16TR-1TR-0AP	ICARDA
L22	Hml/Galleon ICB93-1096-0AP-12AP-21TR-1TR-0AP	ICARDA
L23	W12291/Roho//W12269/3/W12291/Bgs//Hml-02 ICB97-0154-0AP-12AP-10TR-3TR-0AP	ICARDA
L24	Rt013/6/Caco'S'/3/Api/CM67//1594/4/P1382934/5/Lignee527/NK1272 ICB98-0893-0AP-17AP-0AP-7TR-0AP	ICARDA
L25	Lignee527/Chn-01//Gusbe/5/Alanda-01/4/W12291/3/Api/CM67//L2966-69 ICB96-0432-0AP-4AP-10TR-1TR-0AP	ICARDA
L27	Arar/Rhn-03/8/Api/CM67//Hma-03/4/Cq/Cm//Apm/3/RM1508/5/Attiki/6/Aths/7/ DeirAlla106/Cel/3/BcoMr/Mzq//Apm/5106 ICB94-0486-0AP-15AP-11TR-10TR-0AP	ICARDA
Harmal	As 54/Tra // (Cer/Tol 1)* 413/Avt*2 / Ki // Bz/4/Vt/5/Pro.	ICARDA
Rihane-03	As 46//Avt/Aths	ICARDA
A-410	ACSAD 176 ×(Manchuria × Api) CM67- CMB 75A-432-1B-3Y- 1B- 3Y-1B -0Y	ACSAD**
A.1028	ACSAD 214 / Arrivat	ACSAD
Su 12303	ICB 86/Giza123*-C03-3Su-15Su-2Su-5Su – 0 Su	EGYPT
Giza 2000	Giza121*L366/3/1(G117/Bahteem52//G118/FAO86)	EGYPT

*: The International Center for Agricultural Research in the Dry Areas.
**: The Arab Center for the Studies for Arid zones and Dry lands

During growing seasons, plant height, number of spikes/plant, number of grains/spike, 1000-grain weight, grain yield/plant, harvest index and biological yield were recorded. Data were subjected to the combined analysis of variance after seasonal homogeneity F test for each environment. Phenotypic correlation coefficients were also calculated for different pairs of traits. Partitioning of correlation coefficient into direct and indirect effects was done by determining path coefficients using method proposed by Wright (1921). Broad sense heritability (h^2) was computed according to Johnson et al. (1955).

Polymerase chain reaction (ISSR - PCR reaction) was conducted using five specific primers (Table 2). Amplification was carried out in Stratgene Robocycler Gradient 96 which was programmed for 45 cycles as follows: Denaturation (one cycle) 94^{o}C for 2 minutes, followed by 30 cycles: as follows 94^{o}C for30 second, 44^{o}C for45 sec.'s, 72^{o}C for 1 minute and 30 sec.'s, and finally one cycle extension at 72^{o}C for 20 minutes, and 4^{o}C (infinitive). PCR-products of 15 µl were resolved in 1.5 % Nusieve GTG agarose gel electrophoresis with 1x TAE running buffer. The run was performed at 80 V for 180 min and the gel was stained with ethidium bromide. A marker of 1 Kb plus DNA Ladder 1µg /µl (Invitrogen) that contains a total of twenty bands ranging from 12000 to 100 bp was used. Bands were detected on UV-transilluminator and photographed by Gel documentation system Biometra Bio Doc Analyze 2000.

Table 2. ISSR primers names and their sequences

Primer name	Sequence
HB2	(CAG) 5
17898B	(CA)6 GG
17899A	(CA)6 AG
17899B	(CA)6 GG
844B	(CT)8 GC

3. Results and discussion

The test of homogeneity of error variance of the two seasons revealed that error mean squares were homogeneous for all the studied traits except 1000- grain weight. Mean squares of the main source of variation, i.e. seasons (S.) and genotypes (G.) were highly significant (Table 3) for all traits studied in both seasons and combined except seasons mean squares of harvest index, suggesting that all traits were markedly affected by drought stress and the presence of wide range of differences between genotypes concerning the most investigated traits. However, the interaction between genotypes and seasons (G×S) was also highly significant for the investigated traits, except for plant height and harvest index. The previous reports of Afiah et al. (1999, 2001), Afiah and Omar (2003) and Abdel-Sattar (2005) are in harmony with these results.

Table 3. Mean squares of barley genotypes (G.) for different studied traits under rainfed conditions in 2006/07 and 2007/08 seasons (S.) and combined analysis

Season	First season		Second		Combined				
Mean Square	G.	error	G.	error	seasons	R./S.	G.	G.×S.	error
d.f.	32	64	32	64	1	4	32	32	128
Plant height (cm.)	58.15 **	6.44	77.71	10.29	283.39*	20.11	129.95**	5.90	8.37
No. of spikes/plant	1.06**	0.06	0.72**	0.07	0.99**	0.36	1.34**	0.44**	0.06
No. of grains/spike	108.35**	8.12	73.84	5.48	820.0**	5.88	164.10**	18.11**	6.80
1000- grain weight	20.39**	3.43	29.61**	1.09	------	-------	------	-----	-----
Grain yield/plant	1.07**	0.12	1.98 **	0.11	2.68**	0.90	2.74**	0.31**	0.12
Harvest Index	6.70 **	0.27	7.23**	0.40	0.36	4.31	13.54**	0.39	0.33
Biological yield	20.48**	1.76	34.53**	1.74	35.79**	17.08	51.28**	3.73**	1.75

** Denote significance at $P \leq 0.05$ probability level.

3.1. Performance of barley genotypes under moisture stress

Four lines (#14, 17, 19, 20, and 23) and the two genotypes (Harmal and Rihane-030) were the tallest in both seasons. Two lines (#13 and 16) in the first season as well as the five genotypes (Line 19, A-410, A.1028, Su 12303 and Giza 2000) in the second season recorded the highest number of spikes/plant On the other hand, Line 2 in both seasons as well as, the four lines (#8, 18, 22 and 23) in the second season recorded the lowest number of spikes/plant. The number of grains/spike were the highest in two genotypes (Rihane-03 in both seasons as well as Su 12303 in the first season) and three genotypes, (Line 12, Line 16 and Harmal in the second season). Lines 2, 17, 18 and 25 in both seasons and and line19, 20, 21, 22 23, 24 and 27 in the first season and line 21 and 22 in the second season recorded the lowest means for number of grains/spike. For 1000 grain weight, line 17 in the both seasons as well as the cv. Giza126 and lines, 3, 12, 19, and 25 in the first season and Line 21 in the second season recorded the highest values. Five genotypes (line 11, line 24, Harmal, Rihane-03 and A410) in the first season as well as Line 12 in the second season recorded the lowest values. The grain yield/plant was the highest for the newly bred line Su 12303 in both seasons, the values being 6.31, 7.06 and 6.67 g, respectively, followed by the new lines A410, Line 13, Rihane-03 and A1028. On the other hand, line 2 recorded the lowest means in both seasons as well as Line 4, Line 22 and Line 23 in the first season, the values ranging from 3.16g for line 2 in the second season to 4.25g for line 4 in the first season. The harvest index was the highest in cv. Giza 126 and Line 2 in both seasons as well as Line 24 in the second season, values ranging from 33.27% for Line 24 to 33.87% for Line 22 in the second season. On the other hand, line 1, 13, 16, A-410 and Su 12303 recorded the lowest harvest index in both seasons. The genotypes that had high grain yield/plant recorded low harvest index because of higher total biomass and taller plants. The newly bred line Su 12303 recorded the highest values for total biomass in both seasons, values being 22.14, 25.03 and 23.59 g/plant, respectively. On the other hand line 2 and 22 recorded the lowest values in both seasons.

3.2. Phenotypic correlation

Correlation coefficient values among all the studied traits in both seasons and combined are recorded in Table 4. Positive and significant correlation was found between plant height and number of spikes/plant in the first season; number of spikes/plant with each of the number of grains/spike in the second season, grain yield/plant and biological yield in both seasons, number of grains/spike with each of grain yield /plant and biological yield in both seasons and grain yield with biological yield in both seasons. While, negative and significant correlation was found between number of spikes/plant with each of 1000-grain weight in the second season and harvest index in both seasons, number of grains/spike and each of 1000-grain weight and harvest index in both seasons, 1000-grain weight and grain yield in the second season and combined and harvest index with each of grain yield/plant and biological yield. Shakhatreh (2001) reported that the correlations amongst grain yield, biological yield, straw yield, plant height were always significant and positive regardless of the location.

Table 4. Estimation of phenotypic correlation in both seasons and combined data for the studied traits

Traits		(X_1)	(X_2)	(X_3)	(X_4)	(X_5)	(X_6)
Plant height (X_1)	First	1.000					
	Second	1.000					
	Combined	1.000					
No. of spikes/plant (X_2)	First	0.348*					
	Second	0.178					
	Combined	0.299					
No. of grains/spike (X_3)	First	0.035	0.293				
	Second	0.051	0.511**				
	Combined	0.036	0.492**				
1000-grain weight (X_4)	First	0.112	-0.159	-			
	Second	0.052	-	-			
	Combined	0.110	-0.279	-			
Grain yield/plant (X_5)	First	0.318	0.839**	0.554**	-0.241		
	Second	0.197	0.836**	0.635**	-0.410*		
	Combined	0.258	0.879**	0.668**	-0.360*		
Harvest Index (X_6)	First	-0.309	-	-	0.159	-	
	Second	-0.223	-	-0.418*	0.044	-	
	Combined	-0.282	-	-	0.090	-	
Biological yield (X_7)	First	0.317	0.797**	0.563**	-0.240	0.978**	-0.863**
	Second	0.197	0.765**	0.610**	-0.339	0.986**	-0.848**
	Combined	0.259	0.832**	0.642**	-0.308	0.985**	-0.876**

3.3. Path coefficient analysis

The components of the total grain yield variation determined directly and jointly by each factor are presented in Table 5. The main sources of variation in order of importance were the direct effect of number of spikes/plant in first and second seasons (47.03 and 31.19 %, respectively) and its joint effect with number of grains/spike (14.81 and 20.08 %, respectively), then with 1000-grain weight (1.79 and 9.09 %, respectively) as well as the direct effect of number of grains/spike (13.57 and 12.38, respectively) and its joint effect with 1000-grain weight (3.43 and 9.56%, respectively) followed by the direct effect of 1000-grain weight in the second season (3.36 %). The total contribution of four traits studied was 83.62%and 86.45% for first and second seasons.

Table 5. Components (direct and joint effects) in percentage of contribution due to grain yield and four of its attributes in both seasons

Source of variation	First season			Second season		
	CD	RI%	TC	CD	RI%	TC
Plant height (X_1)	0.0019	0.1687	1.24	0.0013	0.0815	0.44
No. of spikes/plant (X_2)	0.5251	47.0302	56.31	0.4975	31.1867	46.05
1000-grain weight (X_3)	0.0076	0.6847	3.33	0.0536	3.3622	12.71
No. of grains/spike (X_4)	0.1516	13.5739	22.74	0.1974	12.3781	27.25
(X_1) x (X_2)	0.0219	1.9605	--	0.0091	0.5706	--
(X_1) x (X_3)	0.0009	0.0761	--	0.0009	0.0544	--
(X_1) x (X_4)	0.0012	0.1059	--	0.0016	0.1024	--
(X_2) x (X_3)	-0.0200	1.7932	--	-0.1450	9.0930	--
(X_2) x (X_4)	0.1653	14.8060	--	0.3203	20.0800	--
(X_3) x (X_4)	-0.0383	3.4266	--	-0.1525	9.5606	--
Residual	0.1828	16.3742	--	0.2158	13.5305	--
Total	1.000	100	83.62	1.000	100	86.45

CD : Coefficient of determination, RI% : Relative importance, TC: Total contribution

Heritability percentages (in broad sense) and phenotypic and genotypic variances with their coefficient of variability for all studied traits are presented in Table 6. The estimates of phenotypic and genotypic variances were relatively high for number of grains/spike, grain yield/plant and biological yield/plant. Values were relatively low for 1000-grain weight and harvest index. The relative differences (RD%) between phenotypic coefficient of variation as criteria of non heritable effects reached the maximum magnitude for plant height followed by 1000-grain weight and number of spikes/plant as shown in Table 6. These findings are in line with those previously obtained by Khattab and Afiah (1999).

Table 6. Phenotypic variance (σ^2 P) and coefficient of variability (PCV%) as well as genotypic variance (σ^2 G) and coefficient of variability (GCV%) of 33 barley genotypes for all traits studied

Traits	Season	σ^2 P	PCV%	σ^2 G	GCV%	RD%	heritability
Plant height	First	23.68	6.62	17.24	5.65	14.65	85.31
	Second	32.76	7.54	22.48	6.25	17.11	82.82
	Combined	28.63	7.16	20.26	6.03	15.78	84.13
No. of spikes/plant	First	0.39	12.53	0.34	11.58	7.58	92.44
	Second	0.29	11.05	0.22	9.55	13.57	86.43
	Combined	0.27	10.68	0.21	9.35	12.45	87.50
No. of grains/spike	First	41.53	22.40	33.41	20.09	10.31	89.69
	Second	28.27	16.19	22.79	14.54	10.19	89.78
	Combined	33.02	18.66	26.22	16.62	10.93	89.11
1000-grain weight	First	9.08	7.58	5.65	5.98	21.11	78.87
	Second	10.60	8.17	9.51	7.73	5.39	94.70
	Combined	7.82	7.02	5.54	5.91	15.81	84.17
Grain yield/plant	First	0.44	13.64	0.31	11.54	15.40	84.62
	Second	0.73	16.78	0.62	15.51	7.57	92.42
	Combined	0.55	14.93	0.44	13.27	11.12	88.89
Harvest Index	First	2.42	5.06	2.14	4.77	5.73	94.16
	Second	2.67	5.34	2.28	4.93	7.68	92.29
	Combined	2.53	5.19	2.20	4.84	6.74	93.15
Biological yield	First	8.01	17.74	6.24	15.66	11.72	88.29
	Second	12.67	21.19	10.93	19.68	7.13	92.88
	Combined	10.01	19.32	8.25	17.55	9.16	90.83

RD%: The relative difference between PCV% and GCV%= ((PCV – GCV)* 100)/ PCV

3.4. Characterization of seven barley genotypes based on ISSR-PCR analysis

There is a concern that much of the genetic variation for improving abiotic stress tolerance has been lost during domestication, selection and modern breeding, leaving pleiotropic effects of the selected genes for development and adaptation. Such genes are critical in matching cultivars to their target agronomic environment, and since there is little leverage in changing these, other sources of variation may be required. In barley, and many other crops, greater variation in tolerance to abiotic stresses exists in primitive landraces and newly bred lines gene pools.

For ISSR analysis, DNAs of the seven barley genotypes were subjected to PCR against five ISSR primers (17899A, 17899B, 17898B, 844B and HB2) as described in Figure 1 and illustrated in Tables 7 and 8. A total of 37 amplicons (amplified fragments) were generated by the five primers in which 34 of them were polymorphic (about 91.89%). The number of amplicons per primer varied from seven (for 17899A, 17899B, 844B and HB2) to 9 (for 17899B). The size of the amplified fragments ranged from 200 bp (AF7) to 1840 bp (AF31). Three primers (17899A, 844B and HB2) scored one monomorphic amplicons (Table 7). Primer 17899A produced 7 bands in which fragment sizes ranged from 730 to 200 bp, 6 of which were polymorphic (85.71% polymorphism). Primer 1899B produced 9 bands in which fragment sized ranged from 920 to 220 bp and all of them were polymorphic (100% polymorphism). Primer 1898B produced 7 bands with fragment sizes ranging from 940 to 340 bp. Poth primers 844 and HB2 yielded 7 bands with the fragment sizes ranged from 1740 and 1840 to 750 and 640 bp, respectively, 6 of them were polymorphic (85.71% polymorphism).

A total of 8 unique bands for different genotypes were identified out of the polymorphic primers under study (Table 8), the two lines Su 12303 and Line 13 were considered as drought tolerant genotypes against Line2 which gave the lowest grain yield/plant under stress conditions. The primer 17899 A discriminated A410 by the unique bands of amplicon fragments (AF4) and Su 12303 by the unique bands of amplicon fragments (AF6). This primer gave one positive marker (AF1) for drought tolerance as it showed a positive band for Su12303 and line13 and negative band for the sensitive line 2. The primer 17899 B discriminated Line 13 by two unique bands of amplicon fragments (AF8 and AF10) and Line2 by the unique band of amplicon fragments (AF15). Primer 17899 B gave one negative marker for drought tolerance by AF9 and one positive marker by AF12. Meanwhile, primer 17989 B discriminated Line2 by the unique band AF23 and also detected one positive marker for drought stress by AF19 and negative marker by AF23. Line13 was discriminated by the unique band AF24 by 844 B operon primer. The primer HB2 discriminated the cv. Giza 2000 by the unique band of amplicon fragment (AF33) and gave one positive marker and two negative markers for drought stress by AF35, AF36 and AF37, respectively. These findings are in line with those reported earlier by Hou et al. (2005) suggesting that the ISSR markers were superior to RAPD markers in the capacity of revealing more informative bands in a single amplification and that ISSR agreed better with the geographic origins of the genotypes and revealed high level of polymorphism. Similar results were observed by El-Halfawy et al. (2006) and Afiah et al. (2007).

Based on ISSR marker polymorphisms, similarity matrix was developed by SPSS computer package (Table 9). The closet relationship was between the genotypes A1028 and Line 13 followed by the two genotypes Line 22 and A1028 and between Rihane-3 and A410 (similarity of 0.862, 0.860 and 0.825, respectively). On the other hand, the most distant

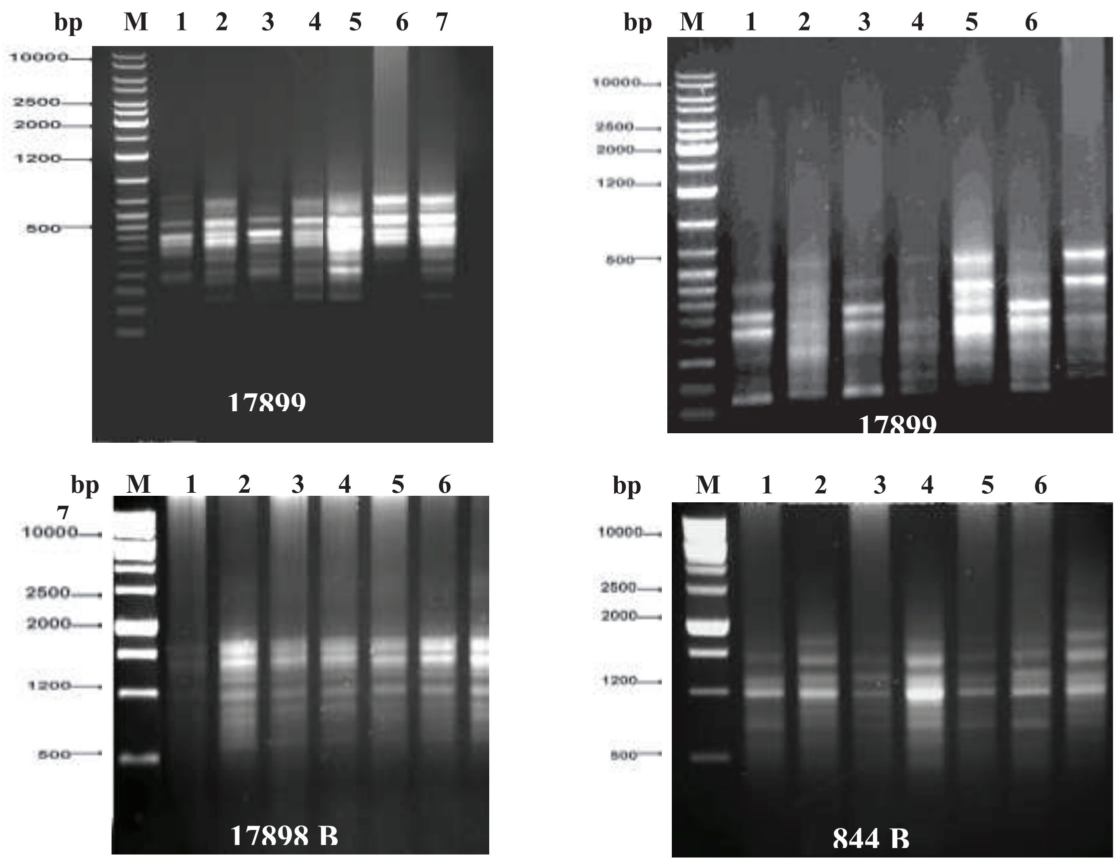
Table 7. ISSR polymorphism in seven barley genotypes using ISSR-PCR with five primers

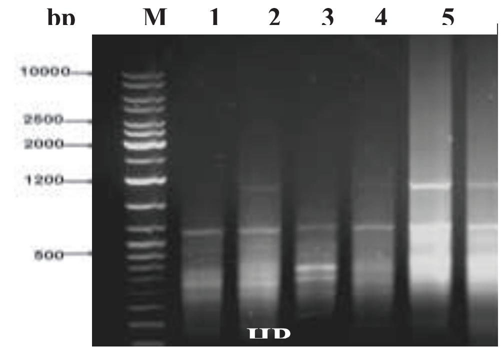
bp	Amplicon	Primer	1	2	3	4	5	6	7	MM*
730	AF01	17899 A	1	0	0	0	0	1	1	PM*
640	AF02		0	1	0	1	0	1	1	
550	AF03		1	1	1	1	1	1	1	
450	AF04		1	1	0	1	1	1	1	
370	AF05		0	0	0	0	1	0	1	
290	AF06		1	1	1	1	1	0	1	
200	AF07		0	1	0	1	1	0	1	
920	AF08	17899 B	0	0	0	0	0	0	1	
850	AF09		0	1	0	0	1	0	0	NM*
780	AF10		0	0	0	0	0	0	1	
680	AF11		1	0	1	0	1	0	0	
560	AF12		0	0	1	0	1	1	1	PM*
500	AF13		1	0	1	0	1	1	0	
420	AF14		1	0	1	0	1	1	0	
330	AF15		0	1	0	0	1	0	0	
220	AF16		1	1	1	0	0	1	0	
940	AF17	17898 B	0	1	1	1	1	1	1	
740	AF18		0	1	1	1	1	1	1	
660	AF19		0	0	1	1	1	1	1	PM*
600	AF20		0	1	0	1	1	1	1	
500	AF21		0	1	1	1	1	1	1	
420	AF22		0	1	1	1	0	0	1	
340	AF23		0	1	0	0	0	0	0	NM*
1740	AF24	844 B	0	0	0	0	0	0	1	
1610	AF25		0	1	0	1	0	0	1	
1450	AF26		0	1	0	1	0	1	1	
1260	AF27		0	1	0	1	0	1	1	
1060	AF28		1	1	1	1	1	1	1	
870	AF29		0	1	0	1	0	0	1	
750	AF30		1	0	0	1	1	1	0	
1840	AF31	HB2	0	1	0	0	1	1	1	
1150	AF32		1	1	1	1	1	1	1	
1060	AF33		0	0	0	0	1	0	0	
940	AF34		0	0	0	0	1	1	0	
820	AF35		1	0	1	0	1	1	1	PM*
740	AF36		1	1	0	0	0	0	0	NM*
640	AF37		1	1	0	0	0	0	0	NM*

Genotypes: 1. Rihane 03; 2. line 2; 3. A410; 4. A 1028; 5. Giza 2000; 6. Su12303; 7. line13 relationship was between genotypes Rihane-3 and Line13 (similarity of 0.490).

The dendrogram (Fig. 2) classified the seven genotypes into two main clusters. The first cluster comprised 3 genotypes (A1023, Line 13 and Line 22), while the second cluster grouped all the rest of the genotypes (Rihane-3, A-410, Giza 2000 and Su-12303).

It could be concluded that number of spikes/plant, number of grains/spike and 1000-grain weight are the major components for grain yield/pant and should be considered in selection programs for the improvement of yield potential of genotypes under water stress. Also, the high yielding genotypes line Su 12303, line A410, Line 13, Rihane-03 and A1028 have more adaptability for drought tolerance and could be used in breeding programs to obtain higher yielding genotypes. Based on ISSR marker polymorphisms, the two primers 17899 B and 17898 B more effective in identifying tolerant genotypes and could be used in differentiating and selecting the desirable genotypes.





Lane M: Molecular marker

Lanes 1-7: Rihane 03, line 2, A-410, A-1028, Giza 2000, Su12303, line13, respectively

Figure 1. ISSR fingerprints of seven barley genotypes using five primers (17899A, 17899B, 17898B, 844B and HB2).

Table 8. Amplification results of the five ISSR primers for the seven barley genotypes tested

Operon primer	TAF	PB	P%	Genotype														
				1		2		3		4		5		6		7		
				AF	SM	AF	SM	AF	SM	AF	SM	AF	SM	AF	SM	AF	SM	TSM
17899 A	7	6	85.71	4	0	5	0	2	1	5	0	5	0	4	1	7	0	2
17899 B	9	9	100.00	4	0	3	1	5	0	0	0	5	0	4	0	3	2	3
17989 B	7	7	100.00	0	0	6	1	5	0	6	0	5	0	5	0	6	0	1
844 B	7	6	85.71	2	0	5	0	1	0	6	0	2	0	4	0	6	1	1
HB2	7	6	85.71	4	0	4	0	2	0	1	0	3	1	4	0	3	0	1
Total	37	34	91.89	14	0	23	2	15	1	18	0	20	1	21	1	25	3	8

TAF= Total number of amplified fragments, PB = Polymorphic bands, P%= polymorphism percentage, AF= Amplified fragments / genotype, SM= Genotype- specific marker including either the presence or absence of a given band, TSM= Total number of specific markers

Dendrogram using Average Linkage (Between Groups) Rescaled Distance Cluster Combine

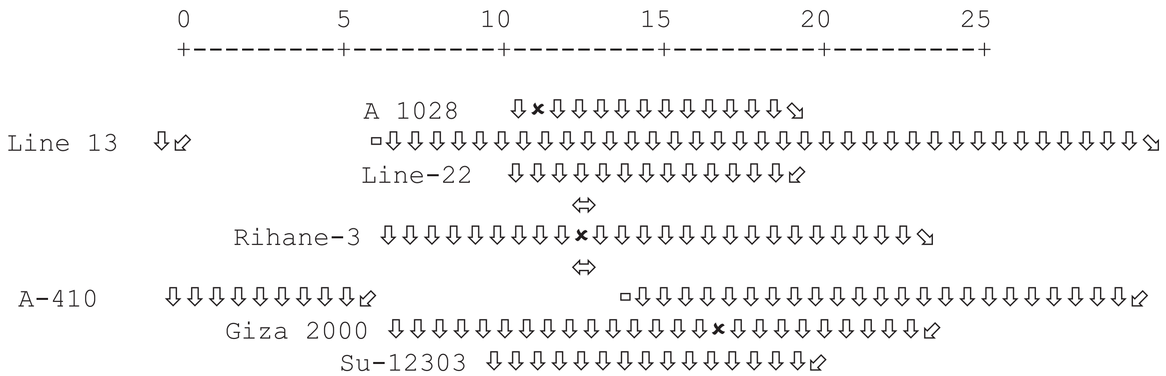


Figure 2. The genetic distances among seven barley genotypes using five primers based on ISSR analysis.

Table 9. Similarity matrices among seven genotypes of barley based on ISSR analysis

Genotypes	Rihane 03	line 22	A410	A 1028	Giza 2000	Su12303
Rihane 03						
line 22	0.630					
A410	0.825	0.630				
A 1028	0.630	0.860	0.746			
Giza 2000	0.702	0.630	0.806	0.702		
Su12303	0.746	0.679	0.804	0.787	0.806	
line13	0.490	0.767	0.679	0.862	0.679	0.767

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7.5. Genotype-environment interaction for barley newly bred lines under different stress environments

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Abstract

Thirty three newly bred barley lines of diverse origin (local and exotic accessions), with 'Giza 126' and 'Giza 2000' as checks, were evaluated under three locations differing in soil, water supply, and climatic conditions for two growing seasons (2006/07 and 2007/08). Two locations were at Fayoum and one at Maryout. The genotypes were tested for variation, mean performance, ecovalence (Wi) and relative deviation (RDi) stability parameters for screening under stress and control (non-stress) environments. The genotype x environment interaction was significant. Mean squares of genotype x environment interaction were less than that of genotypes. Hence, the genotypes tested had a wide diversity and ranked differently among locations and seasons. Both Wi and RDi stability parameters were able to determine the stable genotypes L4, L11, L20 and L27 over all the tested environments with improved mean grain yield (7.0 – 7.4 ardab/feddan). However, the genotypes that produced higher yields (8.4 – 9.6 ardab/fed) under stress conditions,such as L12, L16, Rihane 03 and Su12303, were well adapted only for Maryout conditions but showed below average stability and

1. Introduction

Barley (*Hordeum valgare* L.) is grown in Egypt on a large scale under wide range of environmental conditions. It is considered as one of the most adapted cereals for the environmental conditions where other crops are difficult to grow. The existence of genotype × environment interactions and their effects on selection progress are widely recognized (El-Gayar et al. 1984; Noaman et al. 1992; Ashour and Selim 1994; El-Deek et al. 1994 and Afiah 2001). Estimation of genetic variability and heritability under such stressed conditions are essential in selection program for improving grain yield in barley. In this respect, some researchers (Rasmusson and Cannell 1970; Sharaan 1986; Abul-Naas et al. 1993, El-Marakby et al. 1994; Khattab and Afiah 1999; and Afiah et al. 2000) found that a wide range of variation was evident in most traits and a large part of this variability was genetic in nature and highly heritable under normal conditions. A wide range of variability among the environments, under which evaluation of yield performance and stability of a set of varieties is done, is prerequisite to obtain fruitful and effective results. However, in evaluation trails across different environments, change in genotypic rankings due to the genotype x environment (GxE) interaction makes it difficult for the breeder to decide which genotype should be selected.

Several attempts have been made to exploit GxE interaction effects as a key for developing improved and stable varieties. A variety of methods and statistical parameters are now available to breeders for the evaluation of phenotypic stability of plant varieties, however, particular choices in most cases may be difficult to justify. Lin et al. (1986) concluded that unless the concept of stability and the kind of environments included in the experiment are clearly understood, many stability statistics become of little use. Many authors showed that several of the stability statistics probably measure similar aspect of phenotypic stability (Becker 1981; Becker and Léon 1988; Duarte and Zimmermann 1995).

Three methods with six statistical parameters were compared by Sharaan and Ghallab (2001) for determining wheat varietal stability under diffirent environmental conditions. Great similarity of stability results were observed between r^2_i and b_i (which were negatively correlated) as well as between CV_i% and S^2di (which showed positive correlation) in all of the environments tested. The three measurements, i.e., RD_i, RDD_i and RHD_iDD_i exhibited the least number of stable varieties and showed great similarity with b_i and Ys_i, and all were strongly correlated. In this investigation we used the RDi as a simple and effective statistical parameter as well as ecovalence model (Wi) of Wricke and Weber (1986) for detecting genotype-environment interaction for some local and exotic newly-bred barley lines under different locations through two successive seasons.

2. Method and materials

Six field experiments were carried out in two seasons (2006-07 and 2007-08) at three locations (Dar-Elramad having clay-loamy land and Demo having newly reclaimed and sand-loamy land and Maryout having calcareous soil). Experiments at Maryout were under rainfed conditions (223 and 175 mm rainfall in the first and second seasons, respectively) and at other two locations with irrigation, using 33 barley genotypes (Table 1) including two check varieties (Giza 126 and Giza 2000). Dar-El-Ramad and Demo are two separate experimental farms of the Faculty of Agriculture at Fayoum. The third location was the experimental station of the Desert Research Center (North Western Coast of Egypt). Sowing dates were Nov. 25 and Dec. 5 in the first and second seasons, respectively. A complete randomized block design with three replications was used. The plot area was of 3.0 x 3.5 m. The preceding crop was corn in the first and second locations and Sorghum in the third one. Seed were sown in rows, 30 cm apart. The other agricultural practices recommended for growing barely were followed. The middle six rows per plot were harvested to estimate grain yield per pot. Grain yield (*ardab* per *faddan*) was computed from the plot yield. Analysis of variance for each environment was independently conducted. Following the detection of significant VE interaction, homogeneity test (Bartlett 1947) for error terms of each was done. Error terms among years and locations were homogeneous for all cases (traits recorded in each season at each location) except 1000-grain weight under Maryout rainfed conditions (Table 2), enabling combined analysis of variance over environments.

An ideal genotype is one that combines high yield and the stability of performance, and the inconsistency of yield over environments is due to GxE interaction effect. This effect could be simply measured via determining the sum of square deviation of the trait, the distance of its deviations, or both, in relation to environmental-genotypic mean deviation. These two measurements were used for determining phenotypic stability by the two following methods, one proposed by Sharaan and Ghallab (2001) and the second proposed by Wricke and Weber (1986). In each experiment data were recorded for plant height, spike length, number of spikes / plant, number of grains /spike, 1000-grain weight and grain yield / plant using ten individual plants chosen randomly from each plot. The ordinary analysis of variance for R.C.B.D. was performed according to Gomez and Gomez (1984) and the least significant difference (LSD) was used for comparing the means.

Table 1. Name and / or cross, pedigree and origin of barley genotypes tested

No.	Name/ cross	Origin
Giza 126	Baladi Bahteem/"SD729-Por1276/BC"	EGYPT
L1	Mari/Aths*^{2}//Avt/Attiki/3/Aths/Lignee686/4/Alanda-01 ICB97-0958-0AP-1AP-0AP-2AP-0AP	ICARDA*
L2	Mari/Aths*^{2}//Avt/Attiki/3/Aths/Lignee686/4/Alanda-01 ICB97-0958-0AP-1AP-0AP-9AP-0AP	ICARDA
L3	Mari/Aths*^{2}//Avt/Attiki/3/Aths/Lignee686/4/Alanda-01 ICB97-0958-0AP-2AP-0AP-9AP-0AP	ICARDA
L4	Mari/Aths*^{2}//Avt/Attiki/3/Aths/Lignee686/4/Alanda-01 ICB97-0958-0AP-9AP-0AP-7AP-0AP	ICARDA
L5	Schooner/Sara ICB97-0132-0AP-65AP-9TR-1AP-0AP	ICARDA
L6	Schooner/Sara ICB97-0132-0AP-65AP-9TR-2AP-0AP	ICARDA
L7	Schooner/Sara ICB97-0132-0AP-65AP-9TR-7AP-0AP	ICARDA
L8	Barque//Moroc9-75/Hml-02 ICB00-0017-0AP-46AP-0AP	ICARDA
L9	Avt/Attiki//M-Att-73-337-1/3/Aths/Lignee686/4/Rhn/Lignee527/3/Arar//Hr/Nopal ICB00-0575-0AP-6AP-0AP	ICARDA
L10	U.Sask.1766/Api//Cel/3/Weeah/4/Arar/5/Rhn/Lignee527/3/Arar//Hr/Nopal ICB00-0582-0AP-8AP-0AP	ICARDA
L11	Arbayan-01//M6/Robur-35-6-3/3/Libya ICB00-0591-0AP-5AP-0AP	ICARDA
L12	W12291/4/7028/2759/3/69-82//Ds/Apro/5/Zanbaka/3/ER/Apm//Lignee131 ICB94-0590-0AP-7AP-0AP-0AP-6AP-0AP	ICARDA
L13	Roho//Alger/Ceres362-1-1/3/Kantara/4/ Zanbaka/3/ER/Apm//Lignee131 ICB94-0604-0AP-7AP-0AP-0AP-17AP-0AP	ICARDA
L14	Lignee527/Arar ICB92-0755-22AP-0AP-6AP-0AP-0AP-1AP-0AP	ICARDA
L15	Arar/Lignee527//Arar/Rhn-03 ICB93-0345-0AP-2AP-0AP-0AP-14AP-0AP	ICARDA
L16	Arar/Lignee527//Arar/Rhn-03 ICB93-0345-0AP-2AP-0AP-0AP-19AP-0AP	ICARDA
L17	Eldorado//Alanda/Zafraa ICB94-0184-0AP-5AP-0AP-0AP-5AP-0AP	ICARDA
L18	Eldorado//Alanda/Zafraa ICB94-0184-0AP-5AP-0AP-0AP-11AP-0AP	ICARDA
L19	M126/CM67//As/Pro/3/Alanda/6/UC76252/Agrig88/5/Hml/4/Lth/3/Nopal//Pro/1101 2-2 ICB00-1360-0AP-2AP-0AP	ICARDA
L20	ArabiAbiad/Arar/3/Arar/19-3//W12291 ICB94-0681-0AP-5A-0AP-0AP-8AP-0AP-1TR-0AP	ICARDA
L21	Hml/Galleon ICB93-1096-0AP-12AP-16TR-1TR-0AP	ICARDA
L22	Hml/Galleon ICB93-1096-0AP-12AP-21TR-1TR-0AP	ICARDA
L23	W12291/Roho//W12269/3/W12291/Bgs//Hml-02 ICB97-0154-0AP-12AP-10TR-3TR-0AP	ICARDA
L24	Rt013/6/Caco'S'/3/Api/CM67//1594/4/P1382934/5/Lignee527/NK1272 ICB98-0893-0AP-17AP-0AP-7TR-0AP	ICARDA
L25	Lignee527/Chn-01//Gusbe/5/Alanda-01/4/W12291/3/Api/CM67//L2966-69 ICB96-0432-0AP-4AP-10TR-1TR-0AP	ICARDA
L26	Arar/Rhn-03/8/Api/CM67//Hma-03/4/Cq/Cm//Apm/3/RM1508/5/Attiki/6/Aths/7/ DeirAlla106/Cel/3/BcoMr/Mzq//Apm/5106 ICB94-0486-0AP-15AP-11TR-10TR-0AP	ICARDA
Harmal	As 54/Tra // (Cer/Tol 1)* 413/Avt*2 / Ki // Bz/4/Vt/5/Pro.	ICARDA
Rihane-03	As 46//Avt/Aths	ICARDA
A-410	ACSAD 176 ×(Manchuria × Api) CM67- CMB 75A-432-1B-3Y- 1B- 3Y-1B -0Y	ACSAD**
A.1028	ACSAD 214 / Arrivat	ACSAD
Su 12303	ICB 86/Giza123*-C03-3Su-15Su-2Su-5Su – 0 Su	EGYPT
Giza 2000	Giza121*L366/3/1(G117/Bahteem52//G118/FAO86)	EGYPT

*: The International Center for Agricultural Research in the Dry Areas.
**: The Arab Center for the Studies for Arid zones and Dry lands.

3. Results and discussion

Data (Table 2) indicated significant differences among barley genotypes for all the traits recorded. The environment and genotype × environment interaction effects were highly significant. Thus barley genotypes responded differently to the different environmental conditions suggesting the importance of assessment of genotypes under different environments. These findings are in line with those previously obtained by Afiah and Omar (2003).

The average number of spikes / plant, 1000-grain weight and grain yield / plant were enhanced for plants grown under Dar Elramad and Demo as compared with Maryout conditions while number of grains / spike had the reverse direction. Such findings may be due to the regular irrigation of barley plants at Fayoum locations and the rainfed condition of North Western Coast region. Afiah et al. (1999) found that yield of barley genotypes was affected differently under various soil and irrigation water salinity levels, and that affected the opportunities for selecting appropriate genotypes for certain environmental stress.

Table 2. Mean squares for all traits recorded on 33 barley genotypes as combined data over two seasons at three locations

Source of variation	df.	Plant height	Spike length	No. of spikes/ plant	No. of grains/ spike	1000 grain weight	Grain yield/ plant	Grain yield/ fed.
Dar Elramad location								
Reps	2	98.49	0.717	0.512	19.28	4.728	5.532	3.374
Seasons (S)	1	1.881	0.018	0.087	17.361	81.46*	19.906	11.395
Error (a)	2	38.108	0.915	0.648	1.175	2.945	2.182	1.368
Genotypes (G)	32	92.9**	7.58**	5.43**	89.3**	8.24**	33.03**	19.4**
SG	32	27.064	3.86**	1.61**	1.081	4.04**	3.751	2.259
Error (b)	128	44.176	2.019	0.84	6.912	0.982	3.592	2.116
Demo location								
Reps	2	73.942	13.964	3.248	40.554	13.581	7.332	4.594
Seasons (S)	1	4.102	0.006	1.817	4.545	0.182	0.007	0.505
Error (a)	2	3.993	0.17	0.204	8.276	5.318	1.78	2.716
Genotypes (G)	32	465.5**	14.45**	3.95**	195.4**	227.0**	24.8**	13.3**
SG	32	3.664	0.0003	0.76**	1.84*	3.2*	0.099	0.466
Error (b)	128	4.286	0.102	0.161	1.185	1.965	0.227	0.571
Maryout location								
Reps	2	26.002	0.281	0.018	0.554	1.925	1.182	0.031
Seasons (S)	1	282.01*	4.05*	0.993	822.28*	18.425*	2.679	240.55**
Error (a)	2	14.512	0.202	0.705	11.299	0.817	0.622	0.031
Genotypes (G)	32	129.9**	1.7**	1.4**	164.0**	34.413**	2.74**	0.23**
SG	32	5.924	0.77**	0.44**	18.18**	1.711	0.31**	0.085**
Error (b)	128	8.379	0.062	0.065	6.804	1.784	0.116	0.025

Table 3. Simple correlation coefficients between all possible pairs of barley yield and yield components traits in three locations

Traits	Locations	X2	X3	X4	X5	X6	Grain yield/fed.
Plant height (X1)	Dar Elramad	0.110	0.578**	0.633**	0.448**	0.700**	0.700**
	Demo	0.471**	0.087	-0.106	0.138	0.220	0.273
	Maryout	0.386*	0.298	0.036	0.117	0.258	0.659**
Spike length (X2)	Dar Elramad		-0.377**	0.539**	-0.441**	-0.457**	-0.459**
	Demo		0.004	0.455**	0.372*	0.031	0.033
	Maryout		-0.253	0.768**	0.625**	-0.454**	-0.173
No. of spike/plant (X3)	Dar Elramad			0.824**	0.544**	0.815**	0.817**
	Demo			0.044	0.141	0.845**	0.816**
	Maryout			0.492**	-0.265	0.878**	0.500**
No. of grains / spike (X4)	Dar Elramad				0.736**	0.977**	0.977**
	Demo				-0.657**	0.029	0.071
	Maryout				-0.746**	0.668**	0.556**
1000 grain weight (X5)	Dar Elramad					0.764**	0.764**
	Demo					0.138	0.105
	Maryout					-0.325	0.017
Grain yield/plant. (X6)	Dar Elramad						0.960**
	Demo						0.983**
	Maryout						0.638**

* , ** significant at 5% and 1% probability levels, respectively

Regarding the productivity of the genotypes the data showed that Giza 2000 significantly surpassed Giza 126 at each location, indicating the suitability of the former, than the latter one, due its genetic makeup. Most of the newly bred lines yielded higher than Giza 126 at Dar Elramad and than both check varieties at Demo location. A410 and Su 12303 at Dar Elramad and ten lines, i.e. L13, L16, L19, L25, L26, Harmal, Rihane 03, A410, A1028 and 12303, at Maryout out yielded the best check variety Giza 2000, due to their superior yield components and reflecting their suitability for cultivation under environmental stresses.

Simple correlation coefficients (Table 3) were significant and positive between grain yield per plant and per feddan with number of spikes per plant at all locations. The correlation of these traits with the number of grains per spike was significant under Dar Elramad and Maryout conditions only. Highly significant positive associations were also obtained between number of spikes per plant and number of grains per spike at Dar Elramad and Maryout while the correlation was significantly negative between number of grains per spike and 1000-grain weight under Demo and Maryout conditions. These results revealed the relative importance of number of spike per plant and number of grains per spike as yield components.

In addition to high yield, trait consistency over several environmental conditions is much desired for commercial exploitation of the genotype. Stability measurements such as Wricke's ecovalence (Wi) model was suitable for evaluation. Genotypes with equal to zero Wi is regarded as highly. Wi value (Table 4) were approximately equal to zero for genotypes L7, L9 and L12 indicating their stability. Whereas RDi values of about unity were recorded for genotypes L6, L17, L18, L21 and L24 revealing their yielding stability under all environments. The most important measurements in which both Wi and RDi parameters confirmed each other were recorded for genotypes L4, L11, L20 and L27. These were thus

Table 4. Grain yield (ardab/feddan) and relative stability (RDi) and ecovalence (Wi) of 33 genotypes for grain yield under the six environments (E_1-E_6)

Genotypes	Demo			Dar Elramad			Maryout			Grand mean	Ecovalence (Wi)	RDi
	E_1	E_2	Comb.	E_3	E_4	Comb.	E_5	E_6	Comb.			
G. 126	5.52	5.45	5.49	8.21	7.10	7.66	5.43	3.487	4.46	5.87	1.17	0.52
L1	8.58	8.58	8.58	11.13	11.50	11.32	5.83	3.607	4.72	8.20	0.94	1.83
L2	7.60	7.60	7.60	8.37	6.27	7.32	5.51	3.507	4.51	6.48	0.72	0.63
L3	9.64	9.66	9.65	8.87	7.67	8.27	5.57	3.373	4.47	7.46	0.94	1.26
L4	7.83	7.83	7.83	8.67	8.87	8.77	5.50	3.543	4.52	7.04	0.06	0.86
L5	6.73	6.73	6.73	9.59	9.97	9.78	5.75	3.530	4.64	7.05	0.89	1.15
L6	8.84	8.84	8.84	8.80	7.15	7.98	5.70	3.657	4.68	7.17	0.65	0.90
L7	7.49	7.15	7.32	9.22	7.77	8.50	5.61	3.480	4.55	6.79	0.22	0.78
L8	6.81	6.81	6.81	8.42	7.50	7.96	5.88	3.510	4.70	6.49	0.45	0.56
L9	7.35	7.35	7.35	8.15	7.83	7.99	5.55	3.747	4.65	6.66	0.27	0.56
L10	7.15	7.15	7.15	8.75	9.50	9.13	5.72	3.640	4.68	6.98	0.41	0.88
L11	8.13	8.13	8.13	8.85	9.00	8.93	5.78	3.450	4.62	7.22	0.04	0.94
L12	7.95	7.98	7.97	9.96	9.63	9.80	5.68	3.683	4.68	7.48	0.16	1.14
L13	11.53	11.57	11.55	8.73	9.00	8.87	5.80	3.793	4.80	8.40	2.57	1.90
L14	7.96	7.96	7.96	11.47	12.77	12.12	6.32	3.747	5.03	8.37	2.27	2.16
L15	6.91	6.92	6.92	8.10	9.52	8.81	5.65	3.677	4.66	6.80	0.64	0.80
L16	8.86	8.86	8.86	12.37	13.10	12.74	5.97	3.727	4.85	8.81	2.41	2.56
L17	8.66	8.66	8.66	9.49	6.94	8.22	6.03	3.567	4.80	7.23	0.69	0.95
L18	9.03	9.03	9.03	8.67	6.73	7.70	5.64	3.417	4.53	7.09	1.00	1.02
L19	10.24	10.20	10.22	9.40	8.63	9.02	5.95	3.550	4.75	8.00	0.88	1.43
L20	9.10	9.10	9.10	9.21	8.40	8.81	6.07	3.613	4.84	7.58	0.24	1.02
L21	8.54	8.54	8.54	9.15	7.60	8.38	5.90	3.543	4.72	7.21	0.30	0.89
L22	6.99	7.02	7.01	8.38	5.67	7.03	5.51	3.373	4.44	6.16	1.03	0.58
L23	6.48	6.48	6.48	7.36	5.40	6.38	5.78	3.367	4.57	5.81	1.43	0.37
L24	6.77	6.45	6.61	9.22	8.45	8.84	4.95	3.347	4.15	6.53	0.41	0.93
L25	7.91	10.93	9.42	7.51	5.40	6.46	5.48	3.407	4.44	6.77	3.46	1.34
L26	9.70	9.70	9.70	9.13	8.07	8.60	5.74	3.613	4.68	7.66	0.72	1.21
Harmal	8.19	8.19	8.19	9.70	9.00	9.35	5.82	3.587	4.70	7.41	0.02	1.03
Rihan03	12.07	12.07	12.07	9.01	9.23	9.12	6.47	3.713	5.09	8.76	2.96	2.09
A410	6.95	6.95	6.95	12.43	13.37	12.90	5.63	3.467	4.55	8.13	4.84	3.03
A1028	8.75	8.75	8.75	9.55	11.43	10.49	6.04	3.573	4.81	8.02	0.72	1.53
Su 12303	10.24	11.20	10.72	12.90	13.40	13.15	6.32	3.763	5.04	9.64	2.33	2.88
G. 2000	7.47	7.47	7.47	11.69	12.77	12.23	5.72	3.497	4.61	8.10	3.02	2.46
Mean	8.24	8.34	8.29	9.41	8.93	9.17	5.77	3.56	4.66	7.37	1.08	1.17

the most stable yielding lines under all tested environments. Among them L20 produced high yield (4.84 ardab/fed) under the stressed condition of Maryout. The above four genotypes could be subjected to further improvement via selection for number of spikes per plant and number of grains per spike which are highly associated with grain yield. They can then be utilized for cultivation in a wide range of environments. However, some genotypes that produced higher grain yield (8.4 – 9.6 ardab/fed) such as L13, L16, Rihane 03 and Su12303 due to their drought tolerance and superiority at Maryout, were below average stability and were considered well adapted for harsh environment (rainfed conditions) only. These findings are in harmony with those previously obtained by Omar et al. (2004) and Ghallab et al. (2008).

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7.6. Participatory bread wheat breeding program in Kermanshah, Iran, under rainfed conditions

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Abstract

Conventional plant breeding has mostly benefited farmers in high potential environments and those who can afford inputs such as fertilizers and pesticides and have access to water. The poorest farmers who cannot afford to change their fields through the application of additional inputs get left behind. As a consequence, low yields, crop failures, malnutrition, poverty, and eventually famine are still affecting a large proportion of humanity. Working in partnership with farmers to develop varieties adapted to the conditions they face in participatory plant breeding (PPB) programs can help to overcome these problems. This paper describes the main aspects of a PPB program, the related aspects of variety release, variety adoption and seed production, and the results obtained with a PPB program applied to rainfed bread wheat in Kermanshah province, Iran.

1. Introduction

Agricultural research and development (R&D) plays an important role in increasing food production, which is a priority for the Iranian government. Since 1979, commercial farming has gradually replaced subsistence farming as the dominant mode of agricultural production in Iran. However, small farmers with less than 5 ha of land constitute almost 73% of the country's agricultural producers. In 2006, only 5% of farmers owned more than 20 ha of land (Stads et al. 2008).

The Dryland Agricultural Research Institute (DARI) is responsible for agricultural development in dry lands and low input farming systems of Iran. The rainfed cereal breeding program is one of the main research programs in DARI mainly focused on the improvement of yield potential under rainfed conditions, following a wide-adaptation strategy that tended to neglect areas with lower potential for crop production. In this program, varieties were mostly selected under the favorable and high input conditions of the research stations and then introduced with technological packages to farmers in the target environments. However, since the 2004-2005 cropping season, DARI, along with this strategy, in collaboration with the International Center for Agricultural Research (ICARDA) and the Centre for Sustainable

Development (CENESTA), initiated a strategy based on breeding for specific adaptation and diversified less favorable environments for increasing crop yield. The need for adopting a new strategy came with the severe drought of 2008 when Iran become an importer of wheat (6 million metric tons) from being an exporter of wheat in the past.

The majority of rainfed wheat farms are in the cold and moderately cold regions of Iran where the most commonly grown variety is Sardari and the newly released variety Azar-2, derived from Sardari as maternal parent (Khazaei et al. 2009). Sardari is a widely adapted wheat landrace originated from Western Iran that was released more than 30 years ago. Formal seed multiplication supports the existence and the predominance of Sardari and has caused the displacement of other old local varieties. Sardari is cultivated in both favorable and less favorable conditions, because there are no other options for farmers.

Since 30 years, climatic conditions have greatly changed and global warming is causing water scarcity and together with drought stresses has a negative impact on rainfed wheat production. Within these 30 years, through a conventional rainfed wheat breeding program, we could not identify better varieties than Sardari. Even Azar-2, released 10 years ago, with more specific adaptation than Sardari, has not been adopted extensively by farmers. Thus, a conventional plant breeding program, which leads to the monoculture of a widely adapted cultivar, would not be an efficient strategy to cope with the impact of climate change which will increase the heterogeneity of the growing environment.

In a conventional breeding program, heterogeneous environments make it difficult to apply consistent selection pressure because often it is difficult to identify a single or a few superior genotypes across all sets of conditions (Dawson et al. 2008). Therefore, when the target environment is characterized by heterogeneity of environmental stress, varieties developed in high-yielding conditions may fail to satisfy farmers' needs. To tackle the negative effect of heterogeneous environments, farmers in less favorable areas must be provided with different varieties with specific adaptation for specific environments and with a heterogeneous genetic background. The existing genetic diversity in these varieties buffers their performance when exposed to new environmental conditions (Riley 2003).

In Iran farmers in marginal and less favorable environments have a very important role in agricultural production. They are in the frontier of the challenge posed by climate change and they can offer their valuable knowledge and experience on how to live with harsh environment and protect themselves. But they need the support of researchers in this serious challenge. They deserve to benefit from the final outcome of agricultural research, especially from the varieties released from breeding programs, which genetically buffer their performance when exposed to unpredictable conditions in their fields that are completely different from the conditions of the research stations.

2. Decentralized and participatory plant breeding

Approaches that lead to close farmer-researcher collaboration in plant genetic improvement are known as Participatory Plant Breeding (PPB). Usually, but not always, PPB is initiated by the formal agricultural research sector. PPB consists of identifying breeding objectives, generating genetic variability, selecting within variable populations to develop experimental varieties, evaluating varieties, variety release, adoption by farmers, and seed production. Farmers can participate in breeding programs at many different points in this continuum of processes (Weltzien et al. 2000).

Participatory approaches enable local people to contribute their valuable practical knowledge in regional agricultural development. In a number of cases, PPB has promoted the formal release of greater numbers of varieties as breeders seek to make more choices available to farmers. In many of the examined cases of PPB, farmers test a large number of varieties than is traditionally done during the adaptive or on-farm yield trials of formal research. A usual outcome of PPB programs is that different farmers in different communities select different varieties, and thus PPB in most cases has made a contribution to increased varietal diversity (Weltzien et al. 2000).

3. Seed production system in PPB

In Iran variety release procedures are enforced by the Agricultural Research, Education and Extension Organization (AREEO). The needs of specific regions, especially in marginal areas, and the needs of specific consumers or users are not easily considered in such procedures. PPB is able to accommodate such a variety of needs, as well as needs for biodiversity. Consequently, recommendations on how to change the existing release procedures are often a direct result of working more closely with farmers. Participatory research also contributes to make farmers more aware about these procedures and to convince the variety release decision makers to modify the current variety release laws by understanding the real needs of farmers in marginal areas and by realizing the importance of specific adaptation.

4. Team work research

In Iran the traditional linear sequence of research → extension → farmers is the established way of transferring the research outcomes to farmers' fields. However, as in most developing countries, this sequence is not effective. To be more efficient in transferring new technology and research outcomes, this sequence must be replaced by team work, which not only consists of these three partners but also includes other disciplines like the formal seed sector, people from technical implementation sectors, NGO's, etc. All partners must be involved and participate in conducting research, including variety development in target environments, identification of varieties with specific adaptation, multiplication and maintenance of the locally produced seed and field management.

5. Local seed system in PPB

The potential advantages of PPB, such as the speed with which new varieties reach the farmers, the increased adoption rate and the increased biodiversity within the crop due to the selection of different varieties in different areas, will not be achieved if the seed of the new varieties does not become available in sufficient amounts to all the farming community (Ceccarelli and Grando 2007). In many countries this depends on the official recognition of new varieties. In Iran releasing varieties is the responsibility of the variety release committee, which makes decisions based on a scientific report on the performance, agronomic characteristics, reaction to pests and disease, and quality characteristics of the new variety. The farmers' opinion is not requested because the underlying assumption of the process is that scientists know what farmers need. Unfortunately this assumption is very seldom challenged even though there are several cases of varieties not released but grown by farmers. By contrast, there are several cases of released varieties never grown by any farmer. Similar cases are common in other developing countries. In these cases the considerable investment made a public institution in developing the new variety and in producing its seed has no benefits to the society in general and to the farmers in particular.

PPB can considerably improve the efficiency of the delivery phase by considering farmers' acceptance as one of the main criteria to release a new variety. In Kermanshah province, where we started a participatory rainfed wheat breeding program, during the 2008-2009 cropping season, the amount of rainfed wheat seed produced by the formal seed sectors is about 49% of the total amount of seeds required by farmers (Kermanshah Jihad-e Agriculture 2008). In other crops and countries the situation is even more critical: in Syria the formal seed sector produces less than 10% of the total amount of barley seed (the major rainfed crop) required by farmers. It is clear that the formal seed system does not produce all required seed for all rainfed wheat farms and that 51% of the seed are farmers' seed. Accordingly, a local seed system governed by farmers is active in Kermanshah and should make it rather easy to initiate PPB in this province. The local seed system fulfills a range of functions, such as providing information about seed availability and about new varieties.

6. Formal seed system and PPB

Formal seed systems have developed as a result of progressive successes of plant breeding efforts. These usually are designed to achieve some form of quality control for farmers and a basis for quantifying royalties that might be due to the breeder of a specific variety in countries where the private sector is actively involved in the seed system. If the varieties bred and/or tested by farmers are not released, their integration into the formal seed system needs to occur through variety testing and release. Fortunately, so far 10 seed production private companies have been established in different regions of Kermanshah province. Their main mandates are to purchase, clean and treat certified seeds of released varieties. These companies, which work under supervision of governmental formal seed control and certification institutes, can play an important role in integrating PPB, informal and formal seed production sectors.

7. Wheat PPB in Iran

In 2006, we started a PPB in two villages, Zamanabad and Nojoub in Sarfiriozabad, Kermanshah province, Iran. The trials conducted in the 2006-2007 cropping season were the results of consultations with farmers of the two communities conducted during 2006. The consultations were organized by the staff of the Dryland Agriculture Research Sub-Institute (DARSI), CENESTA, ICARDA and the Provincial Jihad Agriculture Organization in Kermanshah. The trial included 70 bread wheat breeding lines and three checks (Azar-2 and Sardari cultivars and an improved line not yet released, WW33G). Out of the 70 breeding lines, 29 were locally developed breeding lines and 41 were selected from international nurseries sent from the CIMMYT/ICARDA spring wheat breeding program (Table 1). The 73 lines were planted in two locations, Zaman Abad and Nojoub in farmers' fields using an un-replicated design with each of the three checks repeated 10 times for a total of 100 plots. A total of 22 farmers conducted visual selection and, after harvesting, grain yield was measured on all the plots. The data were analyzed with the spatial analysis described by Singh et al. (2003).

Table 1. Farmer score (ms) and grain yield (gy in kg/ha) of the best 10 entries and the three checks in each of the two locations with the respective ranking in parenthesis

Entry	Name	ms_L1	gy_L1	ms_L2	gy_L2
	Best ten in Zaman Abad (L1)				
43	YE2453//PPBB68/CHRC	2.8 (68)	2516 (1)	2.95 (8)	1549 (26)
15	SARDARI-HD35/5/DMN//SUT/AG(ES86-7)/3/	2.91 (28)	2468 (2)	2.39 (42)	2044 (8)
66	ERYT5678-87/F900K//SULTAN95	2.86 (48)	2174 (3)	2.1 (60)	1166 (44)
12	LOV26//LFN/SDY(ES84-24)/3/SERI/4/SERI	2.9 (32)	2155 (4)	2.34 (46)	1662 (21)
26	LOV29/3/JSW6/LOV13//JSW3/4/KREMENA/LO	2.91 (28)	2056 (5)	2.2 (55)	1171 (43)
56	TUI	2.92 (20)	1975 (6)	2.6 (27)	1312 (37)
44	M-70-4/5/Alborz/4/K6290914/Cno//K58/ Tob/3/Wa	3 (2)	1929 (7)	2.51 (32)	1372 (36)
11	OR F1.158/FDL//BLO/3/SHI4414/CROW/4/C	2.85 (55)	1835 (8)	2.75 (17)	1698 (17)
67	SABALAN/4/VRZ/3/OR F1.148/TDL//BLO	2.87 (45)	1831 (9)	2.35 (44)	1607 (22)
60	VRZ/3/ORF1.148/TDL//BLO/4/KS82W409/STP	2.82 (65)	1825 (10)	2.99 (7)	1835 (11)
	Best 10 in Nojoub (L2)				
Entry	**Name**	**ms_L1**	**gy_L1**	**ms_L2**	**gy_L2**
30	shi≠4414/crow"s"//WW33/Vee"s"	2.94 (11)	1396 (54)	2.74 (18)	3878 (1)
55	HARTOG	2.93 (15)	1197 (64)	3.37 (2)	3165 (2)
18	SARDARI-HD35/SARDARI//PRINIA	2.90 (32)	1615 (32)	2.66 (21)	2674 (3)
59	BATAVIA//TAMEX/OPATA/3/ID800994.W/VEE	2.78 (71)	1030 (71)	2.53 (31)	2374 (4)
1	SPII BWSP(F5 : 3)-7MAR	2.96 (7)	1543 (41)	3.29 (4)	2176 (5)
49	VORONAIHD24-1 2/4/KVZ/CUT75/3/YMH/I	2.91 (28)	1577 (38)	2.65 (23)	2135 (6)
23	L 44-29 K 4-1/4/RPB868/CHRC//UT1567.1	2.71 (72)	822 (73)	2.32 (49)	2065 (7)
15	SARDARI-HD35/5/DMN//SUT/AG(ES86-7)/3/	2.91 (28)	2468 (2)	2.39 (42)	2044 (8)
10	TRK13/4/SNB/HN4//SPN/3/WTS//YMH/HYS/5	2.84 (58)	1651 (24)	2.9 (11)	1848 (9)
69	AGRI/NAC//LIRA/3/PONY/OPATA	2.83 (63)	1263 (60)	3.42 (1)	1837 (10)
	Checks				
	Azar 2	3.00 (2)	1715 (16)	2.56 (30)	1591 (25)
	Sardari	2.85 (55)	1663 (21)	2.43 (40)	1576 (23)
	WW33G	2.99 (5)	1633 (28)	2.63 (24)	1673 (20)

Only one of the top 10 yielding lines in Zaman Abad (entry 15 – a cross with Sardari) was also among the top 10 yielding lines in Nojoub indicating a large genotype by location interaction. Only 3 breeding lines out yielded the best check in both locations, i.e. entry 15 (SARDARI-HD35/5/DMN//SUT/AG(ES86-7)/3/), entry 11 (OR F1.158/FDL/ /BLO/3/SHI4414/CROW/4/C) and entry 60 (VRZ/3/ORF1.148/TDL//BLO/4/ KS82W409/STP). Farmers' preferences about these three lines varied with the location.

In Zaman Abad only one of the entries (line 44) was in the top 10 for both grain yield and farmers' score while in Nojoub there were three entries (lines 55, 1 and 69) in the top 10 for both farmers' score and grain yield. Even though average grain yields were similar in the two locations (1551 kg/ha in Zaman Abad and 1331 kg/ha in Nojoub), the two locations were independent from each other and gave a different ranking for both grain yield and farmers' score which were positively and strongly correlated, indicating that in both locations farmers were able to identify the highest yielding lines.

Two of the checks (Azar-2 and WW33G) performed well at Zaman Abad while Sardari had a wider adaptation as shown by its central position in the biplot. Two lines, Hartog and shi≠4414/crow"s"//WW33/Vee"s" were the highest yielding in Nojoub while YE2453//PPBB68/CHRC was the best for grain yield in both locations.

At the end of the process, 11 lines were selected according to their grain yield and farmer's score, which, together with the three checks for revaluation in next cropping season.

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7.7. Resistance of newly bred barely accessions to net blotch disease under certain environmental conditions

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Abstract

Three field experiments were conducted under rainfed conditions of Maryout experimental station and two irrigated locations (Demo and Dar-Elrama) of Fayoum governorate to evaluate twenty nine new barely genotypes for yielding ability as well as net blotch disease caused by *Pyrenophora teres* under the variable environments represented by the sites. The results showed highly significant differences among genotypes in plant performance and disease severity under each of the three environments. At Dar-Elramad and Demo locations, most of the evaluated genotypes were classified as moderately resistant or moderately susceptible to net blotch disease caused by *Pyrenophora teres*. Line 11 recorded less disease incidence and disease severity among all genotypes at Dar-Elrama location. Lines 14, 25 and A410 recorded the lowest disease severity and L13 and L16 lowest disease incidence at Demo location. Line 7 proved resistant under Maryout rainfed condition but moderately resistant and moderately susceptible at Demo and Dar-Elrama locations, respectively. Lines 15, A410 and Su 12303 at Dar-Elrama and lines L1, L12, L15, L18, L19, A410 and Su 12303 at Maryout out yielded the best check variety Giza 2000, due to their superior yield components and reflecting their suitability for cultivation under drought stress. Thus, there is scope for using the selected genotypes like Su 12303 for combined resistance/tolerance to abiotic stress as well as net blotch.

1. Introduction

Egyptian barley germplasm has been found to harbor the genes for drought tolerance and powdery mildew resistance (Czembor 2001), yet little attention has been paid to the biological and molecular evaluation of this germplasm. To improve protection from diseases and abiotic stresses, the genetic variability of any given species should be increased by adding distinct new accessions (Jaradat 1994). Therefore, more barley germplasms must be surveyed to find the resistance genes for pathogens.

Net blotch disease, caused by *Pyrenophora teres* Dreschs (Anamorph: *Drechslera teres* " Sacc " Shoem), is one of the fungal diseases causing substantial losses (10 to 40 %) in the yield of barley (Steffenson et al. 1996). The incidence of net blotch has increased recently in many countries (Mathre 1982). Thus, breeding disease resistant cultivars is essential. *Pyrenophora teres* isolates have a very complicated genetic interaction that differs from one population to another (Legge and Tekauz 1993; Buchannon 1962; Piening and Kaufmann 1969). Strong environmental modification of resistance in genotypes has been reported by Kahn and Boyed (1982).

In Egypt, expansion of barley area in newly reclaimed lands has resulted in a need for developing new genotypes of barley that are adapted to harsh environment and irrigation with marginal quality water available for irrigation. Evaluation of barley germplasm for biotic stresses under such environments is therefore necessary.

2. Materials and methods

Field experiments were carried out in 2006/07 growing season at three locations i.e. at Dar-Elramad (clay loamy soil), Demo (sand loamy soil) and Maryout (calcareous soil with 34% $CaCO_3$, under rainfed conditions, rainfall 223mm) using 29 barley genotypes (Table 1). The experimental area was bordered by varieties susceptible to net blotch caused by *Pyrenophora teres.* All agricultural practices were followed as recommended for each area.

Disease incidence was recorded as percentage of infected plant in a sample of ten plants per replicate for each genotype based on two readings though out the growing season on the scale of 1 to 10 where: 1 to 3 resistant, 3.1 to 5 moderately resistant, 5.1to 7 moderately susceptible and > 7 highly susceptible as described by Tekauz (1985). Disease index was computed from these data following Khan and Boyd (1982.

3. Results and discussion

The average number of spikes/plant, 1000-grain weight and grain yield/ plant were enhanced for plants grown under Dar-Elrama and Demo, respectively, as compared with Maryout conditions while, number of grains / spike had the reverse direction This may be due to the regular irrigation of barley plants in Fayoum locations and the fluctuated rainfed situation of Maryout in the North Western Coast region. Sivakumar and Singh (1987) and Saxena et al. (1990) obtained similar effects with variable moisture supply. Giza 2000 significantly surpassed Giza 126 variety at each of the three locations in yield. Most of the newly bred lines yielded higher than Giza 126 at Dar-Elrama and more than both check varieties at Demo location. Line 15, A410 and Su 12303 at Dar-Elrama and seven lines. L1, L12, L15, L18, L19, A410 and Su 12303 at Maryout outyielded the best check variety Giza 2000. Afiah et al. (1999) and Afiah and Zaki (2001) found that yield of barley genotypes was affected differently under various soil and irrigation water salinity levels, and that affected the opportunities for selecting appropriate genotypes for certain environmental stress.

Data in Table 1 revealed that, the mean performance of barley genotypes for disease severity (DS) and disease incidence at different locations. Disease severity at Dar- Elramad location of most of the genotypes showed moderately resistant to moderately susceptible reaction. Most genotypes recorded a moderate disease incidence (DI). Line 11 recorded less disease incidence as well as DS among all the genotypes at Dar-Elramad location. At Demo location, most of the evaluated genotypes were moderately resistant or moderately susceptible and genotypes L14, L25 and A410 recorded the lowest DS values. Six of the evaluated genotypes (L1, L2, L3, L4, L5, and G126) were classified as (MR-MS). On the other hand, most genotypes recorded a moderate DI rating. Genotypes L13 and L16 recorded the lowest DI value among all genotypes at Demo location. These findings are in harmony with those previously reported by Zaki and Afiah (2002). At Maryout site, evaluated genotypes ranged between moderate resistant to moderately susceptible to net blotch. Line 3 was susceptible

Table 1. Mean performance of barley genotypes tested for disease severity (DS) and disease incidence (DI) at two locations of Fayoum governorate (Demo and Dar-Elramad) and at Maryout (North Western Coast) region; r is simple correlation coefficients between grain yield / plant and each of disease severity and disease incidence values

Genotype	Dar-Elramad			Demo			Maryout		
	DI (%)	DS*	classify	DI(%)	DS*	classify	DI (%)	DS*	Classify
Giza 126	28.3	4.0	MR-MS	35	4.3	MR-MS	65	6.0	MS
L1	23.3	4.3	MR-MS	43.3	4	MR-MS	60	3.0	MR
L2	36.7	3.2	MR	25	3.7	MR-MS	40	3.0	MR
L3	30.0	2.7	MR	36.7	4.3	MR-MS	85	8.0	S
L4	43.3	3.7	MR-MS	38.3	3.3	MR-MS	65	7.0	MS
L5	26.7	2.5	MR	33.3	4.3	MR-MS	30	3.0	MR
L6	30.0	3.8	MR-MS	30	3.5	MR	60	6.0	MS
L7	31.7	3.5	MR	28.3	2.3	MR	25	1.0	R
L8	48.3	3.5	MR	38.3	2.7	MR	65	7.0	MS
L9	31.7	3.0	MR	38.3	2.8	MR	30	2.0	MR
L10	15.0	2.3	MR	31.7	2.3	MR	50	3.0	MR
L11	33.3	3.0	MR	21.7	2.2	MR	45	3.0	MR
L12	51.7	3.5	MR	40	2.8	MR	60	4.0	MR-MS
L13	36.7	3.3	MR	16.7	2.3	MR	50	7.0	MS
L14	33.3	3.3	MR	23.3	2.7	MR	65	6.0	MS
L15	31.7	4.2	MR-MS	20	1.8	MR	65	6.0	MS
L16	26.7	5.5	MR-MS	15	3.3	MR	60	4.0	MR-MS
L17	46.7	5.7	MS	28.3	3.2	MR	40	5.0	MR-MS
L18	26.7	4.2	MR-MS	21.7	3.5	MR	55	4.0	MR-MS
L19	31.7	2.3	MR	33.3	2.2	MR	45	5.0	MR-MS
L20	36.7	2.7	MR	26.7	3	MR	40	3.0	MR
L21	30.0	3.5	MR	41.7	4.8	MS	45	4.0	MR-MS
L22	35.0	4.0	MR-MS	35	4.2	MS	55	6.0	MS
L23	30.0	6.0	MS	30	2.7	MR	40	3.0	MR
L24	18.3	3.5	MR	23.3	2	MR	45	3.0	MR
L25	40.0	4.8	MR-MS	30	1.7	MR	35	4.0	MR-MS
Su 12303	26.8	2.3	MR	20	2	MR	25	1.0	R
A-410	21.7	3.5	MR	25	1.7	MR	30	3.0	MR
Giza 2000	60.0	6.3	MS	23.3	2	MR	50	4.0	MR-MS
Mean	32.89	3.78	-	29.4	3.0	-	50.00	4.31	-
LSD 0.05	10.77	1.32	-	9.84	1.35	-	3.77	2.02	-
r	-0.043	0.068	-	-0.165	-0.294	-	-0.153	-0.30	-

while L7 and Su 12303 were resistant. Tivoli et al. (1986) indicated that the tolerance of some genotypes in the field could be broken under certain conditions of temperature and light, making them susceptible.

Most of the genotypes grown at Maryout showed higher disease incidence than at Demo and Dar-Elramad. L7 and Su 12303 recorded the lowest disease incidence and disease severity values, respectively. L3 recorded the highest disease incidence as well as disease severity among all genotypes in Maryout.

Lines 5, 7 and Su 12303 were the best genotypes recording the lowest disease incidence and severity under the three locations. Insignificant negative association was observed between grain yield/plant and DI and DS under edaphic and climate conditions of the three sites except DS under Dar-Elramad site. This emphasizes the importance of genotypes chosen for improving abiotic stress tolerance and disease resistance. The promising newly bred line Su 12303 could be subjected to further studies under different stress conditions and agricultural practices, as it has desirable gene combinations acting well under drought stress with good yielding ability but fluctuating response to net blotch disease.

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7.8. Improving lentil genotypes under El-Tur - South Sinai stress conditions

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Abstract

Eighteen lentil genotypes with two local checks were tested at El-Tur (South Sinai), during the 2003-04 and 2004-05 cropping seasons. Mean squares of each season revealed significant differences for all recorded traits. The superior genotypes were lines 1 (FLIP-84-112L), 2 (81S15) , 3 (FLIP 86-81L), 5(FLIP 86-39L), 7(FLIP 87-68L) and 18(FLIP 93-20L) for seed yield / plant. Such superiority was due to number of pods/plant, number of seeds/pod and seed index. Phenotypic and genotypic variances with their coefficients of variability and broad sense heritability for all studied traits were calculated. The heritability percentages were high for days to flowering (97.5%), number of pods / plant (97.12%), 1000-seed weight (97.53%), seed yield / plant (97.71%) and straw yield / m^2 (97.67%) in the first season and seed yield / m^2 (97.38%) in the second season. Estimates of phenotypic and genotypic coefficients of variation were relatively high for straw yield / m^2, seed yield / m^2, days to flowering, number of seeds / plant and plant height. Highly significant positive phenotypic correlation coefficient was found between the combinations of days to flowering and days to maturity, plant height and number of branches/plant, number of pods/plant and number of seeds/plant, number of seeds/plant and 1000-seed weight , 1000-seed weight and seed yield/plant, and seed yield/m^2 and straw yield/m^2 in both seasons. The main source of seed yield / plant was 1000-seed weight followed by days to flowering and number of pods / plant in the first season and days to flowering, number of branches / plant and 1000-seed weight in the second season. The joint effect between days to flowering and number of branches / plant negatively affected seed yield variations and had the higher magnitude in the second season

1. Introduction

Lentil (*Lens culinaris* Medik) is not competitive with other winter crops in the irrigated areas in Egypt. Alternative rainfed regions must, therefore, be used for its production. Lentil used to occupy an area of about 70,000 feddan (1fed=o.42 ha) until 1975-76. However, the area has gradually decreased and reached to about 5000 fed in 2000-01. The average seed yield has increased from 624 kg/Fed. in 1950s to 704 kg/fed in 2000-01 (Anon. 2001). Lentil also provides nutritionally rich organic residues and plays a key role in maintaining soil productivity through biological N_2 fixation (Saxena 1988). Therefore, there is a special need for growing lentil in rotations with cereal crops in rainfed regions. The lentil - cultivated area in these regions in Egypt is still low and has reached only about 902 fed (average of 1993 to 1999). The productivity is low in these areas because of limited moisture supply. Silim et al. (1993) found strong linear relationships between yield and moisture supply for 25 diverse lentil lines grown in northern Syria. There is therefore need for identifying cultivars adapted to these new areas characterized by harsh weather and soil and moisture conditions.

Lentil is a moderately drought resistanant crop. Fisher and Maurer (1978) noted that quantification of drought tolerance should be based on seed yield under limited moisture conditions. A few accessions of cultivated lentil have been identified as being adapted to drought (Hamdi et al. 1992) due to their early flowering date. Turner et al. (1996) reported that lentil has considerable potential for drought tolerance through osmotic adjustment. A source of drought tolerance was identified in wild lentil (Hamdi and Erskine 1996). Bayoumi (2003) suggested that only one cycle of single plant selection was sufficient for improving lentil mean productivity and its drought tolerance.

This investigation aimed to explore the variations among eighteen diverse lentil genotypes with a view to identify lines that could be adapted to the new stressful areas. Genetic parameters i.e. σ^2g, σ^2Ph, PCV %, GCV % and broad sense heritability (h^2 %) were estimated under El-Tur stress conditions from data of the two successive seasons.

2. Materials and methods

Eighteen lentil accessions were tested with local check 'Giza 9' and a newly released early maturing variety 'Sinai-1'. These accessions were received from the International Center of Agricultural Research in the Dry Areas (ICARDA). The details of genotypes are in Table 1. Experiments were conducted to study the effect of growing lentil in silty-sand soil and irrigated with water with low level of salinity, under high solar radiation at El-Tur conditions during the winter seasons of 2003-04 and 2004-05. The genotypes were grown in a randomized complete block design with three replications and irrigated by the drip irrigation system. Each plot was 3.5x2.1 m having 7 rows spaced 30cm apart. Sowing was done on 15 October in 2003 and 20 October in 2004. The cultural practices were maintained at optimum levels for lentil productivity.

Number of days from sowing to 50% flowering and maturity were recorded. At harvest, plant height(cm), number of branches/plant, number of pods/plant, number of seeds/pod and seed yield /plant (g) were recorded on random sample of 10 guarded plantstaken from the middle three rows of each plot. Seed and straw yield/m^2 were determined from 4 rows in the middle of the plot. To investigate the difference between the tested lentil genotypes their respective genetic variance was computed as percent from their phenotypic responses by estimating broad sense heritability as proposed by Johnson et al. (1955). Phenotypic correlation coefficients were also calculated for different pairs of traits. Partitioning of correlation coefficient into direct and indirect effects was made by determining path coefficients using the method proposed by Wright (1921).

3. Results and discussion

The test of homogeneity of error variance for the two seasons revealed that error mean squares were heterogeneous for all traits except 1000-seed weight, straw yield / m^2, days to flowering and days to matiority. Mean squares of each season revealed significant differences for all recorded traits (Table 2). These results confirmed the varied genetic background of the tested materials. Abdalla et al. (1982) and Bakheit and Mahdy (1987) recommended multi season study for reliable estimates of genetic effect.

Table 1. Name, pedigree and origin of all lentil genotypes tested

Entry No.	Entry Name	ILL #	Pedigree	Origin	FAO Status
L1	FLIP 84-112L	5782	ILL 883*ILL 470	ICARDA	D*
L2	81S15	5883	UJL 197*ILL 4400	Jordan	D
L3	FLIP 86-81L	6004	ILL 4349*ILL 4605	ICARDA	D
L4	FLIP 86-38L	6024	ILL 262*ILL 3458	ICARDA	D
L5	FLIP 86-39L	6025	ILL 1*ILL 936	ICARDA	D
L6	FLIP 87-17L	6207	ILL8*ILL 212	ICARDA	D
L7	FLIP 87-68L	6258	ILL4353*ILL 4400	ICARDA	D
L8	FLIP 88-35L	6459	ILL5562*ILL 3493	ICARDA	D
L9	FLIP 88-43L	6467	ILL 4605*ILL 2582	ICARDA	D
L10	FLIP 89-63L	6821	ILL 4225*ILL 4605	ICARDA	D
L11	FLIP 92-34L	7199	ILL 1939*ILL5883	ICARDA	D
L12	FLIP 92-39L	7204	ILL 5676*ILL 1880	ICARDA	D
L13	FLIP 92-42L	7207	ILL 5507*ILL 5698	ICARDA	D
L14	FLIP 92-50L	7215	ILL 5737*ILL5726	ICARDA	D
L15	FLIP 92-52L	7217	ILL 3527*ILL 5732	ICARDA	D
L16	FLIP 92-54L	7219	ILL 4605*ILL 2581	ICARDA	D
L17	FLIP 93-3L	7504	ILL 5684*ILL 5593	ICARD	D
L18	FLIP 93-20L	7521	ILL 5883*ILL 5779	ICARDA	D
Giza-9	-	-	UJ82-31L	Local	U
Sinai-1	-	-	81'S Wady Musa	Local	U

D*: designed U: un

Table 2. Mean squares for all traits recorded on 20 lentil genotypes in two seasons

Source of variations	First season		Second season	
	varieties	error	varieties	error
d.f.	19	38	19	38
Days to flowering	243.17**	2.062	182.72**	3.634
Days to maturity	120.33**	2.973	67.37**	3.157
Plant height (cm.)	60.68**	0.741	66.50**	1.790
No. of branches/plant	1.95**	0.042	1.78**	0.092
No. of pods/plant	7.05**	0.069	4.85**	0.303
No. of seeds/plant	54.52**	0.722	34.83**	1.803
1000-seed weight (gm)	39.58**	0.331	33.29**	0.498
Seed yield/plant (gm)	1.403**	0.011	1.119**	0.029
Seed yield/m^2 (gm)	248.68**	0.803	186.94**	1.663
Straw yield/m^2 (gm)	12713.25**	96.403	5871.14**	135.877

** Denote significance at $P \leq 0.01$ probability level

Phenotypic and genotypic variances with their coefficients of variability and broad sense heritability for all studied traits were calculated from data of two seasons. The heritability was high for days to flowering (97.5%), number of pods / plant (97.12%), 1000-seed weight

(97.53%), seed yield / plant (97.71%) and straw yield / m^2 (97.67%) in the first season and seed yield / m^2 (97.38%) in the second season. All other traits also showed relatively high h^2 descending to 83.32% for number of pods / plant in the second season. It was noted that heritability values for most studied traits estimated in the first season were higher than in the second season. Bayoumi (2003) reported that heritabilities in broad sense under drought stress conditions were high for mean productivity and days to flowering and moderate for plant height and seed yield/plant.

When increasing productivity is the ultimate goal of the breeding program, heritability estimates do not present the entire picture. The phenotypic and genotypic variances must be taken into consideration as well. From the data of the two growing seasons, estimates of phenotypic and genotypic coefficients of variation were relatively high for straw yield / m^2, seed yield / m^2, days to flowering, number of seeds / plant and plant height. The estimates were relatively low for all other recorded traits. The relative difference between phenotypic and genotypic coefficients of variation, as criteria of non-heritable effects, reached the maximum magnitude for number of pods / plant (8.78%), number of seeds / plant (7.31%), followed by number of branches / plant (7.29%) and days to maturity (6.74%) in the second season. The obtained results confirmed the above heritability values for such traits. In general, there was no great discrepancy between phenotypic and genotypic coefficient of variability among the two seasons suggesting a small effect of environmental factors on most studied characters. These results are in agreement with those recorded by Afiah and Moselhy (2001) and Sharaan et al. (2003).

The check variety Sinai-1 and the lines #1(FLIP-84-112L) and #2 (81S15) seemed to be the earliest genotypes under El-Tur conditions. El-Karamity (1996) reported that Precoz variety was the earliest variety followed by Giza 370 and Giza-9. Also, Hamdi et al. (2002) found that Sinai-1 was earlier than Giza-9 by 21, 7 and 28 days in North, South and rainfed Egyptian areas, respectively. The superiority of lines # 1, 2, 3(FLIP 86-81L), 5(FLIP 86-39L), 7(FLIP 87-68L) and 18 (FLIP 93-20L) in yield / plant were due to number of pods/plant, number of seeds/pod and seed index(1000-seed weight). Ammar et al. (2003) suggested that 1000-seed weight, plant height, and number of branches/plant could be considered suitable as selection criteria for improving lentil seed yield indirectly. Also, Bayoumi (2003), mentioned that selection for mean productivity in lentil plants under different water regimes will be accompanied by an increase in seed yield in both stress and non stress conditions.

A matrix of simple correlation coefficients of traits under study is presented in Table 3. Highly significant positive phenotypic correlation coefficient was found between the combinations of days to flowering x days to maturity, plant height x number of branches/plant, number of pods/plant x number of seeds/plant, number of seeds/plant x 1000-seed weight , 1000-seed weight x seed yield/plant and seed yield/m^2 x straw yield/m^2 in both seasons. As well as, days to flowering x plant height in the second season and number of pods/plant x 1000-seed weight, seed yield/plant and number of seeds/plant x seed yield/plant in the first season. These results indicated that selection practiced for the improvement of any one of a set of correlated characters, would automatically improve the other. Singh (1977) studied the correlation coefiicient between seed yield / plant and its attributes in lentil and found positive relations between yielding ability and each of the characters such as plant height, number of branches / plant and number of pods / plant. Similar results were obtained by Bayoumi (2003) and Ammar et al. (2003).

Table 3. Simple correlation coefficients between all possible pairs of lentil yield and yield attributes

Characters	season	Plant height (X1)	X2	X3	X4	X5	X6	X7	X8	X9
No. of branches/plant X2	S1	0.85**								
	S2	0.84**								
No. of pods/plant X3	S1	0.26	0.21							
	S2	0.33	0.20							
No. of seeds/plant X4	S1	0.4	0.36	0.79**						
	S2	0.42	0.3	0.77**						
Seed yield/plant (gm) X5	S1	0.16	0.09	0.54*	0.57**					
	S2	0.04	0.08	0.40	0.38					
1000-seed weight (gm)X6	S1	0.17	0.1	0.5*	0.62**	0.81**				
	S2	0.06	0.16	0.44	0.46*	0.71**				
Seed yield/m^2 (gm)X7	S1	0.07	0.16	0.14	0.19	0.07	0.06			
	S2	0.16	0.11	0.08	0.07	-0.04	-0.02			
Straw yield/m^2 (gm)X8	S1	0.04	-0.01	0.17	0.15	0.14	0.03	0.79**		
	S2	0.13	0.14	0.07	0.07	0.06	-0.04	0.79**		
Days to flowering X9	S1	0.36	0.4	-0.15	-0.19	-0.6**	-0.52*	-0.4	0.02	
	S2	0.48*	0.38	-0.09	-0.09	-0.66**	-0.66**	0.15	0.12	
Days to maturity X10	S1	0.06	0.1	0.16	-0.19	-0.19	-0.42	-0.11	0.06	0.64**
	S2	0.15	-0.08	0.08	-0.13	-0.53*	-0.52*	0.06	-0.06	0.70**

* and ** : Denote significance at P 0.05 and 0.01 probability levels, respectively.

Table 4. Direct and joint effects of five attributes in contributing to seed yield in the two seasons. CD: Coeffecient of dtermination, RI: Relative importance and TC: Total contribution

Source of variation	First Season			Second Season		
	CD	RI%	TC%	CD	RI%	TC%
Days to flowering (X_1)	0.136	10.18	21.13	0.406	32.66	43.61
No. of branches /plant (X_2)	0.027	1.99	5.49	0.063	5.09	11.42
No. of pods/plant (X_3)	0.066	4.94	13.13	0.048	3.87	7.06
No. of seeds /plant (X_4)	0.008	0.60	5.04	0.000	0.01	0.31
1000-seed weight (X_5)	0.280	21.04	36.61	0.022	1.76	8.45
(X_1) x (X_2)	-0.048	3.60	-----	-0.122	9.80	-----
(X_1) x (X_3)	0.028	2.13	-----	0.025	2.02	-----
(X_1) x (X_4)	-0.013	0.94	-----	0.001	0.09	-----
(X_1) x (X_5)	0.203	15.22	-----	0.124	10.00	-----
(X_2) x (X_3)	0.018	1.32	-----	0.022	1.78	-----
(X_2) x (X_4)	-0.011	0.79	-----	0.002	0.12	-----
(X_2) x (X_5)	0.017	1.29	-----	0.012	0.96	-----
(X_3) x (X_4)	-0.036	2.73	-----	0.003	0.28	-----
(X_3) x (X_5)	0.136	10.20	-----	0.029	2.30	-----
(X_4) x (X_5)	-0.059	4.42	-----	0.001	0.11	-----
Residual	0.248	18.61	-----	0.363	29.15	-----
Total	1.000	100	81.4	1.000	100	70.85

Simple correlation coefficients illustrated in Table 3 were then partioned by path coefficient analysis to detect the relative importance of the main attributes to plant yield ability. The components of the total seed yield/plant variations determined directly and jointly by each factor are presented in Table 4. The total contribution of the five traits studied was 81.4 % and 70.85 % for the first and the second seasons, respectively. Total contribution showed that the main source of seed yield / plant was 1000-seed weight followed by days to flowering and number of pods / plant in the first season and days to flowering, number of branches / plant and 1000- seed weight in the secnod season. The joint effect between days to flowering and number of branches / plant negatively affected seed yield variations and had the higher magnitude in the second season (CD = - 0.122). Singh (1977) stated that plant height and number of pods / plant showed the highest direct effects in seed yield variations for lentil genetic materials. Also Tuba and Sakar (2008) reported that path analysis indicated that the biological yield and number of pods / plant had the highest positive direct effects on lentil seed yield. These results are in agreement with Ammar et al. (2003). Therefore these traits could be deployed for varietal improvement for the harsh environments of South Sinai in Egypt.

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7. 9. Developing new lentil germplasm pool adapted to climate change

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Abstract

Lentil is a major cool season food legume crop grown in many parts of the world, but mainly in the West and South East Asia, North and Aast Africa, and more recently in North America and Australia. ICARDA has a global mandate for the improvement of lentil. The Center has assembled and developed more than 11,000 germplasm accessions and breeding lines that are being used to develop varieties for different agro-ecological conditions. The material has been shared with national program partners for developing locally adapted cultivars. A good success has been made as more than 100 varieties have been released since this collaborative effort started, with much benefit of improved crop productivity on farmers' field. Recent breeding efforts at ICARDA have been directed to expose the material to extremes of temperatures and drought stress with a view to develop material which may better adapt to the changing global climate. The 2007-08 crop season was one of the driest seasons since ICARDA's inception in1977 with the total rainfall of 222.5 and 173.6 mm at Tel Hadya and Breda (Syria) respectively as compared to the 10 years average of 342.4 and 224.1mm. During the 2007-2008 growing cycle, most of ICARDA's breeding lines/germplasm experienced severe terminal drought and in most cases many of the lines succumbed particularly in the drier test locations e.g. Breda. However, the challenging harsh climatic conditions particularly at Breda provided us with an opportunity to identify lentil lines with the genetic potential to thrive under such extreme conditions. Results from the analysis of the trials suggested that some of the lentil germplasm/ breeding lines performed very well. Early and drought tolerant lines were thus identified.

1. Introduction

Lentil (*Lens culinaris*) is one of the cool-season food legume crops grown in west and south East Asia, North and East Africa and South and North America. It was introduced to Australia about twenty years ago and is now one of the major commercial food legume crops there. The International Center for Agricultural Research in the dry Areas (ICARDA) has a global mandate for lentil improvement. Since its inception, ICARDA has assembled about 11,000 germplasm accessions and breeding lines and distributed to the national agricultural research systems for use in cultivar development suitable to different environments. To date, over 100 adapted and high yielding varieties were released from ICARDA breeding lines and accessions by the national programs and these have significantly contributed to an increased lentil production in the world.

ICARDA is located at longitude of $35^{0}56'$E and latitude of $36^{0}1'$ N and operates in a very harsh environment because it is dry and cold in the early part of the growing season followed by terminal drought and increased temperature during flowering and grain filling stages.

These features have further been accentuated by the on-going climate change. It has been recognized that 19 West Asia and North Africa (WANA) countries will face severe water poverty by 2025; become drier and hotter making the current crop varieties and agricultural technologies irrelevant (El- Beltagy 2005). Roozitalab (2005) also indicated that climate change will further increase the frequency and magnitude of droughts, with a decrease in an average annual precipitation and change in distribution pattern which will have adverse effect on agriculture. This negative effect was demonstrated by the results of the study conducted by Lambi and Molua (2007) on the impact of climate change on crop farming in Cameroon. They reported that the net revenue fell as precipitation decreased or temperature increased. They found that although other physical factors such as soil and relief have an important influence on agriculture, climate remains the dominant factor determining the variety of the crops cultivated and the types of agriculture practiced. Similar experiences are shared by many farmers in the dry environments of WANA where ICARDA is strategically located and operates.

Kurukulasuriya and Mendelsohn (2008) studied the crop switching strategy used by African farmers for adapting to climate change and found that farmers shift crops they plant to match the climate they face. Due to its economic importance and adaptability to such harsh environment, lentil could probably be one of the farmers' choices in the future. Realizing its importance, ICARDA lentil breeding program has major focus to developing new lentil germplasm pool that is adaptable to changing environments with tolerance to cold, heat, salinity and the associated diseases and pests. Therefore, the objectives of this study were to evaluate and identify breeding lines and germplasm accessions that are adapted to climate change in the drier areas.

2. Materials and methods

Three sets of lentil genotypes were planted at Breda research station of ICARDA in the 2007-2008 growing season, since it is the driest site with highly variable and low rainfall. It is located in the southern part of Aleppo at $37^0$10' E longitude and 35^0 36' N latitude. The three sets tested were early, drought tolerant and large-seeded sets. The early set consisted of 25 entries and the large-seeded set 16 entries. They were planted in lattice designs while the drought tolerant set with 15 entries was planted in a randomized complete block design. All the experiments were grown in 4- row plots of 3m x1.2m with spacing of 30cm between rows and about 5 cm between plants in a row. Planting was done on 3rd December 2007. Seed and biological yields were determined from the two central rows and subjected to the statistical analysis.

3. Results and discussion

ICARDA's lentil breeding program works at Breda which is a dry site to develop genotypes suitable for drought prone areas of the world to match with climate change. The rainfall at this site was particularly declining since the 2002-03 crop season (Fig.1). The decrease in rainfall was relatively very high (-12.2%, -24,5%, -53%, -48.8%, -54.9%, -42.8%, -35.2%, -25.6%, and -34.9%) in different seasons from 1998-99 to 2007-08, respectively, as compared to the long-term average. The 2007-08 crop season was one of the driest seasons since 1979. Rainfall was not evenly distributed during the season (Fig.2) thus the lentil crop was exposed to terminal drought from March onwards and most of the lines failed to produce seeds. This extreme drought event gave an opportunity to select for suitable lines adapted to the changing environments since under such harsh climatic conditions (173.6mm of rainfall), some of the lentil germplasm and new breeding lines performed relatively well (Tables1& 2). The first set of early lines (Table1) and the second set of drought tolerant lines (Table2) filled their grains normally and gave reasonable yields. The highest yield of 669.7kg/ha was obtained from new breeding line while the lowest yield of 42.14kg/ha was recorded in Syrian local large (Table1). The drought tolerant lines of the second set gave better yield (up to 778.3kg/ha) and the yields of the two Syrian local checks were the low (23.3kg/ha and 330 kg/ha) (Table2). This suggests that the old cultivars are no more suitable for their old growing areas. It also emphasizes the need of the new varieties to replace the old ones to match with current climatic condition.

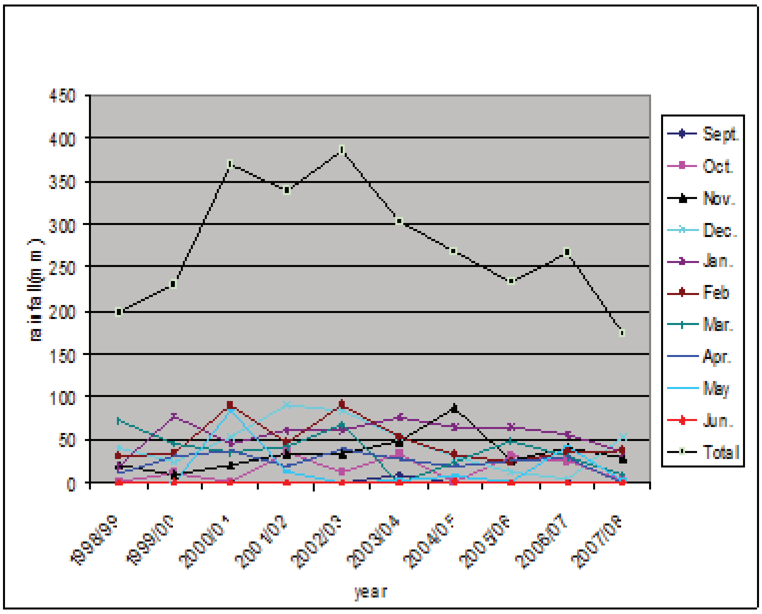

Figure 1 Total rainfall and its distribution at Berda 1998/99 to 2007/08 crop seasons

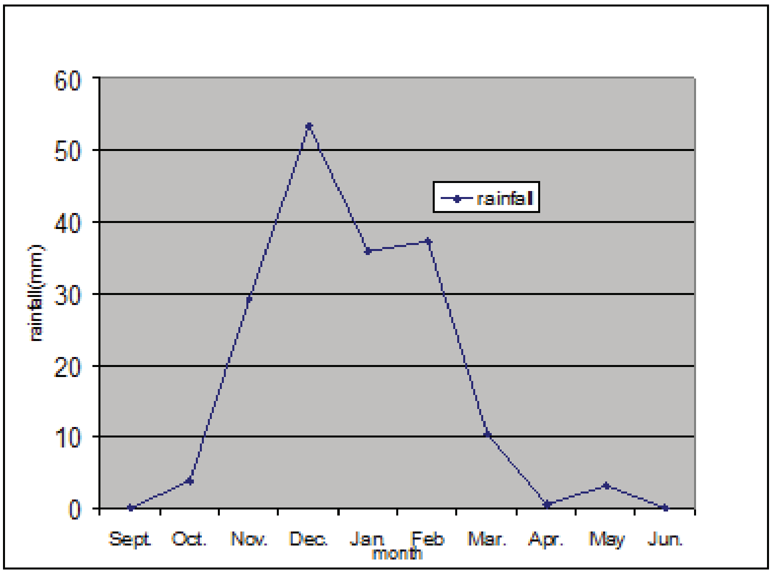

Figure 2 Monthly rainfall (mm) distribution in 2007/08 crop season.

Table1. Performance of early and very early lines at Breda in 2007/08 season

Entry	Seed yield(kg/ha)	Biological yield (kg/ha)
06S 54141-49	669.7	1814
06S 54141-48	638.5	1939.1
06S 54141-52	635.5	1784.4
06S 54152-14	635.3	1873.4
06S 54145-09	624.4	1738.3
06S 54141-34	617.2	1771.1
06S 54141-47	616.7	1500.8
1LL 4605	615.0	1830.4
06S 54141-30	599.1	1735.9
06S 54152-17	595.9	1711.7
06S 54152-16	587.0	1827.3
06S 54208-12	580.8	1875.0
06S 54208-10	578.2	1975.0
06S 54145-13	578.1	1724.2
06S 54152-18	553.2	1807.0
O6S 54173-06	542.7	1707.8
06S 54220-02	541.7	1948.4
06S 54196-03	538.3	1698.4
06S 54142-01	527.6	1807.8
06S 54142-02	511.6	1807.8
06S 54145-17	468.3	1720.3
06S 54145-19	423.4	1704
06S 54153-09	324.7	1885.1
ILL-4400(Local large)	42.14	2138.3
ILL-4401(Local small)	273.1	1866.4
Mean	**532.71**	**1807.7**
LSD(5%)	104.8	223.55
CV (%)	11.04	7.35

Table 2. Seed and biological yields of some drought tolerant lines at Breda in 2007/08

Entry	Seed yield(kg/ha)	Biological yield(kg/ha)
06S 554141-10	778.3	2098.3
1LL-4605	738.3	2075.0
06S 54154-5	688.3	2221.7
06S 54141-20	663.3	1838.3
06S 54144-4	621.7	2125.0
06S 53109-10	573.3	2415.0
06S 54141-23	566.7	1863
06S 54187-2	535.0	2013.3
06S 54141-24	480.5	2435.0
06S 54109-13	475.0	1555.0
06S 54143-2	448.3	1988.3
06S 54107-02	396.7	1911.7
06S 54118-01	331.7	1780.0
1LL-4401(Local small)	330.0	2385
1LL-4400(local large)	23.3	2281.7
Mean	**510**	**2065.8**
LSD(5%)	265.1	438.76
CV (%)	19.6	8.09

Table 3. Seed and biological yields of large-seeded lentils at Breda

Entry	Seed yield(kg/ha)	Biological yield(kg/ha)
ILL-4401(local large)	272.9	552.7
ILL-5582(Idleb1)	231.9	686.2
95S 34121-01	202.9	625.2
04S 54105	163.2	691.7
04S 54105-03	121.6	625.3
04S 54105-09	107.9	707.9
04S 54105-07	101.6	713.4
ILL-4400(local small)	83.5	710.3
95S 34114-09	56.5	710.6
95S 34115-17	54.6	715.1
95S 34114-07	44.7	629.8
95S 43118-01	37.3	718.0
95S 44115-13	27.1	709.5
95S 34115-08	23.5	651.8
95S 34115-20	22.9	673.8
95S 34115-22	21.8	683.3
Mean	**98.4**	**675.2**
LSD(5%)	63.66	101.2
CV (%)	29.53	7.47

The large-seeded lentil lines did not perform well (Table3) and had the lowest seed and biological yields as compared to the other two sets (Tables1 &2) indicating that much progress has relatively been made in breeding small to medium-seeded lentil lines for drought prone areas. Interestingly, drought tolerant lines (Table2) produced the highest seed and biological yields which are equally important to farmers because of the value of the lentil straw as a quality animal feed. Because of severe drought, the price of a kilogram of lentil straw was about the same as that of lentil seed during the harvest time; indicating that feed is important to maintain animals in dry areas. It was also observed that crops of the most of the farmers in Breda failed to set grains and farmers without irrigation facilities used their crop fields either for direct grazing or for making hay. Our observations, therefore, showed that lentil seems to be one of the promising crops in the dry areas of WANA provided that suitable cultivars will be developed to match with climate change. These promising breeding lines are international public goods and will be organized in the form of the Lentil Drought Nurseries and distributed to the National Agricultural Research System having similar environments. It will be shared with all other institutions interested in lentil improvement.

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7.10. Screening faba bean breeding lines for drought and heat stresses

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Abstract

Faba bean is one of the most important legume crops in many parts of the world particularly in the Mediterranean region, China, South America and East Africa. It is seriously affected by drought and heat at early and reproductive stages of growth. The development of drought and heat tolerant cultivars is therefore essential to improve the yield stability of faba bean under climatic variability. Plant breeders normally evaluate breeding materials at drought-prone sites based on grain yield. Two hundred ninety five lines were planted using augmented design in Tel Hadya at 10 April 2008. The total amount of moisture(from rainfall and irrigations) received by crop was 142.7 mm, with the evapo-transpiration ranging from 7 to 16.2 mm/ day from the flowering to maturity and the maximum temperature ranging from 28.5 to 38.4 ^{0}C. Only 27 single plants were selected as drought and heat tolerant based on seed yield. The selection index was 0.61% of the total plants in the field.

1. Introduction

Faba bean (*Vicia faba* L.) is one of the most important grain legumes in China, South America, the Mediterranean Region and in different drought prone regions of the North and East Africa. Faba bean plays an important role in the nutritional security and it is grown in rotation with cereals especially in the Mediterranean region and East African countries. Drought and heat have increasingly affected the faba bean growing areas during the last decades and caused reduction in crop productivity (Chaves et al. 2003). Faba bean is known to be more sensitive to drought than other grain legumes (McDonald and Paulsen 1997). In many areas of the production regions of Mediterranean basin (Sau and Mínguez 2000), Western and Central Europe (Link et al. 1999) and Australia (Loss et al. 1997; Siddique et al. 2001), the faba bean generally relies on stored soil moisture and current rainfall for its growth and development. The crop is often affected by intermittent drought during vegetative growth and by terminal drought during reproductive development (Wery et al. 1994; Ricciardi et al. 2001). Generally, the differences in the amount and distribution of rainfall are the major reasons for variability in seed yield of faba bean (Pliez et al. 1995, Bond et al. 1994; Manschadi et al. 1998; Abdelmula et al. 1999; Siddique et al. 2001). In particular, faba bean is highly affected by heat at early flowering and podding stages of growth. (Abdelmula and Abuanja 2007)

The adaptation mechanisms of faba bean to water limited Mediterranean conditions comprises drought escape (earliness) and vigorous growth. The development of drought and heat tolerant cultivars is essential to improve the yield stability of faba bean under climatic variability. Plant breeders normally evaluate and select breeding materials at drought-prone sites based on grain yield. The main objective of this study was to identify faba bean germplasm with heat and drought tolerance for further use in the breeding program.

2. Materials and method

A total of 295 faba bean lines were planted at ICARDA's Tel Hadya research farm on April 10, 2008 in an augmented design using ILB 1814 as check in every 10 rows. These include 33 F4 "independent vascular supply" types, 80 breeding lines tolerant to *Orobanche crenata*, 80 early maturity lines and 46 highly autofertile types originating mainly from Bangladesh, Egypt, Ethiopia, Yemen, India, Nepal, Pakistan, Afghanistan, China, Columbia, Syria, Lebanon, Iraq, Morocco, France and Spain.

During the growing period, maximum and minimum temperatures, daily precipitation, evapo-transpiration and morphological data such as date of flowering and maturity, and yield components (pods per plant, and seeds per plant and per pods) of the selected plants were recorded. Correlation between yield components of the selected plants was estimated.

3. Results and discussion

The experiment was conducted under semi-controlled environment at Tal Hadya farm where the total rainfall and irrigation provided to crop a total of 142.7 mm of water, while the evapo-transpiration was in the range of 7-16.2 mm/day during the flowering to maturity period. The data on cumulative amount of rainfall, irrigation and evapo-transpiration of each phenological period of the crop growth are presented in the Table 1. The maximum daily temperatures varied from 28.5 to 38.4 ^{0}C during the reproductive stage of the plants. This environment was effective to induce drought and heat stress and therefore useful for screening material for tolerance to these stresses.

Table1. The cumulative rainfall, supplemental irrigation (SI) and evapotranspiration (ETo) for the different vegetative stages

Vegetative stages	Rainfall (mm)	SI (mm)	ETo (mm)
From planting to first leaves	1.4	30	78.0
Early vegetation (4 to 6 leaves)	0.5	30	114.0
vegetation (more than 6 leaves)	10.8	20	103.5
Flowering	0.0	30	147.0
Podding	0.0	20	192.0
Maturity	0.0	0	220.5
Total	**11.7**	**130**	**855.0**

Of the total 4425 plants, only 114 plants reached the grain development stage and produced yield. At the end of the experiment, only 27 single plants were selected with grain number varying from 8 to 15 per plant (Table 2). A strong significant correlation between seed number and pod number of the selected plants were obtained ($r=0.8$ with $p<0.001$), but there was no relationship between pod numbers and seed number per pods. Similar results were reported in by Amede et al. (1999). Those results indicate the possibility of selecting lines resistant to drought based on yield components.

The selected lines matured in 60 to 90 days under these conditions. The artificially induced terminal heat and drought in the present study was severe enough to select only few plants that survived under these conditions. This adverse effect is attributed to high temperature

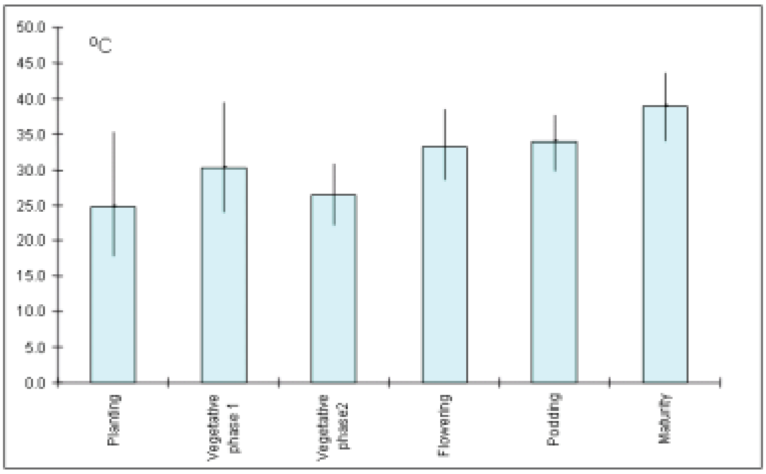

Figure 1. The mean maximum temperature with standard error for each phenological stage; vegetative phase one : 4-6 leaves; vegetative phase 2: more than six leaves to flowering.

Table 2. Number of single plants selected (SPS) for drought and heat tolerance and the mean values of pods per plant (PNP), seeds per plant (SNP) and seeds per pod (SNPP) in selected plants

Origin	Type of plant/nursery source	SPS	PNP	SNP	SNPP
ICARDA	Independent vascular supply type	3	3.3	9.0	2.7
	Orobanche nursery '05/06 B7'	21	5.0	9.3	2.0
Egypt	Early Maturity type 'Giza 716'	2	5	11.5	2.3
Yemen	Auto-fertile type 'ILB 445'	1	9	15.	1.7

under the condition when soil moisture stress was already present. The selected plants will be used by the faba bean breeding program at ICARDA as parents to develop breeding lines for drought-prone areas.

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Theme 8. Reducing greenhouse gas emission through harnessing renewable energy in the dry areas

8.1. Harnessing renewable energy from abandoned salt-affected lands and saline drainage networks in the dry areas

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Abstract

Salt-induced land and water degradation is a global concern, which is expected to intensify in resource-poor countries due to anthropogenic interventions and an increasing possibility of extreme events caused by climate change. Therefore, the areas of salt-affected soils and the volumes of saline waters will greatly increase in the foreseeable future. Although the accumulation of salts in soils continue to affect yields of most food crops, there are emerging beneficial options to use the salt-affected soils for other purposes through harnessing renewable energy. The strategic move towards renewable energy generation from salt-affected soils may include the establishment of annual energy crops, such as sweet-stem sorghum, and multipurpose tree and shrub species. Considering limited freshwater resources in water scarce countries, this intervention avoids pressure on already stretched resources. The cultivation of bio-energy crops on salt-affected waste lands offers an opportunity to put otherwise unproductive land back into production, but ensures simultaneously that no natural ecosystems or food-producing agricultural areas are converted into systems for renewable energy production. Also, such conversions contribute to carbon sequestration by large-scale biomass production, which may contribute to build up soil carbon stocks and reduce the impact of global warming. Besides the option of using saline water to irrigate multipurpose plant species for bio-energy production, the hydraulic pressure heads located at the regulated gated points in the drain and collector networks can be used for operating micro-turbines. As a source of decentralized energy production, these hydro-turbines represent an environmentally clean source of energy for pumping water, lighting and heating for small, remote communities, and for running small-scale enterprises. Since a significant proportion of salt-affected soils are areas inhabited by subsistence farmers, the introduction of micro-turbines bear the potential to make these farmers more resilient against climate change.

1. Introduction

Owing to a gradual depletion of petroleum reserves in different parts of the world, and given the impact of environmental pollution caused by increasing exhaust emissions, bio-energy is considered an attractive source of energy that can partly substitute or complement fossil fuel (Srivastava and Prasad 2000; Hill et al. 2006; Qadir et al. 2008). Bio-energy has appealing advantages; it is renewable, environmental friendly, and produced easily in rural areas that have a great need for improved forms of energy sources. Furthermore, relative to fossil fuels, greenhouse gas emissions are reduced 12% by the production and combustion of ethanol and even up to 41% by bio-diesel. Bio-diesel also releases less air pollutants per net energy gain (Hill et al. 2006). Raising the share of renewable energy up to 20% in the overall global energy consumption seems to be a necessary contribution to the global efforts addressing climate change and variability and towards better control over energy dependence. A major challenge would be to identify those mechanisms and resources in each location that can be used for the targeted renewable energy production without compromising on the sustainability of natural resources.

Salt-induced land and water degradation has become a major concern, particularly in arid and semi-arid regions and in resource-poor countries due to anthropogenic interventions. This is aggravated by the increasing possibility of extreme events triggered by climate change (Janmaat 2004; Aslam and Prathapar 2006; Wichelns and Oster 2006). The degradation of natural resources has imbalanced the functionality of ecosystems that provide goods and services from natural resources such as soil and water (Abdel-Dayem 2005). The extent of salt-induced soil and water degradation has increased steadily over the last few decades, particularly in several river basins (Sarraf 2004; Qadir et al. 2007; Ibrakhimov et al. 2007). Estimates indicate that about 30% of the world's irrigated land is already salt-affected and/or irrigated with waters containing elevated levels of salts (Wyn Jones et al. 2008), resulting in substantial economic losses (Fiorillo and Vercueil 2003; Janmaat 2004; Aslam and Prathapar 2006). The total estimated economic cost of salt-induced soil degradation varies widely, ranging from 15 to 37% of the system's productive potential depending on the peculiarities of the basins (Janmaat 2004).

The declining availability of good-quality water and/or highly productive soil resources for agriculture in many arid and semi-arid countries, combined with the recent trends and future demographic projections dictate the need to produce more food, feed and fiber. This in turn requires the effective utilization of marginal-quality water and soil resources such as the ever-growing areas of salt-affected soils and saline water volumes (Bouwer 2002; Qadir et al. 2007; Khamzina et al. 2008). Although salt-affected soils are predominantly viewed as major environmental burdens that have become a challenge to agricultural producers, these soils still are a valuable resource that should not be neglected, especially in areas where significant investments have established adequate infrastructure such as irrigation and drainage systems (Qadir et al. 2006). The importance of salt-affected soils and saline water resources will grow and hence also the challenge and need to effectively use these resources to counterbalance the adverse impact of climate change.

Abandoned salt-affected lands bear a large potential to be used for renewable energy production. This is greatly needed considering the gradual depletion of non-renewable petroleum reserves in different parts of the world, the impact of environmental pollution caused by increasing exhaust emissions, to aid counterbalancing the soaring food costs that are detrimental for the poor communities worldwide, and easing energy shortages particularly in rural areas of developing countries where energy production has traditionally been put on large supply schemes. A strategic move towards renewable energy generation on salt-affected soils and possibly with the saline water irrigation could consider the establishment of small-scale tree plantations consisting of multipurpose tree and shrub species (Khamzina et al. 2008; Lamers et al. 2008; Qadir et al. 2008).

Considering the limited freshwater resources in water scarce countries, the use of saline waters and salt-affected soils for renewable energy production will contribute to relax the growing pressure on already stretched resources (Lamers and Khamzina 2008). Rather, using salt-affected waste lands for the cultivation of bio-energy crops is a challenge to transfer otherwise unproductive land back into areas for multipurpose use whilst concurrently ensuring that natural ecosystems are not converted into renewable energy production as recently postulated for the degraded areas in Central Asia (Lamers et al. 2008). The same reasoning applies to the increasing use of saline groundwater to grow bio-energy crops such as tree species (Khamzina et al. 2008).

In addition, the hydraulic pressure heads, which are compulsory at the regulated gated points in the saline drainage water collector networks, can be used for operating micro-turbines. As a source of decentralized energy production, these hydro-turbines represent an environmentally clean source of energy for pumping water, lighting and heating, and thus support the development and day-to-day running of small-scale business. This de-centralized source of energy is getting attention, e.g. in parts of India, but totally underexploited throughout the countries of the former Soviet Union in the Central Asia and Caucasus regions.

With the aim to point at opportunities and challenges to counterbalance the adverse impacts of climate change in the most disadvantaged areas worldwide such as the dry areas, we synthesize several examples that all aim at harnessing renewable energy from salt-affected environments. We reveal therefore: (1) the potential of different plant species for renewable energy production under salt-affected environments, and (2) the exploitation of saline drainage water collector networks for operating micro-turbines to produce decentralized, and environmentally clean energy.

2. Plant species for renewable energy production

Recent evidence reveals several plant species for renewable energy production on salt-affected environments. For example, in the Amu Darya River Lowlands, multipurpose tree plantations established on degraded land produced the energy equivalent of 6-10 t oil and 16-21 t coal ha^{-1} five years after planting (Lamers and Khamzina 2008). The mixed-species plantations provided wood, high quality leaf fodder, fruits and all together can potentially meet requirements of rural households in the study area of Uzbekistan (Lamers and Khamzina 2008). The selected tree species used in these studies were representatives of the local flora, underlining that their promotion would not cause adulteration of the local plant biodiversity. Moreover, the findings of various other surveys showed that several plant species have the potential to produce renewable energy from salt-affected environments (Pramanik 2003; Meher et al. 2006; Dagar et al. 2006; Hill et al. 2006; Qadir et al. 2008). In the following, specific examples are presented of the plant species bearing the potential to produce renewable energy while utilizing salt-affected soils and saline water resources.

2.1. Jatropha (*Jatropha curcas* L.)

Among the bio-fuel and bio-energy plant species, Jatropha (*Jatropha curcas* L.) has the potential to produce alternative fuel for compression ignition engines. *Jatropha* is a drought-resistant perennial, which grows well on marginal lands and produces seeds for about 50 years. Studies have been carried out to compare the performance of *Jatropha* with other plant species when grown on salt-affected soils or irrigated with saline water. Dagar et al. (2006) evaluated the performance of some multi-purpose plant species at different stages of growth under irrigation with waters having variable levels of salinity and sodicity. The species used were: (1) *Azadirachta indica* A. Juss — a commercial evergreen medicinal tree; bark used in skin diseases and malarial fever, leaf used as an anthelmintic and insect-repellent in clothes, seed oil used for ulcers and several other health problems. (2) *Cordia sinensis* Lam. — a small drought-tolerant tree; edible fruit, foliage used as fodder, bark as astringent. (3) *Salvadora persica* L. — an evergreen perennial shrub or small tree; seeds yield 40-50% fat for use in soap and candle making, seedcake suitable for livestock feed, and roots used in dental diseases. (4) *Jatropha curcas* L. Table 1 provides information about the different levels of salinity and sodicity in irrigation water and their effects on the growth of these plant species.

Table 1. Performance of some multipurpose plant species at different stages of growth under irrigation with waters of varying levels of salinity (based on the data from Dagar et al. 2006)

Plant species	Growth period (month)	Fresh biomass (kg plant^{-1}) Irrigation treatments T_1[a]	T_2[b]	T_3[c]
Azadirachta indica A. Juss.	18	2.2	3.4	5.8
Azadirachta indica A. Juss.	30	8.9	9.3	9.8
Cordia sinensis Lam.	18	4.2	10.5	16.1
Cordia sinensis Lam.	30	14.1	16.9	17.3
Salvadora persica L.	18	1.0	1.3	2.7
Salvadora persica L.	30	15.1	16.5	20.2
Jatropha curcas L.	18	1.8	5.2	8.8
Jatropha curcas L.	30	4.0	6.4	10.0

[a]*Irrigation with highly saline water (EC = 28 dS m^{-1} and SAR = 26; both salinity and sodicity levels decreased with time).* [b]*Alternate irrigation with highly saline water (EC = 28 dS m^{-1} and SAR = 26) and moderately saline water (EC = 9 dS m^{-1} and SAR = 26).*[c]*Irrigation with moderate saline water (EC = 9 dS m^{-1} and SAR = 26; both salinity and sodicity levels decreased with time).*

Jatropha is believed to be native of Mexico and Central America, but is commonly found throughout most of the tropical and subtropical regions of the world. Several properties of the plant, including its hardiness, rapid growth, easy propagation and wide ranging uses, have resulted in its spread far beyond its original distribution. The seed oil content ranges from 30 to 50% by weight. As the oil burns with clear smoke-free flame, it has been tested successfully as fuel for diesel engines (Pramanik 2003). What is needed is the development of more uniform genetic material to reach more predictable yields that presently are unsatisfactory due to a mixture of genetic lines in the seed material (Raj Paroda, personal communication, 2008)

2.2 Toothbrush tree (*Salvadora persica* L.)

Toothbrush tree (*Salvadora persica* L.) grows well under saline environments and can tolerate salinity levels as high as 50 dS m^{-1}. The seedlings can also be raised by using saline water with EC levels as high as 15 dS m^{-1}. The studies conducted by the Central Soil Salinity

Research Institute (CSSRI), Karnal, India revealed that 5-year-old plantations of this species produced oil yields up to 1800 kg ha^{-1}, giving a net return of US$ 210 ha^{-1} in the final year of plantation. Consequently, the National Bank for Agriculture and Rural Development, India sanctioned schemes for financial support to those farmers who promote the cultivation of this species in salt-affected areas soils of Gujarat state (Gurbachan Singh, personal communication, 2007). Edible fruits and leaves and medicinal value of *S. persica* (Forestry Compendium 2000) further characterize this species as useful in rural households. The species can withstand a very dry environment with mean annual rainfall less than 200 mm. As a highly salt-tolerant plant, it can grow on coastal regions and inland saline soils. Geographic distribution consists of several countries from Africa and Asia.

2.3. Russian olive (*Elaeagnus angustifolia* L.)

Russian olive (*E. angustifolia*) is native to Central Asia, but has been widely planted outside its natural habitat, in Asia, Europe and North America. Due to its ability to grow in a wide range of climatic and soil conditions and particularly on disturbed sites, it has been widely propagated as a wildlife, windbreak, highway and reclamation species (Uresk and Yamamoto 1994; Heinze and Liebman 1998; Forestry Compendium 2000). This species has been reported as salt-tolerant and useful for fruit, fuelwood, gum, leaf fodder, nectar and honey production, medicinal purposes and amenity planting (Hayes 1976; Ayaz et al. 1999; Katz and Shafroth 2003). The nitrogen fixation ability of *E. angustifolia* is utilized to improve performance of valuable tree crops in mixed plantings (Paschke et al. 1989) and to enrich nitrogen content of exhausted soils in improved fallows (Khamzina et al. 2009).

This species has been recently evaluated for suitability in afforestation of degraded cropland in the Amu Darya River Lowlands in Uzbekistan (Khamzina et al. 2006, 2008). The study area is characterized by extensive soil salinization, with 15-20% of the irrigated land marginally suitable for crop cultivation or abandoned. The trees were experimentally grown on 2 ha of degraded cropland with little initial irrigation of 80-160 mm yr^{-1}, which assured tree establishment during the first two growing seasons, and was discontinued thereafter (Khamzina et al. 2008). *E. angustifolia* tolerated the root-zone salinity over 20 dS m^{-1} (highly saline soils), in the presence of the shallow (0.9–2.0 m) groundwater with salinity ranging within 1.2–4.8 dS m^{-1}. The woody biomass accumulation of *E. angustifolia* plantations averaged 25 t ha^{-1} four years after planting (stand density of 2,300 trees per ha), corresponding to energy content of 488 thousand MJ ha^{-1} or 16.6 t of coal equivalent (Lamers and Khamzina 2008) as shown in Table 2.

2.4. Sweet-stem sorghum [*Sorghum bicolor* (L.) Moench]

Sweet-stem sorghum is a multipurpose grass crop that yields food (grain), bio-ethanol, and fodder from leaves and bagasse. Ethanol is a viable alternative to fossil fuels, especially for cooking, lighting and automotive fuel. The crop is largely cultivated as fodder and feed as well as for human consumption by the rural poor, mostly in the remote desert and semi-desert marginal areas (Begdullayeva et al. 2007; Toderich et al. 2008). It grows on diverse soil types and in a variety of climatic conditions and is well adapted to extremely marginal, salt-affected and water-deficit areas. Despite high economic value, sweet-stem sorghum occupies small area in countries affected by salinization of land and water resources. For example, it constitutes less than 3.8% of the total cereal area in Uzbekistan. In certain cases the area under this crop has declined over time. During the mid 1990s, there has been a considerable decrease in the sorghum area in Uzbekistan and Turkmenistan due to a decline in its

Table 2. Production of fuelwood and estimated energy value of 5-year-old plantations with a density of 2300 trees ha^{-1} based on conversion into oil and coal equivalents (based onthe data from Lamers and Khamzina 2008)

Parameter	Unit	Plant species		
		Elaeagnus angustifolia	*Ulmus pumila*	*Populus euphratica*
Stem production	kg tree^{-1}	6.2	6.3	6.2
Branch (Ø ≥ 2 cm) production	kg tree^{-1}	4.9	2.3	7.7
Total wood production	t ha^{-1}	25.5	19.8	32.0
Calorific value of stem wood	MJ kg^{-1}	19.1	18.7	18.8
Energy of stem wood	MJ tree^{-1}	118.4	117.8	116.6
Energy of branch wood (Ø ≥ 2 cm)	MJ tree^{-1}	93.6	43.0	144.8
Biofuel capacity	MJ ha^{-1}	487 623	369 886	601 036
TOE (1 tonne of oil equivalent) = 42 MJ kg^{-1}*	tons	8.2	6.4	10.3
TCE (1 tonne of coal equivalent) = 29.3 MJ kg^{-1}	tons	16.6	12.6	20.5

*Based on average conversion factor of 1 tonne of fuelwood = 0.3215 tonne of oil equivalent (TOE)

consumption. The cultivation of sorghum in the irrigated agricultural zones of all Central Asian countries was replaced by other crops like cotton, wheat, alfalfa and vegetables. Recently, sorghum appears to again becoming popular due to its adaptability to harsh climatic conditions with poor soil fertility. Dual-purpose cereal cropping (grain and fodder) for the widespread crop-livestock (mixed) farming systems is widely practiced and considered as one of the important livelihood strategies of rural communities and farmers.

In contrast to sorghum, sweet-stem sorghum is characterized by high sugar content in the stalk. Therefore, it has a high potential for ethanol production. Central Asia has a large potential as producer of ethanol from cultivation of alternative crops on marginal land otherwise unproductive or of low productivity, e.g. for food production. Recent research for characterizing sweet-stem sorghum varieties for ethanol production in Uzbekistan showed that they produce sugar in the range of 4.1 and 8.5 t ha^{-1}; the dry and hot climatic conditions increase the sugar content in sweet-stem sorghum (Massino 2006). In India, sweet-stem sorghum varieties planted by the Nimbkar Agricultural Research Institute (NARI), a non-profit organization in Maharashtra, yielded 1-4 tons per hectare of grain, 5-7 tons of dry leaves (for possible use as feed or to improve the soil) and 3,000-4,000 liters of ethanol (95 % volume/volume). NARI has also developed the technology to convert sweet-stem sorghum juice into ethanol at an average fermentation efficiency of 90%, using a solar distillation plant that produces ethanol at a cost of 0.30 US$ per liter (Rajvanshi 2003).

3. Saline drainage water collector networks for energy production

Despite the variable levels of energy dependence, virtually all farming operations require energy such as for lifting water for irrigation, plowing, chiseling, among others. Notwithstanding this continuous demand, many rural areas, particularly in developing or transition countries, suffer from energy supply shortages. The collector networks of agricultural drainage water however can be used also for operating micro-turbines in order to produce decentralized and an environmentally clean energy. This could narrow the gap between energy demand and supply, which is of particular importance in rural areas, or in areas where energy production has traditionally been dependent on large supply schemes and where little attention has been paid to small-scale energy production systems. For example, in Central Asia it is estimated that along the irrigation system in the Aral Sea Basin, at least 10,000 sites are available that could be used for micro hydro-turbine schemes and hence for renewable energy production. This becomes interesting in case these sites are located in remote areas or belong to poor communities. Similar is the case with other river basins where a significant proportion of salt-affected soils occur on land inhabited by smallholder farmers, who are dependent on this resource for their livelihoods needs (Qadir et al. 2006).

By now, only 30% of the technically exploitable hydropower capacity is thought to be used for in Uzbekistan (Eshchanov 2006), but this refers mainly to the potential for large dams, and does not address small, de-centralized, off-grid schemes. The hydropower potential from natural water flows in Uzbekistan is estimated at about 20,000 MW by Asian Development Bank (ADB 2003). About 30% of this could come from small hydropower sources, especially off-grid power-generation from the extensive irrigation network that extends over 196 000 km in the Aral Sea Basin, and the drainage water collector network that extends over 110 000 km. Although micro-turbines may not be efficient at the tail-end of the system where the surface is flat, there are many situations in the uplands where sufficient slope is available. In addition, many regulated gated points in the irrigation network as well as small water streams and rivulets can provide sufficient hydraulic pressure heads of approximately 30-100 cm that can be used for operating micro-hydroturbines. These turbines in rural areas therefore represent an environmentally clean source of energy for pumping water, lighting and heating, and additionally running flour mills, among other purposes.

Village-scale mini-grids can serve tens or hundreds of households. Traditionally, mini-grids in remote areas and on islands have often been powered by diesel generators. Alternatives include solar energy, wind, or biomass, and thousands of so-called hydro-based mini-grids that can be found in several countries such as China, India, Nepal, Vietnam, and Sri Lanka (REN21 2007). It has been shown that energy can be produced cheaply under these situations: costs of 0.06 US$/kWh (Kyrgyz Republic) and 0.04 US$/kWh (China) represent one tenth of the costs of grid generation (ADB 2003).

4. Conclusions and perspectives

The declining availability of highly productive soil and freshwater resources for agriculture, in turn, requires the effective utilization of the ever-growing areas of salt-affected soils and increasing volumes of saline water in many arid and semi-arid countries. The cultivation of bio-energy crops on salt-affected waste lands offers an opportunity to put otherwise unproductive land back into production, but ensures simultaneously that no natural ecosystems or food-producing agricultural production areas are converted into systems for renewable energy production. Some promising examples are Jatropha (*Jatropha curcas* L.), toothbrush tree (*Salvadora persica* L.), Russian olive (*Elaeagnus angustifolia* L.), and sweet-stem sorghum [*Sorghum bicolor* (L.) Moench].

Saline water resources can be used to irrigate multipurpose plant species for renewable energy production as well as the hydraulic pressure heads located at the regulated gated points in the saline drainage and collector networks can be used for operating micro-turbines. As a source of decentralized energy production, these hydro-turbines represent an environmentally clean source of energy for several purposes. Since a significant proportion of salt-affected area is inhabited by subsistence farmers, the introduction of micro-turbines bear the potential to make these farmers more resilient against climate change.

In order to maximize the benefits from the salt-affected areas, there is a need to develop community-based approaches. The involvement of local communities for the production of renewable energy and contribution to combat land degradation may follow a stepwise approach, consisting of several components: (1) understanding farmers' perceptions on tree planting and awareness creating among farmers on benefits of growing multipurpose plant species on salt-affected degraded lands; (2) selecting farmers and affected land areas; (3) advising on the selection of the suitable plant species and plantation arrangements and maintenance while considering the objectives and priorities of the farmers; (4) establishing nursery and back-up arrangements for the most successful plant species; (5) selecting appropriate points in the saline drainage and collector networks that can be used for operating micro-turbines; (6) training local researchers and farmers; and (7) monitoring and evaluation of the introduced interventions.

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8.2. Potential dryland oil-bearing trees as a source of renewable energy: *Jatropha curcas*

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Abstract

Jatropha is a tree species that can be planted in the desert with waste water irrigation. The seeds contain about 17 – 20 % oil that can be used for making biodiesel, a renewable fuel, domestically. This biodiesel has the requisite potential of providing a promising and commercially viable alternative to diesel oil since it has desirable physicochemical and performance characteristics comparable to diesel. Blends of 20 % biodiesel with 80 % petroleum diesel (B20) can generally be used in unmodified diesel engines. A pilot plant was developed for biodiesel production from Jatropha oil and a 5.2 kW diesel engine was used to test Jatropha biodiesel and its blends under three load conditions (2, 2.5 and 3.5 kW). The fuel consumption in the diesel engine was about 3 % higher than that of diesel for B20. The brake thermal efficiency for biodiesel and its blends was found to be slightly higher than that of diesel fuel. The exhaust gas temperature increased with increase in load and amount of biodiesel. The highest exhaust gas temperature was observed as 463ºC for B20. The diesel mode exhaust gas temperature was 375ºC. The CO_2 emission from B20-fuelled engine was slightly higher than that operating with diesel fuel. The carbon monoxide reduction by biodiesel was 16, 14 and 14 % at 2, 2.5 and 3.5 kW load conditions, respectively. The emission of NOx from biodiesel was 15, 18 and 19 per cent higher than that of the diesel at 2, 2.5 and 3.5 kW load conditions, respectively.

1. Introduction

Biodiesel is described as a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats. It is oxygenated, essentially sulfur-free and biodegradable (Yuan et al. 2004). The use of non-edible oils compared to edible oils as source of biodiesel is very important because of the increase in demand for edible oils as food and they are too expensive as compared with diesel fuel. Among the various non-edible oil sources, *Jatropha curcas* oil has the advantage of being odorless and easily mixable with diesel fuel.

Pramanik (2003) found that jatropha oil blending up to 40 to 50 per cent with diesel fuel could be used in engine without any modification. It has been reported by most researchers that if raw vegetable oils are used as diesel engine fuel, engine performance decreases, CO and HC emissions increase and NOx emissions decrease accordingly (Sinha and Misra 1997; Goering et al.1992; Altõn 1998; Shay 1993). However, Acrolein is high toxic substance released from the engine due to thermal decomposition of glycerol present in the oils (Schwab et al. 1987). The problems encountered in raw oils are solved by forming biodiesel, which is non toxic, eco-friendly fuel, and has properties similar to diesel fuel (Krawczyk 1996). Biodiesel consists of Fatty Acid Methyl Esters (FAMEs) of seed oils and fats and has been found suitable for use as fuel in diesel engine (Harrington 1986). CO_2 emitted by the use of biodiesel will be recycled by the crop plants resulting in no new addition to the atmosphere (Peterson and Hustrulid 1998).

This study was initiated to study the properties of Jatropha oil for use as diesel fuel substitute, and investigate the effect of blending diesel with Jatropha biodiesel at different concentrations on diesel engine performance and compare the impact on gaseous and particulate exhaust emission levels relative to pure diesel.

2. Materials and methods

2.1. Pilot biodiesel plant

A pilot biodiesel plant was manufactured at Central laboratory for Agricultural Climate for alkaline catalyst based biodiesel production from different vegetable oils (Fig. 1). The capacity was 500 liters per day and the reaction time per batch was 2 hours. The plant consists of a biodiesel processor with heater and agitating pump, chemical mixing tank, glycerol settling tank and washing tank.

2.2. Fuel description

Jatropha seeds were ground and pressed and oil so extracted was filtered for solid impurities. The oil was transesterified using methanol in the presence of sodium hydroxide in the pilot biodiesel plant. Free Fatty Acid content of jatropha oil was less than 5 percent. The molar ratio and sodium hydroxide amount used were 1:6 and 0.8 (w/w), respectively. The fuel properties of jatropha biodiesel and its blends and diesel fuel are shown in Table 1. ASTM standard procedures were adopted for the analysis.

Figure 1. Pilot biodiesel plant.

Table 1. Fuel properties of diesel, jatropha biodiesel and their blends

Properties	Diesel	Jatropha biodiesel				
		20% (B20)	40% (B40)	60% (B60)	80% (B80)	100% (B100)
Specific gravity	0.8396	0.8437	0.8482	0.8530	0.8576	0.8621
Kinematic viscosity @ 40 ^{o}C, cSt	4.86	4.96	5.03	5.14	5.26	5.37
Calorific value MJ/Kg	44.42	43.25	42.072	41.139	40.174	39.174
Flash point, ^{o}	51	55	76	98	109	174
Carbon residue, %	0.21	0.21	0.22	0.22	0.24	0.24

2.3. Methodology for engine testing

Bio-diesel from jatropha oil and pure diesel fuels individually were used to operate an agriculture tractor. The tractor was coupled with dynamometer to apply varying loads to traction engine at rated speed. The dynamometer was equipped with measurement facility of engine speed and brake torque. Four levels of jatropha biodiesel blending (20, 40, 60 and 80 %, designated as B20, B40, B60 and B80, respectively) with diesel, diesel and biodiesel (B100) were used for engine testing. The diesel was tested at different loads. The engine speed was measured by a tachometer. A gas exhaust analyzer was used to determine the compositions of exhaust emission gases (CO, CO_2, NOx and O_2) using an analyzer and all data were stored. The diesel engine in the tractor was a 2-cylinder, Helwan 35-IMT with a maximum power 26.12 kW at 2200 rpm. The bore x stroke was 105 mm x 125 mm, where the compression ratio was16:1, engine rated speed 1800 rpm. The hydraulic dynamometer used was having a maximum power of 220 kw, a maximum torque of 1360 M.m, maximum rpm of 3500 and constant torque number of 10.

The engine was tested with three load levels *viz*., 10, 12.5 and 17.5 kW. The engine was started with diesel and changed over to the desired biodiesel blend.

3. Results and discussion

3.1. Preparation of biodiesel

The free fatty acid content of jatropha used for this study was 3 percent. For trans-esterification, 100 liters of jatropha oil was fed into the reactor by using a feed pump. The reaction temperature was 55 ^{o}C. The chemical tank was used to prepare the sodium methoxide by mixing of sodium hydroxide with methanol and supplied to the reactor. Stirring process was stopped after 1 hour. The reactants mixture was allowed to stand to let the glycerol settle at the bottom of the tank by gravity. The jatropha oil methyl ester was sent to washing tank to get the pure biodiesel.

3.2. Fuel properties

The fuel properties of diesel and jatropha biodiesel and its blends with diesel are given in Table 1. There was no effect on specific gravity of fuels as the proportion of biodiesel in the blend increased, but the kinematic viscosity increased. The viscosity of B20 biodiesel blended fuel was 4.96 cSt which was almost closer to desirable viscosity of diesel fuel (4.86

cSt). The calorific value decreased as the proportion of biodiesel in the blend increasd. The flash point however increased. The fuel properties of jatropha biodiesel blended fuels met the diesel fuel and biodiesel standards.

3.3. Engine performance

The fuel consumption of engine increased with increase in the amount of biodiesel in the blends (Fig. 2). With biodiesel alone, the fuel consumption was about 14 percent higher than the diesel fuel. This may be due to higher specific gravity and lower calorific value of the biodiesel. The calorific value of the jatropha biodiesel was about 12 percent lower than that of diesel fuel.

The power output of the engine was calculated from the output of dynamometer. At 10 kW load, power output of the engine in diesel mode (10.15 kW) was almost same as for the biodiesel alone (1 0.25 kW). The power output of the engine operated with diesel fuel at 12.50 kW load condition was 12.53 kW, whereas it was 12.56 kW for biodiesel alone. But the consumption of the jatropha biodiesel was higher because of the calorific value difference. At this load condition power output of the engine for blended fuels ranged from 12.51 to 12.57 kW. In case of 17.50 kW load condition, the power output of the engine with biodiesel fuel mode was 17.9 kW, whereas it was 17.75 kW for diesel fuel mode and the values for blend varied from 17.75 to 17.85 kW. In general it can be concluded that there was no difference between jatropha biodiesel and its blends and diesel.

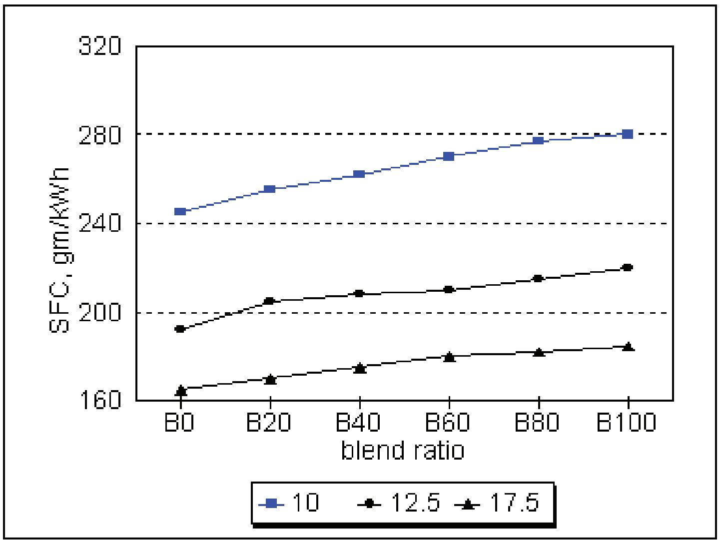

Figure 2. Fuel consumption (g/ kwh)for biodiesel-blended fuels at three different loads.

3.4. Specific fuel consumption

The specific fuel consumption was calculated by fuel consumption divided by the rated power output of the engine. The percent increase in specific fuel consumption ranged from 3 to 14 for B20 to B100 fuels. The range of increase in fuel consumption was found to be similar under all load conditions. The percent increase in specific fuel consumption increased with decreased amount of diesel fuel in the blend. This may due to lower heating value of the fuels and higher mass of fuel flow to meet the engine loads.

3.5. Brake thermal efficiency

According to Canakci and Van Gerpan (2001) brake thermal efficiency is defined as actual brake work per cycle divided by the amount of fuel chemical energy as indicated by lower heating value of fuel. The brake thermal efficiency with biodiesel and its blends was found to be slightly higher than that of diesel fuel at tested load conditions. It varied from 28.6 to 33.0 percent for diesel fuel alone. There was no difference between the biodiesel and its blended fuels on efficiencies. The brake thermal efficiencies of engine, operating with biodiesel mode were 28.8, 30.6 and 33.1 percent at 10, 12.5 and 17.5 kW load conditions respectively.

3.6. Exhaust gas temperature

The exhaust gas temperature gives an indication the amount of waste heat going with exhaust gases. The exhaust gas temperature of the different biodiesel blends is shown in Figure. 3. The exhaust gas temperature of blended fuels and biodiesel at 17.5 kW load condition was 19 percent higher than that of 10 to 12.5 kW load conditions. The highest exhaust gas temperature was observed as 423ºC for biodiesel at highest load conditions while the diesel fuel mode exhaust gas temperature at this load was 375ºC.

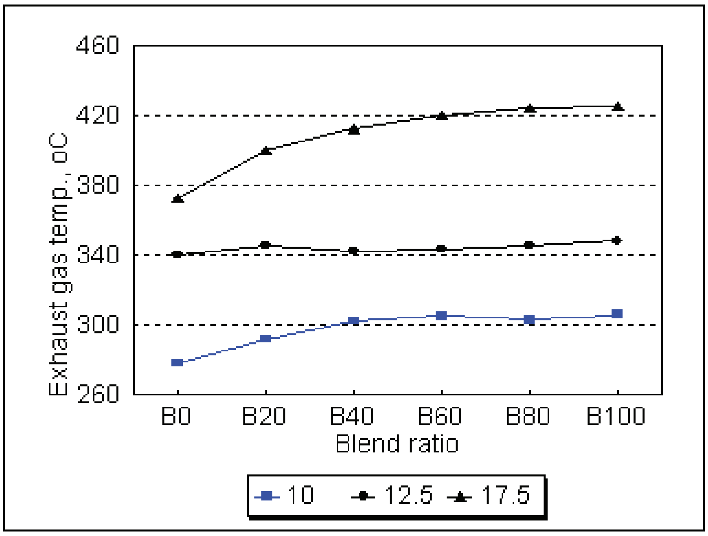

Figure 3. Variation of exhaust gas temperature in diesel engine fuelled with different blended fuels at different load conditions.

The exhaust gas temperature increased with increase in load and amount of blended biodiesel in the fuel. The exhaust gas temperature reflects on the status of combustion inside the combustion chamber (Nichaus et al. 1986). The rise in the exhaust gas temperature may be due to ignition delay and increased quantity of fuel injected. The exhaust gas temperature can be reduced by adjusting the injection timing/injection pressure in to the diesel engine.

3.7. Emission profile

The carbon dioxide emission from the diesel engine with different blends is shown in Figure 4. It increased with increase in load conditions. The increase in biodiesel proportion in the blend resulted in increased emission

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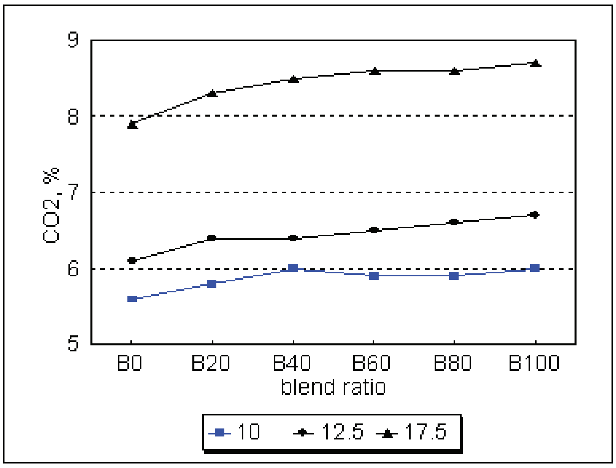

Figure 4. CO_2 emission from diesel engine with different blended fuels.

The CO emission (Fig. 5) was reduced by 16, 14 and 14 % respectively, at 10, 12.5 and 17.5 kW load conditions when biodiesel was used as compared to diesel. Biodiesel blended fuels also gave lower emission than diesel fuel. This could be attributed to the presence of 11 percent oxygen molecules in biodiesel resulting in complete combustion.

The NOx emission (Fig. 6) increased for biodiesel by 15, 18 and 19 % than diesel fuel at 10, 12.5 and 17.5 kW load conditions, respectively. The increase in NOx concentration for blended biodiesel fuels were 6.6 to 19%t when compared with diesel fuel. The NOx emission increased with increase in biodiesel amount in the blended fuels, probably because of the higher oxygen level in the fuel and the type of engine (Anon.1993). Forgiel and Varde (1981) observed that the NOx concentration depended on the size of the orifice; the emission increasing with the reduction in the size of orifice. Heywood (1988) reported that the NOx formation depended on combustion temperature and availability of oxygen. Fosseen and Goetz (1993) reported that the NOx concentration can be reduced by advancing the beginning of injection time. Thus, increase in NOx concentration is the main problem in biodiesel and it can be reduced by making suitable change in the engine parameters.

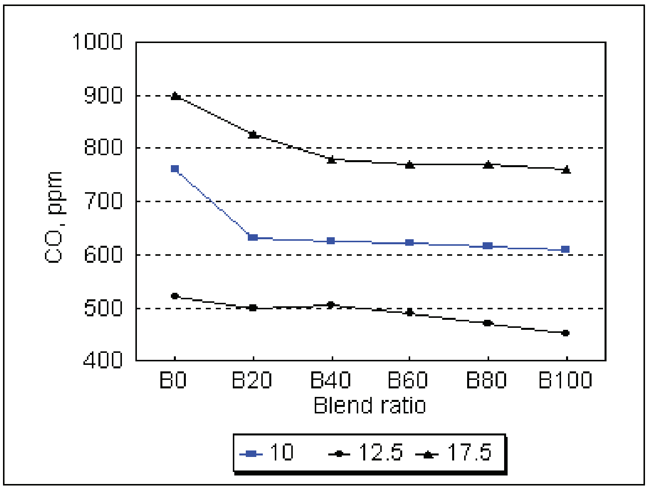

Figure 5. CO emission from diesel engine with different blended fuels at different load conditions.

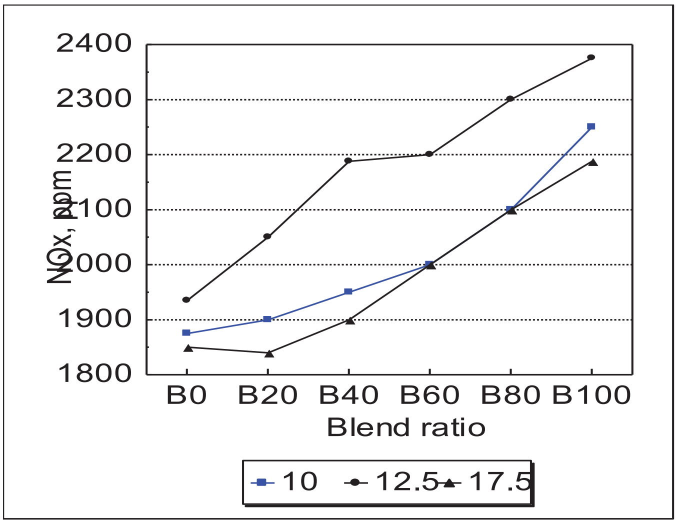

Figure. 6. NOx emission from diesel engine with different blended fuels at different load conditions.

4. Conclusions

The fuel properties of jatropha biodiesel were similar to the diesel fuel. In the case of biodiesel alone, the fuel consumption was about 14% higher than diesel. The specific fuel consumption ranged from 3 to 14 for B20 to B100 fuels. The brake thermal efficiency for biodiesel and its blends was slightly higher than that of diesel fuel at tested load conditions and there was no difference between the biodiesel and its blended fuels. For biodiesel and blended fuels, the exhaust gas temperature increased with increase in the load and amount of biodiesel. The carbon monoxide emission was reduced by biodiesel by 16, 14 and 14 percent respectively at 10, 12.5 and 17.5 kW load conditions. The NOx emission however increased by 15, 18 and 19% respectively. This can however be regulated by adjustments in the engine.

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8.3. A new international cooperation framework for dryland development under 'Public-Private-Academia' partnership -- an example with *Jatropha* project

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Abstract

The 4th report of IPCC indicates that drought-affected areas are likely to increase in their expanse. In southern Africa, longer dry seasons and more uncertain rainfall are already prompting a search for adaptation measures. Therefore, the need is increasing for a new framework of the international cooperation to support community livelihood effectively to cope with the emerging climate situation where conventional cooperation frameworks might not work well. Our new framework is to integrate a research institute and private enterprise in international cooperation activities. For example, a research institute, like a university, conducts research activities on such effects of climate change on environment and community and develops technology which a private enterprise uses in its development project activities as a part of its corporate social responsibility (CSR) from long-term perspectives. This new cooperation framework is expected to make it possible to improve livelihood of local communities in arid land without damaging environment and society, even under the global climate change conditions. Such a cooperation framework is exemplified by our project on Jatropha (*Jatropha curcas* L.) cultivation in Tanzania. In this project, Sekisui Chemical Co. Ltd. is trying to start a new development project on *Jatropha* production in Tanzania on arid lands not suitable for crop cultivation, which would be environmentally sound and contribute to the wellbeing of local societies as a part of the CSR activity of the company. Meanwhile, the Tottori University is conducting investigations with Tanzanian research institutions to develop improved cultivation techniques of *Jatropha* production to increase the productivity and minimize adverse environmental and social impacts. It is hoped that this new framework of the cooperation would contribute to the sustainable development of dry areas under global climate change.

1. Introduction

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) indicated that the increased frequency and severity of extreme climate events (e.g., heat stress and droughts) will have significant consequences for food and forestry production, as well as an adverse impact on food security. Smallholder and subsistence farmers, whose adaptive capacity is constrained, will experience negative effects on the yields of crops grown in low latitudes in addition to being highly vulnerable to extreme events. Many developing countries will experience reduced crop yields and livestock productivity and an increased dependence on food imports.

Africa is especially vulnerable to climate change and climate variability. African farmers have developed several adaptation options for the current level of climate variability; however, the IPCC report stated that such adaptations may not be sufficient for future climate changes. New adaptation measures will be necessary to cope with these changes, and they will have to integrate development strategies and programs, international programs, and poverty reduction strategies.

2. Trends in Japanese international cooperation

A recent trend in Japanese international cooperation is the movement to support economic growth in developing countries though a public-private partnership (PPP) and to aid these countries in dealing with the effects of climate change, especially in Africa. Some recent efforts are summarized below.

(1) Nihon Keizai Dantai Rengokai presented recommendations to strengthen PPP in Japan's International Cooperation Policy (Nihon Keizai Dantai Rengokai 2008) and pointed out priority areas, approaches and a legal framework to create synergy between Japan’s Official Development Assistance (ODA) and the private sector to contribute to aiding local communities and encouraging economic growth in developing countries.

(2) The Ministry of Foreign Affairs of Japan proposed on 18 April 2008 a new cooperation framework integrating Japanese direct investment by private sector into the Official Development Assistance (ODA) to foster economic growth in developing countries (Ministry of Foreign Affairs 2008). Hereby, this new cooperation framework made it possible for the private enterprises to submit proposals for development to the Ministry of Foreign Affairs.

(3) In the Fourth Tokyo International Conference on African Development (TICAD IV), held in Yokohama, Japan, from 28 to 30 May 2008, the importance of generating private-sector-led economic growth and achieving the Millennium Development Goals (MDGs) was highlighted (TICAD IV 2008).

(4) The 34th Summit of the Group of Eight (G8), held in Toyako, Hokkaido, from 7 to 9 July 2008, discussed the importance of achieving at least a 50% reduction in global greenhouse gas emissions by 2050 and agreed the importance of sustainable biofuel production and use in this regard. The group agreed to take a number of actions to ensure the compatibility of policies both for the sustainable production and use of biofuels and for food security and also stressed the importance of private-sector-led growth for economic development in Africa (G8 Summit 2008).

3. A more effective framework of international cooperation

As described earlier, governmental agencies and private entities are working to strengthen efforts for poverty reduction by boosting economic growth through PPP activities, especially for the rural poor in Africa who will be highly vulnerable to the negative impacts of climate change. As Stern (2007) pointed out, however, the impacts of climate change will be outside the range of human experience, so it seems to be necessary to create a new framework to cope with the situation. In our international cooperation framework, which will be described in detail later, we propose a collaboration that will integrate government efforts, university-led research activities, and private-sector-led activities.

4. Utilization of *Jatropha* for dryland development

Drylands occupy 41% of Earth's land area and are home to more than 2 billion people, a third of the human population in the year 2000. At least 90% of the dryland population lives in developing countries and on average lag far behind the rest of the world in human well-being and development indicators (Millennium Ecosystem Assessment 2005).

Drylands support a limited number of cultivable crops with low productivity as a result of water scarcity and rainfall variability. Soil salinization is a common problem stemming from unsustainable land use practices under vulnerable natural conditions. Furthermore, as climate change advances, drylands are becoming drier and there is a greater variation in rainfall patterns, making food production even more difficult (IPCC Fourth Assessment Report (AR4) 2007).

Global interest has grown in the use of *Jatropha* as a new crop to produce biofuel (ICRISAT 2007). *Jatropha* has many advantages over corn and palm oil. For example, the plant requires little care and can grow on marginal drylands that are unsuitable for food crops and it is resistant to drought, so it can be used as a new crop for dryland development (van Eijck and. Romijn). However, as a large-scale *Jatropha* cultivation has been expanding rapidly, concerns about *Jatropha* are increasing (Grain 2008). Some of the concerns are:

(a) A concern about large-scale farming: Taking advantages of *Jatropha* into consideration, many companies have begun to plant *Jatropha* on a large scale because biofuel production requires large economies of scale to be cost-effective and competitive with other fuels in the marketplace (ICRISAT 2007). There is some concern that this will push the poor off their land and exclude them from the benefits of this biofuel (ICRISAT 2007). One international non-governmental organization has called for a moratorium on large-scale developments of new agrofuel (biofuel) in Africa and stated that "the reality is that the gold rush is firmly controlled by giant transnational companies which are taking over Africa's land at an incredible pace, and are bringing about disastrous socio-economic and environmental impacts on our communities, food security, forests and water resources" (Grain 2008).

(b) A concern about food prices: A significant advantage of *Jatropha is* that it can grow on marginal land, but the yield will be better if the plants are cultivated on lands with better soil and water conditions. Therefore, the land previously used to grow food crops could be converted to *Jatropha* cultivation if the production of *Jatropha* oil was more profitable. From this point of view, the expansion in *Jatropha* cultivation had the possibility of a general rise in food prices (ICRISAT 2007).

(c) A concern about environmental issues: *Jatropha* plants have been used as a live fence in many countries for years, but it is not well investigated whether there is any negative environmental impact. *Jatropha* seeds contain toxic substances (e.g., curcin and phorbol ester), but little is known about their effects on humans or the environment. Western Australia banned cultivation of *Jatropha* because of its toxicity to humans and animals and its capacity to quickly become a hard-to-control invasive weed (Department of Agriculture and Food 2007). It is therefore essential to investigate the potential negative impacts on humans and the environment if *Jatropha* is to be cultivated on a large scale.

The cultivation of *Jatropha* is expanding rapidly in many places in the world in spite of these concerns. So, it is urgent to develop mechanisms that can contribute to helping rural people and their society avoiding such concerns before plantations will cause serious problems.

5. Requirement for a sound *Jatropha* project

The Tottori University of Japan is exploring to establish mechanism which can improve livelihood of rural poor and environment without negative impacts by *Jatropha* based on small-scale cultivation and pro-poor growth through integrating research activity of the University, Corporate Social Responsibility (CSR) of a private company, public sector in the recipient country, and others. For this purpose, the University is planning to investigate social, economic and environmental aspect as follow:

- ***Social aspects:*** research on appropriate method of *Jatropha* cultivation which does not have negative impacts on environment and humans
- ***Economic aspects:*** research on cultivation techniques of *Jatropha* on marginal land unsuitable for growing food crops in dryland and on mechanisms to benefit local people and society
- ***Environmental aspects****:* research on and monitoring the impacts of *Jatropha* on environment and human health

Furthermore, to make the benefits of the project sustainable, we are planning to establish a mechanism to earn profit from CSR activities and reinvest it back in the CSR activities and to strengthen the capacity of a public sector of recipient country to work with.

Many private companies conduct activities to contribute to rural areas in developing countries as a part of their CSR activities. The activities are run by corporate profits and companies do not aim to profit from CSR activities. However, there is some concern about diminishing CSR activities during the economic slowdown (CSR EUROPE 2008). Therefore, it is desirable to establish CSR activity which yields profit and operates by the profit. This idea has been put into practice as a business ethics, the so called "sanpo-shoshi," from a few hundred years ago in Japan. Merchants who engaged in business and wanted success over the long term placed emphasis on the benefit not only for the sellers but also for the buyers and their societies. "Sanpo" means three elements – sellers, buyers and societies, and "yoshi" means benefit; in other word, benefit for three elements (AKINDOKaigi 2003). So, it is important that benefits are appropriately shared not only by the target groups and their society as a whole, but also by the companies engaged in CSR activities. By means of this profit it will make the CSR activities more sustainable even in an economic slowdown.

All development projects promoted by the donors generally have a finite time frame and come to an end in the stipulated time. However, it is desirable to continue such activities as environmental monitoring or support for local residents based on the project by public institutions in the recipient country. To this end, Tottori University is planning to work together during the project period to strengthen the capacity of public institutions to make the activities sustainable. The Tottori University has therefore proposed the Public-Private-Academia-Partnership (PPAP) as a new framework of development to benefit the rural poor and society without negatively impacting the environment in the developing countries. With this framework, university research activities are integrated with CSR activities of private-sector and with public institutions in the recipient country.

6. Public-Private-Academia Partnership applied to Jatropha project

The proposed *Jatropha* project, *Environmentally and Socially Sound Development of Jatropha in Dryland Afric*a, is a partnership of the Sekisui Chemical Co., Ltd., Mlingano

Agricultural Research Institute (MARI) of Tanzania and Tottori University. The basic framework of the project is presented in Figure 1.

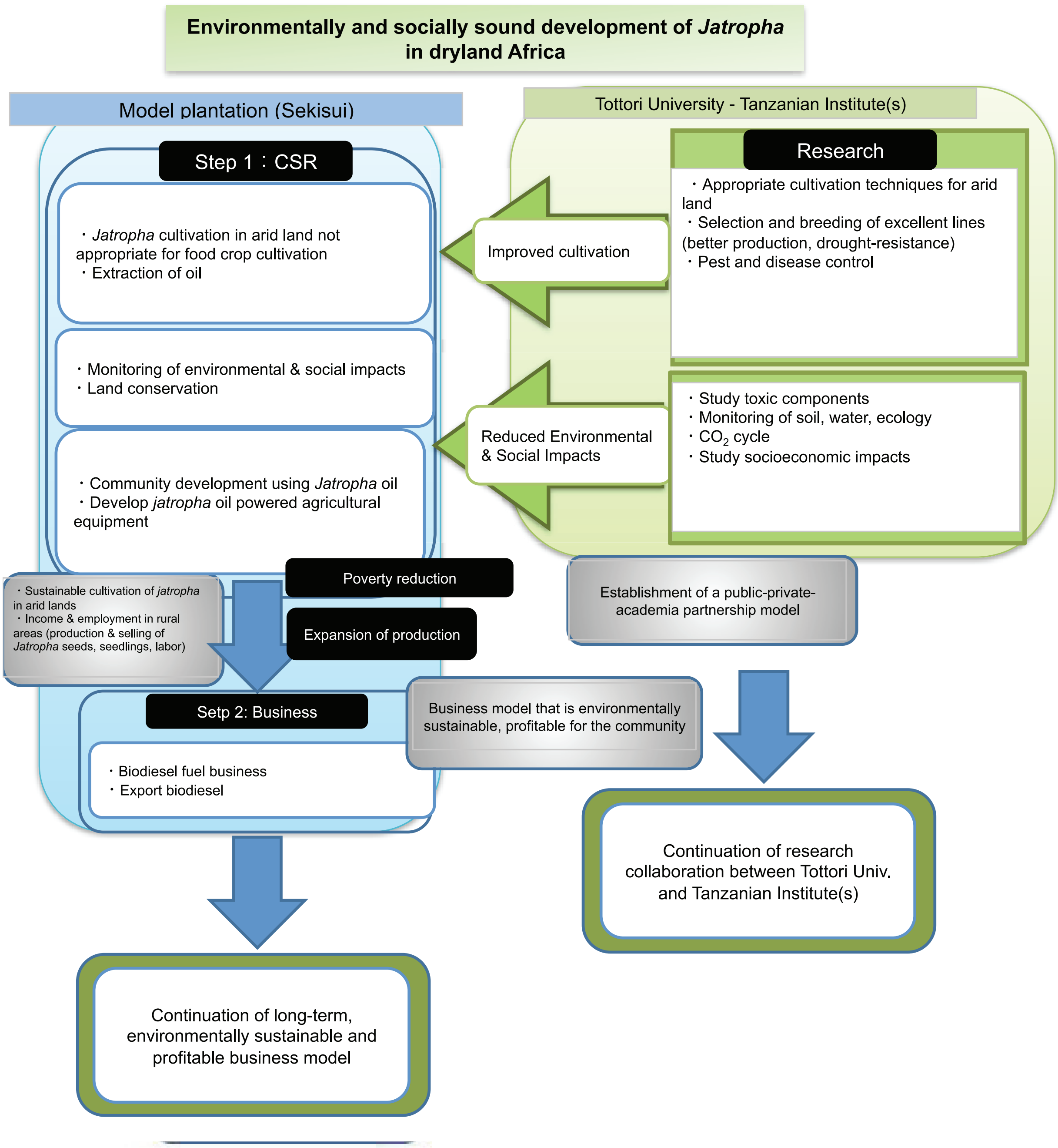

Figure 1. The framework of the project.

6.1 Purpose of the project

The purpose of the project is to establish a sustainable rural development model to benefit the rural poor and their society in drylands in Tanzania through the cultivation, processing, and utilization of *Jatropha* without damaging human health, the environment, or society. To this end, the project will be conducted jointly by Tottori University, Sekisui, MARI, and others.

6.2 The role of Tottori University

Tottori University will conduct research activities in cooperation with Sekisui and MARI on *Jatropha* cultivation in dryland areas in Tanzania that are otherwise unsuitable for growing crops. And the efforts will be made to improve the productivity of *Jatropha* and to develop approaches that allow local residents and their communities to profit through *Jatropha* cultivation and usage of oil. The aims of the research are (1) to establish appropriate cultivation techniques to improve the productivity of *Jatropha* without negatively impacting the environment, residents, and the community and (2) to monitor the impacts on the environment, residents, and the community.

6.3 The role of Sekisui Chemical Co., Ltd.

In 2007, Sekisui began test cultivation of *Jatropha* on underutilized or waste land not suitable for agriculture. It will be cultivated on a small scale to minimize any negative impacts on local residents and on the environment. Environmental parameters such as soil and water will be monitored with Tottori University and MARI because the characteristics of *Jatropha* are not yet well known. The goal is to provide benefit to local residents and communities by improving their livelihoods and to contribute to reducing greenhouse gas emissions through production and utilization of biofuels as well as reducing deforestation of firewood in drylands by afforestation of *Jatropha*.

6.4 The role of Mlingano Agricultural Research Institute

Tottori University will collaborate with MARI during the project period to conduct research and monitoring the impacts of *Jatropha* cultivation. TheTottori University will help in capacity development of the staff of MARI to enable them to continue these activities even after the end of the project.

6.5 Sustainable CSR activities by Sekisui

Sekisui is planning to sell *Jatropha* oil nationally and internationally when the quantity of *Jatropha* oil produced exceeds local demand. The company plans to reinvest the profits from CSR in such activities to improve the standard of living, economic growth, and agricultural productivity of the community. For example, the company has already worked with the University of Dar es Salaam to develop a generator and small agricultural machinery (e.g., a cultivator) that can run on *Jatropha* oil. Taking a long-term view and reinvesting profits from the CSR into the community will thus establish a sustainable model to contribute to achieving the Millennium Development Goals.

7. Possible project outputs in reducing carbon dioxide emission

The cultivation of *Jatropha* and the subsequent use of its oil as a biofuel is expected to contribute not only to improving the daily lives of local residents but also to improving the environment. Three potential positive environmental outcomes are:

- ***CO_2 emission reduction by reduced fossil oil consumption**:* Kerosene lamps are used in many rural areas in Tanzania that do not have electric power. According to a preliminary survey, one lamp consumes about 24 liters of kerosene per year. Carbon emissions will be reduced by substituting *Jatropha* oil for kerosene, and it is estimated that a family could save about US$18.50 per year.
- ***CO_2 absorption increase*:** *Jatropha* will be planted on dry waste land that is not suitable for food crop cultivation. The *Jatropha* plants will absorb carbon dioxide as they grow.
- ***CO_2 emission reduction by reduced deforestation:*** Firewood is used for cooking in many rural areas in Tanzania. According to a preliminary survey, one family (with seven members) was estimated to consume about 4,380 m of firewood (about 8 cm in diameter) per year. If cooking stoves that use *Jatropha* oil can be introduced as a replacement for firewood, absorption of CO_2 will increase by decreased felling.

8. Conclusions

Jatropha cultivation has been expanding rapidly in many places because it is an excellent source of biodiesel. *Jatropha* can grow on marginal drylands not suitable for growing food crops, it is resistant to drought, and its oil is rather easy to extract from seeds for local use. It is therefore important to establish appropriate cultivation and utilization systems of *Jatropha* because the plant has the potential to contribute to dryland development. However, care must be taken because food prices may rise if crop land is converted into *Jatropha* plantations, and poor rural farmers may be pushed off their land by large-scale plantations. Another concern is that little is known about the negative impacts of *Jatropha* cultivation.

Tottori University is currently trying to launch the *Environmentally and Socially Sound Development of* Jatropha *in Dryland Africa* project in Tanzania under a PPAP framework, that will be conducted jointly by Tottori University, Sekisui, and MARI. Sekisui will carry out *Jatropha* cultivation and processing to contribute to local communities in Tanzania as a part of its CSR activities. Tottori University will conduct related research activities in conjunction with MARI. The goal is to establish a long-term dryland development model in which local people benefit without creating negative impacts on the environment or human health and the society.

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8.4. Reconsidering the animal power as the basis of Afro-Eurasian dryland civilization

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Abstract

This presentation is based on author's realization that the region seems to have forgotten the importance of animal power. In today's era of petroleum oil, and the motor machines fueled by it, it appears that the dryland people are a bit shy of using their traditional "TOYOTA" run with animal power. Human history indicates that early civilizations could not have risen to the levels they did without full use of animal power. Especially big animals like camel or dromedary, horse, donkey and cattle were important because they served not only as a source of food but also as a crucial means of transport and travel, both during peace and war. With these big animals, dryland people constructed a large network of trade covering the vast interior of Afro-Eurasian continent, from Sahara to China, and built great empires like those of Mongolians, Turks, Greek, Arabs, Berbers and Fulani's. Even in the history of Europe and Japan, one could find the crucial role played by big animals for the formation of State. Much integration, politically or economically, has thus occurred in the past with animal power and has led to the development of 'civilization.' Although we are in the age of oil and oil-powered machines, we must reconsider the use of animal power that has served as the basis of early human civilization, especially in the Afro-Eurasian dryland region. Dryland people must be proud of their traditional "TOYOTA."

1. Introduction

While reconsidering the animal power as the basis of Afro-Eurasian Dry land civilization it is desirable to consider two old continents, Africa and Eurasia, as one 'Afro-Eurasian Continent'. Secondly, we must recognize that the vast inner area of this continent is occupied by a continuous dryland, from Sahara to Mongolian and Chinese desert, via Middle East drylands, that can be called the 'Afro-Eurasian Inner Dryland'.

We know that this Afro-Eurasian Inner Dryland was the cradle for the old and great human civilizations. Not only the first four oldest civilizations (Egyptian, Mesopotamian, Indian and Chinese) developed here but also most of the great empires and world religions (Buddhism, Christianity and Islam) were created and flourished here.

All of this together can therefore be called as the **Afro-Eurasian Inner Dryland Civilization,** including African Sahara-Sahelian civilizations. I have studied African-Sahelian world for almost thirty years and found that, contrary to other parts of Africa, the Sahelian world has known long history of the State and urban civilizations. That is why, Sahara-Sahelian area constitutes one part of the Afro-Eurasian Inner Dryland Civilization (Fig.1).

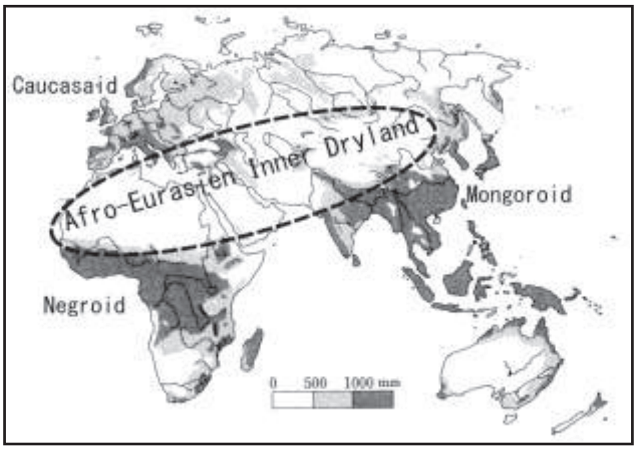

Figure 1. Afro-Eurasian Inner Dryland Civilization.

The principal reason often cited for the formation for these civilizations is the existence of rivers like the Nile, Euphrates, Indus and Yellow Rivers and the development of irrigation technologies. The importance of these factors cannot be denied, but because of them other equally important factor seems to have been ignored, particularly of animal power.

2. Animal power as the basis of Afro-Eurasian Inner Dryland Civilization

The dryland of Afro-Eueasian continent has been the world of mammal animals. The wet rainforest areas were very difficult for mammal animals to live, except for monkeys, because basic mammal animals are grainivorous and they need salt that is richly available in drylands and rare in the rainforests. The latter is also a serious problem for human being living in the rainforest. Several grainivorous mammal animals have been domesticated in drylands. But Afro-Eurasian Inner Dryland has been the privileged dryland, because other drylands like those of Australian and American continents had known little domestication before the arrival of Europeans. Even the drylands of South Africa had not known camel and horses (Table 1).

Table 1. Comparative dryland civilizations

Dryland	Animal Culture	Agriculture	Irrigation
Eurasia	◎	◎	◎
Sub-Sahara	○	◎	○
South Africa	∆	∆	∆
North America	×	∆	×
South America	∆	○	∆
Australia	×	×	×

◎well developed ○ developed ∆ a little extent × absent

The domestication of mammal animals was one of the greatest discoveries in the human history. With it, the mankind found first the way of exploiting the natural energies. Before it, mankind had used only his own energies. He had had to fight with his own arms, run with his own legs, and transport burden on his head or shoulders. After domesticating the mammal animals he could use their power. Especially big animals like camels or dromedary, horses, donkeys and cattle were important as they served not only as source of food but also as means of transport and travel and provide mobility for war. The employment of horse made it also easier to hunt big savage animals. The horsemen became the champion of the dryland instead of big canines like lions.

It became also easier to get water from deep wells and to transport it to the dwellings with animal powers. But more important changes happened. With big animals, dryland people constructed a large network of trade covering almost the entire vast interior area of the Afro-Eurasian continent from Sahara to Mongolia or China. In pre-colonial days, many caravans composed of thousands of dromedary crossed Sahara. With this economic activity many commercial towns were built in the Sahel regions like Timbouctoo, Djenne and Kukawa. The Afro-Eurasian Inner Dryland was the center of the flows of products and peoples (Fig. 2). The dryland people were proud of their traditional 'TOYOTA'.

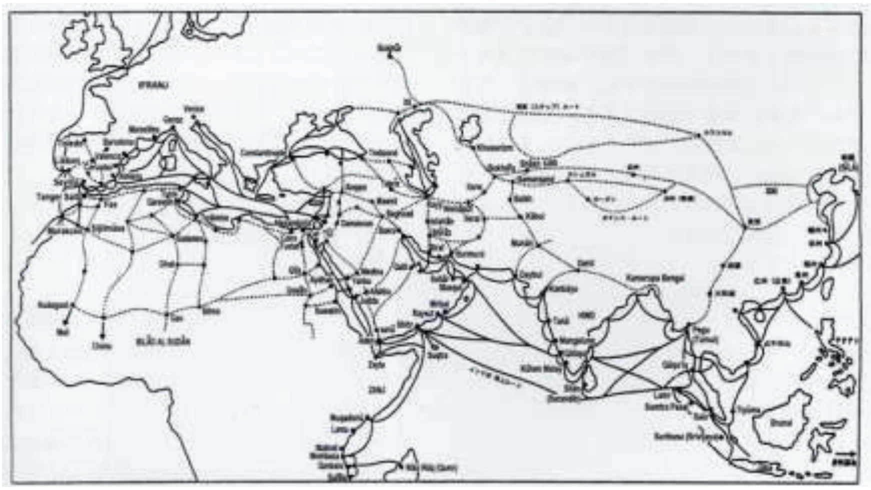

Figure 2. Islamic trade networks in the 7th Century.

With big animals they have also built great empires like Mongolian, Turkish, Greek, Arabic, and Berber. Sub-Saharan Sahel Sudanian region has known also big State formation like those of Ghana, Mali, Songhai, Kamenou-Bornou, since 11th century. Even in the history of Europe and Japan, which are essentially forest regions, big animals were crucial to the State formation. In a word, many things, human or material, have been politically or economically combined with each other with the animal power. I call it the development of civilization.

The importance of animal power is obvious from the fact that neither any important State formation nor commercial economy development occurred in African forest areas, which had refused animal-based cultures. Fulani Jihads (Fig. 3), collective greatest Islamic State formation in the history of Sub- Sahara Africa, were led during the 18th to 19th centuries by a cattle breeding pastoralist people called Fulani (English), Fellata (Arabic) or Fulbe (by themselves). It might appear difficult to understand in the first instance as to why poor nomad people succeeded in establishing great empires by conquering peoples practicing settled agriculture. But the fact was that cattle breeding people were very rich in commercial economy so that they could get not only horses as military means but also get political alliances with their enemies by way of peaceful negotiations, manipulating their valuable cattle as gift or bribe. In that age, one head of cattle could get a slave in barter. If one had a hundred heads of cattle, he could raise a fighting force of one hundred soldiers. One could call cattle breeding people as the capitalist in the bush.

Figure 3. Fulani migration and State formation.

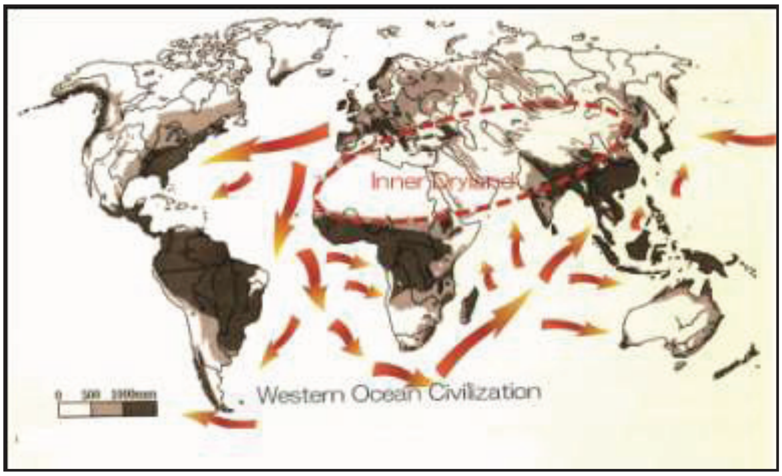

Figure 4. Modern ocean routes.

3. Modern civilization as a reorganization of the world with sea power

The modernization process can be considered as a reorganization of the world with sea power under the initiative of the Western peoples started from the end of the 15th century. The discovery of ocean trade routes offered wider and more range of the economic and political activities to the western people and made it possible for them to colonize almost all the world. This process was accelerated with the invention of internal combustion engine and more largely with that of oil engine. We are now at the end of this age and it is the time to reconsider motor-based civilization and recall the importance of power used on inner continental routes in the past. The motor power has been destructive for the animal transport, the traditional 'TOYOTA'.

4. Reconsidering the animal power

The importance of animal power seems to be forgotten in the region that has seen the rise of civilization because of this power in the long past. Today we are in the age of petroleum oil and the motor machines run from this source of energy. It appears that the dryland people are ashamed of their traditional mode of conveyance based on animal power. But considering human history, and recognizing the fact that the early human civilization could not have developed without animal power, the people of drylands, especially Afro-Eurasian Dryland ones, must be proud of their traditional source of energy.

8.5. The impact of green roof on global warming in urban areas

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Abstract

Increasing worldwide environmental concerns have led to the development of environmentally friendly construction practices. Green roof technology is one possibility for reducing the environmental impact of a building. The green roofs have the ability to regulate the temperature in and around buildings, improve energy efficiency in buildings, reduce the urban heat island effect, retain storm water, and increase the lifespan of a roof. The secondary benefits include their ability to provide health benefits to humans and space for agricultural use, improve public perception/recognition of the building user and the aesthetics of the environment, increase property value, reduce noise inside the building, and provide habitat for airborne species. There are two main types of green roofs, intensive and extensive. Intensive roofs tend to be more than 15 cm deep, allowing for the growth of large plants such as trees and shrubs, chosen based on visual appeal, but with more structural load on roof and greater need for, and cost of, maintenance. Extensive roofs on the other hand, contain smaller plants, such as shrubs, sedums, and herbs. They are self sustaining except for bi-yearly maintenance where the beds are weeded and fertilized and have lower construction and maintenance costs. Due to the low height of the plants, they are subjected more to the vagaries of weather such as high intensity winds and frost, but choosing adapted plants can reduce the risk. Extensive roofs are environmentally more effective than intensive ones. Green roofs can help reduce global warming by sequestering more carbon. While a single green roof will not remove much CO_2, many can have an impact on the environment. The green roofs can also reduce GHG emissions by decreasing need for the use of air-conditioning systems, which often use hydrofluoro compounds (HFCs) as refrigerants and place high demand on power plants that emit pollutants during their operation. It is therefore important to encourage the installation of green roof in the cities to reduce the global warming and save the environment.

1. Introduction

Increase use of ground surface for various purposes has lead to great reduction in the surface covered with green plants in the urban areas. In order to prevent dangerous and uncomfortable urban heat island effects the need of planted surface is quite inevitable as is confirmed by the work of Wong et al. (2003), Eumorfopoulou (2003), Del Barrio (1998), Onmura et al. (1994) and Haefeli et al. (1994). Space constraints have further reduced the feasibility of providing green surface in the areas surrounding the buildings, especially in the big cities and town centers.

Improvement in the surface cover of buildings and constructions that have been covered with cement and asphalt concrete is one of the methods to mitigate the urban heat island effect (Takebayashi and Moriyama 2007). Planted roofs become a promising choice. The roof surface can be transformed into useful space, the building can become economically and functionally more efficient and can have a more benign effect on the surrounding landscape (Carter and Keeler 2007).

The application of vegetation and growing media to the roof surface is an increasingly popular practice which produces improvements in both energy conservation and storm water management. These green roofs provide numerous environmental benefits including decreasing the surface temperature of the roof membrane and energy use in the building (Kumar and Kaushik 2005), retaining storm water (Carter and Rasmussen 2006), increasing biodiversity and habitat in urban areas largely devoid of such space (Kim 2004; Brenneisen 2005), and improving ambient air quality (Clark et al. 2005). While these benefits are inherent in all green roof systems to some degree, depending on the design of the roof, esthetic appeal for the building occupants, sound insulation and urban agriculture are other realistic benefits provided by green roof application (Peack et al. 1999). The aim of this work is to discuss the impact of roof garden on the global warming and other environmental issues.

2. Definition of green roof

Green roof is a roof of a building that is partially or completely covered with vegetation and soil, or a growing medium, planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation system (Wikepedia 2006). It is a stable living ecosystem that makes the urban environment more livable, efficient and sustainable (Hitesh et al. 2005). The planting is done over existing roof structure to help reduce building temperatures, filter pollution, lessen pressure on sewer systems and reduce the “heat island effect.”

3. Types of green roof

There are three main types of green roofs, intensive, extensive and semi intensive. Intensive green roofs have a soil thickness of more than 15 cm allowing the growth of larger plants such as trees and shrubs. With the large soil thickness and height of the plants, there is more structural loading imposed by an intensive roof. As such, they require more maintenance, irrigation and feeding. This extra weight and maintenance makes these roofs more costly. The plants are generally chosen based on visual appeal (Kosareo and Ries 2007).

The semi-intensive green roof provides a more varied landscape, which can include shrubs, heathers, lavenders and wild flowers, but still with a relatively low build up. Requiring limited but scheduled maintenance and irrigation, they combine visual enhancement and ecological benefits with access for recreational use (Peck et al. 1999). In Egypt, different semi- intensive systems are used including table system, container system, hanged bag system, A-shape system, wall system and aeroponic system. Irrigation and fertilization operations can be done manually or automatically.

Extensive type green roofs contain smaller plants, including shrubs, sedums (low laying ground covers), and herbs. They are self sustaining except for bi-yearly maintenance where the beds are weeded and fertilized. They tend to have lower construction and maintenance costs. Due to the low level of all the plants, they are often subjected to more weather elements such as wind and frost (Kosareo and Ries 2007). The plants that are common to the area and can withstand the harsh conditions are desired for this type of green roof.

Extensive roofs are environmentally more effective than intensive roofs. The semi-intensive category is a way to bridge the large gap between a fully extensive roof and a fully intensive roof. By nature, intensive and semi-intensive roofs are visually more appealing and therefore lend well to daily public visits.

Green roofs can be placed on both old and new buildings. However, due to the added weight requirements, it is advised that a feasibility study be completed on any old building to ensure that it can withstand the extra structural load (Liesecke 1999).

4. Global warming

Global warming refers to an average increase in the Earth's temperature, which in turn causes changes in climate. A warmer Earth may lead to changes in rainfall patterns, a rise in sea level, and a wide range of impacts on plants, wildlife, and humans. The "greenhouse effect" is the term commonly used to describe the earth's natural regulation of its temperature. Some of the solar energy that warms the earth's surface and surrounding air is radiated back through the atmosphere. However, some of this energy is absorbed by greenhouse gases(GHGs), which form a protective "blanket" around the earth. By delaying the radiation of heat back out of the atmosphere, GHGs maintain the earth at a temperature 30^{o}C higher than it would be otherwise. Without the presence of GHGs, the average temperature of the earth's surface would be -18^{o}C.

GHGs include water vapor, carbon dioxide, ozone, methane and nitrous oxide. While the gases do occur naturally, human activities also produce them. For instance, carbon dioxide is emitted from the burning of coal, oil and natural gas, methane and nitrous oxide are produced by farming activities and changes in land use. Further, long-lived industrial gases that do not occur naturally are being produced. The levels of these gases in the atmosphere are increasing at an unprecedented speed.

CO_2 emissions account for over 60% of the increased GHG emissions. With the current rates of emissions continuing, the CO_2 levels in the atmosphere will double or even triple from the pre-industrial levels before the end of the 21st century. The result of this increase in GHG's is the warming of the earth's surface and the lower atmosphere. Computer simulation models predict that the enhanced greenhouse gas effect will increase the earth's average temperature by 1.4^{o}C to 5.8^{o}C by the year 2100.

This seemingly small rise in temperature will cause a significant change in cloud cover, precipitation, wind patterns, and the duration of seasons. These changes in the Earth's climate are currently having and will continue to have severe consequences. Unfortunately, some climate change is unavoidable now because of past and current emissions. After 150 years of industrialization, global warming has momentum and will not stop immediately even if emissions were completely eradicated. However, reducing emissions can slow the rate of global warming, and the global community has committed to make this happen.

5. How green roof can mitigate the global warming?

Green roofs can help reduce global warming in three major ways:

- By purification of city's air through photosynthetic conversion of CO_2, water and solar energy into oxygen and glucose
- By decreasing the air-conditioning demand of buildings by decreasing the temperature of a building.
- By reducing the Urban Heat Island Effect (Peak et al. 1999)

Studies have shown that one mature beech tree (80-100 years old), with a crown diameter of 15m, shades 170 m^2 of surface area, has a combined leaf surface area of 1,600 m^2 , and creates 1.71 kg of oxygen and 1.6 kg of glucose every hour (using 2.4 kg of carbon dioxide, 96 kg of water, and 25.5 kJ heat energy). This level of production equals to the oxygen intake of 10 humans every hour (Mink 1982). One of the crucial elements in selecting plant types and densities is the green leaf and stem surface area available for photosynthesis. For example, 25 m^2 of leaf surface area produces 27 g of oxygen per hour during the day, meeting the oxygen need of a human being for the same time period. However, considering the effects of nature, night-time (no sunlight), and winter (no green leaves if using deciduous plants) 150 m^2 of leaf surface area would be required to balance the human intake of oxygen for one year (Peak *et al.* 1999). For green roof 1.5 m^2 of uncut grass surface, with a leaf area of 150 m^2, would meet the yearly requirement of oxygen for one human. On a global scale, some studies indicate that even with all of its industry, technology and the burning of fossil fuels, humanity has had little effect on the total amount of oxygen in the earth's atmosphere. Instead, these studies suggest that it is the quality of the air through the production of greenhouse gases, pollutants and air-borne particulate matter that has been negatively affected by human activities. By increasing the amount of biomass in an urban area, rooftop can contribute by reducing the carbon dioxide levels produced by vehicles, industry, and mechanical systems, leading to improved air quality and reduced respiratory problems.

Green roofs can help the local air quality by reducing smog and by producing oxygen. Smog reduction occurs by reducing the particulate matter in the air, and lowering the ambient temperature. Green roofs filter the air moving across them and remove particulate matter as it passes. According to Johnston (1996), 1 m^2 of grass can remove between 0.2 and 2 kg of particulate matter. Farrar (1996) reported from the City of Toronto study that 2,000 m^2 of un-mowed grass on a roof could trap up to 4,000 kg of particulate matter in its foliage, thus removing it from the air.

A study in Los Angeles found that avoiding NOx production through air conditioning by lowering the temperature inside buildings, as well as reducing NOx by cooling the ambient city temperature by up to 3 ^oC, Los Angeles could reduce its smog output by 25%. Thus, green roofs, by lowering the ambient temperature surrounding the buildings, reduce the need for air conditioning and slow the ozone-forming NOx and VOC (Vapor organic compound) reactions. With the growing ecological problem of deforestation, this is a valuable benefit of green roofs.

There are four fundamental climate levels: climatic zones, regional climate, local climate, and microclimate. Climatic zones, which are characterized by their broad, geographic bands, are affected by land mass and large bodies of water. Global warming, which is a growing world problem, is an example of a significant change to a climatic zone. Regional climates refer to the variations within climatic zones, and local climates, such as the urban heat island effect, are parts of regional climates (Peak et al. 1999). Since climatic zones, regional, and local climates are relatively large scale, they require significant combinations of changes to affect them. However, microclimates, which are smaller and site-specific, are directly influenced by the elements on or around the site. Changing theses elements can produce a significant change in the site's microclimate. An example of a microclimate is the air just above a building, which has a different microclimate than the air at the base of the building. The microclimate above this roof can be changed by altering certain factors. Many studies have shown that the air temperature above a roof can be altered by placing a layer of soil and plants on the roof (Peak et al. 1999). According to Peak et al. (1999), a lot of radiated solar energy is reflected by building materials such as concrete and asphalt, which raises the local temperature. The amount of heat radiated can be reduced by green roofs. When sunlight falls on a leaf of a plant, it is used in the following ways: 2% is absorbed and used in photosynthesis to create biomass and oxygen; 48% passes through the leaf and is stored in the plant's water system, 30% is used as heat in transpiration, and only 20% is reflected. Since less solar energy is radiated back into the air when plants are present, green roofs reduce air temperatures surrounding them.

The 'Urban Heat Island Effect' is a macroclimate caused by the difference in temperatures between a city and the surrounding countryside. This difference is mainly due to the expanse of hard and reflective surfaces in urban areas, which absorb incoming solar radiation and re-radiate it as sensible heat (Johnston 1999). In the surrounding areas, there is a higher proportion of 'greened' surface area, which is able to absorb and transform this radiation into biomass and latent heat. Re-radiated heat, waste heat generated by industry, vehicles and mechanical equipment and increased levels of air pollution, together raise urban temperature levels by up to 8 ºC than their surroundings on warm summer evenings. And if estimates are correct, global warming will exacerbate the Urban Heat Island Effect by raising summer temperatures an additional 5 ºC (Akbari 1992). Higher temperatures also have a direct effect on air quality, since heated air stirs up dust and air borne particulates as it rises. On a hot summer day, a typical insulated gravel-covered roof in middle Europe tends to heat up by 25 ºC, to between 60 to 80ºC. These surfaces will not heat up to more than 25 ºC.

Studying the urban heat island effect is important because it has many implications, including atmospheric pollution and internal climates of buildings. GHG production increases with increasing temperatures. Thus, GHG production will be higher in cities where the urban heat island effect takes place. However, perhaps of more interest to building owners, is the fact that urban heat islands cause the internal temperature of buildings to be higher. This increases the need for expensive and polluting air conditioning.

6. Other benefits of green roofs

6.1 Plants and building insulation

The role of insulation and air/vapor barriers is to slow down the rate of heat transfer between the inside and outside of a building, which is a function of the difference between the inside and outside temperatures. Insulation mitigates the impact of this temperature differential. In the winter, insulation slows down the rate of heat transfer to the outside and in summer it slows down the rate of heat transfer to the inside. The greening of horizontal surfaces has been used as a technique for insulating buildings through exterior temperature regulation. The insulation value of a building can be increased in several ways:

- By trapping an air layer within the plant mass, the building surface is cooled in summer and warmed in winter.

- By covering the building with vegetation, the summer heat is prevented from reaching the building's skin, and in the winter, the internal heat is either prevented from escaping, reflected or absorbed.
- Since wind decreases the energy efficiency of a building by 50% (Mink 1982) a plant layer will act as a buffer that keeps wind from moving along a building surface.

With a green roof, the insulation value is in both the plants and the growing medium. It is unclear which of the two has the most benefit since much depends on the depth of the growing medium and type of plants chosen (Liesecke 1994). An extensive application is much more effective as an insulator than an intensive one (Hooker 1994). A layer of mixed grass performs better than a layer of limited-species grass, which in turn is better than a layer of low-growing plants.

6.2 Sound insulation

Soil, plants, and the trapped layer of air between the plants and the building surface can be used to insulate for sound (North American Wetland Engineering 1998). Sound waves produced by machinery, traffic and airplanes can be absorbed, reflected and deflected. The substrate tends to block lower frequencies while the plants block higher frequencies. Tests have shown that a 12 cm layer of substrate can reduce sound by 40 dB and 20 cm by 46 dB (Hooker 1994).

6.3 Building-life extension

Green roofs protect the roofing membrane against ultra-violet (UV) radiation, extreme temperature fluctuations and puncture or physical damage from recreation or maintenance. The second 'Building Failure/Damage Report' issued by the German government in 1988, identified roof greening as a solution to flat roof membrane failure. For example, a London Department store installed a roof membrane under a planting in 1938 and 50 years later, the membrane was still in excellent condition. This is in a climate where most flat roofs have an average life span of between 10-15 years (Liesecke 1994). On a roof, temperatures can swing from minus 20 to 80 °C over the course of a day. A 10 cm thick green roof layer can reduce this range in temperature from 10 -30 °C, thus ensuring less expansion and contraction stress on the roof membrane, which in turn reduces cracking and aging (Johnston 1996) . The longer life-span decreases the need for re-roofing and the amount of waste material bound for landfill, both of which are direct cost savings for the building owner. Reducing building waste also helps to conserve municipal landfill capacity

6.4 Aesthetic improvements

Urban greening has long been promoted as an easy and effective strategy for beautifying the built environment. A layer of plants can enhance good design or disguise bad design (Johnston 1996). Plants can add visual interest to plain walls and roofs, soften industrial and commercial properties and allow a new building to blend in better with rural or suburban surroundings. The new public library in Vancouver, Canada was designed with a green roof specifically to offer a better view to the residents of the surrounding office towers (Thompson 1998).

6.5 Health benefits and horticultural therapy

The belief that contact with trees, shrubs, grasses and flowers fosters psychological well-being and reduces the stress of urban living dates back to ancient cities like Cairo and Rome. More recently, visual contact with vegetation has been proven to result in direct health benefits. Psychological studies have confirmed these beliefs by clearly demonstrating that the restorative effect of natural scenery holds the viewers' attention, diverts their awareness away from themselves and from worrisome thoughts and elicits a meditation-like state. Swedish studies on brain wave activity also indicate that views of natural settings elicit a wakeful and relaxed state characterized by a decreased heart rate and a quicker stress recovery time (Ulrich 1992).

7. Conclusion

Form the above, it is clear that using green roofs can be an alternative for mitigating the global warming to slow the climate change in the urban and semi urban areas besides providing other benefits.

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8.6. Dry areas provide good prospects for growing *Jatropha curcas* for biofuel production

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Abstract

The risks associated with the dependence on fossil fuel as the main source of energy have become apparent in recent years. There is growing concern about the damage to environment by greenhouse gases released by the use of fossil fuel. The uncertainty of petroleum oil availability and rising prices because of the monopoly of a few oil-rich nations over its production and supply is another major concern. As a response, there has been a growing desire to find out alternative, environmental friendly and renewable sources of energy. Biofuels have emerged as one of the most promising options, but their production from crops traditionally grown for food on prime lands has increased risk for food insecurity and has sent food prices on a new upward spiral. The way out is to produce biofuel from lands that are degraded and marginal for crop production. Such lands are abundant in the dry areas of the world and there is need to identify and improve plant species that could grow there. Pilot research in field is showing that oil-bearing shrub *Jatropha curcas*. can grow in such environments. Research under controlled conditions is confirming drought tolerance, high water use efficiency and good resilience under adverse growing conditions for this species. Some of these results are reported in this paper. To make it an economically viable alternative source of renewable energy, it is necessary that the traits for adaptation to degraded lands in dry areas be combined with high productivity through crop improvement efforts. This would encourage their adoption on large scale for producing environmental friendly source of energy without any threat to food production.

1. Introduction

There is a growing body of evidence that the global climate change is occurring at a rate faster than previously anticipated (Solomon et al. 2007). The mean temperatures are predicted to generally rise and the carbon dioxide levels in the atmosphere are going to increase because of the increasing greenhouse gas emissions. There is therefore a need for taking both preventive and adaptive measures to mitigate the adverse effects of the future global climate change. Of the preventive measures needed, by far the most important is to cut down the greenhouse gas emissions by reducing the use of fossil fuel. The finite nature of fossil fuel resources, monopoly on them of a few, and therefore the risk that the prices of petroleum based fuel might again skyrocket as occurred in July 2008, all necessitate that an environment-friendly and renewable source of energy is developed and increasingly used. Biofuels, in the form of bioethanol and biodiesel, are the promising candidates. However, for a sustainable production of biofuels, it is necessary that the feedstock is grown without competing with food production for land and other resources (Scott et al. 2008; FAO 2008; Tilman et al. 2009).

Jatropha curcas (L.), a perennial deciduous shrub belonging to family Euphorbiaceae, is considered as a plant species that meets this criterion because of its ability to grow on degraded and marginal lands (Openshaw 2000; Azam et al. 2005; Francis et al. 2005; Achten et al. 2008). A native of Central America, Mexico and possibly the Caribbean, the plant got introduced several centuries ago and now grows naturally in different parts of the world with tropical and subtropical climatic conditions and a wide range of moisture regimes (Heller 1996). However, it has essentially remained undomesticated with little attention paid so far to its genetic improvement and enhancement of its adaptation to arid and semiarid areas (Achten et al. 2007; Rao et al. 2008). For full exploitation of its production potential, there is a need to develop better understanding of the genetic makeup, ecological adaptation and production physiology of this species. Fortunately, growing attention is now being paid to these issues (e.g., see Temasek Life Sciences Laboratory 2008).

Plants growing in arid and semi-arid areas, particularly on degraded lands, are often exposed to salinity and moisture stress. How the seedlings *J. curcas,* during the initial stages of their establishment in the degaraded lands would respond to these stresses is not known. Hence, a few preliminary experiments were conducted under the green house conditions at the Arid Land Research Center (ALRC), Tottori University, Tottori, Japan, in the period from June 2006 to May 2007 to develop some understanding on these issues that would help in the production agronomy of this important crop. A great limitation for the studies, however, was the shortage of seeds, which restricted the number of replications used for some of the experiments.

2. Results and discussion

2.1. Effect of saline water on the water imbibition and germination of *Jatropha curcas* provenance from India

The quality of water in several dry areas is marginal and the crop will have to be established with such water. The objective of this study was to find out how the levels of NaCl in the water would affect the rate of water imbibition and germination behavior. The seeds of an Indian provenance (India 1) were surface sterilized with 0.5% NaOCl for 3 minutes, washed thoroughly with deionized water and then placed in a germinator at about 25^{o}C temperature in paper towels wetted with solutions containing 0 (T1), 60 (T2), 120 (T3), and 240mM NaCl (T4). Ten seeds were used for each treatment. They were weighed before the start of imbibition and then at 2 hr interval till 30 hours to follow the course of imbibition. The germination behavior was also studied every day till 28 days after the start of the experiment. Germination behavior was categorized as DSO (quiescent seed), DS1 (radical emerged), DS2 (radical grown about 1 cm), DS3 (curved hypocotyl visible), D4 (hypocotyl straight), and DS5 (cotyledonary leaves open).

Imbibition showed sharp rise in the first two hours attaining a value of 10%. Thereafter, it increased steadily but at a slower rate than in the first two hours and attained the highest value at 30 hr. The effect of NaCl concentration started becoming apparent at 6hr, when T1 had highest imbibition closely followed by T2. This was followed by T3 and T4 in that order, with little difference till 18hr, when T4 showed lower rate of imbibition than T3. Thus the NaCl of 120 mM and 240 mM concentration reduced imbibition as compared to that obtained at 0 and 60mM NaCl concentrations. At the end of 30hr, the imbibition was about 40% for T1 and T2, 35% for T3 and 33% for T4 on the basis of the starting air dry weight of the seeds.

Germination behavior study showed that the DS1 stage was first reached in T1 in 3 days, in T2 on 4 days and in T3 in 5 days, while T4 seeds showed no sign of germination. Thus, there was a tendency for delay in the start of germination process with increase in NaCl concentration from 0 to 120mM NaCl, while no germination occurred at 240mM NaCl. The germination percentage at the end of 28 days was 70% in T2 and T3 and 50% in T1. At this stage, the seeds of T4 treatment showed no sign of germination. They were moved to 0mM NaCl medium to see whether they might start germinating after the salinity stress was removed. But, they failed to germinate indicating that a NaCl concentration of 240mM might have damaged the seed embryo.

The results show that *Jatropha curcas* seeds could germinate well in water with a NaCl concentration of up to 120 mM, and the germination starts when the seeds have imbibed about 35-40% water on the air dry weight basis.

2.2. Response of *Jatopha curcas* seedlings to soil moisture stress as varied by frequency of irrigation

Although *Jatropha curcas* is known to grow under harsh environmental conditions the seedling establishment stage is very critical for getting good field stand of the crop. The objective of this experiment was to examine the effect of soil moisture stress on the growth and some physiological parameters of one and half month old seedlings of an Indian provenance (India 1) to generate information that might help in designing drought management strategies for good establishment of the plants. The experiment was conducted in plastic house with natural environmental conditions during the month of September and October 2006 using 5000 ml plastic pots filled with Dune sand and vermiculite mixture (70%-30% on volume basis) with free drainage. The treatments included irrigation every day (T1), every second day (T2), every 4th day (T3) and every 6th day (T4) with the amount of water lost per pot by evapotranspiration as determined by weighing the pots. There were three replications, and the pots were organized in a randomized block design on a table. The temperatures ranged between 11.5 ^{o}C to 46.9 ^{o}C during the experimental period. The RH ranged from 22 to 99%. Two plastic plots, with their drainage hole closed, were filled with known amount of water and kept along with the planted pots and weighed daily to measure daily evaporation, which ranged from 8.95 to 145.7 g per pot per day.

On 24 July, one 7-day old seedling was transplanted per pot and pots irrigated with tap water to bring the soil to field capacity (FC). The moisture lost was replenished at two to three- day intervals till the start of differential irrigation treatments. Every other irrigation in this period was with full Hoagland nutrient solution to ensure healthy growth. On 1st September 2006, the pots were fertilized with 6.5 g of a NPK (15-15-15) compound fertilizer per pot and the fertilizer was mixed in the top 5 cm soil layer. The plants were allowed to grow till 10 September (55 days after germination) without any differential treatment. On 11 September they were all brought to field capacity to start the cycle of differential irrigation. Thereafter, they were weighed daily to determine the crop water use. The soil moisture content in the first 7 cm of the soil was also monitored using a moisture sensor (Delta-T ML2 SM200, UK) before and after each irrigation. Plant height and number of fully opened leaves were measure at 5-day intervals. Dry matter accumulation in leaves, stem, and roots was determined by harvesting one replication on 10 October (29 days after the start of the differential treatments) and the remaining three replications on 23 October (41 days after the start of the differential treatments). Decision to start early harvest was taken because of the build-up of whitefly on the plants in the plastic house. Before the final harvest, photosynthetic rate in the fully opened leaves was measured. Attempt was also made to determine the leaf water potential using the pressure chamber, but the leaf petiole anatomy made it impossible.

The total number of irrigations given since the start of differential treatment was 36 in T1, 18 in T2, 9 in T3 and 6 in T4 during the entire period of the experiment. The consumptive use (CU) of water was 5894, 6665, 5721 and 4328 g per pot for T1, T2, T3, and T4 respectively, the relative values being 100, 113.1, 97.1 and 73.4% respectively. Thus, the highest CU was obtained when irrigation was given every second day and it decreased when frequency of irrigation was either increased or decreased. Compared to every second day irrigation, the CU reduced by 12% under daily irrigation, by 14.2% under irrigation every 4th day and by 36% under irrigation every 6^{th} day. The CU values reflected the over all growth of the crop as affected by the treatments.

The plants were tallest and gave highest dry matter yield under T2. The final plant height was 40.8, 49.6, 44.1, and 37.7 cm for T1, T2, T3, and T4, respectively. The respective leaf dry weight was 8.61, 10.34, 9.36, and 6.12 g per plant; stem dry weight 16.91, 21.26, 17,38, and 13.16 g per plant; total shoot dry weight 25.52, 31.6, 26.7, and 19.28g per plant; root dry weight was 2.67, 3.87, 2.69, and 2.12g per plant; and the shoot/root ratio was 9.5, 8.1, 9.9 and 9.1. Thus the best growth was observed with T2, which was followed by T3 and T1 in the order. The least growth occurred under T4.

Results showed that irrigation every day was not suitable in this sandy soil perhaps because it caused temporary anaerobic conditions, which adversely affected the plant growth. Small magnitude of soil moisture stress faced by the plants under every second day irrigation proved beneficial, but that caused by irrigation every 6^{th} day was drastic and resulted in significant reduction in growth and consumptive use of water. Irrigation every 4^{th} day had less reduction in plant growth than the irrigation every 6^{th} day, and in a way was better than irrigating every day.

The results suggest that the *Jatropha curcas* can withstand moderate soil moisture stress during the seedling stage and daily irrigation was not needed during this period.

2.3. Response of *Jatropha curcas* seedlings to osmotic stress created by addition of polyethylene glycol 6000 to simulate soil moisture stress

The objective of this study was to investigate the effect of different levels of osmotic stress in the growth medium on plant growth, leaf gaseous exchange properties and the consumptive use of water of the seedlings of an Egyptian provenance of *Jatropha curcas* grown on dune sand. While the plants were initially raised in a plastic house, the stress application and plant response study were done in a growth chamber programmed for 12 hr 30°C light period and 12 hr 20°C dark period and a relative humidity of 50 to 60%. The light intensity during the light period was 80,000 lux (lumens m^{-2}). The treatments consisted of the water potential of 0, -0.32, -0.89 and -1.91 M Pa, over the basic osmotic concentration of the full Hoagland solution, designated as T1, T2, T3 and T4, respectively. This additional osmotic stress was created by adding appropriate amounts (0, 400, 600 and 800 ml per liter for T1, T2, T3 and T4, respectively) of a stock solution containing 300 g of PEG 6000 per liter while preparing the full Hoagland nutrient solution for each treatment. There were four replications.

A 6-day old seedling was carefully transplanted in 5000 ml plastic pots filled with 4500 g of dune sand and having free drainage. Plants were irrigated with sufficient amount of tap water

(EC ~ 0.13dSm^{-1}). When drainage had completely stopped, the pots were weighed and the weight of each planted pot (pot + soil + plant + water at field capacity) was around 6000 g. The pots were arranged on a table in the plastic house where the temperature fluctuated between a minimum of 21.8 °C to a maximum of 45.7°C during the period that the pots stayed there. The pots were irrigated every two or three days with either tap water or with full Hoagland nutrient solution based on the moisture loss by evapotranspiration. The plants were allowed to grow in the plastic house till 8 August 2006 (i.e. 14 days after transplanting) when they reached the age of 20days. On 9 August they were moved to the growth chamber. On 11 August, when plants were 23 days old, the differential osmotic stress treatments were started. Pots were flushed with sufficient amount of nutrient solution containing appropriate amounts of PEG 6000 as per the treatment and then moved back in the growth chamber, where they were randomly arranged. On 1 September 2006, when the plants were 45 days old, the pots were again flushed with excess nutrient solution containing the appropriate concentration of PEG as per treatment to achieve the desired level of soil water potential in the root zone. After several minutes of free flow, the leachate was collected from pots of each treatment for the determination of the osmotic potential. The osmotic potential values were 0.11, 0.47, 1.107, and 2.29 MPa for T1, T2, T3 and T4 treatments, respectively. When the drainage was complete, the pots were again weighed. Thereafter, the pots were generally weighed daily, mostly in the afternoon, to determine the evapotranspiration and the moisture loss was replenished using tap water. The pots were regularly moved in the growth chamber because there was some spatial variation in the strength of the air flow. The moisture loss data were used to compute cumulative consumptive use (CU) of water after the final start of the differential treatment on 1 September.

Gaseous exchange parameters of the top most fully expanded leaf including stomatal conductance, transpiration rate, concentration of carbon dioxide in the stomatal cavity, and photosynthetic rate at the photosynthetic photon flux of 600umol m^{-2} s^{-1}, were measured between 12 am and 2 pm on 2, 4 and 12 September using LI-COR 6400 instrument (LI-COR Inc., Lincoln, USA). On 22 September 2006 (20 days after the start of the treatments) when the plants were 66 days old, plant height and leaf number was counted. Thereafter, plants from three replications of each treatment were harvested to determine dry weight accumulation in leaf, stem, shoot as a whole, root and the shoot/root ratio.

Results showed that the cumulative water use (CU) increased linearly from 3 September to 20 September, but the slope was the highest for T1 and it decreased as the level of osmotic stress increased. The CU on 20 September was 3511g/pot in T1, 2523 g/pot in T2, 2051 g/pot in T3, and 1391 g/pot in T4. Thus there was a decrease of 28.1% in CU under T2, 41.6% under T3, and 60.4% under T4 as compared to T1.

The gaseous exchange in the leaves as affected by the osmotic stress was studied at three different times, one, three and 11 days after the start of the treatments. All the parameters were adversely affected by an increase in the osmotic stress, although the magnitude of effect differed with the parameter. The data on photosynthetic rate are given in Table 3.1. Averaged over the three dates, the photosynthetic assimilation rate was 15.55 umol CO_2 m^{-2} s^{-1} under T1. It decreased by 12.4, 38.9 and 66.4% by the treatments T2, T3, and T4, respectively, as compared to T1, showing that the relative decrease got accentuated as the osmotic stress increased. An examination of data for individual dates (Table 1) showed that the adverse effect of the lower level of stress (T2) on photosynthesis decreased as the time elapsed, while in case of the higher levels of stress (T3 and T4) such a trend was not observed; on the contrary, there was a trend for increase in the adverse effect as the time elapsed suggesting that these two levels of osmotic stress were rather drastic.

Table 1. Effect of osmotic stress on the photosynthetic rate of plants at different days after the start of stress treatment

Stress treatment	Photosynthetic rate (umol CO_2 m^{-2} s^{-1}) 2 September	4 September	12 September	Mean	% decrease
T1	14.72 $\pm$ 0.89	15.34 $\pm$ 0.02	16.60 $\pm$ 0.22	15.55 (100)	-
T2	12.06 $\pm$ 2.19	13.22 $\pm$ 0.82	15.57 $\pm$ 0.39	13.62 (87.6)	12.4
T3	10.15 $\pm$ 1.63	7.96 $\pm$ 0.75	10.39 $\pm$ 1.46	9.50 (61.1)	38.9
T4	5.00 $\pm$ 1.03	5.56 $\pm$ 2.71	5.56 $\pm$ 0.32	5.38 (34.6)	65.4

The data on stomatal conductance on the three dates and the average are given in Table 2. The average stomatal conductance under T1 was 0.352 mol H_2O m^{-2} s^{-1}. It decreased with increase in osmotic stress, but the magnitude of decrease was much higher than the decrease in the photosynthetic rate. The mean decrease as compared to T1 was 35.5, 71.6, and 87.8% with T2, T3 and T4 treatments, respectively. Thus, the stomatal conductance was more sensitive to osmotic stress than photosynthetic rate, however, the difference in the relative decrease in the conductance under the three stress treatments (T2, T3 and T4) were not as high as was the case for photosynthesis.

Table 2. Effect of osmotic stress on the stomatal conductance of plants at different days after the start of stress treatment

Stress treatment	Stomatal conductance (mol H_2Om^{-2} s^{-1}) 2 September	4 September	12 September	Mean	% decrease
T1	0.288 $\pm$ 0.0382	0.335 $\pm$ 0.0503	0.434 $\pm$ 0.0355	0.352 (100)	-
T2	0.161 $\pm$ 0.0495	0.212 $\pm$ 0.0803	0.310 $\pm$ 0.0077	0.227 (64.5)	35.5
T3	0.103 $\pm$ 0.0311	0.071 $\pm$ 0.0133	0.127 $\pm$ 0.0203	0.100 (28.4)	71.6
T4	0.037 $\pm$ 0.1122	0.046 $\pm$ 0.0247	0.046 $\pm$ 0.0028	0.043 (12.2)	87.8

The data on transpiration rate are given in Table 3. The average transpiration rate was 5.12 mmol H_2O m^{-2} s^{-1} under T1 and it decreased as the osmotic stress increased. The magnitude of decrease in the average transpiration rate because of the osmotic stress was intermediate between photosynthetic rate and stomatal conductance, being 27.9%, 56.6% and 77.7%, respectively for T2, T3 and T4 treatments as compared to T1.

Table 3. Effect of osmotic stress on the transpiration rate of plants at different days after the start of stress treatment

Stress treatment	Transpiration rate (mmol H_2O m^{-2} s^{-1}) 2 September	4 September	12 September	Mean	% decrease
T1	4.66 $\pm$ 0.341	5.50 $\pm$ 0.238	5.20 $\pm$ 0.072	5.12 (100)	-
T2	3.20 $\pm$ 0.732	3.66 $\pm$ 0.450	4.21 $\pm$ 0.060	3.69 (72.1)	27.9
T3	2.37 $\pm$ 0.455	1.78 $\pm$ 0.383	2.51 $\pm$ 0.264	2.22 (43.3)	56.6
T4	1.01 $\pm$ 0.245	1.24 $\pm$ 0.593	1.17 $\pm$ 0.068	1.14 (22.3)	77.7

The data on CO_2 concentration in the stomatal cavity are given in Table 4. The average value was 244.7 umol CO_2 mol^{-1} air under T1 and it decreased as the osmotic stress increased. The relative decrease in the average CO_2 concentration because of the osmotic stress was closer to that observed for the rate of photosynthesis under T2 and T3 treatments but was lesser under T4 treatment indicating that it was not as sensitive to the highest level of osmotic stress as the other parameters.

The data for plant growth parameters as observed on 22 September are given in Table 5.

Table 4. Effect of osmotic stress on the CO_2 concentration in the stomatal cavity of plants at different days after the start of stress treatment

Stress treatment	CO_2 concentration in the stomatal cavity (umol CO_2 mol^{-1}air) 2 September	4 September	12 September	Mean	% decrease
T1	230.6 ± 6.90	254.6± 9.20	248.8 ± 2.72	244.7 (100)	-
T2	181.6 ± 26.06	220.5 ± 36.90	230.1 ± 2.86	210.8 (84.3)	15.7
T3	158.1 ± 16.52	160.0 ± 14.80	192.7 ± 5.49	170.3 (68.1)	31.9
T4	118.3 ± 13.94	149.8 ± 6.20	141.3 ± 2.84	136.5 (54.6)	45.4

Table 5. Effect of osmotic stress on different growth parameters of plants measured 22 days after the start of the stress treatment. The plants were 66 days old

Growth parameters		Osmotic stress treatments T1	T2	T3	T4
Height	(cm)	24.8	23.1	23.5	23.1
	(%)	(100)	(93)	(95)	(93)
Shoot dry weight	(g $plant^{-1}$)	19.72	19.98	15.75	14.07
	(%)	(100)	(101)	(80)	(71)
Root dry weight	(g $plant^{-1}$)	7.79	9.46	5.88	5.18
	(%)	(100)	(121)	(75)	(66)
Shoot/root ratio		2.53	2.11	2.68	2.71
	(%)	(100)	(83)	(106)	(107)

The results showed that an osmotic potential of 0.45 MPa only marginally affected the plant heigh, did not affect shhot dry weight, increased root dry weight and reduced shoot/root ratio. Higher higher osmotic stress caused more conspicuous reductions in the growth of shoot and also affected the root growth adversely. These reductions occurred because of reduced photosynthetic rate, perhaps because of closer of stomates, as revealed by reduced stomatal conductance and transpiration rate.

2.4. Gaseous exchange behavior of *Jatropha curcas* leaves at different time intervals after same day exposure to osmotic stress in the nutrient solution by addition of polyethylene glycol 6000

The objective of the study was to examine the effect of the exposure of two-and-a-half months old plants of an Indian provenance (India 2) of *Jatropha curcas* to the moisture stress on the pattern of photosynthetic rate, transpiration, stomatal conductance and carbon dioxide concentration in the stomatal cavity at short intervals after the imposition of stress. The effect of the stress on the daily evapotranspiration and cumulative water use till 8 days after the imposition of stress was also studied. Treatment T1 was control where there was no additional osmoticum added to the full strength Hoagland solution used, and T2 was the stress treatment where the osmotic potential was increased by addition of 600 ml of a stock solution of PEG 6000 (300g PEG L^{-1} of the stock solution) per liter of the full strength Hoagland solution to get a water potential of about -0.89 M Pa. There were two replications.

Plants were prepared for the study in the way similar to that in Experiment 3. When plants were 78 days old, the pots were moved from the plastic house to the growth chamber programmed as described in Experiment No. 3. On 5 October at 10:00 am, two of the four pots were subjected to osmotic stress (T2) by thoroughly flushing the soil with the Hoagland solution containing PEG. The other two pots (T1) were flushed with Hoagland solution. The pots were weighed when drainage ceased. Gaseous exchange parameters of the top most fully open leaf were determined at 1:00, 3:00 and 5:00 pm on the same day (3, 5 and 7 hours after the start of the treatment) using the same procedure as described in Experiment No. 3. The evapotranspiration was measured by weighing pots daily and replenishing lost water by irrigating with tap water. The experiment was terminated on 10 October.

Table 6. Effect of osmotic stress on photosynthetic rate (mol H_2Om^{-2} s^{-1}) and stomatal conductance (mol H_2Om^{-2} s^{-1}) at 3, 5 and 7 hours after exposure of the plants to stress

Time of measurement	Photosynthetic rate No stress (T1)	Photosynthetic rate Stress (T2)	Stomatal conductance No stress (T1)	Stomatal conductance Stress(T2)
1:00 pm	12.46 ± 1.86 (100 %)	3.30 ± 1.80 (26.4 %)	0.1095 ± 0.0205 (100 %)	0.0242 ± 0.0150 (22.0 %)
3:00 pm	9.17 ± 2.22 (100 %)	2.06 ± 1.95 (22.4 %)	0.0701 ± 0.0206 (100 %)	0.0164 ± 0.0123 (23.3 %)
5:00 pm	6.69 ± 1.47 (100 %)	1.62 ± 1.85 (24.3 %)	0.0508 ± 0.0138 (100 %)	0.0147 ± 0.0115 (28.8 %)

Table 7. Effect of osmotic stress on CO_2 concentration in the stomatal cavity (umol CO_2 mol^{-1}air) and transpiration rate (mmol H_2O m^{-2} s^{-1}) at 3, 5 and 7 hours after exposure of the plants to stress

Time of measurement	CO_2 concentration No stress (T1)	CO_2 concentration Stress (T2)	Transpiration rate No stress (T1)	Transpiration rate Stress(T2)
1:00 pm	172.0 ± 1.40 (100 %)	137.9 ± 22.9 3. (80.2 %)	131 ± 0.597 (100 %)	0.699 ± 0.375 (22.3 %)
3:00 pm	150.9 ± 11.1 (100 %)	237.2 ± 86.4 (158 %)	2.213 ± 0.533 (100 %)	0.510 ± 0.366 (23.0 %)
5:00 pm	155.2 ± 8.8 (100 %)	322.5 ± 159.9 (208 %)	1.557 ± 0.359 (100 %)	0.465 ± 0.351 (29.9 %)

The data on gaseous exchange as affected by the osmotic stress are given Table 6 and Table 7. The highest photosynthetic rate (Table 6), stomatal conductance and transpiration rates (Table 7) were at 1:00 pm and the least at 5:00 pm. The CO_2 concentration in the stomatal cavity (Table 4.1) however showed the reverse trend; it increased as the time elapsed after the osmotic stress was started. Osmotic stress resulted in a significant decrease in photosynthetic rate (Table 6), stomatal conductance and transpiration rates (Table 7) at all the three times of the measurement. The CO_2 concentration on the other hand (Table 6) showed no effect of osmotic stress at the first observation time but at the second and third time of the observation there were conspicuous absolute increases because of osmotic stress although because of high standard error for the measurement under stress, the difference did not reach the level of significance.

Results showed that the osmotic stress reduced the photosynthetic rate by 73.6% at 1:00pm, 77.6% at 3:00 pm, and 75.7% at 5:00 pm (i.e. 3, 5 and 7 hr after treatment). The corresponding reductions were 78%, 76.2% and 71.2% in the stomatal conductance and 77.7%, 77.0% and 70.1% in the transpiration rate. Thus, all the three parameters were adversely affected by the osmotic stress to the same level.

The daily consumptive use of water, monitored till 8 days after the start of osmotic stress treatment showed that it was adversely affected by stress. The magnitude of decrease was 52.1% after one day, reached the peak of 71% after 3 days and then started declining steadily till five days, and then faster till the 8 days when the decrease was only 40.4%. This shows that there was a trend for adaptation of the plants to stress with the passage of the time. The cumulative water use (CU) increased linearly with time, but the slope was much higher in case of T1 (no stress) than under T2 (stress). The final CU was 2183 g per pot under T1 as against 908 g per pot under T2. Thus, the osmotic stress resulted in nearly 58.4% decrease in the cumulative evapotranspiration.

3. Conclusion

The studies showed that the *Jatroph curcas* seed could germinate with a water containing 120 mM NaCl, but failed to germinate when the salt content was 240 mM. The early establishment of plant was better with irrigation every second day, rather than irrigating daily. Longer irrigation interval reduced growth. Thus the plant was able to withstand mild soil moisture stress. The plants under increased soil moisture stress showed decrease in photosynthetic rate because of stomatal closure as revealed by decreased stomatal conductance and transpiration rate. The decreases were more severe immediately after the imposition of stress, and plants tended to show some recovery after they adjusted to the stress condition. Thus, the plants of Jatropha curcas would be able to withstand mild moisture stress during the period of early seedling adjustment. This trait would be of value for growing the plant under marginal edaphic environmental conditions.

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Theme 9. Blending indigenous/traditional knowledge and heritage with modern science in the sustainable development of oases

9.1. Indigenous knowledge of browse species and their availability on rangeland: case of a Sahelian zone of West Africa

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Abstract

The feed shortage is a common and crucial problem in the Sahelian rangelands that are subjected to degradation. Browse plants constitute important resource in livestock feeding particularly in dry periods. A survey was conducted with agropastoral people, in the Tongomayel area, to estimate indigenous knowledge of browse plants, their utilisations and preferential classification by farmers according to the production and quality of the species. The species threatened and those adapted to the production systems were also considered. Concurrently, a woody flora inventory was made to determine the contribution of different plants to the existing browse on pasture. The farmers mentioned 56 different browse species during the survey and this number was more important than data from field observations where 44 species from 17 families and 28 genera were found on the rangeland. The knowledge of the diversity of species reflected their importance in the life of the farmers. Farmers' preference for browse species related not only to the objective of feeding, but the multiple utilisations of browse species, such as for human consumption, material for construction and medicinal or veterinary uses etc. When comparing the availability of species (density on pasture) with the percentage of farmers mentioning them, it appears that some species that were well known and cited by all respondents were not abundant in the area and conversely other more abundant species were not cited. With regard to the species adaptation to the existing system of exploitation, *Pterocarpus lucens* and *Adansonia digitata* were frequently cited by farmers. Paradoxically these two species were mentioned as threatened and farmers related this fact to the decrease in rainfall and not to over exploitation. The knowledge of the diversity of browse species and their indigenous uses is important for the maintenance of bio-cultural-diversity.

1. Introduction

Rangeland production in the Sahel is highly seasonal with rainy season occurring from June to September. The herbaceous layer is composed almost exclusively of annual plants, the composition and the growth rate of which are strongly influenced by the pattern and amount of seasonal rainfall (Hiernaux 1996). Most of the shrubs and trees are deciduous but have longer leaf-production cycles than the herbaceous plants. The woody fodder, which are diversified and have various fodder components (green and dry leaves, flowers and fruits), provide extended availability, hence they constitute an essential resource for livestock during the long dry season. Apart from being browsed, woody plants have played significant roles in human live in Sub-Saharan Africa as demonstrated by the multiple usage they are subjected to. Local people are familiar with the species in their area and several studies (Okoli et al. 2003; Roothaert & Franzel 2001) have shown that local farmers can generate richer data as the area under consideration will not be limited as in studies based on direct observation in paddocks. Hence farmers' survey can be a useful tool in screening of indigenous browse plants. This study aims to document indigenous knowledge on browse species and estimate their occurrence on rangeland in a Sahel zone.

2. Material and methods

The survey was carried out in the village of Tongomayel in the province of Soum (13°44′ to 14°50′ N and 0°32′ to 2°07′ W) and the surrounding villages, Nianguel and Gankouna, located 4 km East and West respectively, since these villages used the same area of open pastures. A sample of 70 people (herders, livestock owners and women) was selected randomly among the volunteers for the interviews. They were asked to name the browse species they knew and which were represented in their area. A classification scale from 1 to 10 was used for the 10 most important species, where 10 was the highest score, according to their preference related to the production and the quality of the browse species by comparing them in a cross table allowing scoring of each species. Names of species were given in Fulani, and identified by the corresponding scientific names using a flora guide (von Maydell 1986). The other ways of utilisation of browse species were also mentioned such as veterinary and medicinal uses, the use for construction and fire wood, and food use of leaves or fruits. Farmers' viewpoint about the condition of plants under exploitation (species well adapted and species threatened) was also recorded.

The pastures in the study area were classified according to an interpretation of available aerial photographs in the area from 1981. Five types of vegetation used as pasture: shrubby steppe, sparse woody steppe, lowland pasture (valleys of temporary rivers and flooded basins), tiger bush and cropland area were distinguishing. An inventory of the woody flora was done in 3 random plots of 1 ha in each pasture type (except cropland area). All individual trees and shrubs within the plots were counted and divided into five classes according to their height: <1m, 1 – 3m, 3 – 5m, 5 – 7m and >7m. Then the number of plants/ ha was estimated.

Descriptive statistics in Minitab programme was used to calculate the mean value of species identified by each group of respondents. For species classification, the score obtained for each species was reported, species not classified were given 0 and the means were calculated. The data from the vegetation inventory, the occurrence of species in each pasture type were calculated using descriptive statistics analysis with Minitab programme.

3. Results

3.1. Indigenous knowledge on browse species and preference by ruminants

The farmers mentioned 56 different browse species during the survey. Herders (always males) identified a significantly higher number of species (26) than women (20) and livestock owners (22) ($P<0.05$). The maximum number of species found (34) was recorded with herders. Ten species were found to be well known, as they were cited by >90% of the respondents, 20 species were cited by >50%, while 20 other species were identified by <10% of respondents (Table 1).

Table 1. Browse species citation[1] by farmers and density of browse plants per pasture type[2]

Species	Species cited, % of farmers	Density per pasture type (plants/ha)			
		Shrubby steppe	Sparse woody steppe	Lowland pasture	Tiger bush
Pterocarpus lucens	100	0	46 (71)	2 (3)	460 (389)
Ziziphus mauritiana	100	7 (10)	1 (1)	4 (1)	1 (1)
Adansonia digitata	99	0	1 (0.3)	0	0
Guiera senegalensis	99	20 (20)	36 (27)	493 (196)	57 (15)
Balanites aegyptiaca	96	138 (81)	49 (31)	140 (62)	14 (21)
Acacia senegal	94	2 (2)	110 (137)	2 (2)	51 (35)
Anogeisus leiocarpus	94	0	0	6 (8)	0
Grewia bicolor	91	0	21 (22)	5 (2)	75 (49)
Acacia seyal	90	7 (12)	1 (2)	6 (9)	0
Combretum micranthum	86	0	5 (5)	189 (108)	253 (112)
Acacia nilotica	79	24 (21)	11 (16)	5 (4)	0
Mitragyna inermis	77	0	0	1 (1)	0
Acacia albida	74	0	0	0	0
Combretum glutinosum	67	0	1 (1)	10 (4)	2 (3)
Acacia ataxacantha	66	0	1 (2)	3 (5)	17 (2)
Sclerocarya birrea	63	0	1 (2)	3 (5)	0
Diospyros mespiliformis	60	0	0	1 (1)	0
Boscis angustifolia	59	0	23 (24)	1 (1)	61 (16)
Boscia senegalensis	57	0	94 (97)	0	230 (209)
Piliostigma reticulatum	53	0	1 (1)	13 (11)	0
Dichrostachys cinerea	46	2 (2)	2 (2)	11 (11)	31 (11)
Dalbergia melanoxylon	41	0	1 (1)	0	4 (3)
Maerua crassifolia	41	1 (1)	40 (38)	2 (2)	3 (3)
Grewia villosa	40	0	1 (1)	3 (3)	0
Ximenia americana	39	0	1 (1)	0	0
Combretum aculeatum	40	10 (4)	33 (24)	105 (40)	53 (45)
Bauhinia rufescens	39	0	0	1 (1)	0
Cassia sieberiana	39	0	0	2 (3)	0
Grewia flavescens	33	0	27 (30)	13 (6)	214 (75)
Maerua angolensis	29	0	0	2 (2)	0
Commiphora africana	20	0	11 (17)	1 (2)	52 (31)

[1]Species cited by >20% of the farmers; [2]Means and SD

The ranking of the 20 most important browse species showed 8 species on top of the list that were considered the most valuable because of their availability in the area, high production and good quality of leaves and/or fruits / pods (Table 2). Other ways of utilizing browse species that were mentioned and the actual state of species under exploitation are summarised in Table 3. Almost all plants except *Ziziphus mauritiana* are used for firewood (due to cultural belief). Thirteen species were known for their use as vegetable, fruits or gum (*Acacia senegal*). Among the browse species used for construction purposes, *Pterocarpus lucens* and *Anogeisus leiocarpus* were frequently cited.

Table 2. Scoring of the main browse species (means and SD), their local names and family names

Species	Sp. classification	Local name	Family name
Pterocarpus lucens	8.4 (2.2)	tchami	Papilionoideae
Adansonia digitata	8.2 (3.0)	boki	Bombacaceae
Acacia senegal	6.0 (3.1)	patouki	Mimosoideae
Grewia bicolor	4.3 (3.4)	keli	Tiliaceae
Acacia seyal	4.2 (3.4)	boulbi	Mimosoideae
Balanites aegyptiaca	3.7 (3.3)	tani	Balanitaceae
Guiera senegalensis	3.1 (3.2)	gueloki	Combretaceae
Ziziphus mauritiana	3.0 (3.2)	ndjabi	Rhamnaceae
Acacia albida	2.4 (2.6)	tchaiki	Mimosoideae
Acacia ataxacantha	1.6 (2.8)	ngorare	Mimosoideae
Acacia nilotica	1.4 (2.0)	ngaoudi	Mimosoideae
Boscia senegalensis	1.2 (2.5)	guiguili	Capparidaceae
Dichrostachys cinerea	1.2 (2.3)	mbouri	Mimosoideae
Boscis angustifolia	1.0 (2.1)	danranehi	Capparidaceae
Combretum aculeatum	1.0 (2.1)	laougni	Combretaceae
Sclerocarya birrea	0.8 (1.9)	hedi	Anacardiaceae
Diospyros mespiliformis	0.8 (2.3)	nelbi, ndelbi	Ebenaceae
Maerua crassifolia	0.6 (1.5)	tirehi	Capparidaceae
Maerua angolensis	0.5 (1.5)	elfitahi	Capparidaceae
Combretum glutinosum	0.5 (1.5)	dooki	Combretaceae
Piliostigma reticulatum	0.5 (1.5)	barkei	Caesalpiniaceae
Anogeissus leiocarpus	0.5 (1.5)	kodjoli	Combretaceae
Dalbergia melanoxylon	0.3 (1.0)	Nguelhelahi	Caesalpiniacea
Bauhinia rufescens	0.2 (0.5)	namadi	Caesalpinoideae

[a] score 1-10, 10 is the highest score

With regard to the species adaptation to the existing system of exploitation, the farmers cited 10 species with *Pterocarpus lucens* and *Adansonia digitata* as the most important. Ten species were mentioned as threatened and *Pterocarpus lucens* and *Adansonia digitata* were paradoxically the most cited. According to farmers this was due to low rainfall and not to over exploitation.

Eight species (*Guiera sanegalensis, Combretum micranthum, C. glutinosum, Lannea microcarpa, Anogeisus leiocarpus, Bauhinia rufescens, Kaya senegalensis,* and *Piliostigma reticulatum*) were cited for their medicinal use mainly against malaria, and *Guiera senegalensis* was commonly cited (60% of respondents). Four species were known for veterinary use (*Adansonia digitata*, *Guiera senegalensis*, *Balanites aegyptiaca* and *Combretum glutinosum)*.

With regard to the importance of browse in animal production, farmers stressed the effects on enhancing the strength (87% of respondents), increasing milk production (84%), improving reproduction parameters (23%) and health status (24%) of animals.

Table 3. Utilisation of browse species for other purposes[1] and the present condition of the species in the area

	Edible plants	Wood for construction	Species adapted	Species threatened
Acacia albida			13.0	
Acacia ataxacantha				13.0
Acacia nilotica		20.0	14.0	
Acacia senegal	11.4		31.0	10.0
Acacia seyal			24.0	
Adansonia digitata	85.7		73.0	79.0
Anogeisus leiocarpus		91.4		27.0
Balanites aegyptiaca	67.0		39.0	
Boscia senegalensis	33.0			
Combretum micranthum			61.4	
Dalbergia melanoxylon		30.0		10.0
Diospyros mespiliformis	41.0			
Ficus gnaphalocarpa	14.3			
Guiera senegalensis		41.4	20.0	13.0
Grewia bicolor	60.0	48.6	39.0	26.0
Grewia flavescens	14.3			
Grewia villosa	30.0			
Lannea microcarpa	14.3			
Mitragyna inermis		60.0		
Piliostigma reticulatum				
Pterocarpus lucens		95.7	84.0	47.0
Sclerocarya birrea	21.4			
Ziziphus mauritiana	78.6		16.0	
Ximenia americana	30.0			

[1]percent of farmers mentioning this utilisation

3.2. Occurrence of browse species in the study area

The characteristics of the 4 vegetation types (except cultivated area) distinguished in the study area are presented in Table 4. Lowland pasture had the highest number of species (35) and shrubby steppe the lowest (15). The density of plants was highest in tiger bush and lowest in shrubby steppe, 1602 and 222 plants/ha, respectively. Most of the woody species found were browsed (more than 80% of species recorded) in all pasture types.

The most important browse species found were *Acacia senegal, Balanites aegyptiaca, Combretum aculeatum, Guirea senegalensis, Grewia flavescens* and *Pterocarpus lucens*, with differing contribution according to pasture types; 91% of *Pt. lucens* and 84% of *G. flavescens* were found in tiger bush, 81% of *G. senegalensis*, 53% of *C. aculetatum* and 41% of *B. aegyptiaca* in hollow pasture, and 67% of *A. senegal* in sparse woody steppe. Overall 42 species from 17 families and 28 genera were found on the rangeland. The families well represented were Mimosacea (19.5%), Caparidacea (14.6%), Combretaceae (12.2%) and Tiliaceae (9.7%).

Compared to the number of species identified by farmers (56), 11 species were cited but not found during the inventory, while 5 species not cited by farmers were found (*Acacia macrostachya*, *Cadaba farinosa, Feretia apodantera*, *Gardenia* sp. and *Securinega virosa*).

Table 4. General characteristics of the pastures types in the study area

Pasture types	No of species	[1]Density plants/ha	[1]Browse species %	Dominant species
Sparse woody steppe	27	517 (186)	87.2 (2.7)	*Acacia senegal* *Boscia senegalensis* *Balanites aegyptiaca* *Pterocarpus lucens*
Lowland pasture	35	1051 (66)	83.0 (3.7)	*Guiera senegalensis* *Combretum micranthum* *Balanites aegyptiaca* *Combretum aculeatum*
Tiger bush pasture	25	1590 (283)	86.3 (2.7)	*Pterocarpus lucens* *Combretum micranthum* *Boscia senegalensis* *Grewia flavescens*
Shrubby steppe	15	222 (67)	95.8 (4.2)	*Balanites aegyptiaca* *Acacia nilotica* *Guiera senegalensis*

[1] Means and standard deviation

The main browse species found on the field (Table 1) were identified by at least 20% of respondents. Of the five species frequently cited, two were well represented (*B. aegyptiaca* and *G. senegalensis*) in all pasture types with densities varying from 14 to 140 plants/ha and 20 to 493 plants /ha respectively. *Pt. lucens* was well known by farmers and was dominant in tiger bush pasture, while *Adansonia digitata,* which was also well appreciated, was very rare in the pasture.

4. Discussion

The survey showed the complexity in the utilisation of browse species and allowed to record higher number of species compared to field observation. Several studies have shown that surveys of farmers generate more important information on the diversity of plants species in their area than field observations (Bayer 1990; Okoli et al. 2003). Some species cited by farmers in this study were therefore found in the pasture during the behaviour study, but were relatively scarce in the area. These species can, however, be of importance for the respondents. The knowledge of the diversity of species reflected their importance in the life of the farmers. Various uses of browse plants were mentioned and the preferential classification of species took into account these uses. For instance, a species such as *P. lucens*, which has the highest score, was shown as having a high nutritive value and was browsed by all ruminants, but it was also the first species used as building material. The various uses of browse plants as indicators of farmers preference has been reported by Briggs et al. (1999) in the eastern desert of Egypt and by Mtengeti and Mhelela (2006) while screening the potential indigenous browse species in central semi-arid Tanzania.
The farmers' idea about the adaptation of a species in the production system can be explained by important number of seedling and smaller individual that could be related to a good

regeneration status of the species. Sanon et al. (2007) reported 73% of species has less than 1 m height in the Tiger bush pasture where it is dominant. However the species is well exploited in the area and is now used as a good fodder tree. The branches are often cut down for feeding animal on pasture, and the leaves are sold at the local market.

The stratification of respondents showed that herders are familiar with a wide range of species compared to livestock owners and women, which is probably due to their direct contact with vegetation on pasture, and this makes them the key informants for this type of investigation.

When comparing the availability of species (density on pasture) with the percentage of farmers mentioning them, it appears that some species that were well known and cited by all respondents were not abundant in the area and conversely other more abundant species were not cited or mentioned by a few respondents. *Ziziphus mauritiana* and *Adansonia digitata* were cited by all respondents and are of considerable importance for farmers but were scarce in the area. The leaves of *Z. mauritiana* are well browsed by sheep and goats, and the fruits are edible for humans, and also sold in the local market or processed to extract powder that is sold in the cities. *A. digitata* is well known by Sahelian people for its role in human nutrition and for its cultural importance. All parts of tree are useful. The leaves, high in iron and calcium (Glew et al. 1997), constitute an excellent vegetable used fresh and dry in the form of powder especially in dry season when it becomes the main component of sauce in the diet. The fruits are edible, rich in vitamin C and used in many recipes. The tree also provides fibre from the bark and the wood. Being spongy and high in moisture, it can be eaten by cattle when the tree is cut down.

Among the species identified by farmers, and not met during the inventory, only *Tamarindus indica* (34%) and *Ficus gnafalocarpa* (27%) were cited by >20% of respondents. These two species were found on pasture during the behaviour study, but they were relatively scarce in the area. The same explanation could be valid for the others species, but on the other hand farmers, especially herders, could have cited some species that they had met during grazing in another area. This could be the case of *Bombax costatum, Combretum nigricans* and *Kaya senegalensis*, species known from the Sudanian zone. If species were found on pasture and not cited by farmers it probably meant that these species were rare in the area or not of interest to farmers. For instance, *Securinega virosa* and *Gardenia sokotensis* shrubs found in hollow pasture and tiger bush, were not browsed and represented little interests to farmers while *Feretia apodanthera* is very well browsed by animals but rare in the area and found mainly in hollow pasture. Other ways of utilizing browse species were also important in determining the preferential classification. Thus, the availability of the species, the production and quality of fodder and other utilisation of species were taken into account.

5. Conclusion

Farmers have relatively good knowledge on the main browse species represented in their area. Farmers' preference for browse species depended not only on the objective of feeding, but the multiple utilisations of browse species such as for human consumption and material for construction were also taken into account in their choice. Richer information on the plant biodiversity is obtained with farmers' survey than field observations, the indigenous knowledge should be considered when dealing with biodiversity of plant species and the need of its maintenance.

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9.2. On the local mangrove resource use of Kilwa island in southern Swahili Coast

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Abstract

Swahili Coastal region is rich of mangrove resources amongst Africa. Tanzanian mangrove is well conserved as shown in the reports of UNEP and WCMC: form 1990 to 2000, the mangrove area in Tanzania is almost the same (1,096㎢ in 1990 and 1,081㎢ in 2000). The southern coastal region of Tanzania, around Rufiji and Kilwa, occupies 65% (730㎢) of the domestic mangrove area. The object of this paper is to show how local people use mangrove resource from the case of Kilwa Island. Kilwa Island was the former influential Islamic trading port in the middle age, but now is a small village where less than 1000 habitants live with almost self sufficient life in their mangrove and coral-reef sea. There are eight spices of mangrove in Kilwa. The way mangrove is used can be divide into two: 'direct-use' that is the mangrove poles are used as building materials or firewood, and 'environmental-use' that is the mangrove sea is used as fishing ground or transportation route. Seven kinds of direct and five kinds of environmental uses were confirmed. The relation of these two uses is in a delicate balance. The excessive mangrove pole logging destroys its environment while the prohibition of logging on environmental conservation grounds leads the local people dependent on this direct-use to economic difficulty. Even the balance is unsettled, the mangrove environment in Kilwa is currently not destroyed by the local people's daily use as the population density of the southern coastal region including Kilwa is the lowest (12person/㎢). Recently, the developments in infrastructure and tourism in this region are in progress. It is a further subject to study how the relation between people and mangrove environment would change under these changing social conditions.

1. Introduction

The object of this paper is to show how local people use mangrove resource taking the case of Kilwa Island located at southern Swahili Coast, Tanzania. Kilwa Island was the influential Islamic trading port in the middle ages, but now is a small village where less than 1000 habitants live with almost self sufficient life in the sea of mangrove and coral reef.

Swahili Coastal region, form the southern Somalia Coast to the northern Mozambique, including Madagascar and Comoro Inlands, is one of the richest in mangrove resources in Africa. As the timbers for building materials, this mangrove resource was one of the important trading goods of Swahili ports in the middle ages involved in the Indian Ocean trade between Arab-Persia region and Swahili Coast. This mangrove trade has destroyed the most of the area of mangrove in Swahili Coast. For example, the Pemba Island of Tanzania was once called 'Green Island' because of its richness of mangrove, but now it has hardly any mangrove area left.

Around 1990's, the countries of Swahili Coast started to conserve their mangrove resources. In the Swahili Coast, Tanzanian mangroves have been well conserved as shown by the reports of UNEP-WCMC. From 1990 to 2000, the mangrove area in Tanzania has almost remained the same (1,096 km^2 in 1990 and 1,081 km^2 in 2000). In Tanzania, southern coastal region, around Rufiji and Kilwa, occupies 65% (730 km^2) of the domestic mangrove area.

2. Natural environments and life of Kilwa Island

Kilwa Island is a small lagoon island little off the southern Swahili coast of Tanzania, twenty three kilometers in circumference with about one thousand habitants. Situated in the mouth of three rivers, the island is surrounded by two kinds of seas; inland mangroves lagoon and open sea with a fringing reef (Fig. 1).

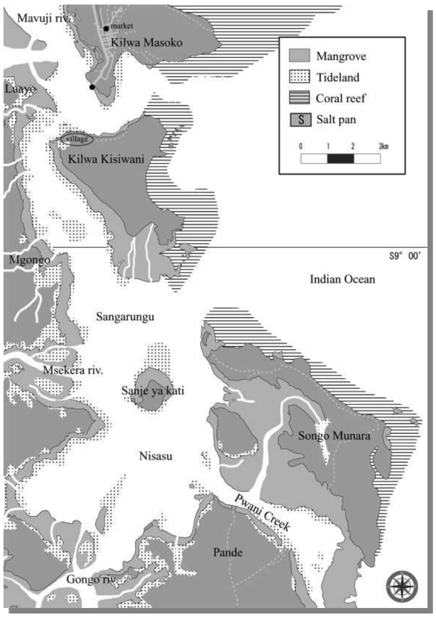

Figure 1. Kilwa Island.

Kilwa Kisiwani, located at nine degrees south latitude, belongs to the East African monsoon area, where the wind blows all the year long. Isolated by 3000 km from the metropolitan area of Tanzania (ex. Dar es Salaam), because of the bad road conditions, the island is almost out of any modern economic development.

The climate is of tropical savanna with about 1000 mm rainfall per year. It has two rainy seasons and two dry seasons. Thanks to the comparative rich rainfalls, most of the families cultivate maize, cassavas, rice, lady's fingers, peanuts, cashew nuts etc. But the field size for each family is less than one hectare, so almost all products are for home consumption. Earning cash is mainly from fishing. Fishermen fish with traditional wooden crafts named *dau*, which are plank-structured boats with keels and Latin sails or with small wooden canoes named *mtumbwi*.

Kilwa Kisiwani is now a small seashore village living almost in a self-sufficient economy mainly by fishing and gathering sea products in the surrounding seas and by cultivating a little bit of land. In the middle ages, however, it flourished as an influential Islamic trading port, known as the Kilwa Kingdom, which was founded in the middle of the tenth century by Ali bin al-Hassan and his followers who migrated from Shiraz (Persia).

3. Three ecological sea zones of Kilwa island

Kilwa Island is surrounded by two seas; mangrove inland sea and open sea having fringing reef. The maritime environments of Kilwa Island can be divided into three ecological sea zones (Fig. 2). Eco-zone 1 is inland sea covered with mangrove, is shallow and is calm of wind and waves. The floor is mainly of mud. Eco-zone 2 is open sea having fringing reef, is deep, has rough waves and strong winds influenced by monsoon. The floor is mainly coral and sand. Eco-zone 3 is intermediate sea between inland sea and open sea. The natural characteristic of eco-zone 3 is a mixture of eco-zone 1 and 2. The inhabitants have developed well their maritime life in these three eco-zones, especially in eco-zone1, the mangrove inland sea.

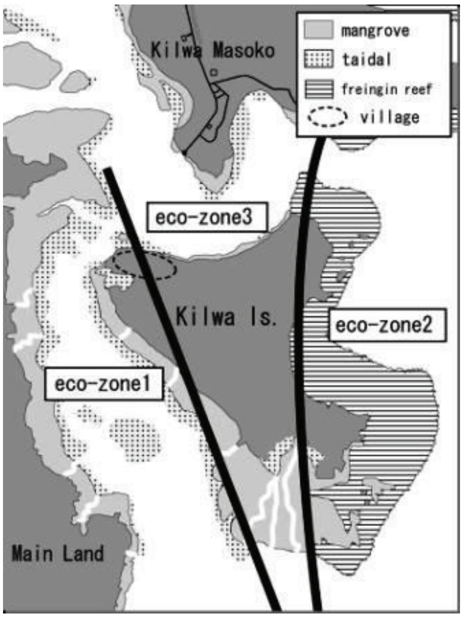

Figure 2. Ecological sea zones of Kilwa Island.

4. Maritime environments and Kilwa kingdom

The heritage of Kilwa kingdom is rich. It is not limited to the stone ruins but also related to the spread of Islam (religious heritage), spread of Swahili language and Swahili cosmopolitan identity etc. But this paper mainly deals with the stone ruins. The stone ruins comprise six mosques, three palaces and four cemeteries originating from the Arabs and one fort originating from the Portuguese (Table 1).

The stone ruins cover three areas (Fig. 3): (a) Around the village: ①*Msikiti kubwa*, ③*Gereza*, ④*Makutani palace*, ⑤*Msikiti ndogo*, ⑦*Malindi msikiti*, ⑧Great house, ⑨*Janguwani Msikiti*, ⑬*Makaburi ya Malindi;* (b) In the bush: ⑥*Makaburi ya Shirazi*, ⑩*Makaburi ya Mashehe arubaini*, ⑫*Makaburi ya Sake;* and (c) On the small hill located about 2 km away from the village: ②*Husuni kubwa* and ⑪*Husuni ndogo.* Of these, *Msikiti kubwa* (Great Mosque) is most important because it was here that every inhabitant came to worship every Friday. It can be supposed that the residence place of Kilwa kingdom was formed around the *Msikiti kubwa,* facing eco-zone 1 and 3.

Table 1. Classification of stone ruins of Kilwa Kingdom

Origin	Kind	Name	Century	location
Arab / Persia	Mosque	*Msikiti kubwa*	11C	1
		Husuni ndogo	17-14C	11
		Msikiti ndogo	15C	5
		Jangwani Msikiti	15C	9
		Malindi Msikiti	15C	7
		Mvinje Msikiti	15C	17
	Palace House	*Husuni kubwa*	17-14C	2
		Great House	14-15C	8
		Makutani Palace	15C	4
	Cemetery	*Makaburi ya Shizaji*	16C	6
		Makaburi ya Malindi	18C	13
		Mashehe arubaini	18C	10
		Sake	?	12
Portuguese	Fort	*Gereza*	16C	3

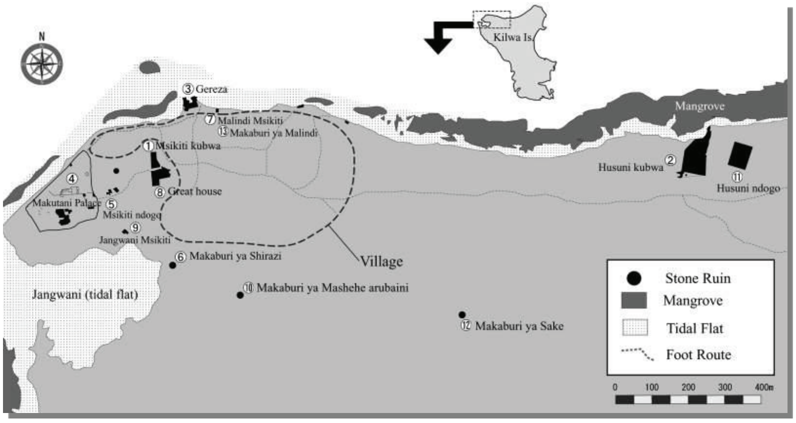

Figure 3. Distribution of stone ruins.

Here, the northwest of Kilwa Island faces mangrove inland sea and it is the most appropriate place for living because of its coolness and little prevalence of malaria mosquitoes in the summer season because of the monsoon wind. Other villages of the Islands on Swahili Coast like Pare, Lamu, Manda, Mombasa (Kenya) and Ibo (Mozambique) are also situated at the northeast part of the Island. In addition, this was also a good place for Kilwa Kingdom to defend against the enemies coming from Indian Ocean with big ships because of its shallow sea.

5. Use of mangrove resources

There are eight kinds of mangroves (Table 2) in Kilwa region. Kilwa's people use the mangrove resources in many ways. In this paper only two uses of mangrove resources are analyzed, 'direct use' and 'environmental use.' Direct use involves use of mangrove timber or pole as the materials for building construction and shipbuilding, firewood, fishing gear material, source of medicine, source of fodder in the dry season and as material for toy makin.etc. Environmental use involves the use of natural environment of mangrove inland sea as fishing ground, transportation route, and bee-keeping ground, etc.

Table 2. Mangroves in Kilwa

No.	Species	Family	Local name
1	*Rhizophora mucronata* Lam.	*Rhizophoraceae*	*mkoko*
2	*Bruguiera gymnorrhiza* (L.) Lam.	*Rhizophoraceae*	*mshinzi*
3	*Ceriops tagal* (Parr) C.B.Robinson	*Rhizophoraceae*	*mkandaa*
4	*Avicennia marina* (Forsks.) Vierh.	*Verbenaceae*	*mchu*
5	*Heritiera littoralis* Dryand.	*Sterculiaceae*	*mkungu*
6	*Lumnitzera racemosa* Willld.	*Combretaceae*	*mkandaa dume*
7	*Sonneratia alba* Sm.	*Sonneratiaceae*	*mpira / mliana*
8	*Xylocarpus granatum* Koenig.	*Meliaceae*	*mkomafi*

5.1. Direct use of mangroves

5.1.1 In building houses

The house of Kilwa Kisiwani is built using mangrove poles as the framework of wall and the beam of ceiling. Mangrove pole contains tannin and is therefore able to resist the wood-eating insects. It is therefore recognized as a good building material. About 700 mangrove poles are needed for building a house. The poles have deferent names depending on their diameter. The one used for the framework of wall, called '*pau*' in Swahili, has a diameter of 3.8 cm to 7.5 cm. The pole used for the beam of ceiling, called '*boriti,*' has a diameter of around 11.5 cm to 14 cm. *Boriti* were one of the main trading goods of Indian Ocean trade. In the era of India Ocean trade, many *boriti* were cut down and, according to one report, more than half of the total mangrove area in Swahili coast was reduced because of this exploitation. The damage due to logging was serious in the northern Swahili coast.

5.1.2 In building boats

The boats, the most important tools for the maritime life, are built out of mangrove. There are several kinds of boats in Kilwa Kisiwani: canoe (*mtumbwi*), double outrigger (*ngalawa*), flat bottomed boat (*mbare*), plank-structure boat with keel (*dau*), plank-structure boat with keel and boom (*mashua*) and plank-structure boat with keel and out-engine (*boti*). In making these six types of boats, the mast, keel, ribs, boom, beam, etc. of *mbare*, *dau* and *mashua* were traditionally built by mangrove materials. Depend on the characteristic of eight different kinds of mangrove in Kilwa Kisiwani, their use in differ*ent* parts for shipbuilding was different. For example *Bruguiera gymnorrhiza* (*mshinzi*) is recognized as the strongest one and it was used for the parts that need more strength like keel, mast and ribs. On the other hands, *Lumnitzera racemosa* (*mkandaa dume*) and *Heritiera littroralis* (*mkungu*) were rarely used for shipbuilding because they were soft and heavy. This reflects that the local knowledge of the people about the use of the mangrove materials traditionally was enormous.

5.2 Environmental use of mangroves

Five kinds of environmental uses are common: 1) Fishing ground; 2) Transportation route; 3) Salt pan; 4) Bee keeping; and 5) wind-wave breaks. The uses as fishing ground and transportation route only are presented here.

5.2.1. Fishing

Figure 4 shows the distributions of fishing grounds of Kilwa Island. The distribution of fishing grounds in mangrove inland sea is shown in Figure 5. There are 66 fishing grounds in Kilwa Island and eco-zone 1 has 30 and each eco-zone 2 and 3 have 18 fishing grounds each.

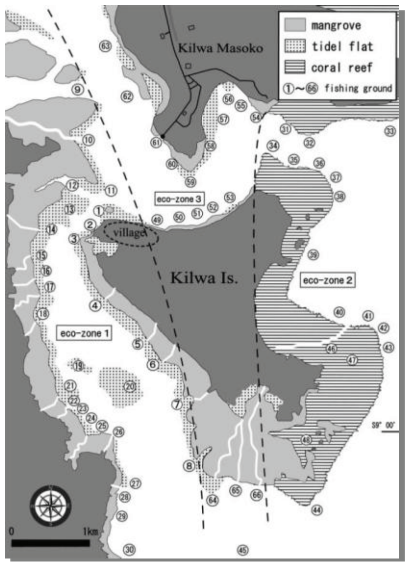

Figure 4. Fishing grounds of Kilwa Island.

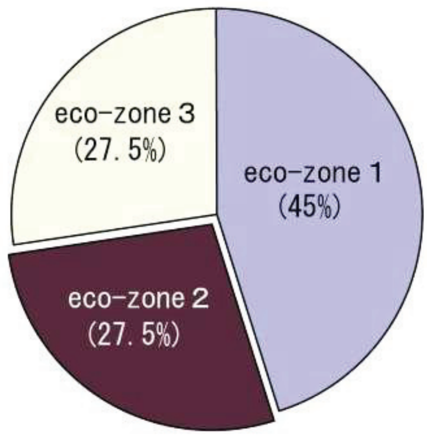

Figure 5. Distribution of fishing grounds.

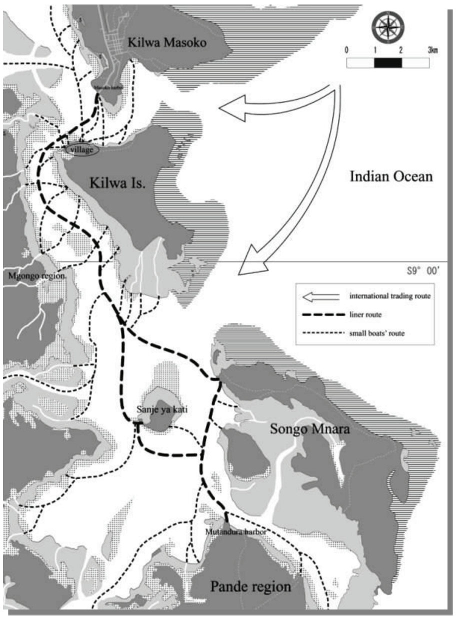

Figure 6. Mangrove inland sea routes.

Some 41 different kinds of fishing methods are practiced in Kilwa Island and more than half of fishing methods are of gathering type, practiced mainly in shallow waters like mangrove inland sea (Fig. 6).

There are 46 boats in Kilwa Island and they can be categorized as big and small boats. The big boats are keeled boats: *dau*, *mashua* and *boti* that can safely sail to open sea but are comparative expensive; the price of *dau* (645,000tsh) is about ten times of that of *mtumbwi* (60,000tsh). The small boats are canoe (*mtumbwi*) and flat bottomed boat (*mbare*) and they are comparatively cheep. Most fishermen of Kilwa Island possess small boats because of the convenience of use and low price. The small boats are more than half of all boats in Kilwa Island.

The fishery is mangrove inland sea centered. Fishermen well recognize each natural characteristics of fishing ground of mangrove inland sea; its depth, floor quality, catches etc. They fish mainly with small boat or by going on foot in mangrove inland sea. The natural conditions of mangrove inland sea (shallow, calm and rich of catches) give the opportunities to fish even to those who do not have fishing gear like net or boat.

5.2.2. Transportation routes

Because of the shallow and calm nature of mangrove inland sea, people use it as a safe transportation sea route. They do not use the open sea as a transportation route. Big keeled boat (like *dau*, *mashua* or *boti*) plies between Kilwa Masoko harbor and Mutandura harbor (Pande region) twice a week as a liner while small boats (like *mtumbwi* or *mbar*e) frequently come and go through mangrove inland sea. Through the latter route people and commodities move and get distributed. This network contributes to form the local community in Kilwa coastal region. For example, of the 101 married women of Kilwa Island, about 63% come from neighboring regions of Kilwa Island; 35% from Pande region, 5% from Mavuji region and 3% each from Kilwa Masoko, Mgongo and Songo mnara. The kinship of Kilwa coastal region has been formed thorough mangrove inland sea route.

6. Conclusion

Kilwa Island has two seas; mangrove inland sea and open sea with fringing reef. The maritime environment around the Kilwa Island can be divide into three ecological zones. The maritime life of Kilwa Island has well developed in these three eco-zones. In eco-zone 1 the inland sea covered with mangroves is more important and necessary than eco-zone 2; open sea is for the maritime life of Kilwa Island. That is why both the present village and the former Kilwa Kingdom were located near the mangrove inland sea.

The mangrove provides materials and the natural environment for use by the people dependent on them. The mangrove material is used directly in house building, making tools for fishing, boats and fishing gears, as the fuel for cooking, all essential for the maritime life in Kilwa Kisiwani. The natural environment of mangrove is used as rich fishing grounds and safe transportation route. It has helped in developing the community network in that region.

The relationship between the two different uses of the mangrove resources (direct use and environment use) hinges on a delicate balance. Excessive mangrove pole logging destroys the environmental value of the mangrove while prohibition of logging for conservation sake can lead to loss of livelihoods of the local people who depend on mangrove direct-use. Fortunately, the balance is not disturbed up till now in Kilwa coastal region in spite the daily use by the local people. One of the reasons is for this is the lowest population density of the southern coastal region include in Kilwa (12person /km^2). Recently the infrastructural and tourism development in this region is growing and offshore oil drilling has also been started near Kilwa Kisiwani in 2008. It' would be interesting to study how the relation between people and mangrove environment would change under these social changes.

The mangrove resources give countless benefits to the Kilwa Island where the living space and natural environment are limited. Island's life is tough, but thanks to the existence of mangrove resources, at one time in the Middle Ages Kilwa Island could achieve outstanding development -as Kilwa kingdom and as an international trading port, and still now people lead a rich maritime life in Kilwa Island.

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Theme 10. Enhancing livelihood of desert communities, socioeconomic studies and cross-cutting issues

10.1. Impact of policy-oriented agricultural research in dry areas: The case of rainfed barley fertilization in Syria

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Abstract

Fertilizer application in barley in Syria is a case where lack of enabling policy environment constrains the adoption of successful technologies. Before 1989, barley, a principal feed crop in the dry areas of the country, was excluded from fertilizer distribution from the government, the only source of fertilizer in the country. Barley fertilization was perceived as risky activity with low economic returns. In 1984, ICARDA and the Soils Directorate of the Syrian Ministry of Agriculture and Agrarian Reform (SMAAR) initiated a collaborative project over multiple seasons, through multiple location trials using a farming systems research approach to address the Syrian policy at the time which restricted fertilizer allocation to barley. The results of the project successfully convinced the policy makers to allocate fertilizers to barley in the two major agro-ecological zones for barley production (Zone 2 and 3) since 1989. Moreover, the new policy extended credit to farmers in Zone 2 for purchase of fertilizer for their barley. This paper established the policy influence of the ICARDA/SMAAR policy-oriented research and assessed its impact using economic surplus models taking into account pricing policy. According to the results of these models, the returns to policy oriented research in Syria are substantial with benefit cost ratio of 4 to1 and an internal rate of return of 70%. In contrast to the estimates under free trade in barley, the pricing policy and trade restrictions apparently did not alter the returns to policy-oriented research significantly. The study attempts to draw some lessons for future policy-oriented research

1. Introduction

Fertilizer application in barley in Syria is a case where lack of enabling policy environment constrained the adoption of successful technologies. Barley is a major feed crop in Syria, accounting for 2.2% of total value of plant production and 9.6% of total value of cereals in 2005. Barley area accounts for 27% of total cropped area and 40% of total cereal area. It represents 96% of the area of rainfed forage crops. Although barley is better adapted to such dry areas (200-350 mm annual rainfall), its yield levels were very low due to limited use of improved inputs, such as fertilizers. Unavailability of fertilizers except through government distribution and the government strategy of fertilizer allocation to strategic crops only were perceived to be the major constraint to wide adoption of barley fertilization. In 1984, ICARDA and the Soils Directorate of the Syrian Ministry of Agriculture and Agrarian Reform (SMAAR) initiated a collaborative project through multiple seasons, multiple location trials using a farming systems research approach to address the Syrian policy at the time which restricted fertilizer allocation to barley.

The influence and impact of the policy-oriented research (POR) analyzed here needs to be viewed in the context of the Syrian fertilizer policy. Fertilizer supply was fully under the control of the government which decided its allocation by crop and by agro-ecological zone. Before 1989, barley was excluded from fertilizer distribution. This policy was mainly based on the perception that barley production, a crop cultivated in drier areas, is too risky for investment in fertilizer use both for farmers and for policy makers. That perception persisted partly because of lack of technical evidence that could prove the contrary. Most of the barley varieties that farmers cultivated during that time were local varieties. However, researchers believed that fertilizer response could be obtained even with local varieties. The project was therefore designed to address this basic technical question and to provide evidence, which can be used to influence the fertilizer allocation policy.

This study examines the role of the policy-oriented project in changing the fertilizer policy to include rainfed barley as one of the crops that received fertilizer in 1989. This came after the project produced clear evidence of both economic response of barley to fertilization in the drier areas and the level of fertilizer treatments that will have no additional effect on yield risk but with clearly higher yields and positive income impacts. After the policy change, government started making credit available to barley farmers in the relatively higher rainfall area of Zone 2. The change in fertilize use increased land productivity and water use efficiency.

The objective of this paper is to provide evidence of attributing the barley fertilization policy changes to the collaborative ICARDA/SMAAR research project, its findings and the model followed to influence policymakers, to estimate the impact of this policy-oriented research in barley and to draw lessons learned from this experience.

2. Farming systems and agro-ecological zones of Syria

Although generally dry, Syria is a country that encompasses a great diversity of agro-ecological conditions and agricultural production systems. The country is divided into five agricultural stability zones according to the expected incidence of annual rainfall and their resulting suitability for rainfed crop production (Fig. 1).

Barley is grown exclusively as a rainfed crop in Zones 2, 3, and 4 on about 1.5 m ha on average annually across the three zones. Zone 2 has an annual rainfall of 250–350 mm in not less than two-thirds of the years. In this zone, it is possible to harvest two barley crops every three years and to grow wheat, legumes and summer crops. The 2,473,000 ha of Zone 2 represent 13.4 percent of the country area. Zone 3 covers an area of

1,306,000 ha occupying 7.1 percent of the total country area. The main crop in this zone is also barley, but legumes could be grown. Zone 4 is a marginal zone for agricultural production between the arable zones and the desert with annual rainfall of 150–200 mm.

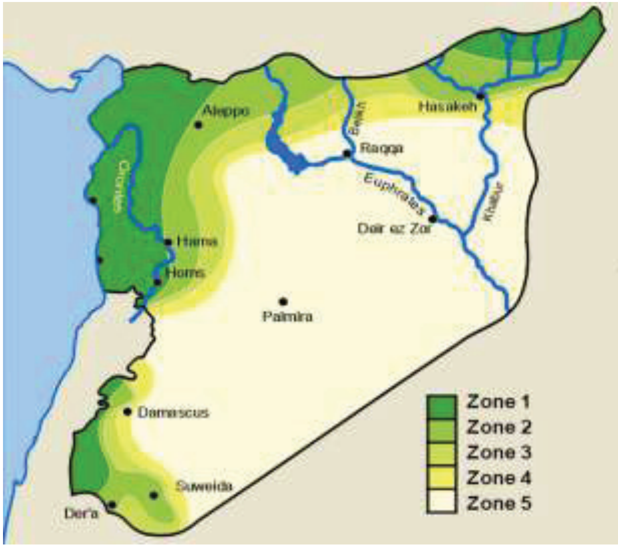

Figure 1. Agricultural Stability Zones in Syria. Source: Syrian Ministry of Agriculture and Agrarian Reform (1999).

The area of barley harvested depends on the erratic rainfall in this dry area. Highly variable crop area and yield lead to substantial output variability. Barley area reached a record high of 2.9 m ha in 1989 when the government encouraged continuous barley cultivation to increase production. At that time, barley was sown even in the drier parts of marginal areas where it encroached on rangeland areas. Since 1989, barley area has declined to its current level of about 1.3 m ha. The reduction in barley cultivated area was caused by:

- Irrigated wheat expansion in Zone 2,
- Farmers shifting from annual crops to perennial fruit trees especially olive,
- Continuous barley enhanced pest and disease pressures causing farmers to revert to barley–fallow rotations, and
- The enforcement of a ban on barley cultivation in Zone 5 (Badia) since 1996.

Despite the declining trend in barley area since 1989, productivity and total production initially rose until 1997 (Fig. 2). Between 1961 and 1989, barley area was expanding at an annual rate of 4.4 % and annual production was rising by 2.4 %, while yields were declining at a rate of 1.9 percent per annum. In contrast, barley area has been declining rapidly at an average rate of 5.5 percent per annum since 1990. During this period, annual yields grew at a positive rate of 1.5 percent, while production was declining at 4.1 percent per year. This yield increase is attributed mainly to the rapid diffusion of barley fertilization, especially in Zone 2.

3. The policy-oriented research project

The project was initiated in 1984 and continued until 1988. This was followed by two years, 1989-1990, of collaborative research between ICARDA and the Soil Directorate focusing on policy makers to modify fertilizers allocation policy and implementation of farmer-managed trials, results of which supported those of researcher-managed trials implemented in 1984-88.

The project aimed at producing sufficient and rigorous evidence to convince policymakers of the benefit of allocating fertilizer to barley and initiate a policy dialogue that eventually led to the policy change. The project also served to promote barley fertilization especially in Zone 3. This second objective would have not been achieved without removing the fertilizer supply constraint as fertilizer is supplied only by the government agency.

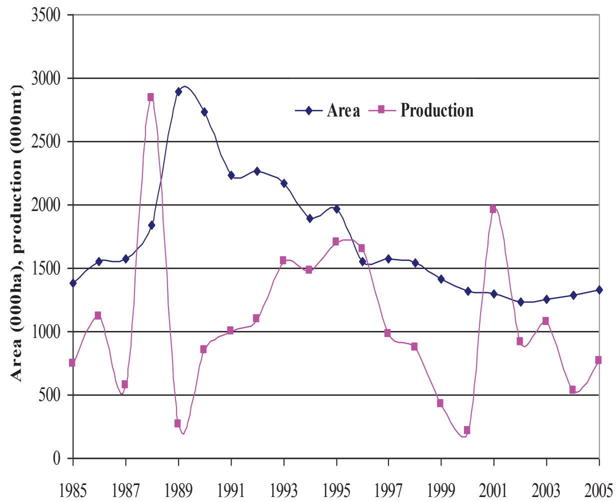

Figure 2: Barley area and production in Syria , 1985–2005), source: FAOSTAT (2008).

The project was interdisciplinary and included agronomic trials to determine the technical feasibility of fertilizer use on barley under drier environments and farm surveys as well as economic and risk analysis of fertilizer use on barley in drier areas. Trials on farmers' fields were conducted over a period of four years to investigate whether the large yield response to fertilizers obtained on research stations could be reproduced under the highly variable soils and rainfall conditions that farmers face in marginal dry areas. The agronomic trials were conducted in 75 sites over 4 years (1984-1988) as adaptive research under farmers' conditions. Data on productivity, soil analysis and rainfall were collected and analyzed. The economic studies included economic analysis of fertilize use as well as risk analysis of fertilizer use. These issues addressed all the basic assumptions which were the basis for the prevailing perception that underlined the fertilizer policy allocation.

Within the project, several workshops on fertilizer use on barley were launched:

- Joint ICARDA-Syria Soil Directorate workshop in 1984 to review 5 years research on barley response to phosphate and nitrogen fertilizers implemented under experiment stations condition.

- Meeting in Aleppo with the Ministry of Agriculture and Agrarian Reform on barley fertilization in Syria, 3-5 February 1986.
- Traveling workshop involving researchers and government and extension staff on fertilizer use on rainfed barley in Syria, 29 April 1987.
- Course on development of efficient fertilizer recommendation in the Mediterranean region (Aleppo), 7-18 March 1990.

Every year the results obtained from this project were discussed in annual national coordination meeting with the presence of large number of people influential in Syrian agriculture and with the presence of the Minster of Agriculture and the Director General of ICARDA.

The main outputs of the research project were:

1. Appropriate fertilizer application recommendations for barley for each zone in low rainfall areas were developed. Nitrogen was found to be more effective when used in split doses and the top dressing in the spring was conditional on the magnitude and the distribution of rainfall. Phosphorous on the other hand had a clear stabilizing effect at medium and occasionally even at higher rates; economic analyses as part of the project indicated that medium rates of 50-60 Kg/ha of P_2O_5 would be optimal;
2. Analysis of the risk of fertilizer use on barley in low rainfall areas indicated that there were fertilizer treatments for which the expected yield was higher than the control and the yield variance would not increase (Mazid and Bailey 1992). This conclusion provided evidence against the mainstream view that fertilizer increased yield variability.
3. A national economic decision (optimization) model was developed as a tool for policy makers for more economically efficient allocation of limited fertilizer supplies in Syria (Alhajj et al. 1990). The model disaggregated crops by the zones and examined alternative strategies for allocation of fertilizers in the country. The model advocated including barley in the government fertilizer allocation policy according to the recommended rates of fertilizer application in each zone. The model also advocated reducing the phosphate fertilization of other crops such as cotton and wheat (Saade 1991). The comparison between government fertilizer allocation strategy and the proposed model allocation of reducing the phosphate fertilization indicates that the model strategy would significantly increase national and farm incomes and aggregate crop output, and would reduce the government's foreign exchange and general budget deficits. Despite the superiority of the alternative allocation strategy suggested by the model results, the government did not adopt that strategy and only included barley in the fertilizer plan. The main reason for not adopting the fertilizer optimization model was the predetermined position of policy makers in giving top priority to fertilization of "strategic crops", and they were not willing to consider fertilizer reallocation.

As the response to fertilizer is significantly influenced by the amount of rainfall, the recommended level of barley fertilization is specific to the Stability Zone. For Zone 2, the policy-oriented research (POR) recommended 40 kg/ha of N and 40 kg/ha of P_2O_5 as compared to 20 kg/ha of N and 20kg/ha of P_2O_5 for Zone 3. No fertilizer is recommended for Zone 4, where almost one-third of total barley is grown, due to the low and erratic rainfall in this zone. The barley recommended fertilization rates are the lowest among all crops (Table 1). For instance, the recommended N fertilizer for wheat is 1.5-2.0 times that of barley.

4. Fertilizer allocation policy in Syria

Fertilizers as well as most other agricultural inputs are allocated to farmers by the government, based on planned crop area and priority for strategic crops (Shideed et al. 2008). The implication of this allocation policy was that irrigated crops and rainfed wheat in the high-rainfall zones received most, if not all their fertilizer requirements. Barley, a rainfed crop grown in the driest zone, was thus excluded from fertilizer allocation until 1989.

Table 1. Fertilizer recommendation for selected crops in Syria

Crop	Stability zone	Fertilizer rate (kg/ha)	
		N	P_2O_5
Irrigated wheat		150	100
Wheat (HYV)	Zone 1	100	80
Wheat (HYV)	Zone 2	80	60
Wheat (local)	Zone 1	80	60
Wheat (local)	Zone 2	60	60
Wheat (local)	Zone 3	30	30
Barley	Zone 1	50	40
Barley	Zone 2	40	40
Barley	Zone 3	20	20
Cotton	Irrigated	200	150

Source: FAO (2003).

About 60 percent of the country's fertilizers requirements are produced locally and the balance is met by imports. The Agricultural Cooperative Bank (ACB) distributes both imported and locally produced fertilizers to farmers directly and through cooperatives. The ACB is both lender of loans and distributor of inputs. The quantity of fertilizers and other inputs is pre-determined according to a recommended crop plan and formalized by issuing a crop license to every farm at the beginning of each cropping year. Such plans were mandatory and subject to severe penalties for non-adherence. Recently, and with the reduction in government restrictions since 1999, these crop plans are becoming indicative but continue to be used to determine the total quantity of inputs a farmer receives from the ACB. Fertilizer loans are provided to barley farmers in Zone 2 by ACB at 4 percent interest rates. No loans are provided for barley fertilizers in Zone 3 while no fertilizer is allocated to barley farmers in Zone 4.

The government sets fertilizer prices based on fertilizer import costs and domestic production or procurement price. Imported fertilizer is sold to farmers on a cost-recovery basis (1 percent above landed value) while the farmers' price of locally produced urea is set not to exceed 10 percent of its cost of production. However, since 2003, urea sales to farmers have been subsidized.

5. Barley pricing policy in Syria

The government determines the barley procurement (official) price in advance, based on estimated cost of production and expected yield plus a margin of profit. In most years (e.g., 1997–2002), the procurement price was above the world price. According to this policy, the government procures barley from farmers directly at this support price level and rations it to livestock owners at a predetermined price. This price is usually about 10 percent above the procurement price (to cover transaction costs), but is lower than the market price level by up to 17 percent as was the case in 2000. Farmers with livestock are allowed to keep part of the barley they grow for their livestock.

In the past, the government imposed taxes on barley imports to protect local production and producers. In 1999, the government partially liberalized barley trade policy by removing barriers on barley imports including import taxes to encourage barley imports to substitute for the drastic reduction in local production in response to severe drought. At the same time, the government eased its requirements for barley procurement. The higher market price encouraged farmers to sell their produce in the market to the private sector rather than to government authorities. In 2004, only 50 percent of barley production was sold through government channels.

6. Perceived influence of POR

In measuring the contribution of research to changes in policy, one of the critical issues is how to assess the causality between research and the implementation of the policy (Norton and Alwang 1998). To establish the policy influence, this study follows the approach used by Ryan (1999). This approach involves interview of partners, stakeholders and policymakers about their perception of how the policy change has taken place and the role of the different institutions in the change. The partners and stakeholder survey was undertaken in the summer of 2007 by interviewing 16 persons who were either partners in the POR or stakeholders in the outcome who are mostly involved in policy making process. The number is reasonable given the nature of the policy itself and the policy making process in Syria at the time. The participants included scientists from the national agricultural research institute and government officials at different departments in the Ministry of Agriculture who were involved in the policy change.

A list of 20 questions was drafted. The questions covered the crop fertilization policy making process, the institutions involved, the evolution of barley fertilization policy, the relationship between research and policy making process and the perceived role of POR project in changing barley fertilization policy in Syria.

Each interviewee was visited, briefed and requested to participate in the survey. It was planned initially to directly interview each of those selected but this was found to be impractical because of the time commitment of most of the participants who were generally senior government officials. The interviewees resorted to written responses and the completed forms were sent to authors. In fact, this alternative appears to remove any bias that may arise in direct interviews. Table 2 summarizes the responses obtained from the interview.

The majority of the respondents agreed that the Fertility Division of the Soil Directorate in the Agricultural Research Authority, the Directorate of Statistics and Planning at the Ministry of Agriculture and Agrarian Reform, the Supreme Agricultural Council and the Agricultural Cooperative Bank were the most important institutions involved in making decisions related to crop fertilization policy in Syria for the role each takes in the decision making. The Fertility Division (formerly known as the Directorate of Land) is responsible of establishing the recommendations on fertilization rates for different crops in all regions based on sound research results. The Directorate of Statistics and Planning estimates the country needs of the different types of fertilizer for all crops and different regions based on the recommended fertilization rates and planned crop area allocation. The Director of the Fertility Division and the Director of the Statistics and Planning are both members of the Technical Committee which is headed by the Minister of Agriculture and which prepares the annual fertilizer plan. This plan is submitted to the Supreme Agricultural Council for deliberation and approval. Members of the SAC included the Prime Ministers, Minister of Agriculture, Minister of Planning, Minister of Economics, Minister of Irrigation and Minister of Finance. The Agricultural Cooperative Bank is the executing agency which delivers and distributes fertilizers to farmers based on the recommended rates and the area allocation for each farm.

These institutions and their roles were taken into account in the attempt to influence the fertilizer decisions. While the Fertility Division of the Soil Directorate participated in the research, this information is used in the policy dialogue to include barley in the fertilizer plan, given the fertilizer policy environment at the time. The role of the researchers in the Soil Directorate was critical as allocation of fertilizer as well as other inputs is based on scientific results. According to the interviews, the fertilizer policy in Syria followed strategic priority system where cotton, an export crop, has the top priority followed by the major food crops (wheat and sugar beet). In general, irrigated crops have higher priority than rainfed due to the perceived risk. As a result, barley, the rainfed crop grown in dry areas with less than 250 mm of rain, has low priority in this plan. The respondents cited risk and uncertainty of rainfall in the dry areas, low response and low returns to barley fertilization as the main constraints to allocation of fertilizers to barley. The barley fertilization project targeted these constraints.

Based on the national fertilizer policy in Syria, fertilizers were not allocated to barley before 1987-88 cropping season. According to the interviews, the main driving forces behind including barley in the fertilizer plan were the results of the scientific research obtained from the collaborative research between the Directorate of Land and ICARDA which were submitted to the Fertilizer Committee and then to the Supreme Agricultural Council. The response praised the role of the Director of Fertility Directorate as the "Champion" in adopting the powerful findings and convincing policy makers.

All respondents indicated that the involvement of ICARDA in barley fertilization project has helped in speeding up the policy decision by at least 10–15 years. Half of the respondents believed that the policy change would have not happened without the joint research involving ICARDA. The other half suggested that an alternative non-scientific policy would have been made without the research, but only after a long period of time. The impact pathway is depicted in Figure 3.

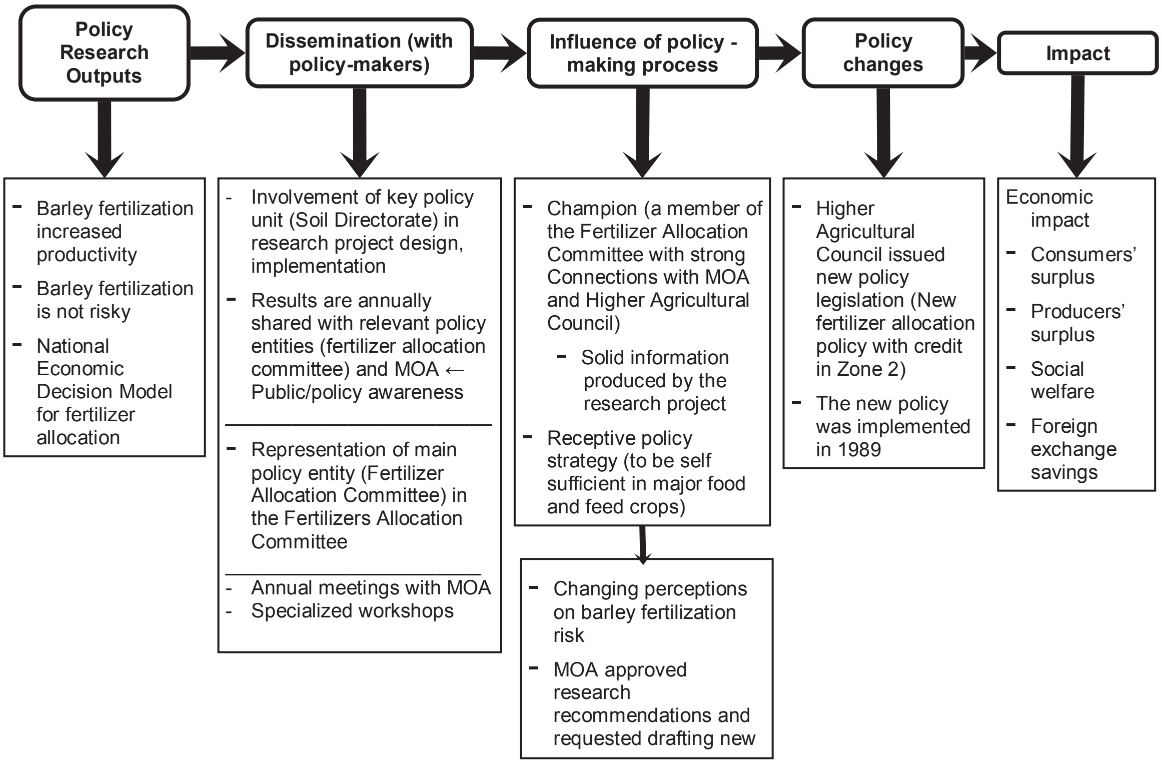

Figure 3. Impact pathways of barley fertilization research.

Table 2. Summary of the responses obtained from the stakeholder interview

Question or issue related to ICARDA study	**Number of responses**	
	Positive	Negative
What role did Syria/ICARDA collaborative research play in barley fertilization decision under rainfed conditions?	17	1
Did you see the involvement of an International Research Organization (e.g. ICARDA) was important and/or necessary to reach the barley fertilization policy?	18	0
Did barley fertilization policy (as you see it) have positive or negative effects on the economy?	17	1
Do you think that the barley fertilization policy would have been achieved anyway (even without the research results of Syria/ICARDA collaborative research)?	9	9
Do you think that ICARDA involvement in barley fertilization research helped in speeding up the policy decision?	15	3
Are there other aspects of barley fertilization under rainfed conditions that need new research?	9	6
Do you think that the use of research results has continued as a reliable information source for policy in fertilizers allocation?	17	1

Source: Compiled by authors from stakeholder interviews.

7. Specifying the counterfactual and attribution

For documenting the impact of the POR, it is important to establish the counterfactual in absence of the policy-oriented research in barley for defining the base case. The most important aspects of the counterfactual are related to farmers' practices before the policy change and how would have the fertilizer policy in Syria evolved in the absence of the POR.

7.1. How would the fertilizer policy in Syria evolved in absence of the policy-oriented research?

Some respondents in the stakeholder survey predicted that the fertilizer allocation policy would have been changed but with a long delay due to factors other than the research, e.g., farmers pressure. Some respondent estimated the delay to be 10-15 years or more. This means that research was only successful in speeding the policy change and the benefits are only relevant during the period by which the policy would have been absent. Consequently, the impact of the policy-oriented research in this study will be assumed to span over 15 years. Based on the above discussion, the counterfactual is defined as follows:

1. The policy of excluding barley from fertilizer distribution would have been eventually reversed and the government of Syria may have responded to other influence to include barley in its fertilizer allocation strategy after fifteen years (beginning in 2004). Therefore, the flow of benefits to consumers and producers of barley in the first fifteen years after the policy change (1989-2003) represents the economic impact of the policy change.
2. Barley fertilization before the policy is unsustainable in the long run because it requires shifting substantial quantities of fertilizer from other crops. Government might have intervened to enforce its fertilizer allocation strategy.

There is evidence that some adoption existed in Zone 2 even before the policy change in 1989. Based on farm survey, half of the farmers interviewed in Zone 2 reported application of fertilizers on barley before the policy change in 1989 (Mazid 1994). No data is available on the level of application of fertilizers to barley. In contrast, adoption was minimal in Zone 3 before the policy change due to the lower rainfall. Because government was the only source of fertilizer during that time, some farmers were apparently shifting some of the fertilizer allocated to other crops to their barley. Therefore, the policy change has two positive productivity outcomes:

(i) Fertilizer became available to barley at the recommended level in both Zone 2 and 3 without the need to smuggle fertilizer from other crops resulting in higher barley yields and larger national output than would have been without fertilizer.

(ii) Credit became available to barley farmers in Zone 2 for purchase of fertilizers, speeding up the adoption of barley fertilization.

(iii) Although data on rates and extent of barley area fertilized is unavailable, barley fertilization before the policy change was likely to have been inadequate and covered only part of the barley area where it was needed most. Moreover, the sustainability of this source of fertilizer is questionable since fertilizer market is controlled by the government. Thus, without the policy oriented research, which led to the policy change, barley fertilization would have continued at best at the 1988 level where an estimated 60% percent of barley farmers in Zone 2 and 7 percent in Zone 3 apply some fertilizer.

8. Documenting the impact of POR

8.1. Conceptual definition of the impact of the POR

In conceptualizing the impact of the POR on barley fertilization in Syria, it is important to examine adoption patterns of barley fertilization with and without the policy change. Based on the adoption survey (Mazid 1999), barley fertilization in Zone 2 was considerable even before the policy change in 1989 with 60% of farmers surveyed in Zone 2 reported some application of fertilizer to their barley. With the government control of fertilizer allocation and absence of other sources for fertilizer, the fertilizer used on barley before the policy change must have been shifted from other crops (e.g., cotton and wheat) for which the government allocates fertilizer based on the recommended rates (see Table 1) and planted area on each farm. Clearly, shifting fertilizer from these crops reduces their expected yields, if the allocated fertilizer rates were optimal, resulting in social losses. Shifting fertilizer from other crops, in theabsence of policy change, may have continued until the value of the marginal product of fertilizer is equated across all crops including barley (equals the price of fertilizer), according to the multi-output optimality principle. For lack of data, we cannot establish whether or when this optimality condition holds.

Under such conditions, the value of barley yield gain from fertilization equals the value of the loss in yield of other crops deprived of part or all of their fertilizer requirements as per the government policy.

The policy change has two results. First, fertilizer becomes available to barley at the recommended levels in both Zone 2 and 3 without the need to shift fertilizer from other crops resulting in higher barley yields and larger national output than would have been without fertilizer. Besides, it made fertilizer available to farmers who may not have had access to fertilizer if their cropping system did not include crops that were part of the government's fertilizer allocation policy. Credit availability to barley farmers in Zone 2, as part of the policy change, has encouraged wide dissemination and intensive use of barley fertilization. Secondly, assuming that recommended fertilization rates of these crops are economically optimal, other crops deprived of all or part of their fertilizer allocation before the policy change started receiving their recommended levels resulting in positive impact (savings in yield losses).

8.2. The policy of excluding barley from fertilizer distribution would have been eventually reversed without the POR.

The government of Syria may have responded to other influence to include barley in its fertilizer allocation strategy after fifteen years (beginning in 2004), according to the stakeholder interviews. In this case, adoption of barley fertilization would accelerate thereafter.

Given the above discussion, two scenarios of adoption paths and associated impact of barley fertilization with and without POR are illustrated in Figure 4. The segment 0A of adoption curve shows the actual adoption path of barley fertilization before the policy change in 1989. Fertilizers applied to barley during this period was shifted from other crops, mainly wheat and cotton. With the POR leading to allocation of fertilizers to barley, adoption of barley fertilization accelerated reaching its ceiling in 2003 and is expected to continue at this level thereafter (curve ABC[1]). The area under this curve represents the entire gains from barley fertilization with the POR.

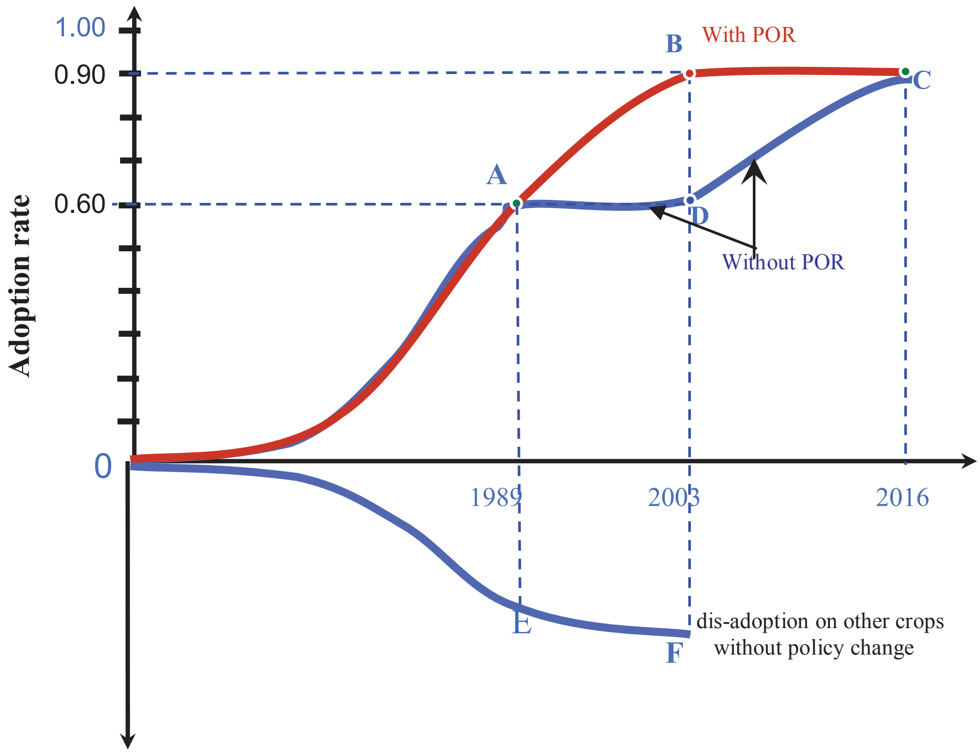

Figure 4. Alternative adoption paths and impact of barley fertilization with and without POR.

However, the fertilizer policy in Syria was predicted to be reversed naturally (without the POR) to include barley into fertilizer allocation after 15 years. In this case, adoption would have initially accelerated slowly or remained at pre-policy level until 2003 (curve AD) and then accelerate faster thereafter (curve DC). This means that adoption in this case will reach a ceiling level identical to the ceiling of barley fertilization associated with the POR in 2016 (point C). The area under the curve segment ADC represents the gains from barley fertilization without the POR. However, since adoption of barley fertilization before 2004 would have resulted in shifting fertilizer from other crops, it would lead to dis-adoption of fertilization on other crops until 2003 (curve 0F). If

[1] AB is the observed adoption path of barley fertilization from 1989 to 2003. Since adoption is perceived to have reached its ceiling, it is expected to continue at this level to point C.

recommended fertilizer rates are optimal, area above this curve represents the losses from barley fertilization in absence of policy change.

In principle, the impact of the POR is given by the difference between the benefits from barley fertilization with the policy change and the gains without the policy change (Ryan 1999). Without the policy change, the gains from barley fertilization equal the gains in barley yields without POR (area under the curve 0ADC) minus the losses in yields of other crops resulting from illegal shift of their fertilizer to barley (area above segment of the curve 0F). With the policy change, the benefits equals the gains from barley fertilization associated with adoption after the policy change (area under the curve ABC) plus the gains from restoring pre-policy yield losses of other crops made possible by the policy change (the negative area above the curve EF). The issue is whether there are losses in yields of other crops resulting from illegal shift of their fertilizer to barley. This depends on economic optimality of the recommended fertilizer rates of other crops. When the quantity of fertilizer applied to the crop is higher than the optimal level, the value of marginal product is smaller than fertilizer price and returns to fertilizer application can be increased by reducing the quantity of fertilizer until optimality is restored. In this case, shifting fertilizer from other crops does not reduce their yields. Therefore, marginal loss in other crops can be neglected. In this case, the benefit due to the POR in barley equals the gains from increased barley yields associated with barley fertilization after the policy change, i.e., the area under the curve ABC minus the gains from increased barley yields from shifting fertilizer from other crops without the POR (area under ADC) during the period of 1989-2016.

If recommended rates of fertilizer are optimal, shifting fertilizer from these crops to barley results in yield losses. Therefore, the benefit due to the POR in barley that led to the fertilizer policy change is equal to the gains from increased barley yields associated with barley fertilization after the policy change (area under the curve ABC) minus the positive difference between the marginal gains in barley fertilizer (area under ADC) and the marginal losses in other crops (area above EF) without the POR (Fig. 4). This implied that the actual benefits from POR are larger if recommended rates of fertilizer are optimal than the previous case. For lack of data, this paper cannot establish whether recommended levels of crop fertilization in Syria are economically optimal. Optimal fertilizer level depends on output prices, fertilizer prices and the expected increase in yield from fertilization (MP of fertilizer) which depends on rainfall in rainfed agriculture. As such, we expect the optimal fertilizer rates to vary from season to season, by crop and from area to another. In Syria, the recommended fertilizer rates are based on agronomic yields and some simple profitability calculations. Although the rates of fertilizer in Syria on all crops (see Table 1) are not excessive, the observed shift of fertilizer to barley before the policy change weakens the optimality assumption.

We assume that the recommended levels of fertilizer on other crops were higher than optimal and that farmers didn't lose much by diverting excess fertilizer to barley (the first scenario above). This is equivalent to assuming that marginal loss in other crops is zero. This reduces the benefits attributed to POR by the value of the losses to other crops compared to benefits under optimality assumption. For lack of data, this value cannot be determined. Therefore, the benefits attributed to POR can be approximated by the area ABCD of Figure 4. This will then be a conservative estimate or a lower-bound estimate of benefits attributed to POR taking into consideration the possibility that the recommended fertilizer rate of other crops may be optimal or below optimal.

8.3. Theoretical framework

In this study, we assessed the returns to policy-oriented research in the output market based on the economic surplus model commonly used in the impact assessment literature. As commonly practiced, the social returns to policy-oriented research in barley are measured as the change in social welfare defined as the sum of the changes in consumers' and producers' surpluses resulting from the shift in the barley average and marginal cost (supply) curves of individual farmers. Several forms of demand and supply functions are used in the literature to estimate the benefit from research. Measures of total research benefits and their distribution between producers and consumers are quite insensitive to choices of functional form but quite sensitive to the choices concerning the nature of the research-induced supply shift (Alston et al. 1995). Thus, assumptions about these are unavoidable. We assume a constant elasticity supply and demand functions in this study following Akino and Hayami (1975).

The policy change led to a shift of the barley supply curve by making fertilizer available to farmers so that they can increase barley yields. We will analyze the impact of the fertilizer policy change in terms of its effect on the barley output market. It is important to note that the fertilizer allocation to barley did not negatively impact other crops in Syria as wheat and cotton continued to receive their recommended fertilizer requirements. That is, fertilizers allocated to barley were supplied from additional fertilizer imports. The costs of these as well as other associated costs (fertilizer application and additional harvesting costs) will be taken into consideration.

As shown in Figure 5, d and S_o represent the observed demand and supply curves (after the policy change) and S_n represents the supply curve that would have existed in absence of the policy-oriented research (and policy change). The equilibrium price that would have cleared the quantity (Q_n) is P_n. Syria is considered as small producer of barley with trade restrictions on barley for most of the years during the 1980s and 1990s. Assuming that barley in Syria is not traded internationally, the shift of the supply curve from S_n to S_o would result in lower equilibrium price (P_o) and larger quantity Q_o. The change in consumers' surplus is given by *area abc* + *area* bP_nP_oc, the producers' surplus by *area ac0* – *area* bP_nP_oc, and social benefit by *area abc* + *area ac0*.

The analysis is more complicated for tax or subsidy policies where a research-induced supply shift causes changes in government revenues as well as changes in the surplus measures (Alston et al. 1988). Until 1999 when grain barley market was partially liberalized, the Syrian government was pursuing a price support and strict procurement policy requiring farmers to deliver their barley output to government stores at a predetermined price. The procurement (official) price is based on estimated per unit cost of production and expected yield plus a margin of profit. This policy kept the domestic price of barley above the world price for most of the years. The producers know the level of the procurement price in advance each year, and thus they aim to produce whatever amount they wish to supply at the announced price, subject to their resource endowments. Because of the higher procurement price, they produce a larger quantity, implying that excess supply exists at the procurement price.

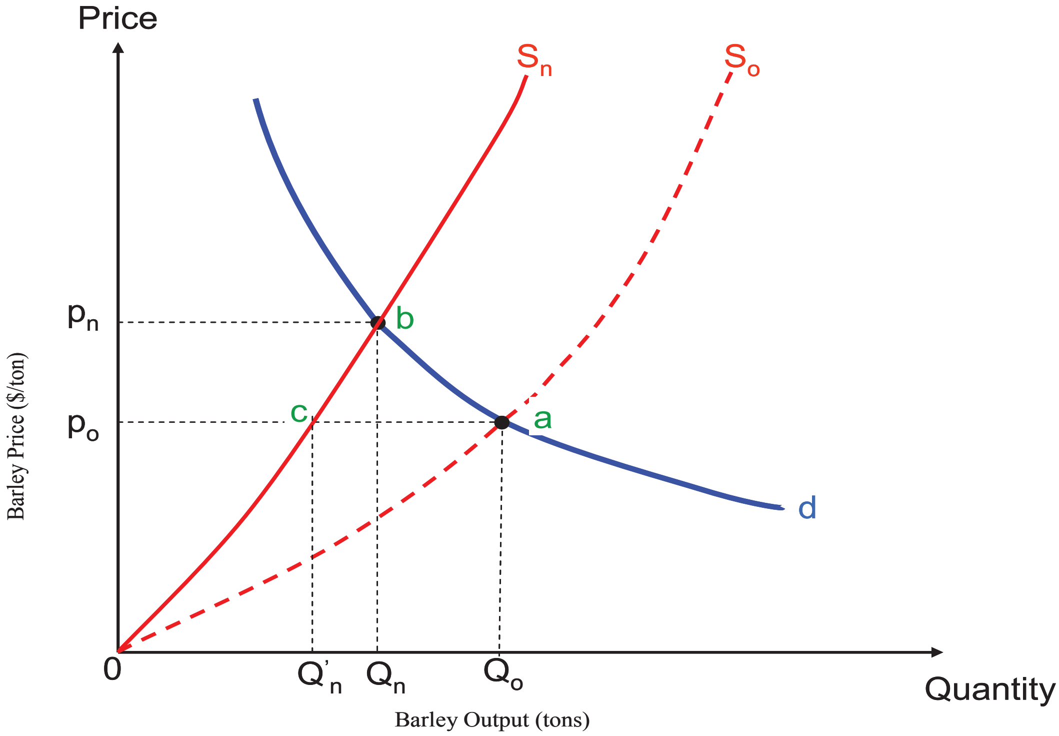

Figure 5. Model of estimating social returns to policy-oriented research in barley
Source: Akino and Hayami (1975).

Figure 6 depicts the effect of procurement price on research benefits in a closed barley economy (with trade restrictions). Without government price intervention, the market equilibrium is defined by P_n and Q_n, the price and quantity of barley. Given a price support level, $\hat{P}$, producers supply *Q'* in the barley market that clears the market at a lower price *P'*. The gains to producers from the procurement price policy are first, receipt of a higher price than with no program for quantity Q_n and, second, the net gains on the additional quantity they choose to produce at the higher support. These gains sum to *area* $\hat{P}E_obP_n$ of Figure 6. On the other hand, consumers of barley gain because they pay a lower price, P_o, on Q_n and can obtain additional barley that they value at more than the price P_o. The consumers' gains sum to *area* abP_oP_n in Figure 6. The government cost of the price support policy in this case is given by the area $\hat{P}E_oaP_o$. Subtracting the producer and consumer gains leaves *area* abE_o as the net social loss (deadweight loss). This is the social cost of the guaranteed price policy.

With the supply shift to S_o attributable to the fertilizer policy change, producers supply a larger quantity *Q'*, given the procurement price $\hat{P}$. This quantity clears the market at price *P'*. The change in producers' surplus is given by the *area* E_oE_1O, the change in consumers' surplus equals *area* $adP'P_0$, the government incurs additional cost of the price support policy of $E_oE_1de + eP'P_0a$, and the social cost of the price policy is given by the triangle E_1df (Figure 6). Research benefits are estimated as the change in consumers' surplus plus the change in producers' surplus minus the change in government cost (Alston et al. 1995).

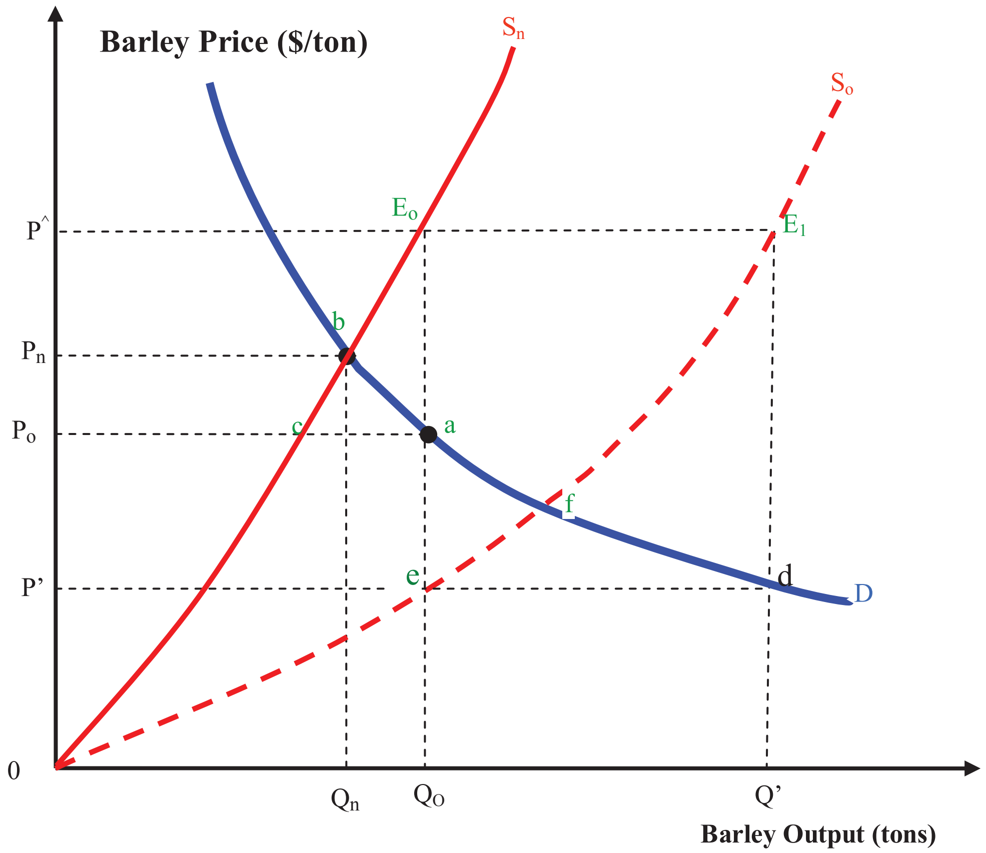

Figure 6. Benefit from POR under procurement price policy. Note that $P^{\wedge}$ is the government procurement price and Q_o and Q' are the corresponding quantities produced without and with the supply shift, respectively. P_n and Q_n are the equilibrium price and quantity in absence of both government price support and supply shift. P_o and P' are, respectively, the market clearing prices in the presence of the price support policy before and after the supply shift. Source: Adapted from Akino and Hayami (1975), Gardner ((1987), and Alston et al. (1988).

The above model assumes that the price paid by consumers is freely determined in the market, i.e. livestock owners pay the price that clears the market at the larger quantity produced (*P'*). However, the price support policy of the government did not allow for market forces to determine the equilibrium price that clears the barley market. Rather, the government, the largest single seller of barley to consumers (livestock owners), rations barley to consumers (livestock owners) at about 10% above the procurement price to cover its transaction costs[2]. Given that there was no evidence of significant surpluses of barley and the procedure used in setting the procurement price, the government has adjusted the level of procurement price based on the new policy-induced supply curve. In this case, the change in consumers' surplus is eliminated and

[2] The government rationed barley was the major barley market until 1999 when the government partially liberalized the grain market and eased its restrictions on procurement.

the entire research benefit is captured by producers. The implication of this is that change in consumers' surplus and the additional government cost approaches zero as consumer price approaches the procurement price. Therefore, during the period of the procurement price policy, the gross benefits from research are reduced to the change in producers' surplus (*area* E_oE_1O).

In recent years, the barley price support policy becomes ineffective as government output delivery requirements were eased and farmers began to take advantage of the higher market prices by selling their barley in the free market. During this period 1999-2003, the policy-induced benefits are based on the model of Figure 6 presented above. Although the output market is now relatively liberalized, the input market is still under government control. The government is still the main supplier of fertilizer to barley and other crops.

8.4. Quantitative estimation

The quantitative estimation of the benefit from the policy-oriented research is based on the model developed by Akino and Hayami (1975) for estimating the benefit from rice breeding in Japan as illustrated in Figure 5. Akino and Hayami (1975) assume a constant elasticity demand and supply functions of the form:

$Q_d = Ap^{-\beta}$

$Q_s = Gp^{\alpha}$

where Q_d and Q_s are respectively the quantity demanded and supplied and β and α are the price elasticities of demand and supply, respectively. The supply curve that would have existed in the absence of policy-oriented research is given by $Q_s = (1-h)Gp^{\alpha}$ where h represents the rate of shift in the supply function due to barley fertilization. The rate of shift in the supply function (*h*) is related to the proportional shift of the aggregate production (k) by the following approximation:

$h \approx (1 + \alpha)k$ .... (1).

Based on Akino and Hayami (1975), the following approximations hold in equilibrium in absence of price support policy (Figure 5):

$$area\ ABC = \frac{1}{2} P_o Q_o \frac{[k(1+\alpha)]^2}{\alpha+\beta} \quad \ldots \quad \ldots\ldots\ldots\ldots\ldots \tag{2}$$

$$area\ A0C \approx kP_oQ_o \ \ldots\ldots \quad \ldots\ldots\ldots\ldots\ldots\ldots \tag{3}$$

$$area\ BP_nP_oC \approx \frac{P_oQ_ok(1+\alpha)}{\alpha+\beta}\left[1 - \frac{\frac{1}{2}k(1+\alpha)\beta}{\alpha+\beta} - \frac{1}{2}k(1+\alpha)\right] \tag{4}$$

and,

$$area\ ACQ'_nQ_o \approx (1+\alpha)kP_oQ_o \ \ldots\ldots\ldots\ldots\ldots \tag{5}$$

With procurement price policy (Figure 6), equation 3 can be modified as follows:

$$E_0OE_1 \approx kP^{\wedge}Q' \tag{3a}$$

Equations 2-4 and 3a are used here to estimate the change in consumers' surplus, producers' surplus and economic surplus due to policy-oriented research in barley. Equation 5 measures the gain to foreign exchange to country should the country choose to import an equivalent quantity of barley. The net change in economic surplus is defined as the sum of changes in consumers' surplus and producers' surplus resulting from the rightward shift of barley supply curve minus the research, extension, additional inputs (fertilizer and labor for distribution of fertilizer and additional harvesting and transportation costs). Fertilizer cost is computed as the quantity of fertilizer applied to barley times the import price of fertilizer.

The estimation procedure involves estimating the welfare changes with and without POR. With POR, the benefit stream begins in 1989 to 2016 based on the observed adoption path where diffusion of barley fertilization reached its ceiling of 82% in 2005 in Zone 2 and 24% in 1994 in Zone 3 and expected to continue thereafter (see Figure 6). Without POR, adoption continues at its pre-policy level of 1989 (59% and 7% in Zone 2 and 3, respectively) for fifteen years (until 2003). Adoption then accelerates in both zones, as a result of the anticipated change in the fertilization policy without the POR influence, to reach its ceiling in 2016. The difference between the welfare change with and without POR is the attributed benefit to the POR.

The basic case, as defined by the counterfactual, represents the actual policy environment in Syria during the period of analysis, i.e., producer procurement price and administered –fixed- consumer barley prices up to 1999 followed by free market pricing. The model is then used to conduct a systematic sensitivity analysis varying the important model parameters to test the stability of the results and to determine the important factors determining the benefits from barley policy-oriented research.

8.5. Parameters and data

Based on the economic surplus models depicted in Figures 3 and 4, values for price elasticities of supply and demand are needed to generate estimates of the returns to collaborative ICARDA–SMAAR research project. A price elasticity of supply of 0.395 was estimated from a constant elasticity supply function founded on time-series data on barley output produced and procurement price for the period of 1985–2005. A similar regression was used to obtain the price elasticity of demand from data on the total country commodity balance and barley consumer price during the same period. An estimate of -0.495 was obtained.

The rate of the shift in barley production depends on the yield gain from fertilizer application and the rate of adoption of the fertilization as measured by the percentage of area fertilized and is given by the following equation (Allen 1975):

$$k_t = [1-(y_t^{\wedge} / y_t^{o})]a_t \qquad (1)$$

where: $y_t^{\wedge}$ is the yield of unfertilized barley in year t, y_t^{o} is the yield of fertilized barley in year t, and a_t is the proportion of total barley area fertilized as a result of the policy change. Thus, the term $[1-(y_t^{\wedge} / y_t^{o})]$ measures the yield gain as a result of barley fertilization using the POR recommended fertilizer rate while a_t measures the diffusion rate of barley fertilization caused by the policy change (i.e., the ratio of barley area fertilized to total barley area).

The response of barley yield to nitrogen and phosphate fertilizer and rainfall was estimated by Mazid et al. (1999) using on-farm, fertilizer-trial data from the collaborative ICARDA–SMAAR research project. A quadratic function was used to predict the yields of barley with and without the recommended rates of fertilizer separately for Zones 2 and 3 (Shideed et al. 2008). In Zone 2, the yield gain associated with the recommended barley fertilization rate of 40 kg N + 40 kg P_2O_5 ranged from 31 percent to 43 percent and averaged 33.5 percent. Similarly, the application of the recommended rate of 20 kg N + 20 kg P_2O_5 in Zone 3 results in 20-88 percent increase in barley yield with an average yield increase of 30 percent.

The estimated cumulative adoption rates of fertilizer use (the proportion of farmers applying fertilizer) on barley in Zones 2 and 3 are based on Mazid et al. (1999). Barley fertilizer is not recommended in Zone 4 due to the low and erratic rainfall. In fact, the collaborative ICARDA–SMAAR research project did not recommend the fertilization of barley in this zone. Based on an adoption survey in 1993, nearly 85 percent of the adopters in Zone 2 apply fertilizer to all their cultivated barley. But in Zone 3, only 15 percent of the adopters apply fertilizer to their whole barley area (Mazid 1994) due to the sparse rainfall, lack of credit to purchase fertilizer, and low barley productivity. To extrapolate the change in the proportion of fertilized barley area over time, we assume that both the proportion of farmers applying fertilizer and the proportion of fertilized land changed at the same rate (Shideed et al. 2008). The aggregate adoption intensity, i.e., the proportion of fertilized barley area in each zone, is then calculated as the product of proportion of farmers applying fertilizer and the proportion of fertilized land.

The cost of the project was relatively small, and the project was built on ICARDA research on barley fertilizer in dry areas. Research operations were funded from research grants received by ICARDA in 1985 (US$ 0.2 million from the United Nations Development Programme –UNDP), in 1986 (US$ 0.3 million from UNDP), in 1987 (US$ 0.418 million from UNDP and Near East Foundation NEF) and in 1988–1989 (US$ 0.091 million from NEF). The calculation of the human resource cost of ICARDA and NARS scientists is based on the methodology described by Aw-Hassan and Shideed (2003). One scientist year is assumed to be allocated to the POR by ICARDA and NARS. This is multiplied by the cost of scientist time of ($0.125 m for ICARDA and $0.05m for NARS) for each year. The extension cost is estimated at $10,000 per year throughout the entire period of adoption (1989-2003). Other secondary data on costs were assembled from the Syrian Ministry of Agriculture and Agrarian Reforms (2006).

9. Results and discussion

Until 1999, the Syrian government imposed taxes on barley imports to protect local producers. At the same time, the government was using output procurement, price support and fixed consumer price system. The price support kept the domestic price above the world price. During this period, the barley market can best be described as a closed economy with substantial policy distortions. The implication of this policy environment is that consumers' surplus as the welfare gain from technological change is eliminated while producers accrue positive gains[3]. The difference between the guaranteed price and the price that would have prevailed in the absence of the policy represent a welfare transfer from consumers to producers. In year 1999, the government partially liberalized barley trade policy by removal of barriers on barley imports including lifting of import taxes to encourage barley import to substitute for drastic reduction in local production due to severe drought. Besides, the procurement requirements were eased allowing farmers to sell to other buyers. Market prices since then were higher than the government guaranteed level. This encouraged farmers to sell their production in the market to private sector instead of the government authorities.

The estimation of the benefits from the barley POR followed a dynamic approach to clearly reflect the pricing policy switch of 1999. In the first period of 1989–1999, the returns to research were estimated using the model with procurement price policy illustrated in Figure 6 above. During the second period (since 2000), the welfare impacts are based on the model represented in Figure 5 as explained earlier. The change in consumers' surplus, producer's surplus, and economic surplus (consumers' plus producers' surpluses) and net economic surplus (economic surplus minus research, adoption and extension costs) are summarized using the net present value and the average annual flow in real 2003 dollars in Table 3. A discount rate of 5 percent comparable to the borrowing rate in Syrian commercial banks was used to calculate net present value (NPV). In addition, estimates of the internal rate of return (IRR) and benefit–cost ratios are also presented in Table 3.

Based on the economic surplus model estimates, the NPV of the change in consumers' surplus exceeded US$ 37 million with an average annual flow of US$1.34 million (Table 3). The NPV of the change in producers' surplus approached US$37.76 million (Table 3). Net economic surplus was equivalent to US$73.42 million. The IRR to investment in research and extension was 70 percent. These are respectable levels of returns to research and compare to returns obtained elsewhere, e.g., sorghum research in the Sudan (Ahmed et al. 1995) and the rates of return to research and extension for crop genetic improvement reported by Evenson and Rosegrant (2003). However, the benefit–cost ratio to the POR in barley of 41 is significantly below that reported by Ryan (1999) for the case of rice policy changes in Viet Nam where estimated benefit–cost ratios ranged from 56 to 187.

Since the Syrian government policy objective is based on food/feed security and import substitution, an important impact indicator of the policy change is the savings in foreign currency on barley imports. The accumulated savings from 1989–2016 was about US$ 92.4 million with an average annual flow of US$ 3.3 million (Table 3). Several factors explain these high estimated levels of benefits. First, the barley sector in Syria is fairly large in terms of area and output. Second, diffusion of fertilization was rapid especially in Zone 2 reaching a ceiling of 90 percent within few years, and the yield gains were high despite the variability of yield over time. Third, the flow of benefits continued for a

[3] In our model and as a result of the pivotal supply shift, producers benefit only when demand is elastic (Lindner and Jarrett 1978; Alston et al. 1995). When demand is inelastic, as is the case of barley in Syria, producers necessarily lose from a pivotal supply shift.

reasonably long period of time (28 years). Finally, the research duration was short (only 4 years) for the low cost of only US$0.22 million a year on average.

What would have been the benefits from research to influence barley fertilization policy in Syria if barley market is fully liberalized? To estimate the benefits under liberalized market, the Syrian barley economy is assumed to be a small open economy without trade restrictions and barley is traded at the import price for Syria. Since consumers' surplus would remain unchanged under this assumption, the change in consumers' surplus is eliminated and the producers' gain would be equivalent to the total benefit produced from the policy change. This is because the consumers will be indifferent to whether the additional quantity they purchase is produced locally as a result of the policy change or imported since it is valued in both cases at the world price. All benefits are captured by producers with the change in producers' surplus amounting to US $ 64.425 million. With net returns of US $ 62.6 million, the IRR is 70% and the benefit-cost ratio exceeds 35 (Table 3). The average annual net benefit in this case amounts to US$ 2.235 million. As such, the policy distortions, namely the trade restrictions and procurement pricing during the 1990s, in the barley market in Syria did not significantly reduce the net benefit from the fertilizer policy change[4]. The reduction in benefits from POR is caused by the lower world price used to value barley output. These results are consistent with FAO (2003) findings that estimates of the value cost ratio defined as ratio of the value of the increase in output due to fertilizer use divided by the total fertilizer cost, derived from international prices is lower than estimates of VCR derived from domestic prices. Domestic research benefits are greater under target price than with free trade (Alston et al. 1988). The liberalization of the barely market in recent years has allowed consumers to capture some of the benefits attributed to policy-oriented research.

Table 3. Welfare changes associated with the POR on barley fertilization in Syria

Welfare indicator	**NPV $ million**	**Average annual flow ($ million)**
Benefits under observed pricing policy		
Change in consumers' surplus	37.500	1.339
Change in producers' surplus	37.757	1.348
Economic surplus (CS+PS)	75.257	2.687
Net economic surplus	73.423	2.622
Foreign currency savings	92.391	3.300
Internal rate of return	70.16	-
Benefit/cost ratio	41.03	-
No policy distortions		
Change in consumers' surplus	0.000	0.000
Change in producers' surplus	64.425	2.300
Economic surplus (CS+PS)	64.245	2.300
Net economic Surplus	62.591	2.235
Foreign currency savings	54.547	1.948
Internal rate of return	70.08	-
Benefit/cost ratio	35.125	-

[4] These results, however, do not imply the superiority of policy distortions. Rather, it implies that policies that create a divergence between private producer and social returns to research may lead to misallocation of research resources.

The policy-oriented research aimed at creating the enabling policy environment for adoption of barley fertilization in Syria. While this was successfully achieved, other policy distortion remained. Nevertheless, the returns to policy-oriented research in Syria are still substantial with high rate of return to investment in public research.

10. Conclusions and lessons learned

The policy-oriented research aimed at creating the enabling policy environment to speed adoption of barley fertilization in Syria. While this was successfully achieved other policy distortion remained which have influenced the impact of the policy changes. Nevertheless, the returns to policy-oriented research in Syria are still substantial with high rate of return to investment in public research. Based on economic surplus model estimates, the POR resulted in an internal rate of return to investment in research, dissemination and adoption of 64% and a benefit-cost ratio of 14. Clearly, the returns to the policy-oriented research appear to be substantial.

The policy-oriented research has encouraged government investment in marginal dry areas by allocating fertilizer to farmers in Zone 3 in Syria. This has led to the intensification of barley production, increased yield and farm income, and thus enhanced farm feed security. In this zone, crop-livestock system is a major source of livelihoods. Given that most of the poor are located in marginal dry areas, increasing public and private investment has important equity dimension in addressing poverty reduction.

The successful implementation of POR research in Syria on rainfed barley fertilization was scaled out to neighboring countries (Iraq, Jordon and Lebanon) through the Mashreq project on increased productivity of barley and small ruminants in low rainfall areas of Mashreq countries during 1989-92, and then through Mashreq and Maghreb project on the development of integrated crop/livestock production systems in low rainfall areas of West Asia and North Africa region during the 1994-98. This spillover effects are additional impact of POR.

This study has provided important lessons some of which are:

1. Policy makers only partially adopted the results of the POR. Particularly, the reallocation of fertilizer among crops was not adopted by policy makers as suggested by the national economic decision model. Of particular concern to government was the reallocation of fertilizer from wheat and cotton to other crops, as these crops are considered as strategic commodities.
2. The design of the POR project reflects the importance of having the relevant and effective partner national institution in POR. Involvement of Soil Directorate has greatly facilitated the policy influence through the leading role of the "Champion" to effectively and timely communicate the results of POR to policy makers. Besides facilitating the policy influence this also speeded up the policy change.
3. Building the mechanism of policy influence in the project design and implementation and the ability of POR to develop sound research outputs directly addressing the concerns of policy makers are extremely important.

Although this case study represents an ex-post with a time lag long enough to realize the impact of the POR, it has its complications in attributing the achieved benefits to the POR due to the change in other government policies. Also the use of fertilizer on barley before the policy change complicated further the calculations of benefit stream due to lack of data on the extent of the negative effect on crops before the policy change. To our knowledge, most studies analyzing the level and distribution of benefits from research in the presence of government interventions are theoretical (e.g. Alston et al. 1988). This case study is a contribution to the limited empirical literature dealing with returns to research under policy distortions.

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10.2. Impact of investment in crop improvement research: the case of winter-sown chickpea in Syria

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Abstract

This study generated information from farmers regarding the performance of winter-sown chickpea technology developed by ICARDA in comparison with the traditional spring planting, and assessed the impacts of the winter chickpea technology. The data was gathered from 480 farmers in Aleppo, Idleb, Dara', and Hama provinces in Syria, in collaboration with the Syrian National Program. The results indicated that ascochyta blight, insects, diseases, and weed were the most important factors affecting the productivity of winter sown-chickpea in Syria. Variety was widely adopted and most farmers have in addition adopted other components of the recommended package. The area under winter-sown chickpea is expanding, particularly in drier regions like Zone 2 in Aleppo province that are not traditional chickpea-growing areas. Adoption intensity is higher for better-off farmers, as poorer farmers are more risk-averse and prefer to see the positive effects before adopting the new technology themselves. An examination of adoption over time shows it is still increasing at an accelerating rate, and is projected to reach its maximum of 90% by 2015. The benefits are obvious, as winter-sown chickpea technology has increased yields by about 18% in the drier areas and 32% in other parts of the country. All farmers, poor and better-off, earned increased incomes. These gains are extremely important given that chickpea contributes about 21% to the average household's income of about US$13,900 with winter chickpeas accounting for 14% and the spring crop for only 6%. Therefore, the winter-sown technology is profitable and proved appropriate for all types or wealth categories of farmers who obtained high net returns from growing winter-sown chickpea. Household incomes of chickpea farmers in Syria have also been shown to have increased following their adoption of winter-sown chickpea technology with the resulting impact being higher among poor farmers. The technology also increased employment opportunities for women. The water productivity increased in terms output per unit of rainfall.

1. Introduction

Chickpea *(Cicer arietinum* L) is an annual grain legume that is used extensively for human consumption. The dried seeds of this plant are commonly used in soup, while in the Middle East and India they are more frequently cooked and blended with rice dishes. The primary use in Syria is to prepare *Homus bet-hina* dish or *falafel* sandwich. Major chickpea producer countries include India, Pakistan, Mexico, Turkey, Canada, Syria and Australia. Chickpea makes up more than 20 percent of world pulse production, after dry bean and pea.

Chickpea provides important economic advantage to the small farm households as alternative source of protein, cash income and soil improvement through rotation in cereal dominated farming system. In spite of its importance, chickpea productivity has remained very low; the major constraints contributing to low productivity are low yield potential of landraces and their susceptibility to biotic and abiotic stresses, and poor cultural practices.

In Syria chickpea is the second most important rainfed food legume, following lentil in terms of area planted. This has been the case for the past twenty five years. Over the same period, the place of chickpea in terms of percentage of area planted to all rainfed crops has remained relatively constant at about 2%. Annual production, however, has trended to move upwards during the period 1981– 2005 at an average rate of 1.6% per annum. Estimated annual growth rates of the area during the same period was 1.4% and for the yield was only 0.29%. Although there has been a noticeable trend towards increasing area planted to chickpea, the trend in increased production is less noticeable due to the downward trend in yield. It was initially to reverse this downward trend that the new winter varieties were developed.

Chickpea in Syria is traditionally sown during spring on the soil moisture conserved from winter rains and therefore its productivity is constrained by terminal drought and vascular wilt. The farmers plant chickpea in spring if sufficient rainfall has taken place during the winter months. Since pressure on land is increasing, the economic benefit one can get from spring chickpea is declining relative to other crops in the farming system; therefore, the area and production has not been stable.

Chickpea farmers in Syria like those in other West Asia and North Africa (WANA) countries avoided winter sowing because of the risk of heavy crop losses due to two factors: a fungal disease called Ascochyta blight that can kill the plants, reduce yield and affect seed quality; and cold stress in years with a severe winter. However, winter sowing produces plants with a longer flowering period, more pods, and higher yields than those sown in spring (Singh et al. 1997). This is because crops get the benefit of winter rainfall, and lower temperatures as they approach maturity, so that the moisture they do receive is less subject to evaporation. Therefore, winter-sown chickpea, through its higher yield potential. promises more productive use of land, stabilize chickpea area, and sustain the farming system.

2. Winter chickpea technology development and transfer

The International Center for Agricultural Research in the Dry Areas (ICARDA) has a regional responsibility for the improvement of Kabuli chickpea. In its mission to meet the challenge posed by a harsh, stressful and variable environments; ICARDA is involved in the development and delivery of improved technologies to the national programs in collaboration with the national agricultural research systems and advanced research institutions. The breeding objectives at ICARDA are targeted to address the specific needs of different agro-ecological regions and to address key stresses prevailing locally. Full-fledged breeding programs are in operation in case of chickpea. Following a bulk pedigree method, and a decentralized breeding strategy, the breeding programs developed new genotypes to deliver to the national institutions. To aggregate desirable genes, rigorous gene mining and their pyramiding became an important part of integrated gene management program at the Center.

The first winter-sown chickpea variety developed by ICARDA and released in Syria in 1982 was Ghab 1. It was followed by a second variety, Ghab 2, in 1986; then Ghab 3 in 1991. Two other new varieties, Ghab 4 and Ghab 5, which have relatively larger seed size than Ghab 3, were released in 2002. The five new varieties offer the potential of considerably increasing national chickpea productivity. The new winter-sown varieties were developed to be resistant to both ascochyta blight and cold. In over ten years of scientific trials, both on-station and on-farm, winter-sown chickpeas have consistently out-yielded the local spring-sown cultivars. The yield difference is usually between 50% and 100% (ICARDA 1987). The higher yields are due to a longer growing season, better utilization of moisture during growth and maturation, a higher germination rate, more favorable soil moisture and temperature conditions during reproductive growth, better nodulation, and less damage from insect pests (ICARDA, 1981).

Improved agronomic packages were developed by ICARDA with about 10 years of joint work with the national programs, very useful information on date of planting, plant population, rhizobia inoculation, weed control (including herbicides and mechanical harvest) were generated. An on-farm assessment of chickpea practices in northwest Syria was carried out by ICARDA (Pala and Mazid 1992). Thirty on-farm trials were conducted during 1985-89. The results indicated that changing the sowing date from spring or late winter to early winter increased seed yields. *Rhizobium* inoculation produced inconsistent seed yield response. Weed control with herbicides increased seed yield compared with unweeded control, but was less effective than hand weeding. Application of 50 kg P_2O_5/ha increased seed yields in the first 3 seasons. The overall yield increase was 10%. Drilling chickpea seed increased seed yield by 10% compared with broadcast sowing commonly practiced by farmers. It was concluded that a combination of early winter sowing, drilling, weeding, and, where appropriate, Phosphorus application, is likely to produce high seed yields and maximize net revenues.

ICARDA in collaboration with the Department of Agricultural Extension in the Syrian Agricultural Ministry and the General Commission of Scientific Agricultural Research in Syria (GCSAR) has played a vital role in dissemination of winter chickpea technology in Syria. Many field days were jointly organized by ICARDA and the Syrian National Programs in the farmers' fields; small amount of seeds of new varieties has been distributed to chickpea producers, and extension material on winter-sown chickpea has been printed and distributed.

Currently, the recommended winter-sown chickpea package comprises of two components: main and optional components. The main component included:

- Using improved varieties: Ghab 3, Ghab 4, Ghab 5
- Seed rate: 120 Kg/ha
- Planting date: First half of January
- Chemical seeds treatment
- Protecting spray against ascochyta blight during the second half of March
- Weed control when plant height reached 10 cm

The optional component included: Reliable seed source, using drill for planting, super phosphate fertilizer at the rate of 100 kg/ha, using herbicide before planting, using mechanical weed control, and using additional fungicide spraying (1-2 times) as and when needed

3. Study objectives and methods

Impact assessment of agricultural research program is generally conducted to evaluate how well the research program has done in the past, to inform stakeholders on the return to their investment and convince research financers for continued support, and to draw lessons from past performances for improving efficiency of research program (IAEG 1999). This study was conducted in collaboration with Syrian national Program to get information from chickpea farmers regarding the performance of the winter-sown chickpea in comparison with the traditional spring planting, to conduct impact analysis of winter chickpea technology, and to know the constraints, if any, to the adoption of winter chickpea technology for ICARDA back up

Cross-sectional sampling was used in this study to include farmers who received winter chickpea seeds from official sources such as ICARDA or General Organization for Seed Multiplication (GOSM) in addition to other farmers who are growing chickpea. The sample of household surveyed was drawn from lists of farmers growing winter chickpea in the 2004/2005 season provided by the Extension Directorate of Agriculture Ministry and GOSM. In addition to these lists, lists of other farmers who grow chickpea, either spring and/or winter, in the target areas were also used. However, the sample in this study included two types: (1) Farmers applying the winter chickpeas technology including farmers who received seeds from ICARDA in 2004/2005 season and those who bought seeds from GOSM in 2004/2005 season and (2) other farmers.

The sample chosen included 470 farmers on the basis of their seed source and province. About half of the entire sample got their seeds from official sources (ICARDA or GOSM) assuring that they used new chickpea varieties, and the other half got the seeds from other sources. About 63% of farmers in the sample grew only winter chickpea, 27% grew spring chickpea, and 10% grew both winter and spring chickpea. The sample covered about 160 villages located in 40 sub-districts, 15 districts in Aleppo, Idleb, Hama (Al-Ghab), and Dar'a provinces in the agro-ecological zones 1 and 2. The survey questionnaire focused on: the place of chickpea in the farming system, cultivation practices, production economics, crop performance and yield, household assets, household livelihood, and farmer evaluation of adoption potential. Several tools were implemented in this study for the analysis including descriptive and econometrics methods.

4. Farmers' perception on winter chickpea

Farmers' assessments of new varieties provided insights into the farmers' adoption decision behaviour. Understanding the criteria that farmers use to evaluate new crop varieties allows breeders to effectively set priorities and target different breeding strategies to different communities in the dry areas. For this purpose, farmers were asked to rank the factors affecting productivity of winter chickpea technology. It is important to note here that these farmer assessments were not facilitated by any agricultural professional, hence they are independent, individual, farmers' views based on their own judgments of the performances of the varieties and their preferences. Ascochyta blight, insects & diseases, and weeds were the most important factors affecting the productivity of winter sown chickpea (Table 1). Variety was an mportant factor but was ranked as moderate by the surveyed farmers.

Table 1. Factors affecting productivity of winter chickpeas (% of farmers)

Factor	No affect	Low	Moderate	High
Variety	14.9	6.0	43.4	35.8
Previous crop	18.0	17.4	39.6	25.0
Date of sowing	4.7	5.6	39.4	50.3
Method of sowing	14.9	13.6	43.7	27.8
Seed rate	6.3	8.5	43.9	41.4
Seed treatment	8.2	12.3	30.4	49.1
P- application	21.5	10.9	29.3	38.3
Insects & diseases	3.8	5.8	19.9	70.5
Weeds	2.2	5.0	27.1	65.6
Ascochyta blight	4.2	8.0	15.7	72.2
Credit	29.1	15.2	32.1	23.5
Marketing	24.5	15.4	28.1	32.0

The ranking of winter chickpea varieties compared to the spring cultivar was done by farmers who planted the varieties and observed their yield performances and other attributes. They indicated that the characteristics of winter chickpea were better than spring chickpea except for their grain size, grain colour, and price of grain (Table 2).

5. Measuring adoption and diffusion of winter- sown chickpea

Three adoption indicators were used: (1) Adoption rate which represents the percentage of farmers adopting the technology, (2) Degree of adoption which represents the proportion of land under the new technology, and (3) Intensity of adoption which is equal to adoption rate time degree of adoption (Shideed *et al.* 2005). Table 3 shows these indicators by stability zones, provinces, and wealth quartiles of the farmers. Adoption of winter chickpea is expanding in Zone 2 which is drier compared to Zone 1 and which is not a traditional chickpea-production area. As a result, Aleppo province that covers part of Zone 2 also showed high intensity of adoption compared to other provinces. Dar'a is a traditional chickpea production area; however, due to the lack of extension support to farmers, adoption is relatively low there. It is also evident that the intensity of adoption is highest for the well-off farmers. Poorer farmers are sensitive to the risk associated with early adoption of any new technology, and they take time to observe the positive effects before increasing adoption intensity.

Table 2. Comparison of the characteristics of winter and spring chickpea (% of farmers)

Characteristic	Winter is better	Spring is better	No difference	No idea
Frost resistance	64.2	8.3	6.1	21.3
Ascochyta resistance	48.9	16.9	11.4	22.8
Drought resistance	38.2	21.2	13.2	27.4
Yield under marginal conditions	54.7	7.4	9.9	28
Earliness of maturity	72.3	6.1	2.5	19
Needs more weeding	54.6	8.7	17.9	18.9
Easiness for mechanical harvest	71	1.8	5.6	21.5
Resistance to shattering	27.6	12.4	30.9	29.1
Grain size	11	69.1	4.1	15.9
Grain color	14.5	53.7	11.9	19.9
Grain yield	66	7.9	6.1	20.1
Straw yield	34.6	21	19.4	24.9
Cooking time	30.4	11.6	13.4	44.6
Price of grain	14	58.4	9.2	18.4
Taste	15.6	26.8	20.8	36.9
Consumer demand	23.5	39.3	14	23.2

Table 3. Adoption rate and adoption intensity of winter chickpea varieties

	Area of winter chickpea	Total chickpea area	% of winter chickpea	Adoption rate (%)	Adoption intensity (%)
Zone:					
Zone 1	1.2	1.8	65.7	64.0	42.0
Zone 2	3.0	4.6	65.8	72.7	47.8
Province:					
Aleppo	2.3	2.6	85.6	75.0	64.2
Idleb	1.3	2.0	67.8	66.2	44.9
Hama/El Ghab	1.0	1.4	68.1	63.8	43.4
Dar'a	1.8	4.7	37.8	43.6	16.5
Wealth quartiles					
Lowest 25%	0.8	1.4	56.6	56.5	32.0
25%-50%	1.1	1.8	64.7	64.6	41.8
50%-75%	1.1	1.7	66.0	67.5	44.5
Highest 25%	3.0	4.6	65.7	73.3	48.1
Average	1.6	2.4	65.7	66.0	43.4

The Syrian extension agents provided farmers with full package and it was farmers' decision on the uptake of individual components or the full package. Results of this study indicated that only three farmers adopted the full package and most farmers adopted one or a few technology components in addition to winter chickpea variety. Table 4 summarizes adoption rate for the main and optional technology components associated with using new (winter chickpea) varieties. In addition to the new variety more than 50% of farmers adopted planting date, seed treatment, fungi and weed control. These results are consistent with previous adoption studies which showed clear tendency of farmers towards the adoption of individual technological components compared to full package adoption.

Table 4: Adoption rate of winter-sown chickpea components (% of farmers)

Component	Zone 1	Zone 2	Both zones
Main components			
No. of observations	*253*	*77*	*330*
Seed rate	38.7	13.6	32.7
Planting date	53.6	40.5	50.7
Seed treatment	49.0	63.6	52.4
Fungi control	69.9	50.6	65.5
Weed control	98.0	79.2	93.6
Full package	1.1	0	0.9
Optional components			
Reliable seed source	72.1	61.0	69.1
Using drill	64.1	57.3	62.5
Appling super phosphate fertilizer	70.3	44.2	64.2
Appling 100 Kg/ha of super phosphate	22.5	23.3	22.7
Using herbicide before planting	29.2	11.7	28.2
Using mechanical weed control	8.7	0	6.7
Using (2-3) spraying against Ascochyta	18.9	7.8	16.4

The ultimate effect of technology on producer and consumers depends on factors such as household resources, markets, social assets, and institutional context. The existence or absence of effective extension mechanism, market, favorable credit system, and social assets greatly determine the uptake of the agricultural technology thereby determining their ultimate effect on the well-being of producers and consumers. Economic gains from a technology among different social groups may vary depending on their control on resources and access to information, credit and market. At early stage of introduction of a new technology, the poor may not adopt the technology until they are sure that risk of adopting the new technology is minimal. Thus, at initial stage, the benefit that could be derived from adoption of technology goes to the well to do farmers, who can absorb risks associated with new technology.

Logistic Regression (Logit Model) was applied in this study to identify factor influencing winter chickpea adoption. This model estimates the probability of adopting a new technology, given certain conditions. It is a quantitative relationship between adoption and influencing factors that would determine whether a farmer will or will not adopt the new technology based on series of characteristics of the farm and the farmer to predict the probability of adoption. The results indicate that stability zone, total holding area, having irrigation source, farmer's age, chickpea yield obtained by farmers in 2005, score of wealth index, and farmer's participation in field days were the most important factors influencing farmer decision to adopt winter chickpea technology. All these factors were significant and positively affected farmer's decision to adopt winter chickpea technology, except 'acceess to irrigation source' (Table 5).

Table 5. Coefficients of factors influencing adoption of winter chickpea

Factor	B	S.E.	Sig.	Exp(B)
Zone	1.347	0.447	0.00	3.84
Total holding area	0.064	0.023	0.00	1.07
Having irrigation source	-0.877	0.317	0.01	0.42
Farmer's age	0.037	0.012	0.00	1.04
Chickpea yield in 2005	0.001	0.000	0.00	1.00
Wealth index	0.685	0.341	0.04	1.98
Participating in field days	0.724	0.377	0.05	2.06
Constant	-6.535	1.188	0.00	0.00

-2 log Liklihood 292.747; Cox & Snell R2= 0.251; Nagelkerke R2=0.349
Percentage of correct prediction = 76%

The time dimension is essential in the diffusion process; it is an important aspect of any communication process. Researchers (Rogers 1983; CIMMYT 1993) have shown that adoption of an innovation when plotted against time often follows a normal distribution curve. If the cumulative number of adopters is plotted over time, the resulting distribution is an S-shaped curve, and the logistic curve is the most common way of representing technology diffusion.

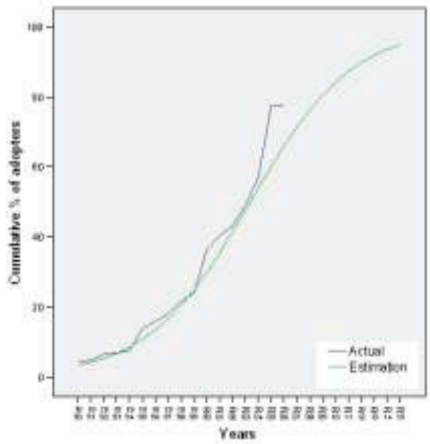


Figure 1. Diffusion of winter chickpea varieties.

Based on the time-series data of the number of adopters of winter chickpea varieties which were gathered in this study, the coefficient values of the logistic functions which gave the best fit of the time-series data was estimated, and the actual and predicted cumulative percentages of adopters is shown in Figure 1. Adoption increased at an accelerating rate and it is expected that its maximum (90%) will be reached by 2015.

6. Impact assessment of winter chickpea technology

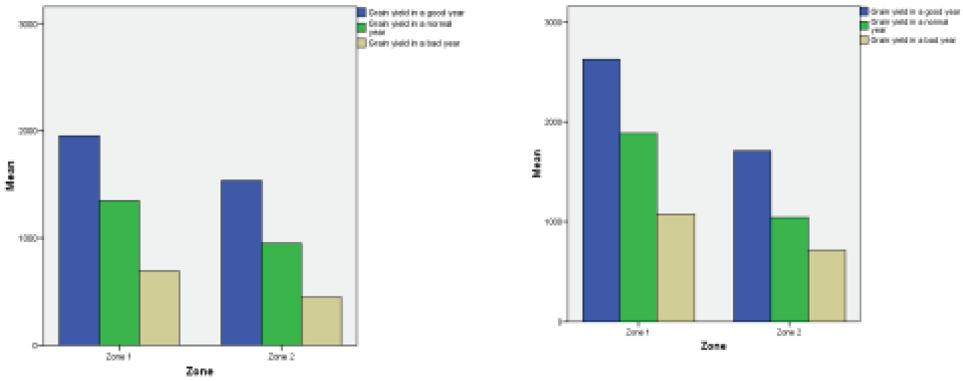
Adoption and diffusion of a new technology is essential to achieve an impact. Impact assessment of research is a special form of evaluation and deals with effects of research output on target beneficiaries (IFPRI 2004). In general it attempts to look at both intended and unintended effects. Basic concepts of impact assessment are: causality, attribution and incrementality. The typical impact chain starts from the set of inputs and activities of a project or program to the most highly aggregated results, such as productivity, profitability, poverty reduction, food security, environmental protection, etc. The chain also specifies all the main intermediate steps: the activities of a project, the output, the use that others make of this output, the direct as well as possible indirect effects, and the implications of the use of these outputs on the ultimate beneficiaries. Impact refers also to measurable effects of the outputs and outcomes on the well being of the ultimate beneficiaries of the research and development efforts, namely the poor, the food and nutrition insecure, and the environment. Most socio-economic impacts and developmental impacts fall in this category (IFPRI, 2004).

6.1. Impact on productivity

Agricultural productivity is a widespread indicator for impact assessment of new technology. Successfully increasing the productivity of resources devoted to crop production will bring a real income gain for farmers. Simple measurement, specifically grain yield per unit area, was used in this study to measure changes in factor productivity.

Results show that the winter-technology had a positive effect on crop productivity. Yields obtained by farmers, in both Zone 1 and Zone 2, who adopted the full or some components of the technological package were higher compared to non-adopters during good, normal, and dry years (Figure 2). The magnitude of the yield difference between winter and spring chickpea obtained by farmers varied from 33% to 54% in Zone 1, and from 9% to 61% in Zone 2, and depended on the rainfall in the season and other climatic conditions. Improved variety was an important component in increasing yields; spatial distribution of yield gain due to shift to winter sowing using improved varieties was about 32% in Zone 1, and 18% in Zone 2

Multiple linear production function was also developed for chickpea in Syria. The dependent variable was grain yield obtained by farmers in 2005 season. The independent variables included rainfall, variety, seed rate, use of supplemental irrigation, amount of super phosphate applied use of pest control, and total labor needed per hectare. All these variables affected positively and significantly the yield as shown in Table 6. In terms of productivity effect, the coefficient on winter-sown variety adoption dummy variable was positive and statistically different from zero at 1% level.



Spring chickpea **Winter chickpea**

Figure 2: Estimated average chickpea yields in good, normal, and bad seasons; first, seond and third bar respectively.

Table 6. Estimated multiple linear production function for chickpea in Syria

Variables	Unstandardized Coefficients		Sig.
	B	Std. Error	
Constant	-624.184	169.038	.000
Rainfall in 2005	2.990	.271	.000
Variety (Dummy variable, 1=use winter sown variety)	379.941	60.960	.000
Seed rate (kg/ha)	4.004	.867	.000
Supplemental irrigation (Dummy variable)	379.952	104.944	.000
Amount of super phosphate (46%) on winter chickpeas	1.070	.369	.004
Using pest control 1 time	100.936	64.331	.117
Using pest control 2 times	549.896	97.016	.000
Total labor used per hectare	5.019	.836	.000

Dependent variable: Grain yields in 2005
Adjusted R Square = 0.456 F (493, 7) = 51.22***

6.2. Impact on profitability

Winter chickpea is profitable technology for farmers, it is possible to increase the net revenue by more than US$ 200 per hectare, and the ratio of the net revenue increase to the additional costs is about 318%. All categories of farmers very poor, poor, moderate, and well-off (Table 7) obtained higher net revenues from winter chickpea as opposed to spring one. This result provides evidence of the appropriateness of the technology for all type of farmers.

6.3. Impact on household income

Income is widely used as a welfare measure because it is strongly correlated with the capacity to acquire many things that are associated with an improved standard of living. Income gains are a valid indicator of the impacts because the productivity gains attributable to the adoption of technologies logically should be reflected in income gains.

The average annual household income in the sample was estimated at US$ 13,900. The contribution of chickpea in the total household income represented about 21%, which is distributed between winter chickpea (14%) and spring chickpea (6%). This contribution was higher for the farmers who grew winter chickpea, and for the poor farmers compared to well-off

Table 7. Costs and revenue of spring and winter chickpeas (Syrian Pounds/ha)

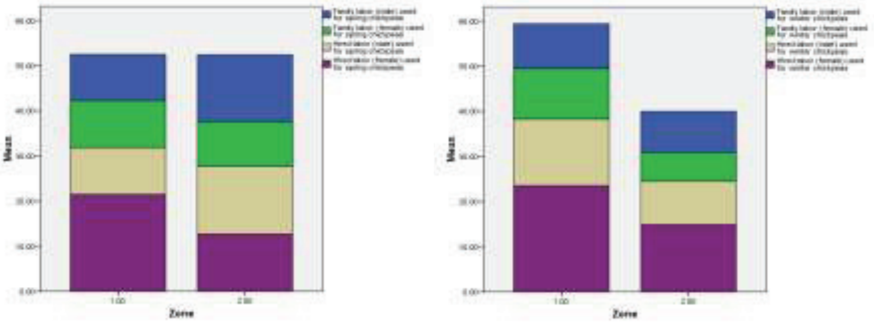
	Spring			Winter		
Wealth quartiles	Total revenue	Total production costs	Net revenue	Total revenue	Total production costs	Net revenu e
Lowest 25%	50288	16098	34191	63122	19684	43437
25%-50%	45689	14641	31048	58074	18818	39256
50%-75%	46079	15960	30119	59935	18278	41657
Highest 25%	46458	16569	29889	62404	19204	43201
Average	47404	15839	31565	60869	18974	41895

6.4. Impact on labors employment

Adoption of winter chickpea technologies has generated job opportunities for laborers. Adopter farmers started using hired labor for different farm operations and this has locally generated job opportunities for rural laborers. Figure 3 show the estimation number of labor needed per hectare by gender for winter and spring chickpea for Zone 1 and Zone 2 in Syria. There is clear indication that winter chickpea increased labor requirement for certain operations such as weeding. Because weeding operations are mostly carried out by family and non-family female labor in rural areas, increased adoption of winter chickpea provides more opportunity for women to find work.

6.5. Impact on water productivity

Water productivity indicator is measured in this study as the ratio of plant productivity (yield of chickpea) to rainfall. Based on the data collected from farmers on chickpea and from extension agents on the rainfall, it was 5 kg/mm in winter chickpea compared to 3.6 kg for spring one. This productivity was varying according to amount of rain and its distribution due the season. However, water productivity was higher for winter chickpea than spring in all administrative districts where this study took place (Table 8)



Spring chickpea Winter chickpea

Figure 3. Estimated number of labors needed per hectare for winter and spring chickpea; family labor (male), family labor (female), hired labor (male), hired labor (female) in that order from top to bottom of the bars.

Table 8. Water productivity by districts (kg/mm water)

District	Spring chickpea	Winter chickpea
Izaz	3.5	4.1
Samaan	3.5	5.5
Efreen	2.4	6.6
Idleb	4.2	5.4
Ariha	2.3	3
El Ma'arra	4.8	5
El Ghab	3	4.9
Mesiaf	5	8.6
Dar'a	2.9	2.4
Izra'	2.8	3.1
Sanamein	3.1	4.2
Average	**3.6**	**5**

6.6. Net impact

An appropriate technique for assessing the impact of improved cultivars on productivity usually is the regression analysis. Cobb-Douglas production function is a frequently used function for estimating the productivity impact of a new technology. The impact of a new technology on the total factor productivity can be estimated by adding a dummy variable to the function (Lin 1994).

Data obtained from the adoption surveys was used to estimate productivity impacts of improved crop cultivars. Cobb-Douglas production function was estimated on the total sample level and for Zone 1 and Zone 2 (Tables 9 and 10) by adding a dummy variable to the function which took the value one for using winter chickpea varieties or adopters and zero for non-adopters. The estimated coefficient of the dummy variable measures the shift in the intercept of the production function resulting from the new technology. The shift captures the impact of the dummy variable on total factor productivity. This will give the net effect of adopters to non-adopters. Formation of the model was influenced by a number of hypotheses. Estimated coefficients represent elasticities which measure the percentage increase in output in response to a percentage point increase in the respective inputs. Results of econometric estimation of production function confirmed the positive net effect of the improved chickpea technology package on crop productivity.

Based on Cobb-Douglas production function, net impact of winter chickpea variety was estimated. The formula used was:

Net impact = e^{b-1}, where b = coefficient related to variety in Cobb-Douglas model

The results indicated that spatial distributions of yield gain due to shift from spring to winter production were: 32.3% in Zone 1, 17.7% in Zone 2, and 33.2% on the sample level.

Table 9. Estimated *Cobb-Douglas* Production Function

	Unstandardized Coefficients		Sig.
Variables	B	Std. Error	
Constant	-2.107	.559	.000
ln Rain	1.042	.070	.000
ln Seed rate	.565	.081	.000
ln Labor	.066	.023	.003
Variety (Dummy)	.287	.040	.000
Using supplemental irrigation (Dummy)	.322	.072	.000
Using pest control 1 time	.059	.044	.182
Using pest control 2 times	.237	.066	.000

Dependent Variable: ln Grain Yield in 2005

Adjusted R Square = 0.484 F (481, 7) = 66.65***

Table 10. Estimated *Cobb-Douglas* Production Function by Zones

Variables	Zone 1		Zone 2	
	Coefficients	Sig.	Coefficients	Sig.
Constant	2.509	.004	-6.638	.000
ln Rain	.590	.000	1.602	.000
ln Seed rate	.181	.063	.858	.000
ln Labor	.076	.002	.063	.189
Variety (Dummy)	.280	.000	.163	.086
Using supplemental irrigation (Dummy)	.210	.005	.649	.001
Using pest control 1 time	.063	.175	.005	.966
Using pest control 2 times	.277	.000	.013	.960
Adjusted R square	0.278		0.542	

Dependent Variable: ln Grain Yield in 2005

7. Conclusion

The winter chickpea research has made great effort to overcome the production constraints and to increase productivity of chickpea in Syria. This research program was a collaborative program between the International Center for Agricultural Research in the Dry Areas (ICARDA) and other national research organizations to improve productivity of chickpea. The research program benefited from the collaboration in the areas of capacity building development, information exchange, technology dissemination, and acquisitions of germplasms and advanced materials for breeding programs.

Based on this study and analysis, it is possible to conclude that winter-sown chickpea technology is expanding in the study area. Ascochyta blight, insects, diseases, and weed were the most important factors affecting the productivity of winter sown chickpea in Syria. Variety is widely adopted and most farmers have in addition adopted other components of the recommended package. Expansion of winter chickpea area in Zone 2 was clearly noticeable. The technology is profitable and proved appropriate for all types or wealth categories of farmers who obtained high net returns from growing winter-sown chickpea. Household incomes from chickpea increased following adoption of winter-sown varieties and the positive impact is relatively greater among poor farmers. Similarly, employment opportunities were created for female labor and water productivity increased in terms output per unit rainfall.

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10.3. Impacts of Crop Technologies on productivity, food security and poverty in Nile Valley Region

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Abstract

This study focuses on impact assessment of Nile Valley-IFAD project and was conducted by ICARDA in collaboration with the national agricultural research programs in the region to examine the adoption of improved wheat, faba bean, and chickpea technologies, and assess productivity, technical efficiency and the impacts on the livelihoods of rural households using a sample of 850 households randomly drawn from the three countries. The results indicate that farmers' adoption of technologies introduced through the project has been selective and the full packages adopted by a low proportion of farmers. However, the productivity and efficiency impacts are clear but mixed across countries. The recommended technologies are profitable and generated high margins to adopters compared to non-adopters. The impact indicators estimated in the study provide empirical evidence on the effectiveness of the project in increasing farm income, improving food security, and reducing poverty among technology adopters. Some positive environmental benefits have been recorded among adopters through a successful breakage of cereal monoculture and increased soil fertility in Ethiopia while chemical pesticides use was reduced in Egypt. The positive impacts are likely to stimulate a wider adoption and substantial impacts over time. Because addressing adoption and other system-wide constraints will enhance technology impacts, the study provides also important information on the main constraints that are facing the wide dissemination of the technologies to the end users. Given the project's lifespan, some farmers are still experimenting components of the technological package which explains the variations in adoption rates from one country to the other. Similarly, risk aversion may be an important factor associated with farmer's decision not to uptake the full package at the beginning of the adoption process. The most important implications are the need to address the constraints through additional and more targeted interventions in making improved seeds accessible to farmers, for creating awareness among farmers, and for scaling up the positive impacts. Continued efforts through extension service supports and other means may be necessary to sustain the positive food security and poverty impacts over time.

1. Introduction

Wheat, faba bean, and chickpea are some of the most important food crops in the Nile Valley and Red Sea Region, and they represent a large share in the diet of households, particularly the poor in rural areas. Productions are not adequate to satisfy the demand of a combined population of 195 million that is growing at an average rate of nearly 2.2% a year. Except in Egypt, crop yields under farmers' conditions are very low compared to the potentials, and they fluctuate considerably from season to season. Demand for wheat product has increased over time in urban areas and wheat consumption has gradually shifted to many rural areas induced by substantial shift in consumption habits away from the traditionally used sorghum, millet, and maize. Although the production of these crops expanded in recent years, most of the increase is attributable to more land being brought under cultivation while productivity changes have been somewhat limited. Over time crop yields have been highly unstable due to extreme variability in rainfalls within and between years in the rainfed production systems, and the susceptibility of cultivated landraces and cultivars to biotic and abiotic stresses. The economically threatening stresses are wilt root rots and chocolate spot diseases for faba bean, rust on wheat, and various threats from viruses, insect pests, heat, cold and drought for other crops.

For several years an adaptive research project was funded by IFAD in the region to combat the biotic and abiotic stresses that reduce crop yields and cause yield instability of the main food legume and cereal crops (wheat, faba bean, chickpea, and lentil). Most of the activities of the project are of predominantly applied nature, supported by back-up research, wherever required and a strong technology transfer component. The technology packages disseminated through the project include: improved crop variety with recommendations on seeding rate, planting date, fertilizer application, irrigation regime, weed control, pest control, and a tillage system. There were some variations in these recommendations across the crops and countries. The main goals of the project are to increase the income of small-holder farmers and improve food security and livelihoods through improving the productivity and sustainability of the highly diverse agricultural production systems. Since the completion of the project in 2005, key socioeconomic research questions remain unanswered, among them, whether the improved technologies have effectively contributed to achieving the intended impacts. The objective of this study is to document at an early stage of adoption, if the technological packages relating to these crops and disseminated in Egypt, Ethiopia, and Sudan are having the productivity, food security, income, and poverty impacts on the livelihoods of small-scale farmers. The specific objectives are to:

- Document the adoption rates of improved technologies;
- Identify the technical, socioeconomic, and policy constraints that hinder the wide adoption; and
- Assess the impacts of the technologies on crop productivity, household food security, income, and poverty in the respective countries.

2. Adoption and impact indicators and methodologies

The adoption of recommended packages is measured by adoption rate, defined as the percentage of farmers adopting the technology under consideration. Productivity of each crop under the recommended package, income level and its distribution, per capita production and percentage of households below, within, and above the poverty lines of $1 and $1.2 per day, were used as economic, food security and poverty indicators.

Production function analysis provides a theoretical framework to estimate the comparative productivity of inputs used in a production process. The most straight forward approach to formally linking notions of technical change with measured rates of productivity growth is to assume that an index of the state of technology can be incorporated directly in a production function. Hence technological progress is perceived as an upward shift in production function. Many functional forms (Griffin *et al*. 1987) have been defined in the literature for the analytic study of production process. However, economic theory provides mainly generic conditions but little guidance for specifying a function. The Cobb-Douglas functional form is by far the most widely used in agricultural economics research because of its simplicity and ease of estimation. It is also the model used in the current study. The net effect of technology adoption is obtained by taking the anti-logarithm of its coefficient minus one, i.e. $(e^{\beta_d} - 1)$.

In addition of the production function analysis, descriptive statistics are used to compare the food security, income, and poverty indicators among technology adopters and non-adopters. The equality dimension of the income change was taken into account by calculating the Gini coefficient. The latter Gini is a number between 0 and 1, where 0 corresponds to perfect equality and 1 to perfect inequality.

The study covered 9 locations in the four countries. A formal questionnaire to collect farm-level data was developed and pre-tested with farmers. A total of 850 households in the three countries were selected using stratified sampling approach in each location. The distribution of the sampled households is as follows: for wheat 60 households in Egypt; for faba bean, 80 in Egypt and 198 in Ethiopia; and for chickpea 100 households in Ethiopia. The sample includes 312 households in Sudan. There was flexibility in the sampling design as partner researchers from the national systems selected samples according to the situation and research focus in their countries.

In Sudan the surveys were conducted in communities within Dongola Governorate covering the Selaim Basin for faba bean, and Benna irrigation scheme for wheat. In Ethiopia the locations include Munesa, Hetosa and Lode districts in Arsi region, where Peasant Associations (PAs) were selected randomly from a list of PAs. In Egypt the survey was carried out for faba bean in the Beni Mazar District (Minya Governorate), and for wheat in the Tamia District (Fayoum Governorate). The samples in the three countries included farmers who participated in the project activities as well as farmers who did not. These non-participants represent the counterfactual against which the performance of cereal and cool season food legume technologies were evaluated.

3. Results

3.1. Faba bean technologies in Egypt, Ethiopia, and Sudan

3.1.1. Adoption of faba bean technologies

Adoption of a given technology refers to continued use of the technology. Those farmers who have continued using at least one of the disseminated faba bean varieties are categorized as adopters. Those who have started using certain varieties and discontinued using all of them and those who have never tried the varieties are categorized as non-adopters. Table 1 below shows the adoption rates of all technology components across the countries.

Table 1. Adoption rates of faba bean technologies (% of farmers)

Technology component	Faba bean		
	Egypt	Sudan	Ethiopia
Variety	100	8	71
Sowing date	44	8	22
Weed control.	100	80	100
Pest control	100	63	45
Full irrigation	100	90	0
Seed rate	58	25	4
Fertilizer	50	0	15

Source: from survey data

In Ethiopia awareness was first documented and it was found that of 93% of farmers have heard about the presence of the new faba bean varieties disseminated in the target areas. There is a systematic association between awareness of farmers about the newly introduced varieties and participation in faba bean technology transfer activities at 99% confidence level. Hence, it can be concluded that the reason for high level of awareness among participant farmers is the presence of the project activities in the study areas. As normally expected, the highest rate of adoption (80%) was observed among the participants. On the contrary, about 43% of the non participants were found to be adopters of the faba bean improved varieties disseminated through the project intervention. At the same time 20% of participants were non-adopters and 57% of non-participant did not adopt. The difference in rate of adoption between participants and non participants was statistically significant at 1% level. A considerable proportion of farmers indicated that they are using an improved variety which they could not identify by name. However, they knew that this variety was introduced to the area through the project activity. The non-availability of seed of the improved faba bean variety was the major constraint enumerated by 21% of farmers, and 94% of adopters used less than the recommended seed rate. Susceptibility to disease, high price of seed, and unattractiveness of yield were mentioned by only 2 to 3% of farmers.

In Egypt, faba bean cultivated area is about 45%, followed by wheat 27% from the winter season land use. All farmers used the new varieties regardless of participation in the project. The variety Misr-1 is the most widely used variety followed by G-429 and G-674. The difference however, is that non-participants used their own seed from previous years. About 58% of sampled farmers applied the recommended seed rate, while 42% applied more than the recommended rate. Extension service was the major source of the new variety (47% of the farmer). In term of soil fertility management on faba bean, 50% of farmers who adopted the improved package applied manure, 100 % of them applied phosphate fertilizer. The rates of fertilizer applications are 90 kg/ha and 44 kg/ha respectively for phosphorus and nitrogen. All farmers used irrigation with an average of 8571.43 m^3/ha per cropping season (3600 m^3/feddans/season). Almost all of the farmers applied surface irrigation. Finally 58% of the farmers did not apply tillage, 29% applied tillage two times and 31% three times.

In Sudan participation in IFAD demonstration plots and field days was the most positive and significant factor influencing adoption of faba beans improved varieties. However, variety was the least adopted component (21% of farmers) while the recommended number of irrigations was respected by only 36% of respondents. Non-availability of improved seeds was the major constraint hindering the use of faba beans improved varieties according to more than 80% of respondents while 8% mentioned that the variety did not perform better than the local ones, and about 4% indicated that yield of this variety is not stable but declines from time to time.

3.1.2. Effect of the technologies on crop productivity

Results of econometric estimation of Cobb-Douglas production functions for Egypt, Ethiopia, and Sudan confirmed the positive net effect of the improved faba bean technology package on crop productivity.

In Egypt seed, labor, phosphorus fertilizer, machinery and adoption of technologies all contributed positively and significantly to increased productivity. The adoption dummy variable was highly significant, therefore the improved package of faba been has positively significant impact of 5.6% on faba bean productivity (Table 2). An increase by 10% in the quantity of the inputs included in the production function would increase faba bean output by 0.9% for the amount of seed, 1.45% for phosphorus fertilizer, 0.36% for nitrogen, 5.7% for labor and 3% for machinery respectively, assuming that other variables are constant.

Participation on the project was found to be significantly and positively affecting total production of faba bean in northern Sudan. The estimated coefficient of the participation dummy of 0.119 indicated that the total factor productivity of participation was higher than that of non-participants (Table 3). That is, given the same level of inputs, participation in IFAD project contributed to an increase in faba bean production by about 12% over non-participants. This contribution is achieved through knowledge and skills acquired through participation beside the improved technologies. However, there was no significant productivity effect due to the improved variety.

In Ethiopia the most significant determinants of faba bean output are adoption of improved varieties and amount of fertilizer used. The coefficient on the adoption variable was highly significant indicating that the new of faba been varieties have more than doubled (105%) the productivity among adopters. A 10% increase in fertilizer would increase output by 1.24%; for land area 0.4%, labor 0.15%, and number of tillage 0.83% respectively, assuming other variables are constant. Each percent unit increase in the quantity of seed may increase production by 0.037% (Table 4). For the outcome relating to fertilizer, the explanations is that farmers do not usually apply that input on faba bean fields. However, the project recommended to use up to 100 kg of DAP fertilizer, depending on the fertility status of the soil. Along with improved faba bean seeds, farmers were trained to apply fertilizer. Those farmers who applied DAP to their faba bean field have got better harvest as shown by the model.

Table 2. Estimation of faba bean production function in Egypt

Variable	Coefficients	SE	P-Value
ln-seed	0.09	0..051	0.069
ln-phosphorus	0.145	0.080	0.076
ln-nitrogen	0.036	0.014	0.012
ln-labour	0.568	0.097	0.000
ln- Mach	0.302	0.066	0.000
Adoption dummy	0.055	0.021	0.012
Constant	-1.657	0.121	0.000
Adjusted-R^2	0.87		
F-statistic	88.5		

Source: data from survey in Egypt

Table 3. Estimated coefficients of the faba bean production function in Sudan

Independent variables	Regression coefficients
Intercept	6.565*** (11.742)
ln farm size (ha)	-0.195*** (-3.730)
ln faba bean area (ha)	1.102*** (12.260)
ln seed (kg)	0.141** (0.043)
ln irrigation (no.)	0.122 (0.844)
ln age (years)	-0.160* (-1.841)
Dummy – improved variety	-0.005 (-0.619)
Dummy – participation	0.119* (1.772)
Adjusted R^2	0.80
F – test	151.126***

Source: data from survey in Sudan. Number in parenthesis refers to calculated t-test
*, **, *** significant at 10%, 5% and 1% levels respectively.

Table 4. Estimation of faba-bean production function in Ethiopia

Variables	Coefficients	Standard Error	t-statistic
Constant	.246	0.247	0.998
ln-seed	.037	0.041	0.912
ln-fertilizer	.124***	0.031	4.048
ln-Larea	.198*	0.119	1.659
ln-labor	.015	0.036	0.413
ln-tillage	.083	0.151	0.546
ln-weeding	.053	0.138	0.386
Adoption dummy	.717***	0.113	6.347
Adj-R^2	0.40		
F-statistic	19.052		0.000

Source: data from survey in Ethiopia
*** Significant at 1%; * Significant at 10% respectively.

3.1.3. Impact of faba bean technologies on household income and food security

Farm income may increase through cost reduction, price and /or yield induced revenue increase or a combination of all. In Egypt the estimated average costs of faba bean production is $495 per ha for adopters and $494 for non-adopters. The contribution of material inputs (seed, manure, fertilizer and pesticides) to the total variable costs of all inputs represents about 42% and 41.4% of the total variable cost for adopters and non-adopters respectively. Seed is the important cost item followed by fertilizer. Labor-related costs represented the largest shares of the total variable cost and accounted for 58% and 59% of the total for adopters and non-adopters respectively. Similarly, the net returns are $962 and $820 per ha for adopters and non-adopters respectively, which shows higher income (17%) for the former group although production costs were the same. Values of the Gini coefficient for adopters (0.70) and non-adopters (0.88) proved that adopters have less inequality in income distribution (Table 5).

Table 5. Comparison of income and food security indicators between adopters and non-adopter

Country	Parameter	Adopters	Non-adopters	Difference
Ethiopia	Average net return ($)	164	108	56
	Average costs ($)	190	159	31
	Gini coefficient	0.27	0.99	-
	Average production per HH (kg)	467	339	128
	family consumption (kg)	198	144	54
Sudan	Average net return ($)	369	293	103
	Gini coff	0.42	0.47	-
	Average costs ($)	220	182	38
	Per capita income per year	627	540	87
	Per capita income per day	1.7	1.5	0.2
Egypt	Average net return ($)	961.8	820.4	141.4
	Gini coff.	0.70	0.88	-
	Average costs ($)	494.6	494	0.6
	Total production per HH (kg)	494	241	253
	Family consumption (%)	8	9	-1.0

Note: Participants versus non- Participants in Sudan

In Ethiopia the average production cost per ha is higher for adopters than non-adopters; however, due to increased productivity the net returns followed the same pattern ($164 and $ 108 per ha, respectively) providing evidence of increased income for adopters. The average return, Gini coefficient, total production and consumption of faba bean show statistically significant differences (at 1% level of probability for all the variables) between adopters and non-adopters. The Gini coefficient, indicating the level of inequality in income distribution, is higher for non-adopters showing very high level of inequality among this group of farmers.

Analysis of net revenue from faba bean for the whole sample in Sudan showed that participation in the project has improved distribution of the net revenue of faba bean producers. Participants had a net return higher by about US$ 103/ha compared to non-participants as the average for the former group was $369 as opposed to $293 for the latter. The technology package is cost increasing and the average production cost was $220 /ha and $182 for participants and non-participants respectively. However, the increase in net return does not necessarily benefit poor or low net return producers equally. Participants obtained per capita annual income of $ 627 that is 14% higher than that of non-participants. The Gini coefficient is used to measure the degree of income inequality within each group shows a slight improvement in income equality among participants (0.42) compared to non-participants (0.47).

The difference in outcomes reflects the production systems in these countries as faba bean was produced under irrigation systems in Egypt and Sudan, as opposed to rain-fed farming system in Ethiopia. In addition, the production system in Egypt is more intensive compared to other countries. The Gini coefficient was low within the sub-sample of adopters of faba bean technologies in the countries and implies that these technologies also reduced income inequality among households who adopted them.

The per capita production for each crop is used as indicator for the project's impact on the food security of farming households. This indicator was estimated by dividing total production of the household for the specific crops by household size, and compared between adopters and non-adopters of the introduced technologies. Results in Table 6 demonstrate the importance of the technologies in increasing the food security of adopting farmers. In Ethiopia the amount of faba bean available to household consumption is higher for adopters (467 kg) than the non-adopters (338 kg). Similarly, the average quantities consumed are 198 kg and 144 kg respectively. Since faba bean is a major food staple that is consumed almost daily and nearly by every farm household, it is possible to conclude that adoption of faba bean improved varieties has had significant impact on the food security situation of households. On average, per capita faba bean production in households which did not adopt any component of the technologies was 428 kg in Egypt, 339 kg in Ethiopia and 138 kg in Sudan. Households who adopted the technology increased over non-adopters their production by 8% in Sudan, 13% in Egypt, and 39% in Ethiopia.

Table 6. Average per capita faba bean production (kg)

County	Adopters	Non-adopters	Change (%)
Egypt	485	428	13
Ethiopia	467	339	39
Sudan	149	138	8

3.1.4. Impact on poverty reduction

All non-adopting households in Ethiopia were classified under poverty line, whereas among adopters, 1% was above poverty line and 2% within poverty line. While an improvement was observed, the depth of rural poverty may be very high in this country and would require more than one crop-based technological package to significantly reduce household poverty. In Sudan, 56% of adopters against 68% of non-adopters fall under the poverty line. At the same time, 17% of non-adopters were above the poverty line. This result rather reflects the project's targeting of the poor and shows it succeeded in reducing the percentage of household under the poverty line among adopters compared to the general population. Similarly in Egypt, the percentage of households above the poverty line is higher among adopters compared to non-adopters, suggesting the positive impact of the project through faba bean technologies on poverty reduction. It is clear that poverty status of technology adopters is less severe than that of non-adopters. Technology adoption resulted in lifting some households from below poverty-line to poverty-line or from poverty-line to above poverty-line, approximately by 12% in both Egypt and Sudan, and 3% in Ethiopia (Table 7).

Table 7. Comparison of poverty status of faba bean farmers

Country/Poverty status	Adopters (%)	Non-adopters (%)
Egypt		
Above poverty line	66	46
Within poverty line	3	19
Below poverty line	21	35
Sudan		
Above poverty line	0	17
Within poverty line	44	15
Below poverty line	56	68
Ethiopia		
Above poverty line	1	0
Within poverty line	2	0
Below poverty line	97	100

3.1.5. Environmental impacts

In Ethiopia, an important element of the faba bean technology transfer activity is to break the mono-cropping culture and its associated problems in the study areas and particularly in the crop-livestock mixed farming system of Arsi zone. It was observed that faba bean is being successfully integrated into crop rotations leading to visible improvement in soil fertility and crop productivity as a result of nitrogen fixation, the application of mineral fertilizer by farmers and its residual effects. Land use pattern shows that wheat is still a dominant crop covering 54% of total area followed by barley (14%) and faba bean (6%). Other crops like linseed and rapeseed are also expanding as rotation crops through similar initiatives. Market factors are also playing a role in encouraging farmers to diversify their crop enterprises; the later crops are fetching high prices in contrast to wheat. Thus, more than any other direct or indirect impacts of the project, the impact on crop rotation in particular and cropping pattern in general is a very visible and important aspect for which the project is credited. This implies that cereal monoculture has already been broken and the project intervention has hit its target in the study areas.

In Egypt results of pesticides use show that the 100% of sampled farmers used same chemical for pest and weed control, however comparing adopter and non-adopters, it was found that non-adopters have higher percentage. It was very clear that adopters use less chemical than non-adopters, which means adopters would contribute less to environmental pollution.

3.2. Results obtained for wheat and chickpea related technology packages

3.2.1. Adoption and productivity impacts of wheat-based technologies

Adoption rates for improved wheat varieties were 68% in Egypt and 62% in Sudan. Yield increases to variety adoption also vary from 15% to 36% in the respective countries with differential increments depending on the level and number of technology components adopted. In Egypt, farmer's education and exposure to the technology significantly influenced the decision to adopt the new technology; estimated adoption rate is 53% while adoption intensity was 36% showing potential for more adoption. The main constraints to adoption in Egypt are the lack of inputs such as improved seeds and fertilizers, at the right time; weakness of extension service in the process of technology adoption, shortage of policy intervention in the area of input and output markets, credit, and financial support; the very short time during which technology dissemination was promoted through the project.

In Sudan the high adoption rate of improved wheat varieties compared to faba beans could be explained by the government policies to promote and encourage production of wheat to achieve self sufficiency and reduce the escalating bill for wheat importation. Only 17% of farmers respected the recommended seed rate while 56% used more seed than the recommendation and (27%) used less. Sub-optimal doses of phosphorus fertilizer (114 kg /ha) and nitrogen (86 kg /ha) were applied by farmers growing improved varieties. These fertilizers were sourced from local input markets. The use of manure was very low, and most farmers applied fertilizer by hand. Of those who did not apply fertilizer about 85% indicated that high cost and risk of crop failure (10%) were the main reasons for not doing so.

For Egypt the production function results show that the coefficient on the adoption dummy variable was highly significant; this implies that the improved package of wheat has positive impact on the production with a net effect of 11% increase. The quantity of seed sown contributed significantly to total output by 0.31%, while phosphorus fertilizer and machinery contributed by 0.44% and 0.30 % respectively.

For Sudan adoption of improved wheat variety was found to be significantly and positively affecting total production of wheat in northern Sudan. The estimated coefficient of 0.199 of the improved variety dummy indicated that the total factor productivity had improved. That is, given the same level of inputs, adoption of improved wheat variety had increased wheat production by 22% compared to non-adoption. Similarly participation in the project had increased total wheat production over non-participants. Productivity of wheat in the River Nile State was lower compared to the Northern State (Table 10).

Table 8. Adoption rate of wheat technology components (% of farmers)

Variables	Egypt	Sudan
Using improved varieties	68	62
Adopted sowing date	74	53
Planting Method	27	
Seeding rate	65	17
Nitrogen fertilizer rate	58	
Phosphate fertilizer rate	62	
Weed technology	68	66
Pest control	0.0	64
Irrigation number	88	17

Table 9. Estimation of wheat production function in Tamia district in Fayoum Governorate, Egypt

Variable	Coefficients	SE	P-Value
ln-seed (1)	0.306 **	0.121	0.014
ln-phosphate	0.435 ***	0.124	0.001
ln-labopur	0.152	0.097	0.124
ln-machinary	0.304 ***	0.070	0.000
Adoption dummy(2)	0.107 ***	0.021	0.000
Constant	-1.391 ***	0.113	0.000

Source: survey data. Adjusted $R^2 = 0.98$; F-statistic =252.
(1) D-seed is the interaction of seed and planting method (Handing, Planter)

Table 10. Estimated coefficients of the wheat production function in Sudan

Independent variables	Regression coefficients	t-statistics
Intercept	6.504***	9.476
Ln farm size (ha)	0.026	0.425
Ln wheat area (ha)	0.768***	5.071
Ln seed (kg)	-0.055	-0.777
Ln urea fertilizer (kg)	0.300**	2.438
Ln irrigation (no.)	0.027	0.178
Ln age (years)	-0.113	-1.085
Ln family size	-0.118	-1.569
Dummy – improved variety	0.199***	2.634
Dummy – participation	0.115*	1.670
Dummy - state	-0.607***	-4.452
Adjusted R^2	0.80	

Source**:** survey data from Sudan; Adjusted-R^2 = 0.80. t-test. *, **, *** significant at 10%, 5% and 1% levels respectively.

3.2.2. Impacts of wheat technologies on households' incomes

Introduced wheat technologies in Egypt reduced production costs, therefore, the average net return for adopters was 43.5% higher than non-adopter, while average cost to non-adopters was 21.5% higher than adopter. The Gini coefficient estimate indicates more inequality in income distribution among adopters (0.75) than non-adopters (0.32). In Sudan the average annual per capita production of wheat for adopters exceeded that of non-adopters by about 49% implying that adopters were more food secured than non-adopters. In addition adopters derived higher average net returns by about 74% compared to non-adopters. Although the Gini coefficients were regarded as high for adopters and non-adopters (0.58 and 0.63 respectively), the analysis showed a slight improvement towards more equitable distribution of net income from wheat production in the case of adopters (Table 11).

Table 11. Impact of improved wheat technologies on net return (US$/ha)

Country	Technology		Adopters	Non-adopters
Egypt	Full package	Average net return	1191	830
		Gini coff	0.75	0.32
		Average costs	502	640
		Per capita /year	1019	352
		Per capita /day	2.8	1.0
Sudan	Variety	Average net return	510	134
		Gini coff	0.58	0.63
		Average costs	556	510
		Per capita /year	537	468
		Per capita /day	1.5	1.3

Source: survey data.

3.2.3. Impacts of wheat technologies on food security and poverty

Total wheat production per household in Egypt was higher (1219 kg) for adopters than for non-adopters (537 kg), while the average rate of family consumption were 15%, 19% of the total production for adopters and non-adopters. In Sudan the average annual per capita production of wheat for adopters of wheat improved technology (319 kg) exceeded that of non-adopters (163 kg) by nearly two times implying that adopters were more food secured than non-adopters.

The impact on poverty is estimated by $ 1.8 daily per capita income in Egypt showing a positive effect of using the improved wheat package compared to $1.0 per capita income for non-adopters. These technologies seem to have moved a substantial number of households (35%) previously under poverty line to within poverty line category whereas 29% of non-adopters (as opposed to 6% of adopters) are above the poverty line reflecting the targeting of the poor with wheat technologies in the respective communities. In Sudan, the average per capita income for wheat variety adopters was higher by about 13% compared to non-adopters. Adoption of wheat improved variety had positive effect on the poverty status of wheat growers at the bottom level of income compared to non-adopters. About 15% of adopters lied within poverty line against only 6% (Table 12) of non-adopters. Because the project targeted poor households, the high percentage of participant households within the poverty line compared to non-participant suggests that the project may have actually lifted 9% of households which were initially below the poverty line.

Table 12. Comparison of poverty status of wheat farmers (% of farmers)

	Mean	%	Mean	%
Egypt				
Above poverty line > 1.2 $/day	3.71	6	1.66	29
Within poverty line 0.99 –1.2 $/day	1.07	69	1.08	11
Below poverty line < 0.99 $/day	0.70	25	0.62	60
Sudan				
Above poverty line > 1.2 $/day	3.42	28	2.42	37
Within poverty line 0.99 –1.2 $/day	1.10	15	1.12	6
Below poverty line < 0.99 $/day	0.6	57	0.54	57

3.2.4. Adoption and productivity impacts of chickpea-based technologies

In Ethiopia and contrary to expectations a high rate of adoption (78%) was observed among the non participants in the project. This might be due to two important reasons: first the presence of overlapping interventions in the project area that are disseminating improved chickpea varieties. The other is the farmer to farmer information dissemination and spillover effect of the project. Though the project reached limited number of households, the technology has reached several households in the areas. Those farmers who have access to seed from the research or the formal seed system had higher chance of adoption than others. The yield was 1.8 tones/ha for adopters and 1.1 tones/ha for non-adopters showing a statistically significant difference of 39% yield between the two categories. The production function analysis shows that improved varieties, amount of seed, plot size, and the amount of labor spent on different production practices positively influenced the output (Table 13). The contribution of improved varieties was highly significant indicating that they have enabled farmers to boost their chickpea yield by 63%. Frequency of tillage and hand weeding have negatively contributed to the increase in output in that farmers have used extremely high frequency of tillage, and weeding which are not economically sound.

Table 13. Estimates of chickpea production function in Ethiopia

Parameters	Estimates	Std. Error	t-statistics
Constant	-0.515	1.275	-0.404
ln-area	0.738***	0.162	4.554
ln-seed	0.097**	0.040	2.449
ln-labor	0.277**	0.116	2.377
ln-weed	-0.185	0.246	-0.751
ln-tillage	-0.299	0.400	-0.748
ln -age	0.011	0.278	0.040
Adoption dummy	0.488**	0.176	2.774

Source: survey data

*** Significant at 1%; ** Significant at 5%

In Sudan about 50 percent of growers of improved varieties applied recommended seed rate compared to 20 percent for the local varieties. Traditional farmers depended on their own stock while some of the improved seeds were secured from research institutions. Recommended irrigation number was applied by 30% of adopters compared to 5% of non-adopters. The adoption rates for package component varied among farmers because of non-availability of resources, high production cost, and management systems. Irrigation number is the least adopted component (15%) while manual weed control showed the highest adoption level (89%).

Adoption of the components of chickpea production technology had positive effect on chickpea yield. Increases in yield ranged between nil, in the case of pest control, to 51% in the case of seed rate adoption. The large difference attributable to recommended seed rate is due to low seed rate used by non-adopters. Pest control showed no effect while variety and sowing date resulted each in about 20% positive change in yield. In aggregate the overall productivity effect of the new technology is negligible because no significant difference was found between growers that used improved and local varieties, the average yield being 0.94 ton/ha and 0.92 ton/ha respectively.

3.2.5. Impacts of improved chickpea technologies on incomes, food security, and poverty

Adopters of improved chickpea varieties have higher annual per capita income relative to non-adopters in Ethiopia. Similarly, adopters have got more access to food in that they produced more chickpea per household than non-adopters. Higher income means better entitlement for food through purchases even in cases where on-farm food production is not sufficient for household consumption. It goes beyond food security to better financial capacity to pay for health, education, and housing. The opposite however, was observed in Sudan where the technology was newly introduced. The average annual chickpea production per household for non-adopters is nearly twice that of adopters in Sudan. These results show that in this country farmers are still trying these packages (Table 14).

Table 14. Income distribution and food security effects of Chickpea technologies

Indicator description	Ethiopia		Sudan	
	Adopters	Non-adopters	Adopters	Non-adopters
Income distribution				
Average net return (USD)	551	201	496	286
Average costs (USD	350	318	429	397
Gini coefficient	0.85	0.02	0.68	0.73
Per capita income (USD /year)	222	179	590	998
Per capita income (USD /day)	0.61	0.49	1.63	2.73
Food security: Average production per HH (kg)	1068	960	261	449

Source: survey data

In Ethiopia there was high level of income inequality among adopters of improved chickpea varieties while in Sudan the distributions are relatively similar. The Gini coefficient showed a slight improvement towards more equitable distribution of net income from chickpea production among participants even though it is high for both groups. However, it is very hard to attribute this aspect of impact entirely to the project intervention. Such differences may be due to the underlying income distribution among these groups before the technology transfer efforts. Although chickpea technologies are cost-increasing, the net returns above these costs are higher for adopters compared to non-adopter in both countries suggesting increased profitability for the former group (Table 14).

The average daily income of the people above poverty line was higher for the adopters than the non-adopters in both countries. On the contrary this average is nearly the same for adopters and non-adopters among household falling in 'within' and 'below' poverty line categories. The proportion of households below poverty line is higher for technology adopters relative to non-adopters while remaining the same for those within the poverty line (Table 15). Because the project targeted the poor from start it is extremely difficult to determine the proportion of households that improved their poverty status through the project even though incomes have improved.

Table 15. Evaluation of sample households' income against poverty line

Poverty Line ($ average per capita /day)		**Above $1.2**	**Within $0.99 to $1.2**	**Below $0.99**
Ethiopia				
	Adopters	5.2 (4.6)	0.99 (3.1)	0.33 (92)
	Non-adopters	1.5 (12.1)	1 (3.1)	0.3 (83)
Sudan				
	Adopters	7.37 (14.3)	1.03 (28.6)	0.47 (57.1)
	Non-adopters	5.24 (45.7)	1.15 (6.5)	0.48 (47.8)

Note: Percentages are in parentheses.

4. Conclusions and implications

The study provides important information on the main constraints that are facing the wide dissemination of the technologies to the end users. The major constraints to wide adoption also vary by technology and by country but can be summarized as follows. In Egypt the non-availability of inputs such as improved seeds and fertilizers at the right time; weakness of extension services, shortage of policy intervention in the area of input and output markets, lack of credit and financial support, and the relatively short time for technology dissemination were the constraints. In Ethiopia unavailability of improved seeds due to weak performance of the formal seed system, and lack of awareness of the new technologies among farmers was identified. Similarly in Sudan, unavailability of improved seeds of wheat and faba bean, lack of credit, and high costs of seed and fertilizer were identified. A small percentage of farmers mentioned that the faba bean variety did not perform better than the local ones and about 4% indicated that yield of this variety is not stable and decline from time to time. Such constraints have important policy, research and extension implications.

The most important implications are the need to remove the above constraints through additional and more targeted interventions. First non-availability of seed of the new varieties is the most common factor hindering adoption across the three countries. Poverty and food security impact of agricultural research may not be realized unless there are effective seed multiplication and delivery systems to ensure seed availability and access to farmers. Concerted efforts should be made to improve seed production and distribution. Second, although adoption is sequential in terms of package components, the use of variety alone with disregard to other recommended inputs as the case was for faba beans in Sudan is unlikely to lead to increased productivity. Availability and affordability of inputs that are complementary to seed should be addressed to encourage adoption of recommended packages. Third, differences in technology outcomes reflect the degree of intensification in production systems across these countries, and results provide empirical evidence of the potential of crop related technologies and the feasibility of making high productivity impacts in production systems which are currently less intensive. Continued efforts through extension service support and other means may be necessary to sustain the positive food security and poverty impacts over time and to extend technology benefits to whole communities and production systems in the region. To that end, training would be required to improve their skills and that of other agencies involved in the dissemination of the new package.

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10.4. The challenge of measuring impacts of sustainable land management–Development of a global indicator system

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Abstract

Sustainable Land Management (SLM) in drylands is significantly impeded by a current incapacity to track its impacts, particularly at the global level. Efforts to identify and effectively capitalize on previous experience from SLM initiatives have been further hampered by a lack of comprehensive knowledge management fora. A group of United Nations organizations and regional development banks has joined hands to address these needs through an initiative on Knowledge from the Land (KM:Land), aiming to strengthen the scientific-technical basis for the selection of indicators to record the impacts, results and compare effectiveness of SLM projects in the Global Environment Facility (GEF) Land Degradation Focal Area. This initiative, executed and led by the United Nations University, engages a Learning Network approach, through which lessons and experience can be shared amongst global SLM communities. This paper focuses on two major aspects of that initiative. First, a conceptual framework has been developed, realigning traditional environmental indicator frameworks to a step-change in thinking on dryland poverty and resource degradation processes, as recommended by the Millennium Ecosystem Assessment. Second, the initiative has identified four core global indicators, from which a baseline global SLM assessment can be drawn. This assessment is anticipated to support the prioritization of resource allocation by the GEF. The identified socio-economic and biophysical indicators are all measurable through available databases and ongoing remote sensing and monitoring initiatives. The paper briefly summarizes the next step for the KM:Land initiative: to develop indicators at the project level, in an effort to demonstrate environmental and livelihood benefits at the local scale from SLM interventions. We perceive that such a comprehensive approach to SLM assessment also represents a significant opportunity to strengthen the global basis for the design and assessment of SLM initiatives beyond the GEF portfolio.

1. Introduction

Land degradation is internationally recognized as a global process that results in decline and loss of ecosystem services with adverse impacts on poverty, food security and human well-being (Millennium Ecosystem Assessment 2005). Despite efforts to combat land degradation, and high investments over at least 40 years, the worldwide rate and extent of land degradation appears to be increasing (United Nations University 2007).

In the past two decades, Sustainable Land Management (SLM) emerged as a holistic approach to prevent and mitigate land degradation. However, knowledge and lessons from SLM initiatives are not well documented or easily accessible. This constrains wider dissemination of SLM knowledge and makes it unavailable to those working in similar situations and seeking to achieve similar objectives. While there are a number of initiatives that have aimed to strengthen knowledge management on SLM, efforts remain fragmented.

A fundamental challenge is that global benefits from combating land degradation cannot be quantified unless there is a consensus on indicators that can capture baseline conditions as well as impacts of SLM initiatives (see also Bai et al. 2008a). Indicators are required to compare effectiveness of different types of interventions. These indicators need to be accessible, simple, robust enough for wider application, and inclusive of the social, economic, and environmental dimensions of SLM.

The Global Environment Facility (GEF) has acknowledged the need to strengthen systematic knowledge management within its own Land Degradation Focal Area and thus initiated a long-term programme entitled "Knowledge from the Land" (KM:Land) together with a group of United Nations organizations and regional development banks. Executed and led by the United Nations University, the first phase of KM:Land focuses on selecting indicators to measure and track the environmental and livelihood benefits from GEF SLM interventions and to record results and best practices of projects in the GEF Land Degradation Focal Area. The project also intends to create an SLM Learning Network to promote the exchange of lessons learned and experiences between SLM professionals.

This paper focuses on two aspects of this initiative, describing: 1) the development of a conceptual SLM framework and 2) four core global indicators selected to measure the status of land systems.

2. Challenges regarding the identification and measurement of global SLM benefits

SLM is intended to counter or prevent land degradation, thereby reducing the impacts of land degradation on people and the environment. In other words, SLM generates environmental, social, economic and other side benefits. Some of these benefits will be generated locally, others regionally or even at a global level. For example, SLM practices may increase tree cover, which would enhance the livelihood of the local population through increased availability of wild fruits, but at the same time may contribute to a better global carbon balance.

One of the key challenges faced by the GEF, and in turn the KM:Land initiative, is the definition of global environmental benefits in the context of SLM. Current scientific discourse characterizes global environmental benefits of SLM almost entirely in terms of benefits addressing other global environmental issues like climate change and biodiversity. Combating land degradation is thus perceived to yield global environmental benefits (Pagiola 1999; Gisladottir and Stocking 2005). Introducing the concept of "global scope", the Overseas Development Group (ODG 2006) suggests that global environmental benefits should result from addressing environmental problems that occur worldwide. ODG (2006: 54) concludes that "some impacts are global because the impacts are on truly global processes such as climate, others are global because they affect global public goods or because they occur sufficiently frequently and/or at sub- and supra-national scales to be of global concern."

Niemeijer and Moran (2006) suggest that global environmental benefits could be defined in terms of alleviating "cross-generational impacts". All the "standard" global issues of climate change, biodiversity loss, and degradation of international waters involve cross-generational impacts and would fit within this definition. The loss of fertile land must be of a similar level of concern for humankind to that for the loss of local species or habitat.

Based on the foregoing, three different ways to define global environmental benefits emerge:

1) Reduction of global environmental problems (global functions)
2) Reduction of local environmental problems occurring worldwide (global scope)
3) Reduction of environmental problems of common concern of human kind (cross-generational)

As land degradation has wide-ranging impacts on many environmental processes the application of SLM contributes significantly to global environmental benefits in all of the above definitions. Still, if one is to assess the benefits of SLM, the choice of definition is not merely an academic issue. The selection of the definition affects not only which benefits are to be counted, but also determines what variables are to be measured, how to measure them and how the benefits of multiple local interventions may be aggregated at the global level. This, in turn would determine what should be considered to be effective implementation of SLM – and what should not.

If global environmental benefits are only defined in terms of effects on the function of global environmental systems the biggest challenge is that it may not be possible to locally measure changes at the point of intervention. At the same time, the contribution of the GEF-supported SLM projects is likely to be too small a drop in the ocean to register an immediate impact at the global level. In this case only modelling could allow for impact assessment of the SLM interventions over the long term. The second and third definitions not only allow for a much wider range of benefits, but many of those benefits will be measurable locally, making it possible to aggregate data collected by individual projects at the global level. But, as the latter two definitions also include ecosystem functions that are global in scope such as climate regulation, also here some level of modelling is likely to be useful.

Some of the relevant variables to measure global environmental benefits can be monitored at the local level and then aggregated to the global level, whereas others can only be modelled or measured at the global level. There is thus a need for two sets of indicators, one focused at the local or project level and one focused on the global level. Given that the contribution of GEF-supported SLM projects may be important, but unlikely to cause immediate changes at the global level, data from a global level indicator set cannot be used to track the local impacts of SLM, and is likely to be more useful as a tool to make investments where the greatest impact can be expected or the greatest needs are apparent. Local level indicators instead can serve as the basis for aggregation of SLM impacts to the global level and at the same time help individual projects to track and assess their impacts. While the KM:Land initiative works on developing indicators at both levels, this paper will focus on presenting progress made in the global level indicator set.

3. Development of an SLM framework

Land degradation entails a range of interacting physical, chemical and biological processes influenced by human action as well as climate change. Land degradation has traditionally been a topic of study for the natural sciences, but, recognizing the complexity of the inter-linkages, the last decades have seen an increased interest in land degradation from the social sciences. Different scientists have applied different conceptual models to the problem of land degradation. Within the natural sciences the Driver - Pressure - State - Impact – Response or in short DPSIR (Smeets and Wetering 1999), which centres on how biophysical processes are driven by human and natural drivers, has been applied to land degradation. More recently, the Millennium Ecosystem Assessment (MA) has combined elements of the social and ecological sciences in its MA framework, which emphasizes the link between environmental services and human well-being (Millennium Ecosystem Assessment 2005). Both of these causal chain frameworks have their strengths.

The DPSIR framework is widely recognized as a scientifically sound framework for environmental evaluation and used by many international organizations including the OECD and the European Environment Agency. Additionally, through its Response and State categories, which are not explicit in the MA framework, it draws attention to key components of the causal chain. It is important to bring Response to the foreground, as this is where society responds with policies and management to counter changes in the ecosystem services and influence the drivers. Human actions are present in the services framework through the drivers and the “control points”, but do not have a category of their own in the causal chain. The distinction between State and Impact of the DPSIR framework is also very useful, because many changes start at the state level (e.g. level of toxicants in the air, nutrients in the soil) and only indirectly or in the long term or when certain levels are exceeded lead to impacts in the form of changes in ecosystem services.

The MA or ecosystem services framework, though formulated recently, has seen a quick uptake in international policy circles. The MA framework supports a focus on the two central aspects of the human-environment interaction: ecosystem services and human well-being. Conceptually, this approach introduces two interlinked notions. First, improvement in human well-being is the primary purpose of development efforts like SLM approaches. Second, measuring and understanding ecosystem services is a useful and robust way of quantifying the value of ecosystems to the society. Such focus on human well-being is not present in the DPSIR framework, which represents more of a natural scientist's perspective. The SLM framework presented in this paper combines the strengths of the two existing frameworks in a way that it covers the physical, ecological and human dimensions and yet is sufficiently familiar to most land degradation scientists.

Figure 1 shows both frameworks in one picture. At the drivers/driving force/pressure level, the DPSIR and MA frameworks directly overlap, whereas the connection at the ecosystem services and impact level can be provided by the concept of ecosystem functions. These are the many individual functions of ecosystems that together provide the major ecosystem services. It is the impact of changes in these functions that can lead to a decline in, for example, provisioning services. Once these components are linked the categories absent from the other framework fit naturally in place as can be seen in Figure 2.

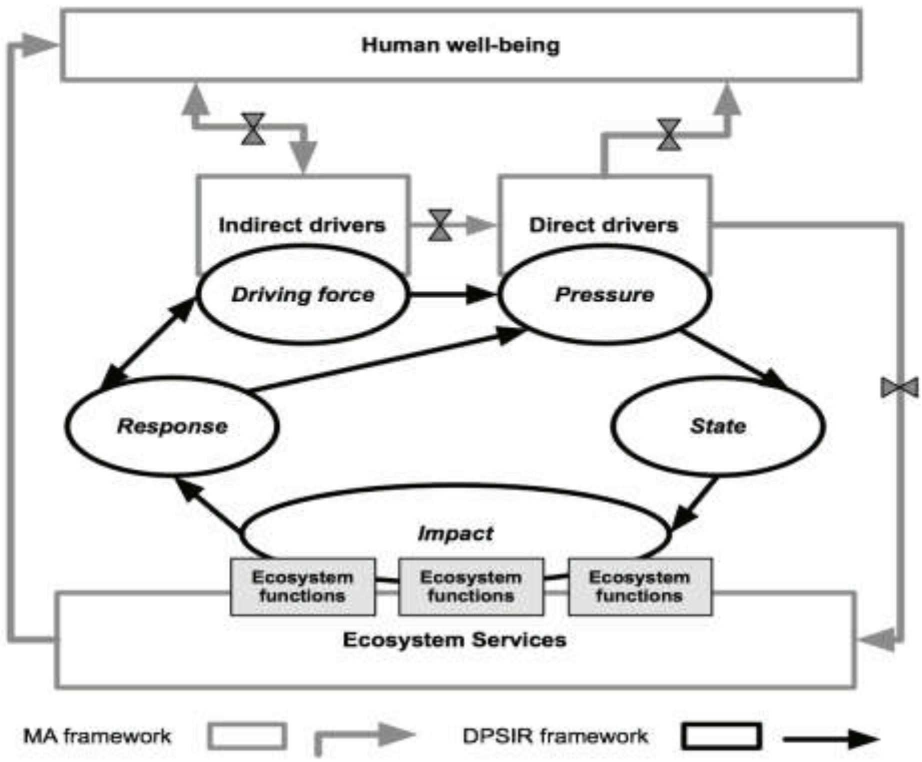

Figure 1. The relation between the DPSIR and MA frameworks.

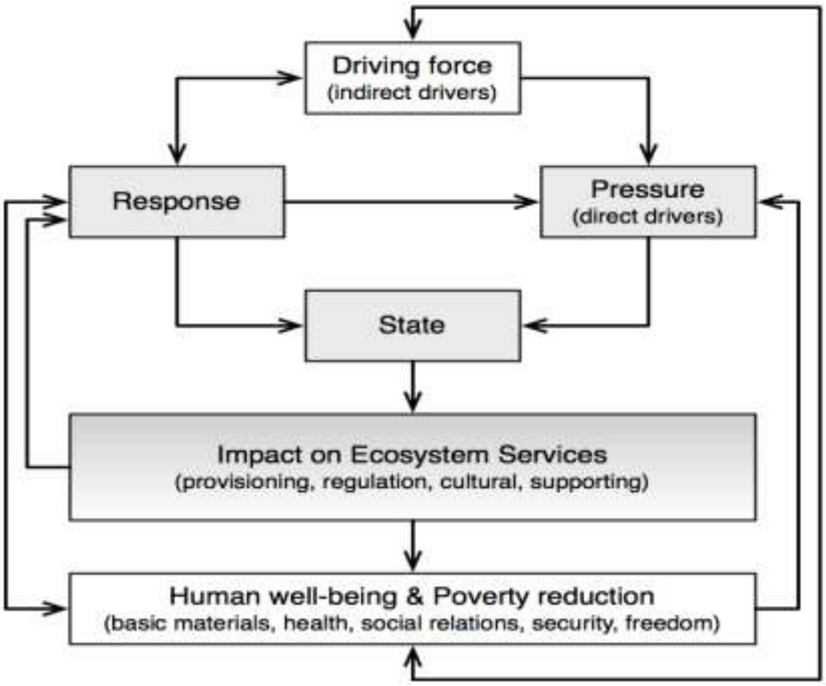

Figure 2. The universal SLM framework merging the DPSIR and MA frameworks.

Combining the two frameworks into a universal SLM framework facilitates the assessment of the impacts of SLM on global environmental benefits. In this context the Response category of DPSIR is very important in the sense that SLM forms the "response". For the same reason the Ecosystem Services and Human-well-being components are important as they provide a way to express the impact of SLM at the ecosystem level as well as the impact on human well-being. Also, while we are ultimately interested in the effect of interventions on ecosystem services and human well-being, the typical time frame of an intervention often prevents the measurement or observation of changes in ecosystem services or human well-being. Here the State category can be of use as it can be used as a proxy for changes in ecosystem services and subsequently human-wellbeing that we can expect to happen over a longer time frame.

4. Global-level indicators

In order to populate the above-described SLM framework with global-level indicators, a comprehensive consultative process with environmental and social scientists, indicator specialists, GEF project managers and representatives of international agencies was conducted. The indicator selection process was then lead by an Expert Advisory Group, comprising eight internationally recognized experts in SLM, and underpinned by background research undertaken by the Centre of International Earth Science Information Network (CIESIN) in partnership with UNU-INWEH.

In the KM:Land initiative global-level indicators are defined as over-arching indicators that relate to the global goal to mitigate the causes and negative effects of land degradation and are measured at the global level using global data sets. At this level, some truly global environmental benefits (see definitions above) can be tracked, which may not be apparent at the local level. Due to their coarse resolution both in space and time, global-level indicators are not sufficiently sensitive to detect impacts derived from each and every GEF SLM project. Thus, global-level indicators were developed mainly for the purpose of prioritising areas with greatest need for or greatest impact of resource allocation. Considering this purpose, the two main requirements for global indicators were: 1) they must be measurable globally and consistently; 2) they do not need to have very high spatial or temporal resolutions. At the same time, global-level indicators were developed to meet pre-defined selection criteria such as scientific credibility, robustness, cost-effectiveness etc.

A mix of four bio-physical and socio-economic global-level indicators was selected in order to assess the status of the global land system. The indicators can be classified according to the different categories of the SLM framework (Table 1) and include:

- Land cover;
- Land productivity;
- Water stress; and
- Rural poverty.

In the following, a brief overview is provided of definitions, measurement methodologies, global datasets and applications of these four indicators based on a commissioned report to KM:Land by CIESIN (2008).

Table 1. Placement of Global-Level indicators in the SLM framework

Indicator	Placement in SLM framework
Land cover	State
Land productivity	Impact on ecosystem services
Water stress	Pressure; impact on ecosystem services
Rural poverty	Human well-being & poverty reduction

The **Land Cover** indicator shows the distribution of the world's major land cover categories, as classified by the Global Change Cover 2000 product (GLC 2000) available through the European Commission's Joint Research Centre. This indicator measures the current land cover, and especially the distribution of land cover types of greatest concern for land degradation (cropland, rangeland, forests etc.). Although used alone the indicator does not provide information about land degradation or SLM, land cover information is required to evaluate other indicators such as land productivity and water stress. For the future, it would be desirable to incorporate global datasets monitoring changes in land cover.

The **Land Productivity** indicator was included to identify regions with declining vegetative cover or biomass productivity as an early warning of possible land degradation in a particular area. The indicator is measured as the global trend in "greenness" based on a product developed jointly by the International Soil Resources Information Centre (ISRIC) and FAO's Land Degradation Assessment in Drylands (LADA) project (Bai et al. 2008b). This product adjusts the Normalized Difference Vegetation Index (NDVI) for rainfall variability using rain-use efficiency (RUE) - the ratio of NDVI to rainfall - where greenness is limited by rainfall and also accounts for the effects of irrigation. Areas of declining greenness - net of the effects of rainfall - are expressed in terms of Land Productivity to demonstrate the long-term trend of declining productivity which may be summed up as loss of tons C/ha. It should be noted that this indicator cannot be used alone to definitively conclude that land degradation has taken place (because changes in greenness may be caused by other processes such as conflicts or economic developments). But it can help to identify areas that require more fine-scaled investigation.

The **Water Stress** indicator measures the ratio of water withdrawals to water availability from rivers, streams or aquifers as computed by a water model developed by the University of New Hampshire Water Systems Analysis Group (UNH WSAG 2006). This indicator expresses the degree of pressure put on water resources and freshwater ecosystems by the users of these resources, including domestic users, industries, power plants, agriculture etc. Since agriculture accounts for approximately 70% of water withdrawals worldwide (Siebert et al. 2005), stress on water resources is highly correlated with irrigation in the agriculture sector. The higher the ratio of withdrawals to availability, the more often the water in a basin is degraded or depleted. The UNH WSAG model defines that a river basin is water stressed if annual withdrawals are between 20 and 40% of annual supply, and severely water stressed if this figure exceeds 40%.

The **Rural Poverty** rate is the percentage of the rural population living below the national rural poverty line, classifying as poor all individuals whose consumption (or income, when consumption is unavailable) falls below the rural poverty line. Country-specific rural poverty lines are used to measure welfare levels in rural areas, track impacts of poverty alleviation interventions, and monitor progress in poverty reduction. Information required to monitor this indicator is available in the public domain through the Millennium Development Goals Indicators Database (2008). For the future, global datasets should be developed that provide more detailed information on the distribution of income and consumption in rural areas.

The data needed to measure the four selected global-level indicators are available publicly. However, it should be noted the all these indicators are derived from global data sets and models that may be constrained either by the limited availability of observatory systems or assumptions used in models. Thus, their values are only as robust as the quality of the available underlying data which are not controlled by the GEF Secretariat. Another constraint is that the required data are not necessarily updated on an annual basis and it is not guaranteed that new global inventories are conducted for the update of global indicators. This may mean that data acquisition for global indicators could be expensive.

5. Use of indicators at the project-level

Given the constraints as described above and that the global level indicator set cannot be used to track the global impacts of SLM projects, the KM:Land initiative, in a next step, will select indicators that will be compiled within individual GEF projects. These project-level indicators will be designed to track and assess impacts of individual projects, but will at the same time serve as the basis for aggregating and synthesizing

SLM impacts at the global level. Data for these indicators will be regularly collected and measured by the respective GEF project teams, enabling the GEF Secretariat to conduct a periodical impact analysis of their Land Degradation portfolio, without having to rely on data sets owned by other institutions. Ultimately, this will permit the development of a decision- and planning support system which will guide the GEF Secretariat in analyzing the efficiency and effectiveness of their investments.

In order to allow comparison of projects and their impacts, a minimum set of indicators and standardized, simple measurement methodologies will be selected. Since the global-level indicators have already been decided, it is logical to refer to them in the consideration of project-level indicators.

A review of the current use of indicators relating to the selected global set (land cover, productivity, water-related indicators and rural poverty) in a selection of GEF projects was conducted for KM:Land (King 2008). This review included projects implemented at a country level, and others that were regional or global, of a more strategic nature. The review demonstrated that project designs in country-level projects typically incorporated basic information on land classification classes and areal extent (e.g. agricultural land, rangeland and forests). Projects also proposed to measure improvements in local livelihoods and enhanced productivity (or reduced degradation) as part of the achievement of intended global environmental benefits. The reviewed country-level projects in the SLM portfolio focus on changes in land use systems and adoption of SLM practices, which are not explicitly captured by the global set of indicators.

On the other hand, strategic projects at the global and regional levels do not normally seek to monitor an impact on land cover, productivity, rural income and water stress within a defined geographical area during the implementation period. These initiatives often work to improve SLM through the creation of enabling environments (strengthened institutional, technical and financial capacity and improved policies) for eventual effects on land cover, productivity, rural income and water stress to be created over a broader scale and timeframe. Hence, the design of these projects may be considered to be taking an indirect route to the achievement of the same global environmental benefits as the country-level projects. Country-level projects also increasingly incorporate such strategic approaches, together with proposals for direct intervention in land management practices.

Experiences of indicator use gained by GEF project managers have been systematically incorporated into the expert discussions of KM:Land, and will continue to inform its future work on selecting universal project-level indicators and appropriate measurement methodologies. This will require the design of a suite of methodologies to enable all intervention types to monitor and report on environmental and livelihood impacts.

6. Conclusions

With the design of a hybrid SLM framework, the KM:Land initiative provided the scientific basis for the selection of meaningful indicators to measure global environment benefits derived from SLM interventions. This framework was instrumental for the formulation of global-level indicators that will meet the need of the GEF Secretariat to justify and prioritize future investments in the Land Degradation Focal Area and provide the basis for quantifying global benefits from the combating land degradation. The project-level indicators that will be developed in a next step are needed to strengthen existing GEF SLM projects and assist future project proponents in the design of suitable interventions. Overall, the emerging indicator system will provide guidance to the future strategic development of the GEF Land Degradation Focal Area and will support the GEF Secretariat to identify trade-offs between initiatives funded through different Focal Areas.

The KM:Land initiative is further expected to generate benefits beyond the direct GEF realm. In particular, it is envisaged that the indicators selected by this initiative could be used by other development partners and bilateral donors. Additionally, this conceptual development can benefit and provide inputs to the ongoing indicator development work of the UNCCD. Thus, the KM:Land initiative puts an emphasis on involving the international community, creating a consensus between the various United Nations organizations and developing indicators that reflect the multi-dimensional impact of SLM.

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10.5. Analysis of desertification in the dry lands of Nigeria: causes, extents and impact on human migration and agricultural productivity

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Abstract

The extent and severity of desertification and rate of its progress in Nigeria has not been fully established and documented. The general consensus is that desertification is by far the most pressing environmental problem in the drylands of the country. The natural causes of desertification include the poor physical conditions of soils, vegetation, and topography as well as the inherent extreme climatic variability as evidenced in periodic droughts. Climate variation is observed as the most important natural cause of desertification and drought in the dry lands of Nigeria. The visible sign of this phenomenon is the gradual shift in vegetation from grasses, bushes and occasional trees, to grass and bushes; and finally to desert-like sand. Estimations show that between 50% and 75 % of Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe, and Zamfara states in Nigeria are being affected by desertification. The pressure of the migrating human and livestock populations from these areas are absorbed by pressure point buffer states such as the Federal Capital Territory (Abuja), Plateau, Adamawa, Taraba, Niger, Kwara and Kaduna states. These buffer states therefore have about 10-15 % of their land area threatened by desertification. Additional pressure is put on the pasture resources by livestock from other Sahel countries, especially from Chad, Niger and Cameroon. The overall consequence of this is increasing rate of desertification which is estimated to be progressing at the rate of about 0.6 Km per year in the country. This study traces the Nigeria government failure at combating desertification problem, despite all her efforts, due to the fact that it still follows a top-down approach in its policy formulation and implementation. In order to solve the menace of desertification, there is a need to employ the bottom up approach where all resource users and other stakeholders will have access to the decision-making process that directly affects them and their resources.

1. Introduction

In the past five decades, the threat of 'desertification' has dominated dryland development policy and debate. Desertification is a process of land degradation in areas vulnerable to severe edaphic or climatic aridity. This degradation leads to the reduction or destruction of the land's biological potential, to a deterioration of living standards and to the intensification of desert-like conditions. It ranks among today's greatest environmental challenges in developing countries, particularly in Africa, Middle East and parts of Asia has serious local and global impacts especially in areas affected by drought, deforestation and climate variability.

Over the past several decades, desertification has emerged as one of the major research themes in Nigeria**.** Though significant efforts have been initiated to combat desertification, the problem is worsening. The focus of this study on desertification in Nigerian dryland is driven, in part, by : (a) the ongoing drought and associated human tragedy in the Northern part of the , (b) an intense interest by scientists in the interactions between surface processes and climate, and (c) the many important questions on causes, effects and how affected areas can cope. This paper reviews the causes, severity, and consequences of dryland and desertification in Nigeria with particular emphasis on the northern part of the country.

2. Characteristics of dryland vegetation in Nigeria

Of the 350,000 plant species that have been described in drylands, only about 3000 are reported to be sources of useful material for people. Less than 100 of these plants are cultivated on a large scale and none are xerophytic. However, the search for xerophytic plants of economic value has been intensified in recent years. Another striking feature of the use of biodiversity in drylands is the use of plants, which might have multiple values. For example, the plants that supply fuel are generally those which adapt well to different sites, establish easily, require little care, can protect steep hillslopes in many areas, generally have low nutrient requirements and are not consumed by goats and wildlife. Dryland ecosystems are generally characterised by tree-shrub savanna woodlands and sparse forests. With increasing aridity, the diversity of trees decreases and thorny xerophites and dry resistant species become more important. Most of such trees are slow growing and difficult to regenerate. Species diversity and regeneration ability are generally lower than in humid ecosystems; biological productivity and moisture supply are highly interdependent.

Primary productivity tends to be patchy in response to the spottiness of rainfall and the run- off characteristics of the land. In consequence, a small portion of the land provides a large proportion of the available biomass. Native plants tend to have efficient mechanisms for resilience both as individuals and populations. In the case of grasses, the predominance of perennial species, with strong development of underground organs and a root-shoot ratio generally above one is well related to their tolerance of such stresses as drought, fire and herbivory. The co-existence of trees and grasses and the competition between them for resource acquisition particularly water, are reduced by differences in root distribution in the soil. The establishment of tree seedlings is therefore best limited to wet years in order to allow their roots to cross the soil layer dominated by grass roots. Complementarity between grasses and dicotyledonous plants also allows grasses in general to be more dependent on nitrogen supply while legumes and other dicots are more limited by phosphorus supply.

The fact that dryland vegetation is nutrient limited emphasizes the significance of symbiosis for nutrient acquisition. Legumes' *Rhizobium* and mycorrhizal symbiosis and rhizospheric associations with free living nitrogen-fixing bacteria are widespread. The activity of root symbiosis together with the presence of blue green algae provide a good basis for establishing nutrient budgets, particularly the recovery of nitrogen loss induced by extreme burning. The overriding feature of dryland ecosystems is their nutrient variability due to lack of available moisture. This means that the biological processes in these regions are highly dynamic, sometimes on a time scale of a few weeks and months. A year or two may pass in which precipitation is well below average and then followed suddenly by years of sufficient rainfall. Intensification of traditional farming systems to meet growing demands often has undesirable ecological effects such as erosion, salinity, water logging and the contamination of groundwater because fundamental ecological principles are ignored. This means that the use to which dryland ecosystems can be put must be as dynamic as the environment itself.

3. Causes of desertification in Nigeria

In Nigeria, as in other dry areas of the world, the process of desertification is a result of the interaction of several factors, natural and human (anthropogenic). The causes of desertification that are most commonly identified include poor physical conditions in terms of soils, vegetation, topography and inherent extreme variability of climate as manifested in frequent drought, and anthropogenic disruption in the ecological balance caused by poor land use and ever-increasing demands being made on the available resources by the expanding population and socio-economic systems of the affected areas. Other causes include: over-cultivation, over-grazing, deforestation, inappropriate irrigation practices and improper land-use practices, woodland destruction, unsustainable development/public policy, alienated land ownership structure and legislations and wasteful energy policy all add to accelerate of processes already common in dry land, such as the physical and biological degradation of soils, wind and water erosion, and soil salinization even though the intensity and combination of causes and processes differs under different land uses

4. Status and extent of drylands and desertification in some selected African countries

The latest estimate by the Millennium Ecosystem Assessment concluded with “medium certainty” that between 10 and 20% of the drylands are seriously degraded, a global area that is more than twice the size of India. Drylands are especially vulnerable to degradation because of the slow regrowth of vegetation after clearance. In Africa, two thirds is classified as deserts or drylands. These are concentrated in the Sahelian region, the Horn of Africa and the Kalahari in the south. Africa is especially susceptible to land degradation and bears the greatest impact of drought and desertification. It is estimated that two-thirds of African land is already degraded to some degree and land degradation affects at least 485 million people or sixty-five percent of the entire African population. The natural resource base of drylands in Africa is under continuous threat from erosion and nutrient mining resulting in severe land degradation and desertification. Climate change may still aggravate this situation. Estimates from individual countries report increasing areas affected by or prone to desertification. In Ghana, desertification is said to be creeping in at an estimated 20,000 hectares per year, with the attendant destruction of farmlands and livelihoods in the country. Seventy percent of Ethiopia is reported to be prone to desertification, while in Kenya, around 80 percent of the land surface is threatened by desertification. The actual extent and magnitude of desertification in Nigeria is still being established. But the country is reported to be losing 351,000 hectares of its landmass annually to desert and desert-like conditions. Such conditions are advancing southwards at the rate of approximately 0.6 kilometres per year. Land degradation, either through deforestation, pollution, erosion or other extraneous factors, are gradually narrowing the confines of agricultural land and creating conflicts among communities.

Although in Nigeria the extent and severity of desertification have not been fully established neither the rate of progression properly documented, there is a general consensus that desertification is by far the most pressing environmental problem in the drylands parts of the country. Desertification affects the country's eleven northern states with between 50 % and 75 % of Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe, Adamawa and Zamfara States, with the soil being dusty and water resources minimal, forcing thousands of people to move southwards each year. This movement exposes the green belt of the savannah to more exploitation and degradation. These states, with a population of about thirty million people, account for about 40 percent of the country's total land area. Vulnerable as the area is, it supports about 90 percent of Nigeria's cattle population, two-thirds of its goats and sheep and almost all of the donkeys, camels and horses found in the country.

Desertification accounts for about 73 percent of the US$5.11 billion that the World Bank has estimated Nigeria loses annually due to environmental degradation (Federal Ministry of Environment of Nigeria 2001). The most visible sign of this phenomenon is the gradual shift in vegetation in these areas. The original vegetation of grasses, bushes and occasional trees gives way to vegetation composed entirely of grasses and bushes, then, in the final stages, to expansive areas of desert-like sand. An average family of five using firewood as a source of energy will consume one hectare of wood every year, which translates to more than 25 million hectares being lost annually by the 100 million households said to be relying on wood for domestic energy.

5. Consequences of desertification

A major impact of desertification is biodiversity loss, and loss of productive capacity, such as the transition from grassland dominated by perennial grasses to one dominated by perennial shrubs. Desertification and drought result to food insecurity, famine and poverty. The resulting social, economic political tensions, create conflicts, causing more impoverishment and further increase land degradation. Desertification in Nigeria is found to engender economic problems and social strife over land resources use. The competitive uses of the *fadama* are a source of potential conflicts among the various rural land users. These include conflicts among settled farmers, between farmers and pastoralists, between farmers and fishermen and between fishermen and pastoralists. The pastoralists are now forced to move through cultivated land with their livestock making farmers to be at a loss as to how to protect their crops. Most often violent confrontations are increasingly reported between farmers and migrant *fulanis* from the desertified northern parts of Nigeria in an effort to stop herds from grazing in a protected area.

Desertification in Nigeria can be termed as both a cause and an outcome of climate change and of biodiversity loss. It has led to the loss of some habitats and those that survive are often small and fragmented. As a result, there is considerable risk of extinction of certain species because the remaining habitats are not large enough to support viable populations. Some habitats are also in danger of being compromised as they contain human settlements. Some fauna species such as the antelope, cheetah and lion are now almost extinct, while others like giraffe and elephants are endangered. Among other endangered species are the crowned crane, the bustard, the ostrich and the tree duck. With regard to the flora, most of the indigenous plant species identified some decades ago are now hard to find, especially those with medicinal or edible value, such as *Acacia senegalensis* and *Adansonia digitata*.

Desertification have far reaching adverse impacts on human health due to wind-blown dust, including eye infections, respiratory illnesses, allergies, and mental stress. It affects food security, economic activity, physical infrastructure, natural resources and the environment, and national and global security. Combating desertification is a priority in efforts to ensure food security and enhance the livelihoods of more than 2 billion people. Desertification often triggers economic, environmental, and social hardships for poor rural people, who are sometimes both the cause and the victims of desertification.

The deterioration of life support systems as a result of desertification causes significant social and economic disruptions. Desertification has a debilitating impact on the capacity of populations and communities to sustain the means needed for livelihood. In extreme cases, as during periods of drought, the land is no longer capable of supporting the people who live there. Often they have no other alternative but to leave the countryside for urban areas. Where rural human settlements gradually disappear, what is left is often a socio-ecological situation in which no development is possible. Furthermore, dryland and desertification increases downstream flooding, reduced water quality, sedimentation in rivers and lakes, and the siltation of reservoirs and navigation channels. Because desertification brings about the loss of vegetation, it can result in the extinction of plant and animal species, and therefore contribute to the loss of biodiversity. Drylands are the source of many of the world's varieties of food and medicines. The loss of these plants through desertification represents the loss of valuable and irreplaceable genetic material. Additional impacts include an increase in particulate and trace gas emissions from biomass burning in drylands and an increase in atmospheric dust loads. A combination of climatic stress and dryland degradation lead in turn to extreme social disruption, migrations, and famine.

6. Desertification and human migration

Desertification has serious effect on human migration. Statistics show that Nigeria loses 350,000 hectares of arable land per year. In the northern 11 states of the country (such as Bauchi, Gombe, Kano, Jigawa and Sokoto, Zamfara and Kebbi where desertification become severe), each year the desert advances another 600 metres further south. People moving in this area are directed to the urban centers in the northern and southern states. The other pattern of migration is rural–rural, particularly directed to the *fadamas* and river/lake basins for grazing, the cultivation of cowpeas and maize and also for fishing. Research has shown that over tens of thousands of farmers, nomadic *fulani* and their families always move further south in the hopes of finding better grazing areas for their herds and some in search of jobs and land that does not exist. The pressure of the migrating human and livestock populations from affected areas are absorbed by pressure point buffer states such as the Federal Capital Territory, Plateau, Adamawa, Taraba, Niger, Kwara and Kaduna states. Report has shown that these buffer states have about 10-15 % of their land area threatened by desertification. This action leads to an intensified use of fragile and marginal ecosystems resulting into progressive degradation even in years of normal rainfall.

7. Efforts at combating desertification

The difficulty in defining desertification has complicated efforts to measure and combat it. Nevertheless, the fight against desertification confronts many real and serious issues such as persistent dryland poverty, recurrent droughts, eroding soils and shrinking market opportunities for smallholder farmers and herders who live far from the coastal gateways of commerce.

Literature has shown the existence of many activities that are potentially relevant to combating desertification. Because perceptions, intensities, extents, consequences and causes of desertification are multiple and vary in both time and space, activities that may contribute to combating desertification are equally so. National Action Programmes (NAPs) is one of the vehicles for CCD implementation and may include a wide array of activities, policies and strategies aiming, directly and indirectly, at (a) preventing; (b) rehabilitating; and/or (c) reclaiming land degradation. Successful NAPs outline long-term strategies and are formulated with the active participation of local communities, aspects which are essential in ensuring sustainability, ownership and continuity for long-term programming.

The Nigerian government has realized that poverty alleviation is a major weapon for combating desertification. Consequently, a number of poverty alleviation programs have been established. Notable among them are the Northeast Arid Zone Development Program (NEAZDP), the Model Village Program, the Sokoto Environmental Protection Program (SEPP) and the Katsina State Agricultural and Community Development Project (KSACDP). The government has also been embarking upon economic-empowerment programs such as the community banks to enable the rural poor access to credit facilities. Under the present administration, these have now been brought under one umbrella of the National Agricultural, Co-operative and Rural Development Bank. Furthermore, the government has fashioned out a comprehensive National Poverty Eradication Program (NAPEP) as one of its top-priority programs.

The Federal Government of Nigeria in collaboration with Niger Republic have also initiated direct programs to combat desert encroachment, though with the funds being sought from the United Nations Environmental Program (UNEP), the World Bank and the Global Environment Facility (GEF). Their strategy was to establish shelter-belt for controlling land degradation; development of environmentally sustainable model villages in Kano, Zamfara, Adamawa, Borno, Kaduna and Niger States and the reactivation of existing model village Sabon Nangere in Yobe State; reintroduction of house-to-house inspection by Environmental Health Officers (EHOS) in the country; incorporation of the N500 million to be spent yearly on poverty alleviation into the proposed National Rolling Plan and the Yearly budgets; and lastly the formulation of a national Action Program (NAP) in which the United Nations (UN) convention to combat desertification using a bottom-up, interactive and decentralized approaches.

The review of the Federal Government of Nigeria efforts shows the following projects have been approved for implementation by the Federal Government of Nigeria since year 2002 (federal Government of Nigeria, 2005):

7.1. The Greenbelt Program

In order to combat desertification and increase vegetative cover and soil productivity in the drylands of the country an Arid Zone Afforestation Project (AZAP) was instituted in 1976 through the establishment of wood lots, shelterbelts and windbreaks. Over ten million seedlings were raised annually between 1978 and 1984. Approximately 150 kilometers of shelterbelts and 3,680 hectares of wood lots were established, as well as 24 boreholes and 70 tree nurseries. Effective from 2002, government also approved the greenbelt program which includes the establishment of a shelterbelt across the extreme strip of the northern parts of the country (i.e. from the Sokoto basin in the Northwest to the Lake Chad Basin in the Northeast). The project is to be jointly executed by the Federal, State and Local Governments, and will spread over a period of 14 years. The project has since taken off with 51 nurseries being established in the frontline and buffer states. Each of the nurseries is capable of producing 1 million seedlings per annum.

7.2. Model Village Development

This project, which is estimated to cost about US $4.0m and for which 14 communities spread over the eleven desertification frontline states have been selected, is now being implemented with the following components:

- Rural water supply through the provision of solar-powered boreholes
- Environmental education and awareness creation through the construction of Viewing Centers equipped with necessary facilities
- Sanitation through the provision of landfills and public conveniences
- Popularization of Renewable Energy Technologies (RETs) such as biogas digesters and box solar cookers. In addition, fuel-efficient clay stoves and sawdust stoves are being popularized
- Establishment of community plant nurseries
- Establishment of woodlots
- Establishment of wind breaks
- Establishment of botanical gardens for conservation of threatened and fauna species

7.3. Pilot project on sand-dune fixation

This pilot project is being implemented to raise awareness level and demonstrate the appropriate technologies for sand-dune fixation for adoption by the communities. Two pilot sites have been selected in each of the following arid states: Borno, Jigawa, Kebbi Kano, Katsina, Zamfara Sokoto and Yobe. This Pilot project is expected to cost about US $3.9m.

7.4. Pilot project on rangelands

This project is designed to demonstrate technologies for establishing rangelands in order to improve the carrying capacity of the land for livestock. The project is also an attempt to sedentarize the nomadic herdsmen. It covers the desertification frontline states of Adamawa, Bauchi, Borno Gombe, Jigawa, Katsina, Kano, Kebbi, Sokoto, Yobe and Zamfara. The project will cost about US $2.8m.

7.5. Development of national drought forecasting and early warning system

The Federal Government of Nigeria has approved the provision of state-of-the-art meteorological instrumentations at various locations in the country for drought forecasting. Subsequent to the forecasting other biological and socio-economic components of early warning system will be identified and developed. Capacity-building program for drought forecasting and early warning is also being developed. This project, expected to cost about US $564,285, is being implemented in collaboration with the Nigerian Meteorological Agency (NIMET).

7.6. Assessment of the severity and extent of desertification and preparation of desertification map for Nigeria

This project, which is expected to cost US $2.85m has been approved for implementation, is expected to produce a National Desertification Map using satellite imagery and GIS, providing credible data on the extent, severity and rate of desertification in Nigeria.

7.7. Nigeria-Niger trans boundary ecosystem management project

It is a GEF funded project aimed at creating conditions for sustainable integrated ecosystem management and thereby improve livelihoods in areas covered by the Maiduguri Agreement between the two countries. This will be achieved through: a) Developing an integrated legal and institutional framework for collaboration and coordinated financing from the Nigeria – Niger Joint Commission for Cooperation to community-based organizations; b) Harnessing and improving on research-based and indigenous knowledge, and cultural values, to support natural resource management, conservation and productivity; and c) Developing and implementing sub regional catchments and community level ecosystem management plans through participatory and inclusive processes. These plans when implemented will consolidate regional cooperation, conserve habitats and biodiversity, manage water resources, promote sustainable land use practices, control degradation trends, build institutional capacity, improve equity and reduce the vulnerability of local communities to environmental change.

7.8. Nigeria-Japan (JICA) master plan for utilization of solar energy in Nigeria

A master plan study for utilization of solar energy in Nigeria is being carried out by the Japan International Cooperation Agency from June, 2005 in collaboration with the Energy Commission of Nigeria, Federal Ministry of Power and Steel, and the National

Planning Commission in Jigawa, Ondo and Imo States as well as in the Federal Capital Territory.

7.9. UNIDO-Energy Commission of Nigeria Small Hydro Power (SHP) Program

The program includes training of trainers for the River Basin Development Authorities, survey of potential sites, preparation of feasibility reports and detailed project reports, advice, guidance and assistance to Local Government Councils, communities, State Governments and private individuals for taking up SHP projects. Two pilot and two re-furbishing SHP project s are being implemented with the assistance from China

8. Experience and constraints in combating dryland and desertification problems in Nigeria

Exhaustive evaluation of Nigeria's and international communities' efforts at combating desertification problem identified the following factors constraining the effective desertification control in the country: top-down approach that limits consultation between and among the various stakeholders, inconsistency of government policy, a lack of proper co-ordination and monitoring, neglect of indigenous knowledge, use of inappropriate technology, sectoral approach, inadequate funding, inadequate awareness, and rural poverty which compels the people to rely heavily on the environment. These, coupled with inadequate facilities, constrained data collection towards the establishment of the country profile on dryland and desertification.

9. Conclusion

The issue of desertification deserves special attention due to the disastrous consequences it has on populations and the environment. Desertification and recurrent droughts are determining factors that seriously hamper sustainable development in the drylands and affect the quality of life of people in many regions of the world. Desertification in Nigeria is overwhelmingly visible only in some states. Dryland communities in Nigeria are especially vulnerable to drought; they often depend on livestock or subsistence crops and lack reserves of food, money, insurance or other forms of social safety nets to cope with difficult years.

Desertification reflects fundamental ills, such as poverty, underdevelopment and lack of food security. At its root is the fact that, in order simply to survive, many people are forced to engage in environmentally-unsustainable activities. Solving the problem of desertification will not be possible without simultaneously attacking the causes of poverty and addressing the basic needs of rural people.

Drylands contain significant untapped resources that could aid in development. These resources include: solar radiation for crop production; solar and wind energy; and, in some areas, untapped surface water or groundwater. In order to harness the full potential of drylands, policy should ensure that future development options are not foreclosed, by being proactive in enabling people to respond to changing natural and economic circumstances. For example, targeted infrastructure could be provided to help develop potentially lucrative market niches. Drylands should not be treated as mere welfare sinks or ‘problem areas.

Reference

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10.6. A comprehensive approach to desertification and drought management in Nigeria

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Abstract

Desertification has been a recurring feature of arid and semi-arid areas of Nigeria. Desert encroachment results in an annual loss of about 350,000 sq m of arable area, causing extreme hardship to people living there. This paper reviews the current extent, severity and consequences of desertification and drought in the northern part of the country. The approach to the problem in the past has been rather haphazard resulting in unsustainable land management. The current approaches and efforts to formulate national plans and policy to manage desertification are examined. Information on conceptualization and operation of Green Wall Sahara program, Agridev Desert to Food Program, National Shelterbelt Development Program, and Rangeland Management, Sand-dune Fixation and Oasis Management Program is presented. It is recommended that formulation of a policy and implementation for integrated management of drylands is imperative for mitigating the impacts of drought and desertification in the areas prone to these events.

1. Introduction

Nigeria has varied ecological zones (Table 1) ranging from dry drought-prone Sahel to humid swampy lands. Drought and desertification are major constraints to agriculture production in the country. Desertification is a term that has been used to describe the change of productive land into desert like condition. The concept of desertification takes into cognizance land degradation process that involves continuous of changes from slight to severe devastation of vegetation and soil resources due to man's activities and climate variability. Drought is a complex climatic condition, which occurs as a result of natural reduction or non availability of rainfall over a long period of time (Oladipo 1983). Drought is primarily a periodic natural event with clear beginning and continuous progression. Drought therefore constitutes a dynamic process of social, economic, political and other deprivations which can affect individual, households, communities and nation resulting in a lack of access to basic needs of life, and even loss of life, home and property.

Agricultural drought is the most pronounced drought type in Nigeria. Famines associated with agricultural drought occurred in Nigeria in 1883/85; 1903/05; 1913/15; 1923/24; 1942/44; 1954/56; 1962/64; 1972/73; and 1982/83. The major agricultural droughts are regional and have been established to have 30 years cycle covering the entire Sahel and Sudan climatic belts and could be traced from Egypt and Libya through Sudan Niger, Chad to Nigeria. The 10 years cycle droughts are usually localized. Drought in 1972 and 1973 caused considerable reduction in yields of major crops and loss of livestock (Table 2 and 3).

In monitoring agricultural drought in Nigeria the most suitable indicators are those that are responsive to soil moisture status and are therefore based on the soil water balance. The reason is that the timing of soil moisture deficit in relation to crop water requirements and sensitivity to moisture stress is of major importance in assessing the impacts of drought on crops. Monitoring by satellite techniques is most appropriate for detecting the status of soil moisture.

Table 1. Agro-ecological zones in Nigeria

Zone	Area (%)	Wet season			Monthly temperatures (^{0}C)		
		Rainfall (mm p.a)	**Kind**	**Days**	**Max**	**Mean**	**Min.**
Mangrove swamp	2	2000+	Extended	300-360	32	28-25	23
Rain forest	14	1200-2000	Bimodal	250-300	33	28-24	21
Southern guinea savanna	21	1100-1400	Bimodal	200-250	37	30-26	18
Northern guinea savanna	26	1000-1300	Unimodal	150-200	37	30-23	14
Plateau	2	1400-1500	Unimodal	200	31	24-20	14
Mountain	4	1400-2000	Bimodal	200-300	36	29-14	5
Sudan savanna	27	600-1000	Unimodal	90-150	39	31-21	12
Sahel	4	400-600	Unimodal	90	40	32-33	13

Table 2. Effects of drought on the yield of some main crops (means for 125 family heads in five villages)

Crop	Yield (kg/ha)			Percentage of pre-1972 yield	
	Pre-1972	**1972**	**1973**	**1972**	**1973**
Early millet	1462.5	585	172.5	40	12
Guinea corn	1190	330	52.5	28	4
Late millet	350	117.5	12.5	34	4
Maize	190	40	0	21	0
Groundnuts (shelled)	950	350	17.5	37	7
Average				29	7

Table 3. Loss of livestock in the drought of 1973 and 1974 (survey of 125 families in five villages)

	Cattle	Sheep & Goats	Donkeys	Horses	Camels	Birds
Livestock June-July 1972	**350**	**837**	**93**	**24**	**17**	**701**
Mean per family	2.8	6.7	0.7	0.2	0.15	5.6
Deaths	30	44	14	9	8	144
Sales	132	320	47	10	8	268
Not accounted for	14	114	-3	-3	1	30
Total losses	176	478	58	16	17	442
Livestock, June-July 1974	174	359	35	8	0	259
Mean per family	1.4	2.9	0.3	0.05	0	2.1
Percentage reduction	50	67	62	67	100	63

2. Extent and consequences of desertification and drought in Nigeria

Nigeria is a large country with substantial part of its area extending into the Sudano Sahellian belt, which, together with the neighboring northern guinea savanna, constitutes the dry lands of Nigeria. Desertification constitutes the most serious environmental problem facing this part of the country with direct socio-economic consequences on the entire nation. The major states affected by desertification are Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe, Adamawa and Zamfara States. It has been suggested that between 50% to 75% of the area in these states is desertified. The desertification occurs as the advancement of sand dunes, due to strong prevailing winds. The moving sand dunes have become a threat to the arid and semi-arid environments as they encroach and bury agriculturally productive lands. Rural communities here face horrible situation and are forced to abandon their settlements. A living memory of this is the relocation of Gidan Kaura village in Sokoto State, which was overtaken by sand dunes.

The pressure of the migrating human and livestock population from these highly desertified areas is absorbed by buffer states such as FCT, Plateau, Taraba, Niger, Kaduna Kwara States with population of 30 million, and 20% of land mass. It is reported that some of these buffer states have about 5 – 10% of their land mass affected by desertification. In addition, more pressure is put on the pasture resources by livestock from other Sahel countries, especially Chad, Niger and Cameroon. Livestock from these countries are attracted to these zone because of the abundant supply of fodder and the presence of wetland areas of the Lake Chad and beyond. The over all consequence of these is the increasing rate of desertification.

The effect of drought/desertification does accumulate slowly ever a considerable period of time and may continue even after the termination of the event. The on set and ending of drought are difficult to determine, also the impact of drought are less obvious and are spread over a larger geographical area than the damage that result from other natural hazards. The economic impacts of drought range from direct losses in agriculture related sectors including forestry and fishery, to loss in recreation, transportation, etc. Environmental loses are the result of damage to plant and animal species, wild life habitat, and water quality degradation. Socio-impacts involve mainly public safety, health, loss of life, rural-urban migration, reduced quality of life and poverty.

3. Past desertification and drought management strategies in Nigeria

The drought of 1971 – 1973 was recognized as a national disaster and Nigerian government responded by appointing a National drought committee, setting up of emergency relief packages, encouraging tree planting, establishment of afforestation programs, dam construction for irrigation, water supply and afforestation, planting of early maturing/drought resistant crops, intercropping, shifting cultivation/nomadism, finding alternative employment in trading, weaving, etc., mobilizing social network (rich helping the poor) as well as liquidating accumulated assets (livestock), destocking during droughts; and construction of wells, boreholes, stock ponds, strategic grain reserves, irrigation etc.

4. Lessons from past desertification and drought management strategies

Past efforts in drought and desertification management have been largely geared toward reactive rather than proactive approach. Policy makers and drought administrators responded to drought and desertification situation through emergency relief materials, irrigation, tree planting etc. Public sector approaches have been inconsistent, uncoordinated, sectoral and *ad hoc*. Information flow to government decision makers was usually slow and ill-defined to generate actions and anticipatory decisions. For management of a crisis such as desertification and drought, an **early warning system** should be put in place. This was missing. This has resulted in many deaths, and loss of properties, migration and fund wastage. There is duplication of function in reactive management and lack of involvement of social partners (NGO, CBO, IGO, etc.) in planning and evaluation.

5. Stakeholders mobilization for managing drought and desertification

Meaningful mobilization for development must identify relevant interest groups, which are expected to influence or participate in the planning and implementation process. A clear understanding of the composition and characteristics of stakeholders facilitates consultation and mobilization through provision of appropriate and relevant information. A stakeholder in drought is an individual, group and corporate entity whose action or interest is affected by drought/desertification. The ministry has to carry stakeholders along in it desertification management. To ensure effective mobilization of stakeholders, relevant drought and desertification policy and legislation have been enforced by the federal Government of Nigeria. Documentaries, features and news items on problem of drought and desertification including recommended best practices are produced distributed through the broadcast and print media by the Federal Ministry of Environment. Regular consultations and national campaigns are carried out to create awareness among stakeholders and general public about the challenge and management of drought and desertification by federal government.

6. Government action in managing drought and desertification

Special fund from the ecological fund office have been set aside for drought management in Nigeria. National Committee on Ecological Problems (NCEP) was established which created the national sub-committee on desertification and drought control, as one of its technical sub-committees with secretariat at the Drought and Desertification Department of the Federal Ministry of Environment. The sub-committee established the drought and desertification control programme, arid zone afforestation programme etc.

The programs of the National Committee on Drought and Desertification Control include establishment of nurseries and seedling production, provision of irrigation water for nurseries, forest plantation, pastures, cropping etc., establishment of wood lots, shelter belts, wind breaks, fodder banks etc., procurement and distribution of required imputes such as fence material, irrigation equipment, poly pots, planting materials, fertilizers, agrochemicals; development and promotion of alternative sources of energy, increased use of coal, biogas, solar energy etc.; and support research into various aspects of arid zone management such as sand dune stabilization, development of drought resistant species of trees and development of alternative sources of energy and improved cooking stoves.

Nigeria in compliance with Article 10 of the UNCCD prepared a national action programme (NAP) as the key operational tool for the implementation of the convention in the country. NAP was launched on the 17th June, 2001 in Borno State, Nigeria. The main objectives of the NAP are to develop long-term integrated strategic that focus simultaneously in affected areas on improved living conditions, particularly at community level. Actions include identification of factors contributing to desertification and practical measures necessary to combat desertification on and mitigate the effect of droughts, specification of roles of various stockholders, enhancing the capacity of the nation to provide drought early warning, and mainstreaming the NAP document into the country's development plans, particularly as they relates to dry lands.

Agro-Dev, a Swedish based consulting firm conducted a site survey of desertified areas of northern Nigeria, with a view to develop effective strategies for the shelter belt implementation and sustainable utilization of land resources. As a part of the project, three standard plant nursery centres will be established in each of the 11 desertification states. In addition, one existing plant nursery will be rehabilitated in each of the eight most affected states of Borno, Yobe, Jigawa, Kano, Katsina, Zamfara, Sokoto and Kebbi. One nursery centers will be established in eight of the buffer states of Plateaus, Niger, Kaduna, Nasarawa, Kwara, Benue, Kogi, Taraba and FCT.

To address the issue of firewood deficit and further protect the fragile dry lands of the country, a 10 ha wood lot has been established in Bauchi, Taraba, and Adamawa states. Plans are under way to establish additional 10 ha woodlots in the remaining northern state.

An integrated model village programme based on the UNEP concept is a strategy of attacking desertification at grassroot level on sustainable basis and ensuring the participation of the affected people in the implementation of all desertification control measures. The components of the programme are provision of energy efficient wood stores, biogas for domestic energy, ventilated improved pit latrine (VIP), and solar power water pump boreholes, installation of house hold water harvesting technologies and sensitization of communities through posters, video and radio.

The ongoing/completed projects include:

- GEP/UNEP sub-regional trans-boundary project between Nigeria and Niger Republic
- Water harvesting for drought management in selected states.
- Introduction and population of alternative sources of energy
- Development of desertification/drought data bank for Nigeria
- Development of national policy on drought and desertification and drought preparedness strategies
- Assessment of the magnitude and extent of desertification in the country.
- Oases inventory and rehabilitation projects
- Sand dune stabilization.

7. Green Wall Sahara Program (GSWP), Nigeria

GWSP is a unique model for arresting desertification and mitigating the affect of droughts in 24 African counties that border the Sahara desert. It was presented to the African Union in Libya in 1995 by president Obasanjo of Nigeria and it was deliberated and adopted as a rural development strategy for arresting desertification. The Nigeria sector of the program was further initiated and implementation has started. The purpose is to combat land degradation and desertification in the affected Sahel and Saharan counties in order to improve livelihoods, alleviate poverty and ensure environmental sustainability in the context, goals and objective of NEPAD, NEEDS and MDG. The major shelter belt is located 10km south of Nigeria – Niger border and is 500 meter wide. The minor shelter belt which marks the southern most end of the belt is only 100 meters width.

Immediately south of the major shelter belt are the primary activities of the GWSP. Each state has been allocated 5 cells of activities comprising: 'desert to food', 'livestock' , 'Jatropha plantation' and '*Cactus opuntus* plantation' programs. Jatropha will produce oil for diesel and products for pharmaceutical and cosmetic industry. *Cactus opuntus* will provide fodder and the fruit for making juice. The 'Desert to Food' program is based on collaborative effort of both the public and private sector and international communities. At the core of the project is the establishment of farm settlement for mechanized farming, irrigation and use of high yield crops. There will also be smaller demonstration farms, commercial tree planting and grassing. The settlement and villages will be supported by basic amenities like water, electricity, roads, schools etc. The GWSP will cost $10 billion Naira, which will cover the development of 32,000 hectares of land in each of the participating states.The Federal Government, will provide 50%, states/local governments. 30%, and Agriddev and donor partners 20%.

8. Drought/desertification preparedness plan for Nigeria

To provide an effective and systematic means of assessing drought conditions, developing mitigation action and programs to reduce risk, economic stress, environmental losses this plan was prepared. Its purpose is to reduce the impact of drought/desertification by identifying the principal activities, groups or regions that are most at risk and to develop mitigation actions and programmes that will reduce vulnerability.

9. Conclusion

Inadequate funding and non-timely release of funds remain the major obstacles to combating desertification and drought in the country. Other constraints include inadequate institutional and human resources capacities, existences of obsolete as well as poor enforcement of environmental laws and regulations. Early warning system has been poorly developed, and the political will seems to be lacking. In order to move the process forward, the problems indicated above need to be attended to. The government should ensure greater involvement of local communities, timely and adequate funds release, harmonization of environmental laws at all levels, continuous strengthening of institutional and human resources capacities and greater collaboration and partnership for increased technical and financial resources availability, transparency and diligence in the management of funds and equipping Nigerian meteorological agency, Nigerian satellite agency and other related agencies with technical equipment to provide timely early warning system for drought and desertification management.

10.7. Effect of water insecurity on agricultural productivity and human security in dry land areas of Nigeria

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Abstract

This study assessed the effects of water insecurity on current agricultural system and human security in the dry land areas of Nigeria. Water insecurity is the unreliable availability of an acceptable quantity and quality of water for production, livelihood and health; coupled with an acceptable level of risk to society of unpredictable water-related impacts which may arise from marked rainfall and run off variability including extreme drought and flood. Water has always played a central role in agricultural production and human security. It is an input to almost all production in agriculture, industry, energy, transport and health. Compared to other areas in Nigeria, water in drylands becomes very scarce relative to demand leading to the fear of trans-boundary conflicts, constraining growth and food security. The drylands in Nigeria form an undulating plain at a general elevation from about 450m to 700m. Average annual rainfall there varies from 500mm in the northeastern part to 1000mm in the southern sub-area. The rainfall is highly variable in spatial and temporal dimensions, with an inter-annual variability of between 15 and 20 percent, and is characterized by high concentration in a few months, intermittence and violence of storms. Thus the area is prone to recurrent and sometimes intense and persistent periods of drought. The high water deficits associated with these areas usually compel municipal, state and federal governments to explore and exploit groundwater through boreholes and hand-dug wells in tapping one or more of the aquifers. Many people, especially the youth, have been trading water through tankers and selling through kegs as coping strategies. For an effective water management, strong institutional design, sustainable governance, accountability and equity, appropriate investment and proper operations and maintenance of sound and reliable water infrastructure are necessary.

1. Introduction

The assertion that water sustains life cannot be a mere saying. Water is one of the world's most important natural resources for the socio-economic growth of a country and for the survival of humanity. It has a great influence on a nation's economy. For the purpose of this paper, four terms with respect to water were developed for of greater clarity. These include: water shortage, water scarcity, water stress and water security. Water is said to be scarce when it is insufficient to satisfy normal requirements. The degrees of scarcity may be absolute, life-threatening, seasonal, temporary, cyclical, etc. The symptomatic consequence of scarcity which may manifest itself as increasing conflict over sectoral usage, a decline in service levels, crop failure, food insecurity etc. is known as water stress. While water shortage is used to describe an absolute shortage where levels of available water do not meet certain defined minimum requirements. Water is said to be secure when there is reliable and secure *access* to water over time. Water insecurity currently afflicts 1.2 billion people in the world and without taking climate change into account; the number of water insecure people was predicted to increase by 600 million by 2025. Household water insecurity is a pressing problem in developing countries. Unsustainable water withdrawal is increasing due to population growth, industrialization, urbanization, and increasing agricultural production. Over 10% do not have adequate means of water purification leading to loss of human life annually.

2. Water insecurity in Nigeria

In Nigeria, the application of water and its use has been an essential factor in raising agricultural productivity and ensuring output predictability. Water is essential to bring forth the potential of the land and to enable improved varieties of both plants and animals to make full use of other yield-enhancing production factors. Water is essential in maintaining human and animal life. Permanent water supplies tend to lead to permanent settlement. On the other hand, the provision of water at or near human settlements tends to increase the stresses on the local environment, which can ultimately lead to desertification. Arid areas like the Sahara and the Sahel have one short and sporadic rainy season, followed by a dry season of eight to nine months. Annual rainfall is one 100 to 400mm.

Water insecurity occurs in Nigeria as a result of natural factors to human activity. Water insecurity increases with increase in population growth, food production, climatic change and variability, land use, and increase in water demand and quality. The Sudano–Sahel would seem to be one of the most at risk in Africa, due to the huge inconsistencies in rainfall. Semi-arid zones, like the Sudano–Sahel, are characterized by a three-to-four month long rainy season with an annual rainfall in the region of 400 to 600mm. Overgrazing (due to an increase in livestock that is often linked to cultural factors) and the gathering of firewood (leading to bush fires, drought and the destruction of vegetation) in these areas have led to increased degradation of lands, and to desertification. The gravity of these climatic perturbations in Africa, and notably the frequent droughts, has been brought to world attention since the 1970s. An estimated one million 'ecological refugees', a sixth of its population, was forced to leave Burkina Faso during the Sahel drought of the early 1970s, and another 500,000 people fled Mali during the same period.

In this light, numerous governing bodies and institutions over the past thirty years have initiated broad-based programs and projects aimed at the conservation and regulated usage of freshwater resources with runoff harvesting mostly favored among a number of possible technical options: Runoff harvesting can be carried out safely to prevent soil erosion while maintaining a necessary level of groundwater. Although there have been encouraging results in certain programs, the majority have failed to give expected results. This poor performance has largely been due to an often interventionist approach and a reliance on techniques that are unsuitable to the local socio-economic and ecological conditions and the real needs of local beneficiaries.

3. Features of the Nigeria dry land

Nigeria's drylands are in the Sudano–Sahelian area. It extends across sixteen of Nigeria's thirty-six states and territories, although environmental conditions are harsher in the north than they are in the more humid southern areas. The potential evapo-transpiration (Et) in these areas is much higher than the annual rainfall, which leads to a water balance deficit of about 230mm in the southern part to about 1,309mm at the northern edge of the region. The high water deficit associated with this region has compelled local, state and federal governments to explore and exploit groundwater resources. Currently, the extraction of groundwater through boreholes and hand-dug wells is tapping one or more of the aquifers underlying the area, which results in over-exploitation.

For example, a decline of 1.5 meters was recently recorded in the dynamic level from boreholes in Maiduguri, in northeastern Nigeria. Currently, the situation is probably worse in most parts of the drylands. The soils in most parts of the drylands, though well drained, are sandy, low in organic matter and characterized by low water-holding capacity. The only exception is *fadama* soil, which is fine-textured with higher organic-matter content and a relatively higher water-holding capacity. It is also a region in which farmers have encroached on grazing reserves and climatically marginal areas, leading to an increase in pastoralist-farmer conflict and exacerbating the desertification process.

4. The threats of water insecurity in the Nigeria dryland areas

Dryland is characterized by insufficient quantity and quality of water leading to water related diseases. As a results of the high rate of drought in some states in the Northern part of Nigeria there is reduction in the volume of water supply and an increased concentration of pathogens in water sources which results in increased rate of water-borne diseases. As the volume of water decreases people are forced to use more contaminated sources.

In addition to high inter-annual variability, the rainfall regimes of dryland of Nigeria are characterized by high concentration in a few months, intermittence and violence of storms. The nature of the rainfall in the region supports mostly savanna vegetation. Thus, apart from some relic forests in low lying ground along the southern boundary, the whole region is covered by savanna vegetation consisting of Southern Guinea Savanna, Northern Guinea Savanna, Sudan and Sahel with the density of trees and other plants decreasing as one moves northwards. The high water deficit associated with this zone has compelled municipal, state and federal governments to explore and exploit ground water sources, which are more available in the zone than surface water. Currently, the extraction of groundwater through boreholes and hand-dug wells is tapping one or more of the aquifers that underlie the area. However, there is the general fear that there is over-pumping of groundwater such that the water table of the area continues to fall. For example, a decline of 6.5 m in the mean groundwater level was measured from a concrete well in Maiduguri, between 1963 and 1972. In the same period, a decline of 1.5 m was recorded in the dynamic level from boreholes in Dalori area of Maiduguri. The situation is currently probably worse in most parts of the dryland. Thus, a full study of the exact recharge rate and the magnitude of the recharge area are required.

The problems associated with the lack of adequate water resources in the Nigeria threaten the health of about 40 million people. It will cost the country in excess of US$ 109 a year to correct such problems due to contamination of ground and surface water.

5. Coping strategies by people living with water scarcity in the dry areas of Nigeria

Most of the dwellers in the Nigeria dryland have difficulty in getting groundwater. They therefore result into drilling of boreholes at very high cost. During the rainy season, runoff is limited to intermittent streams that run along broad depressions. While some of these streams simply vanish into the desert. The rural and nomadic populations in these areas are forced to migrate during the dry period in search of water and grazing land.

The Nigerian Government and the local population have explored and pursued possible means of using runoff water in arid and semi-arid regions to secure the availability of drinking water, food and fodder and to discourage this migratory trend. Water harvesting and spreading using traditional and advanced techniques is considered essential, as it enables the population to exploit the alluvial clay thereby relieving the pressure of animal and human presence on the fragile sandy soils. Besides controlling the state of desertification on sands, water harvesting and spreading secures food and fodder during years of drought and low rainfall. The main methods employed by people in Nigeria to catch water during rainfall are: roof top harvesting, runoff harvesting and flood water harvesting. It has been proven that water-harvesting is likely to increase agricultural output; improve pasture; help regenerate forest in degraded areas; minimize the effects of erosion; and replenish groundwater.

Conscious of the fact that the management of water resources and desertification processes constitutes a challenge for the development of the African continent and Nigeria in particular, FAO has taken measures to study long-term solutions to the problem of increasing agricultural yields in eroded lands. In this context, FAO, in close collaboration with appropriate groups within the United Nations, has developed the International Action Programme on Water and Sustainable Agricultural Development (IAP-WASAD). This represents an integral part of the United Nation's implementation of the Mar del Plata Action Plan, which emphasizes the importance of using water efficiently (a key element towards the effective management of water resources to ensure sustainable agricultural production). With the help of African experts, the FAO has also launched the International Scheme for the Conservation and Rehabilitation of African Lands (ISCRAL). The FAO has also evaluated the potential of Africa’s water resources. It has studied endogenous resource management techniques and, importantly, the socio-economical, political and environmental impact of these techniques.

6. Water policies and legislation in Nigeria

Water legislation in Nigeria is use-oriented dealing with navigability, shipping, and domestic use Because of the destructive nature of navigability and the confusion over the legal ownership of water as a resource thereby impeding irrigation development in Nigeria, decentralization becomes the defining feature of water administration leading to different ministries and agencies at different levels administering laws without adequate coordination. While the functions of the Nigeria River Basin Development Authorities related to irrigation are defined in the River Basin Development Authorities Act No. 35 of 1986, the Environmental Impact Assessment Decree No. 86 of 1992 lists drainage and irrigation as a Mandatory Study Activity, thus prescribing those environmental impact assessments to be carried out for irrigation projects.

The Water Resources Decree No. 101 of 1993 therefore gives the Federal Ministry of Water Resources (FMWR) significant power to control and coordinate activities for proper watershed management and resources protection and for public administration of water resources. It confers to the FMWR the responsibility to make proper provision for adequate supplies of suitable water for, amongst others, agricultural purposes in general and irrigation in particular.

7. Conclusion and recommendations

Water insecurity in the northern part of Nigeria is likely to increase because of the greater frequencies of droughts in some states in this area. The growing pressure on availability of water resources is increasing and increase in competition is coming from alternate use of water in agriculture, industrial and domestic sector. Water insecurity gives rise to conflicts over the use of surface water and groundwater, as well as over water quality, particularly for human consumption. It is for the national water authorities to draw up contingency plans for the distribution of available water resources in accordance with national priorities and, depending on circumstances, for more or less stringent restrictions on the use of water for domestic purposes and for irrigation. All those concerned should be associated in this task under the authority of a senior national official endowed with appropriate powers. It is definitely possible to equalize water supply and demand by combining conservation efforts and better water management. It is also possible to improve water and land use, and to reduce pollution and protect the environment.

10. 8. Engagement with local and scientific knowledge to address environmental change in oasis ecosystems: cases from Egypt and Tunisia

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Abstract

Since the emergence of complex societies in the Saharan oasis settlements, generations of scientists have observed the interactions between human management efforts and ecological processes occurring in these dryland systems. The long duration of many of these settlements may be seen as a demonstration of their notable potential for resilience. Over the past fifty years, land degradation and desertification affecting oasis ecosystems has been observed. These trends are attributed to the management challenges faced by centralized governments in order to sufficiently take into account the complexity of natural and social processes underpinning the maintenance of resilience in oasis ecosystems. In recent years, efforts to reengage local and scientific knowledge in the formation of management strategies have emerged in various parts of North Africa. This paper introduces current research underway to retrace the past fifty years of efforts to engage both local and scientific knowledge in the improved management of groundwater resources and ecosystem services in oasis ecosystems. A preparatory review of contributions made by Egyptian and Tunisian scientists to contemporary understanding of the management of social and ecological change processes and resilience in oasis ecosystems is presented. This review incorporates cases studies at four oasis locations.

1.Introduction

In recent years, efforts to engage local and scientific knowledge in the formation of environmental management strategies have emerged in various parts of North Africa. Oasis settlements have existed in this region for millennia, resisting climatic change through the development of ecological patterns and processes that have ensured their continuity (Brooks et al. 2005: p897). International recognition of the demonstrated resilience of oasis systems has grown, creating interest not only in the traditional forms of oasis settlement and cultivation, but also in the social processes that have enabled them to adapt to changes over time (Laureano 1999).

The definition of resilience used by the recent Millennium Ecosystem Assessment underlines the importance of human understanding and management: ‘Resilience depends on ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics’ (MA 2005: p897). An oasis is defined as ‘a human settlement which uses the locally available resources in arid geographical conditions to create an amplification of positive effects and to build a niche that can sustain itself and a fertile environment, in contrast with the unfavorable surroundings’ (Laureano 1988). Oasis ecosystems are resilient to environmental changes because the local climate and cycling of water and geochemicals through the system are regulated by humans through the application of groundwater, the cultivation of shade-giving plants and the management of chemical balances in the soil. The availability of groundwater resources and the coordination of management processes amongst cultivators are therefore prerequisites for the survival of oasis systems. Traditional management practices in oasis ecosystems have been contrasted to more recent land reclamation and agricultural development projects in marginal desert environments, which have frequently resulted in increased vulnerability, due to degrading effects on land and water resources (UNCCD 2000; FAO 2007; IBRD 2007).

This paper briefly traces trends in desert development policies affecting management processes in oasis ecosystems in Egypt and Tunisia over the past fifty years, drawing on the available literature on two oases in each country. Increasing scientific engagement with local knowledges in both countries has enabled significant contributions to the available understanding of oasis ecosystems and their management. A thematic review of this local ecological knowledge identified in oasis ecosystems is presented. The review focuses on aspects of this literature relating to the resilience of oasis ecosystems that may be of broader significance to contemporary dryland management and development efforts. Current gaps in this literature are identified. The concluding discussion highlights similarities and differences between the management processes adopted to engage with local knowledge in the cases considered.

2. Four Oasis Case Studies

2.1. Wadi El-Natroun, Western Desert, Egypt

The Depression of Wadi El-Natroun (E 30°00'- 30°30' and N 30°15' - 30°30') is located in the Governorate of Behaiyra. Depth below sea level reaches up to 24 metres in the North West, and there are around 10 small permanent lakes, with other seasonal and smaller lakes. The depression is up to 10 km wide and 50 km long (GoE 1999). Average annual rainfall is 55mm. Wadi El-Natroun is a small city with a local council (Omda), and also a regional center (Markaz), administering surrounding villages. In 1986, the total population of Wadi El-Natroun City and surrounding villages was over 21,700, but by 2006, it had reached over 70,000 (CAPMAS 2007). Population growth progressively accelerated to reach over 180% between 1996-2006. Between 1986-96, the population of Wadi El Natroun City grew by 43% (UNHABITAT 2008). The surrounding villages grew even faster over the same period, recording growth rates of over 240% in Beni Salama village and 420% in Al Gaar (Ayyad et al. 2002; Ayyad et al. 1999; CAPMAS 1986, 1996). Numerous projects for land reclamation based on the use of groundwater have taken place in the area and more are anticipated to continue the growth of the population (GoE 1999; Attia et al. 2007).

2.2. Siwa, Western Desert, Egypt

The Siwa Depression (E 25° 16' - 26° 7' and N 29° 7' and N 29° 21') is located in the Egyptian Governorate of Matruh, close to the Western border of Egypt with Libya. Around 18 lakes of varying sizes have formed in a depression, reaching up to sixty meters below sea level. Average annual rainfall does not exceed 9mm (MALH 2005). In 2006, the population totalled over 20,000 full-time or part-time residents. It had approximately doubled since 1975, and quadrupled since the 1950s (CAPMAS 2007). The cultivated area has been expanded through land reclamation, which accelerated during the 1980s. The increase in the irrigated area has led to the expansion of the lakes receiving drainage water, and salinization problems associated with rising groundwater levels around the lakes (Misak et al. 1997; Masoud and Koike 2006). The City Council (Maglis El Madina) in Siwa is the administrative center for all of the villages in the Siwa Depression (Abd El-Rahman 2007). The Siwa Environmental Amelioration Project (SEAP) engages with traditional local processes for decision-making, as well as with NGOs and the management of an adjacent Protected Area, which was formally established in 2002 (SEAP 2002; Ahmed et al. 2002). In 2005, investors, politicians and intellectuals with an interest in conserving the self-sufficient and ecofriendly nature of Siwa formed an NGO called the Friends of Siwa Association. Local NGOs play a key role in international cooperation and development projects.

2.3. Kebili, Nefzaoua Region, Tunisia

Kebili town (E 8° 58' N 33°42') is the administrative centre of the Governorate of Kebili. There are two Delegations surrounding Kebili: Kebili North and Kebili South, including private, collective and State held lands. An oasis settlement has been present at Old Kebili since Roman times (Bisson 2005). Between 1950 and 2000, the population and cultivated areas grew with the increasing sedentarization of nomads from the surrounding area. In the Nefzaoua region as a whole, the cultivated area has tripled over the last fifty years, while pumping of groundwater increased six-fold (Belloumi and Matoussi 2006). However, the average size of land-holding continued to fall over this period, creating challenges for land management and the timing of irrigation by the Associations d'Interet Collectif (AICs) (Sghaier 2006). Environmental management and development activities are carried out by the AICs under the supervision of the Commission de Developpement Regionale Agricole (CRDA). A regional office of the Institut des Regions Arides provides scientific expertise and facilitation to environmental management initiatives such as the Regional Action Plan for Combating Desertification (MEDD/GTZ 2006b). The Regional Action Plan addresses salinization threats to land and groundwater resources in the oases, which are predicted to be exacerbated by climatic change and continuing pumping of groundwater for irrigation (Zammouri et al. 2007). The ecological model presented in this study indicates that salinization affecting areas to the South and East can be anticipated to advance towards Kebili if current patterns of groundwater use are maintained.

2.4. El Faouar, Nefzaoua Region, Tunisia

El Faouar (E 8° 40' N 33° 21) is located in the South the Governorate of Kebili. Annual rainfall is 96mm. The Delegation of El Faouar is made up of a series of oasis villages

(Imadat), including Sabria East and West, Grib, Ghidma, Rjim Maatoug and Matrouha (MEDD/GTZ 2006a). The smallest administrative unit is the village council or Omda (MARH 2006). El Faouar, Sabria and Rjim Maatoug are local centres rather than towns, but gaining in significance (Sghaier 2006). Before the digging of wells, the oases were cultivated and inhabited by mobile pastoralists during the winter. The history of the oases is traceable back to Roman times. Between 1950 and 2000, the population of El Faouar grew and sedentarized. Between 1970 and 1994, the number of inhabitants multiplied from 1,000 to 10,000. The most rapid period of sedentarization was during 1975-82, when the digging of a well under the PDES enabled the allocation of 134 hectares of newly created palmeries (Auclair et al. 1996). In the 1990s, the agricultural lands of El Faouar included 1,358 ha of private land, and 2,160 ha held by the State, including the new oasis of Rjim Maatoug (CRDA 1997 in Sghaier 2006). The Regional Action Plan for Combating Desertification, administered from Kebili, addresses environmental management issues affecting oasis development in El Faouar, including current projections of groundwater salinization, loss of artesianism and loss of biodiversity. One of the villages of El Faouar, Sabria, also has its own Local Action Plan for Combating Desertification (MEDD/GTZ 2006a).

3. Background to desert development policies in Egypt and Tunisia

The cultivation of new desert lands has represented a central element of both Egyptian and Tunisian national development strategies since the nineteen fifties (Goudie 1990; Tomich 1992; Nielsen and Adriansen 2005; Bocco 2006). Nomadic pastoral populations in both countries have undergone a process of sedentarization in and around the old oasis settlements, while traditional management institutions have been partially restructured. Explicit targets continue to be set by both governments for the spatial extension of cultivated areas, the reclamation of desert lands, and the improvement of settled living conditions, including provision of water supply, sanitation and other services (e.g. MALH 2005; FAO 2005). However, administrative approaches to the ongoing greening of the desert have shifted considerably over the past fifty years (Enien et al. 2000).

The following brief review of successive trends in desert development policies and associated scientific efforts is divided into three periods 1950-70, 1970-90 and 1990-2010. Globalized shifts in economic and development policy approaches affecting both countries may be conveniently segmented into these time periods. Nevertheless, it is important to qualify the observation of these shifts with recognition that institutionalization of successive approaches to desert development and the engagement of the scientific community in each country has also ensured considerable continuity and overlap between the three approaches identified.

***1950-70: State-led desert development policies marginalize local decision-making*:** Early rural development policies in both countries focused on centralized State-led efforts to develop agriculture and settle populations on the land (Sghaier and Seiwert 1993; Auclair et al. 1996; Altorki and Cole 2006; Bocco 2006; Elloumi 2006). Drilling of wells had begun in both countries during the colonial period, and was continued under the new governments, together with the provision of extension services, and State control of prices. Agrarian reform proceeded slowly in remote desert areas over this period. Some attempts to restructure land and water rights in the oases were included in socialist development projects (Kassah 1996; Attia 2002). Physical access to the old oases was difficult due to a lack of transport infrastructure. The oasis of Siwa was effectively closed to outsiders until a road was constructed in the 1980s. State development efforts generally focused on more fertile areas in the Nile Valley and the North of Tunisia. The Egyptian Desert Development Agency began transferring populations and agricultural extension services from the Nile Delta into the desert oases from the 1960s (Cole and Altorki 1998; Parrish 1999).

Both governments incorporated traditional land rights into new legal frameworks to promote the sedentarisation of nomadic tribes in desert areas. Tunisia's laws # 16-57 in 1957 and # 59-83 in 1959 clarified procedures for allocation of land to members of collectives that had planted it *('mise en valeur'*). While traditional rights to land privatisation under the law '*d'Il Ihya'* were observed by the authorities, they were considered illegal by the agricultural services (Sghaier 2006). Similarly, Egypt's Law 100 of 1964 promised land ownership (tamlik) to those who developed farms with fruit trees in Matruh and other frontier governorates, following principles established by the Shari'a and the Qanun. Nevertheless, studies amongst the Awlad 'Ali and Jawabis Bedouin have observed that they were often not able to document their ownership of land during this period (Cole and Altorki 1998,; Altorki and Cole 2006).

International research programmes to investigate the conditions of desert populations and the available development options during this formative period were conducted by experts, including Arabs and foreigners, the majority of whom did not originate from the oasis regions (Pavlov 1962; Shata et al. 1962; LaMoreaux 1962; Parsons 1962). These studies could build on the work of existing institutions, such as the Egyptian Desert Institute and Geological Survey. The elite of experts engaged in these early studies adopted what may be regarded as a broadly paternalistic approach to development, more recently criticised for lack of understanding and appreciation of local conditions (Mitchell 2002; Bocco 2006).

1970-90: Reorientation of development policies challenges local capacities: Efforts to bring more land under reclamation and to increase productivity accelerated in Tunisia over the 1970s and in Egypt over the 1980s. Progress in Egyptian development efforts during the 1970s has been described as erratic, as the growth of the oil industry caused a loss of interest in agriculture, and increased vulnerability to international market forces accompanied economic liberalization in both countries (Pautsch and Abdelrahman 1998; El-Ghonemy 2003; Bush 2007). However, extensive hydrogeological investigations conducted in the desert areas during this period enabled the digging of deep wells in the oases, and more abundant provision of irrigation water to private farmers under the Tunisian Plan Directeur des Eaux du Sud (PDES) and the Egyptian General Authority for Reclamation Projects and Agricultural Development (GARPAD). In both countries, a contracted view of the role of the State in delivering development emerged and was promoted by international institutions.

The commoditization of land resources took hold in the desert regions, and former nomads increasingly acquired and sold properties where they could (Altorki and Cole 2006; Sghaier 2006). With increasing market orientation in desert development strategies, agroindustrial processing of dates and olives developed (Aly 1991). In Tunisia, the Enquete Oasis was created with support from the commercial producers association Groupement Interprofessionel des Dattes (GID 1976). Specialised agricultural research institutes were established in Tunisia, such as the Centre de Recherches Phoenicoles de Degache (1984) and the Institut Olivier (1981). On the other hand, as the need to take into account the effects of market forces gained sway in Egypt, centralized extension programs for small farmers were seen as inefficient (Tomich 1992).

Development policies in both countries increasingly focused on handing on local management responsibilities to local groups, known in Egypt as Water User Associations (WUAs), and in Tunisia as Associations d'Interet Collectif (AIC), and subsequently by a succession of other acronyms (Selmi 1998; Romagny et al. 2004; Sghaier 2006). These groups were required to manage their own development choices in the globalizing economy (CEDARE 2006; IBRD 2007). Many lacked management capacity, and struggled to maintain their finances, depending on the State to bail them out (see e.g. NEPAD-CAADP 2005). This perpetuated a sense of dependence and lack of local empowerment (Brochier-Puig 2004). In contrast, large private agroindustrial developments achieved greater financial sustainability (Belloumi and Matoussi 2006).

1990-2010: Local participation in environmental management reengaged: Decentralization policies took hold in both countries during this period, and were translated into institutional changes, including efforts to decentralize State budget allocation to the governorate level (Nawar 2006; Elloumi 2006). By the 1990s, improvements had been observed in development indicators concerning dwellings and access to basic services had improved in oasis regions. The main challenge identified by development policy-makers increasingly concerned the observed threats of land degradation and salinization to the future availability of resources on which the oasis settlements were dependent (Misak et al. 1997; Kadri and VanRanst 2002; Zammouri et al. 2007).

National sustainable development agendas focusing on tourism, cultural heritage and the designation of protected areas have became recognized as an essential element of economic development strategies in both countries (GoE 1999; Belloumi and Matoussi 2004). New development projects are increasingly evaluated on the basis of their social and environmental sustainability. These policies are reinforced through commitments to international environmental agreements and access to international assistance for combating desertification, conservation of biodiversity and adaptation to climate change. In Tunisia, Local and Regional Action Plans for combating desertification have been created to address development challenges in the oases of Nefzaoua (MEDD/GTZ 2006b; MEDD/GTZ 2006a). In both countries, local planning processes for protected areas and ecotourism development have been pursued, incorporating environmental management dimensions (SEAP 2002; Al Adawy et al. 2006).

The shift to mainstream consideration of environmental and social sustainability in desert development policies has introduced new agendas and methods for the scientific community. Instead of linear transfers of technology, a more interactive research model has come into favour, based on two-way communication between cultivators and the policy level, through facilitation by researchers working with local institutions and NGOs (Sallam 1994; Enien et al. 2000; Sghaier 2004; Nasr 2004; Nawar 2006). Increasing scientific engagement with local knowledge through this model has enabled significant contributions to the available understanding of oasis ecosystems and their resilience. These scientific contributions are reviewed in the following section.

4. Scientific engagement with local ecological knowledge of resilience

A review of recent scientific literature on ecological processes in human-managed oasis ecosystems (King 2008) identified numerous contributions by Egyptian and Tunisian scientists working with oasis cultivators in efforts to promote sustainable development. The following summary highlights four elements of ecosystem function and that are synergistically managed and adapted to amplify positive effects supporting life in otherwise arid environments. This review draws on examples from local practices and scientific investigations published from the selected oasis locations described above.

4.1. Climatic regulation and multiple uses of water

The 'oasis effect' creates microclimatic regulation beneath a date-palm canopy or walled enclosure, due to shading and reduction of evapotranspiration (ETP). This effect has been referred to since the ancient accounts of oases. The effect in traditional oasis ecosystems is created through the use of floodwater irrigation, with the standing water also contributing to the cooling effect through evaporation, further reducing plant evapotranspiration. Water uses in many traditional oases are based on high volumes of water moving through a hierarchy of uses and reuses within the system of human settlement and cultivation. The incorporation of multiple uses of water and wastewater reuse into conventional calculations of water-use efficiency has posed a challenge for agronomists in other regions (see Siebert et al. 2007). The oasis effect has been examined by Tunisian and Egyptian scientists using various measurement approaches in traditional oasis environments (El Ammami and Laberche 1973, see Riou 1990; Taha et al. 1991; Sellami and Sifaoui 1998, 2003). Recent scientific contributions have continued to explore new possibilities for wastewater reuse (Mtimet and Hachicha 1995), through the observation of local practices (Kadri and VanRanst 2002).

4.2. Low energy extraction of salts and waste management

The evaporite products of saline wastewaters in oasis lakes have been used over the centuries in food preparation and preservation, pest control, medicines, detergents, embalming agents and for making glass (Wilkinson 1843; Ayyad et al. 1999; Parrish 1999; Shortland 2004). Building blocks made from a mixture of salt and mud, known in Egypt as karsheef, are traditionally cut out of the salt lake beds and used to build houses that remain cool in the summer. These have demonstrated contemporary appeal for construction of ecotourism facilities (Chaouni 2007). Naturally occurring materials and processing agents are considered less harmful to human health and the environment than synthetic chemicals manufactured at a higher energy cost. They are also more easily recycled or safely washed away, minimizing wastes and pollution threats to groundwater for drinking, industry and food production. Studies systematically quantifying avoided pollution and waste management costs in oasis ecosystems were not yet identified during this review. However, attention to the use of indigenous oasis plants for the removal of excess salts and other contaminants has featured in investigations over recent decades (El-Hakim and Draz 1991; Misak et al. 1997; Masoud and Koike 2006; Williams et al. 2008).

4.3. Conservation of nutrients and carbon in soils

Desert soils are usually considered poor in organic matter (Fathi et al. 1971; AbdelSalam et al. 1972; Harga et al. 1975). However, with cultivation, nutrient levels are increased, and the soil progressively becomes more productive, enabling increased sequestration of carbon both above and below ground. Documented traditional practices for nutrient conservation used in the oasis of Siwa included placing bundles of Zammar Grass, and Fasool (*Alhagi graecorum*) around the roots of the trees every year (Stanley 1912) and the application of manures from livestock (see also Sghaier and Seiwert 1993). Integrated agricultural research has continued to pursue management practices including the application of manures, plant matter and ash to maintain the soil within the nutrient cycle created by the harvesting of foodstuffs for human and animal consumption. In recent years, conservation studies have contributed to the literature on traditional uses of wild plants to supplement nutrients in oasis soils (Ahmed et al. 2002). Increasing market interest in organic produce has created a premium for crops grown without the use of chemical fertilizers and pesticides, rendering traditional practices more profitable in the short-term, as well as reducing risks to the environment and human health (Nabhan 2007). No published scientific assessments of carbon sequestered in oasis plants and soils, including soils reclaimed from desert lands around oases, were yet identified in available literature from Egypt and Tunisia at the time of this review.

4.4. Cultivation and use of diverse locally adapted species

The diverse mix of species that has developed in many oasis ecosystems ensures macro-scale resilience to disease and variable climates. The Bayoud disease, which attacked 'deglet nour' dates in North Africa but was resisted by other varieties illustrated the importance of the conservation of diverse local varieties (MEDD 2006; Watson and Snyder 1973). Following this experience, various projects have pursued local knowledge of date palm varieties and other species (see e.g. Nasr 2004; Nabhan 2007). New engineering uses of date palm products continue to emerge (El Nemr et al. 2008). Traditional and potential new uses of wild plants surrounding oases for household, medicinal and other uses is increasingly documented through conservation studies (Ahmed et al. 2002; Hamed et al. 2002). The use of local species for shelterbelts and sand dune stabilization around oases has been explored and implemented (El-Hakim and Draz 1991). Agrosystems studies have examined the social dimensions of cultivation in oasis ecosystems, engaging with the skills and infrastructure required to efficiently conserve, produce, process and market produce (Sghaier 1994). As botanical studies continue to identify indigenous knowledge of the agrobiodiversity of oasis ecosystems (IRA 2004), further opportunities for processing and marketing studies are created.

5. Conclusion

Similar trends in the expansion of cultivation and settlement can be observed in each of the selected oasis locations included in this review. Land degradation threats associated with salinization of water resources have been exacerbated by similar climatic and other hydrological changes affecting all of the locations considered in this study, due to increasing application of irrigation water and high rates of evaporation. Local institutions and processes for adaptation to ecological threats from hydrological change and salinization vary between the four cases examined. Local community planning activities for Combating Desertification (Sabria and Kebili), Protected Area conservation (Siwa and El Faouar) and local urban development planning (Wadi El-Natroun and Kebili) have engaged differently with local knowledge to enhance environmental management and development. These differences in environmental management approaches, their local scientific findings, and their comparative outcomes in strengthening the resilience of oasis ecosystems, merit further attention through the comparative research project on oasis ecosystems and global change.

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10. 9. Community agricultural development in semi-arid lands, Kenya experience

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Abstract

Community Agricultural Development Project in Semi Arid Lands (CADSAL) has been established as a result of a desire of the Kenyan Government to increase agricultural production in semi-arid lands. The Economic Recovery Strategy for Wealth Creation (2003-2007), which is the current national development plan in Kenya, identifies arid and semi-arid lands (ASALs) as crucial for accelerated development to offset pressure in high potential areas. The ASALs cover over 80% of the total land surface and are home for over 25% of population and 50% of all livestock. CADSAL is collaborative project between the Ministry of Agriculture (MOA) of Kenya and the Government of Japan with technical cooperation assistance through Japan International Cooperation Agency (JICA). The objective aims to sustainably increase the agricultural production of small holder farmers with outputs that 1) participatory project planning and implementation are strengthened, 2) pluralistic extension service delivery system is promoted, 3) appropriate technologies to increase crop and livestock production are verified, and 4) guidelines for community agricultural development are prepared in the project period from October 2005 to October 2010. As of June 2008, about 50 Community Initiated Projects (CIPs) such as dairy goats and dairy cows rearing, camel rearing, poultry keeping, vegetable cultivation, and water tank have been selected and implemented. Apart from CIPs, Community Participatory Technology Development Projects (CPTDPs) such as New Rice for Africa (NERICA) trial, drought tolerant maize demonstration, soil/water conservation, and establishment of a dairy goats association have been implemented in collaboration with farmers in the target area. In order to prepare the guidelines, the activities mentioned above are linked together through the Pluralistic Extension Service Delivery System implementing more CIPs and CPTDPs with a view to achieve the project purpose.

1. Introduction

Kenya's economic growth relies on agriculture, which contributes directly about 27% to the total GDP and another 27% indirectly through linkages with other sectors. The sector employed more than 80% of total workforce and generated over 65% of total foreign earning in 2002. The average annual agricultural growth rate was 1.2% in 2001 as against 2.48% in 2000, showing a decline in the performance of agriculture sector (Ministry of Agriculture 2005).

As first step to dealing with the economic problems facing the country the government of Kenyan (GoK) launched the "Economic Recovery Strategy for Wealth and Employment Creation" (ERS) in 2003. Particular emphasis was laid on revitalizing agriculture as the engine of growth of Kenyan economy (Ministry of Agriculture 2004) and consequently Strategy for Revitalizing Agriculture (SRA) as a National Policy Document was developed in 2004. The SRA suggested capacity building for planning at community level and broader participation of stakeholders in agricultural extension, namely Community Based Organizations (CBOs), Non Governmental Organization (NGOs) and private sectors.

2. Arid and semi arid lands (ASALs) in Kenya

Kenya's total land excluding water bodies is 576,075km^2. About 17% of this land is suitable for rain-fed agriculture and supports subsistence and commercial agriculture. About 83% (48 million ha) is covered by the arid and semi arid lands (ASALs), mainly supporting pastoral livestock production systems on large communal grazing land and ranches (31%) and drought tolerant crop farming (19%). In general ASALs support 5 million people, 50% livestock, 3% of agricultural output and 7% of commercial output, all based on between 400 – 800 mm of annual precipitation (Ministry of Agriculture 2005). The major challenges relate to population growth, sedentarization of pastoralists, land privatization, encroachment of pastoral land, and development of water and appropriate farming techniques and tourism. There is has been an uncoordinated development of ASALs in Kenya due to lack of ASALs policy. There is however a draft policy paper at advanced stages of formulation. By implementing the draft policy, the following results would be realized, at least in the next 15-20 years: (a) The needs of the poor people in the ASALs are reflected in national policy and planning frameworks; (b) The vulnerability of poor people to climatic shocks, particularly to droughts and floods, are reduced, and capacities strengthened to respond to the effects of climate change; (c) People in the ASALs benefit from systems of good governance; (d)The private sector investment increase with decreasing insecurity and improved physical infrastructure; and, (e) ASALs communities take full charge of managing their natural resource base and have a voice and sufficient say on land tenure and resource utilization issues that impact on their lives (Ministry of State for Special Programmes 2004).

3. Community Agricultural Development in Semi Arid Lands (CADSAL)

3.1. General information on the project

In 1999 the GoK requested the Government of Japan to assist in the rural development of the ASALs. The Japan International Cooperation Agency (JICA) was requested to undertake the "Study on the Integrated Rural Development Project in the Baringo Semi Arid Land Area," from 2000 to 2002, to propose a sustainable development methodology in ASALs. Based on the Study "the Master Plan" was developed. The GoK submitted a project proposal to the Japanese Government based on the participatory rural development approach suggested in the Master Plan from where CADSAL was formulated in 2005 to increase agricultural production in the semi arid lands, namely Keiyo and Marakwet districts.

Maize is a major crop because it is the staple food. More over, cassava, bananas and mangoes are grown in Marakwet than in Keiyo due to higher irrigation potential. Finger millet is common to both districts as it is used for food and during vital traditional ceremonies. More beans and sorghum are grown in Keiyo than in Marakwet because of the higher precipitation in Tambach area. Livestock is mainly zebu cattle and small east African goats. Keeping of pure or cross breeds of livestock is not common perhaps because of the inadequate knowledge of farmers about the advantages of improved livestock, distance to sources of breeding/improving materials, lack of knowledge of the sources, transport cost, unsuitable environment, inadequate fodder and water availability, livestock diseases, and high costs of improved livestock management.

It will operate from October 2005 to October 2010 with the aim of increasing agricultural production in a sustainable manner in the target area. The expected outputs include: (a) participatory project planning and implementation are strengthened; (b) pluralistic extension service delivery is promoted; (c) appropriate technologies to increase crop and livestock production are verified; and (d) guidelines for community agricultural development are prepared. The project is located at the escarpment and lowlands in the districts of Marakwet (Tunyo and Tot divisions) and Keiyo (Metkei, Soy and Tambach divisions) in Rift Valley Province. The annual average rainfall ranges from 850-1000mm at the escarpment and 450-850mm at the lowlands. The annual average temperature of the escarpment and the lowlands are 22℃ and 30℃ respectively. The target groups are smallholder farmers, farmers' organizations, pastoralists, women and youth. The input from the Japanese side is dispatch of a long-term expert (Chief Adviser on Semi Arid Land Agriculture and Coordinator of Community Development), dispatch of short-term experts (on crop, livestock, participatory development etc.), provision of equipment and vehicles, training of counterparts in Japan or in third countries; and allocation of operational costs for the Project. The input from the Kenyan side includes: assignment of counterpart personnel (Project Director and Project Manager) and administrative and support staff, provision of land, building, and other necessary facilities and allocation of operational costs for the Project. The project addresses the current agricultural policy of the Kenyan Government of promoting community-based or people-centered participatory project planning and implementation, pluralistic agricultural extension, and agro-based cottage industry. To accomplish this, the project has a close link with relevant ministries, Kerio Valley Development Authority, NGOs, CBOs, Faith Based Organizations, political leaders, private sectors (seed companies, etc.) and all the major stakeholders.

3.2. Project approaches

Giving cognizance to the inherent technological know how of the communities in the project area, the project endeavors to link modern technologies from diverse sources within and outside Kenya to develop agriculture in the target area. The project sources technological innovations which have been tested and proved suitable for ASALs areas, sets a demonstration site with the farming community and carries all the necessary practices in conjunction with the field officers of the line ministries. Continuous training is done during these demonstrations culminating in the staging of a field day when surrounding farmers are invited and other messages are passed to them by CADSAL and any other invited stakeholders. The second, bottom up, approach involves empowering communities to harness the full potential of their resources at their disposal without compromising the quality of the environment, in a sustainable manner. CADSAL mobilizes the community groups that have common aspirations and have stayed together to develop their synergies for their own development. The groups are encouraged to mobilize their human and material resources through intensive planning, implementation and monitoring and evaluation of the project of their choice and encouraged to follow simplified Project Cycle Management (PCM) techniques. The Community Initiated Projects (CIPs) which farmers' groups apply to CADSAL by owns initiative are unique with cost sharing (*20% by a group*), material basis assistance (*no cash basis*), Basket of Choices (*alternative technologies*) and field selection of groups (on*site group selection with interview*). CADSAL has so far assisted 50 CIPs.

3.3. Organizational structure

The organizational structure and work flow of CADSAL is shown in Figure 1. The Ministry of Agriculture (MoA) is the implementing body and holds overall responsibility with support by JICA. The Director of Training and Extension department of MoA is Project Director to administrate and implement the Project. The main implementers of the government side are composed of Project Management Unit (PMU), District Working Group (DWG) and Divisional Implementation Team (DIT). The PMU comprises Project Manager, the JICA experts' team, Kenyan counterparts (Semi arid land agriculture, Livestock and Community project). The office is responsible for overall supervision, planning, implementation, and monitoring, reporting and financial management. The office advises on cross cutting regional issues and provides technical backstopping. The DWG comprises the District Agriculture Officer, District Livestock Production Officer, District Irrigation Engineer, PMU and Co-opted members such as District Veterinary Office and local leaders. The duties of DWG are to approve divisional work plans and budgets, to supervise and coordinate of the project activities, to provide technical and managerial backstopping and to produce reports. The DIT is composed of the relevant officers drawn from relevant organs referred to in DWG. The team provides technical advice to farmers, conduct training and deliver extension services, monitor and evaluate CPTDPs and CIPs, assist communities to formulate Community Action Plans and Budgets and write reports

3. 4. Research and development activities of CADSAL

3.4.1. Variety trial for drought tolerant hybrid maize

In order to introduce higher and more stable yield of maize variety in the target area, field variety trials of the Drought Tolerant Hybrid Maize were carried out in cooperation with core farmers in their farms. The maize seeds were given by Kenya Seed Company (KSC) and planted in each division under conventional cropping method. The characteristics of each maize variety are shown in Table 1. In general, the late maturing varieties give higher yield but are subject to water shortage while early maturing varieties give lower yield but are not subject to water shortage very much. According to instruction by KSC, the H series is for planting at medium attitude ranging from 1000 – 1700m (a.s.l.) and is late maturing with higher yield potential while the DH series is dry land hybrid with early maturity and lower yield. The Pwani series is mainly targeted to hot humid lowland zones between altitudes 1 – 1200m (a.s.l.) with medium yield potential. Table 2 shows the yields of the trails in 5 divisions. The variety of DH04, PwaniH4 and H515 achieved higher average yield than DH02. The yield of DH04, which is a dry land hybrid, exceeded the expected yield perhaps because of relatively high rainfall in 2007. Yield response to water of DH04 should be studied to get clear understanding on such high yield because farmers are utilizing river water originating from a forest through traditional furrows to irrigate in Marakwet. If they utilize water effectively and efficiently, DH04 can be a promising variety in the area. Additionally further investigations such as soil fertility and marketing analysis are required to prepare the basket of choice for the CIPs. Presently effectiveness of manure is under investigation in farmers' plots to utilize local materials and minimize fertilizers. The variety of H515 and H513 become popular among farmers in the area these days and its sales are increasing since CADSAL started the trials.

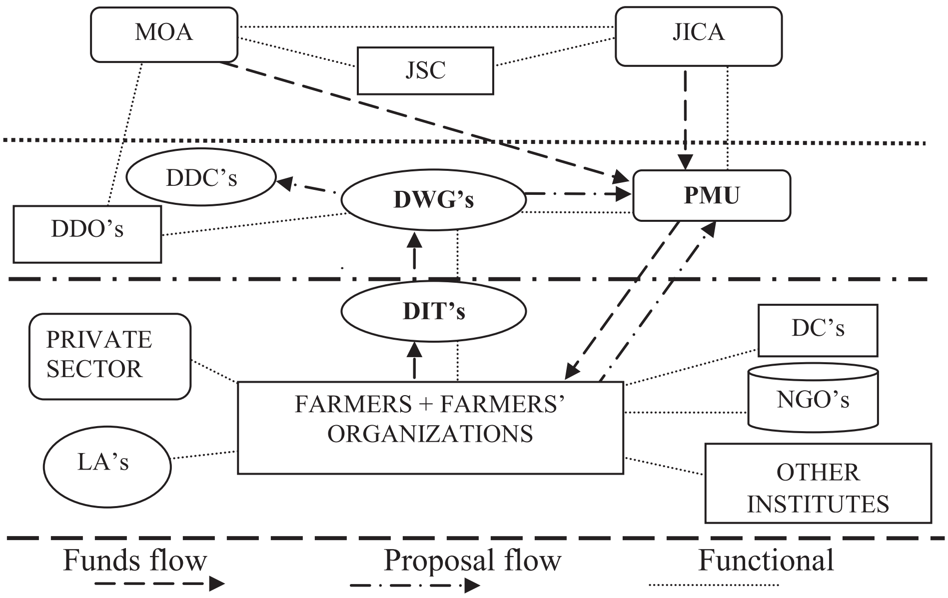

Figure 1. Organizational structure and work flow of CADSAL. (MOA = Ministry Of Agriculture, JSC = Joint Steering Committee , DDC's = District Development Committees, PMU = Project Management Unit, DDO's = District Development Officers, DWG's = District Working Groups, DIT's = Divisional Implementing Team, DC's = Development Committees LA's = Local Authorities)

Table 1. Characteristics of drought tolerant hybrid maize varieties

riety	Expected yield (t/ha)	Altitude range (a.s.l.)	Length of rainy season (month)	Drought tolerant Level*	Remarks
H513	5.0	1200 - 1600	4 – 5	3	Recommended in ASALs
H515	5.4	1200 - 1600	4 – 5	2	Rainfall not less than 800mm
DH02	3.4	900 - 1400	2 – 4	5	Highest resistance to drought
DH04	3.6	100 - 1600	2 – 4	4	High resistance to drought
Pwani H4	5.0	1 -1200	3 – 4	3	Hot humid lowlands

*Drought tolerant level: 5 High ⟷ Low 1 (Source: Kenya Seed Company)

Table 2. Yield (t/ha) of drought tolerant hybrid maize varities in 5 divisions of Kenya

Variety	Keiyo Dist. Soy Div.	Keiyo Dist. Tambach Div.	Keiyo DistMetkei Div.	Marakwet Dist. Tunyo Div.	Marakwet Dist Tot Div.
H513	4.5	4.1	3.6	3.4	3.4
H515	4.7	4.5	4.1	3.9	4.3
DH02	2.7	3.2	2.9	3.4	4.1
DH04	5.2	4.3	5.4	4.5	4.7
PwaniH4	4.5	4.1	4.7	4.5	5.0

(Source: CADSAL annual report)

3.4.2 Adaptive trial for New Rice for Africa (NERICA)

The production of rice in Kenya has remained low at an annual average of about 52,000 tones, which is only 34% of the national consumption requirement (Ministry of Agriculture 2004). NERICA is new crop developed from native African rice varieties in Western Africa and Asian varieties to enhance the livelihoods of people in Sub-Saharan Africa. Since 2004, various trials for its suitability and productivity have been carried out in Kenya at Mwea, Ahero, Coast Province, Juja and Bungoma, Marakwet and Keiyo. CADSAL is carrying out the trials with the community in a participatory manner. Table 3 shows the yield of 8 farmers' plots. NERICA4 showed higher potential than NERICA11 in the area. Farmer A recorded yield of 4.1 t/ha of NERICA4 as well as 3.4 t/ha of NERICA11. The reason for such high yield gained by farmer A was introduction of the basin irrigation with bund and leveling compared with other farmers.

Table 3. Yield (t/ha) of NERICA4 and NERICA11 rice varieties on eight farms

	Farmer A Keiyo Soy	Farmer B Keiyo Soy	Farmer C Keiyo Soy	Farmer D Keiyo Tambach	Farmer E Marakwet Tunyo	Farmer F Marakwet Tunyo	Farmer G Marakwet Tunyo	Farmer H Marakwet Tunyo
NERICA4	4.1	—	1.7	3.0	1.5	1.9	2.1	2.3
NERICA11	3.4	1.2	—	1.1	—	1.3	—	—

(Source: CADSAL annual report)

This method has an advantage in keeping optimum soil moisture for longer period than others. Actually rain water could stand for a while inside the plot surrounded by the bunds. It has been proved that the Keiyo Valley has a potential for NERICA through several adaptive trials at farmers' plots. As mentioned above, the maximum yield of some 4 t/ha has been recorded during adaptive trials in 2006 and 2007 by CADSAL. Rainfall of 20mm/5day for 80 days can give higher yield (Tsuboi 2008) and the supplementary irrigation is essential to achieve such yield in the area. Especially Marakwet district has high potential because of the traditional furrow system of irrigation.

3.4.3. Rainfall data analysis and proposed cropping season for NERICA

The Figure 2 shows 5 days rainfall in 15 years, from 1991 to 2005, in Tunyo division in Marakwet district, using the moving mean method. There are three peaks within the year whereas two bottoms fall onto February and September. More than 20mm/5days rainfall ranges from the middle of April to middle of May. This period is suitable for the panicle initiation and heading stages of NERICA rice which need more water. Any other period will need additional water for vigorous growth of NERICA. According to the rainfall pattern (Fig. 2), the land preparation may start in March and the harvest occurs in July during the first season. Since another peak of rainfall ranges from the middle of October and the middle of November, the second season of NERICA can start in September and end in January. The cropping period of NERICA is about 110 to 120 days, so combination of other crops like maize, legumes and vegetables should also be taken into consideration. The cropping calendar can be created based on the farmers' preference and their farm management as well as water availability. If NERICA is willingly accepted by the farmers in the area, water allocation among crops should be considered because of the newly introduced crop.

3.4.4. Supplementary irrigation for NERICA

Figure 2 clearly shows that the supplementary irrigation is required for higher yields due to lack of rainfall in some period considering the target of 20mm/5days.

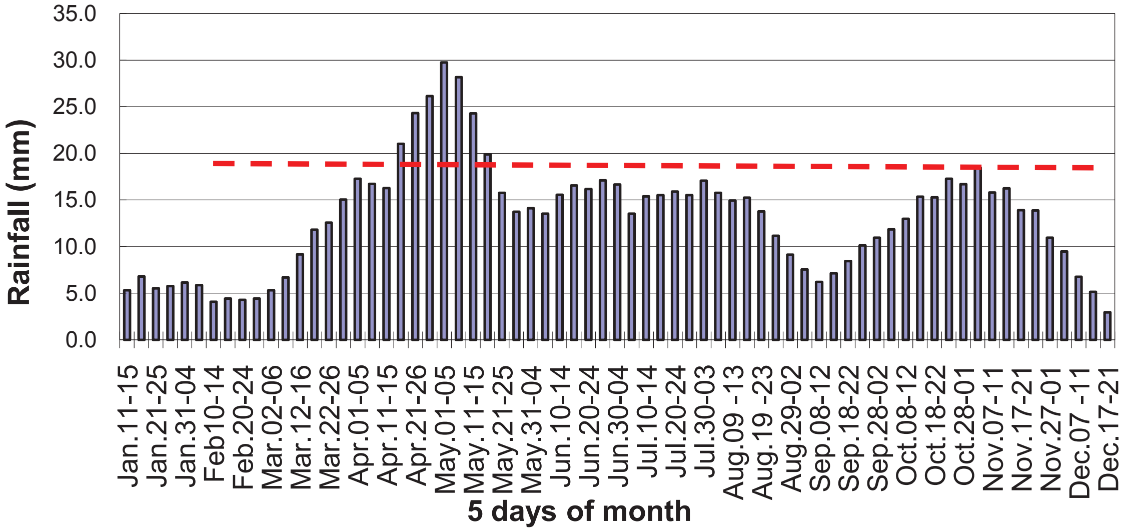

Figure 2. Five days rainfall by moving mean method in Tunyo from 1991 to 20053.4.4. Supplementary irrigation for NERICA.

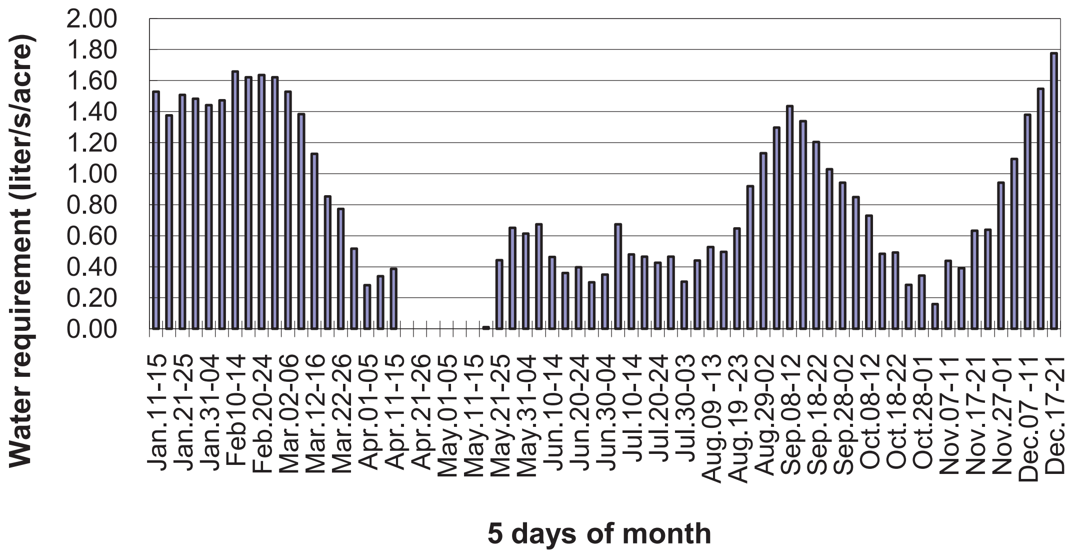

Figure 3. Supplementary water requirement for furrow irrigation in Tunyo

The Figure 3 shows the water requirement (liter/s/acre) every 5 days to reach 20mm/5days in case of furrow irrigation. Assuming the efficiency of the furrow irrigation as 30% and irrigation period of 8 hours, the water requirement will be between 0.4 to1.6 liter/s/acrey in the first season and 0.2 to 1.8 liter/s/acre in the second season to get good yield.

The Figure 4 shows the water requirement in case of sprinkler irrigation with the efficiency of 60%. Because of better irrigation efficiency sprinkler irrigation is recommended. Furrow irrigation also can be improved in efficiency by shortening the furrow length and stone pitching along the furrows. Also the proper water management is necessary for irrigation along water conveyance level and on farm level. Appropriate selection of soil is also very important for irrigation activities. Sandy is not found suitable for NERICA cultivation..

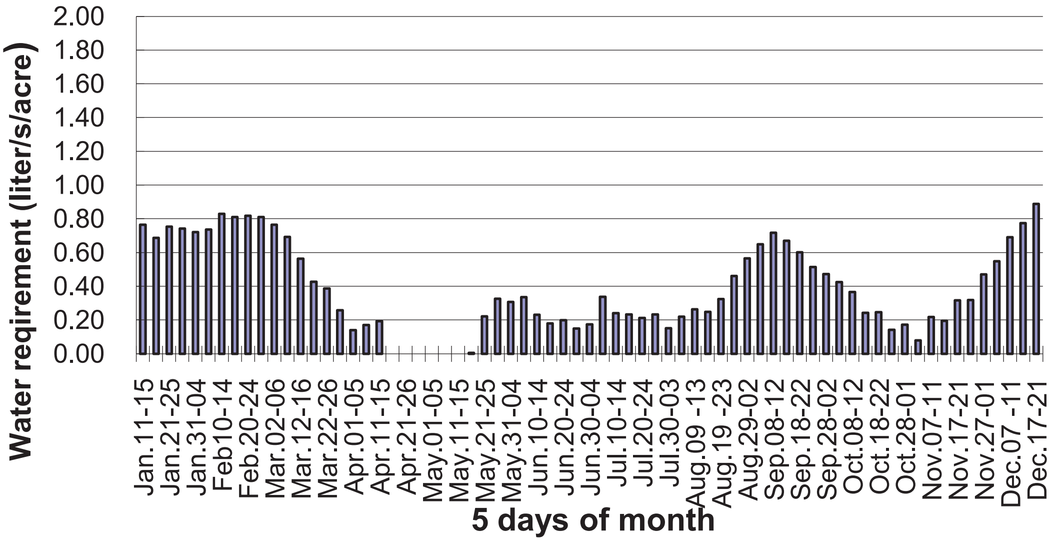

Figure 4. Supplementary water requirement for sprinkler irrigation in Tunyo

4. Other activities

4.1. Introduction of camel and better breeds of cattle and goats

CADSAL introduced camels in Keiyo district for the first time as CIPs. for milk and meat production and for promoting ecotourism. Camels are **e**nvironmentally friendly in that their feet are padded and hence they can not cause soil erosion. Furthermore, they browse tree tops avoiding overgrazing that can cause loss of ground cover. The project has continued to train the farmers on the need to introduce and maintain high yielding livestock breeds like grade cows and dairy goats through CPTDPs and CIPs.

4.2. Water harvesting

Water harvesting techniques are vital for supporting agriculture in ASALs. In the Kerio Valley, there are traditional furrows that are constructed and maintained by communities. CADSAL encourages farmers to make the most efficient uses of water through training/demonstrations and farmers tours. Simple structures like water retention ditches are encouraged as well as contour farming. Repair of water channels is supported while Water Users Associations (WUAs) are strengthened through registration and training.

4.3. Mosaic virus free cassava

The project introduced virus free cassava varieties, as well as improved varieties of bananas and sweet potatoes, in cooperation with KARI. Agronomic practices are demonstrated by the CADSAL and frontline extension staff.

4.4. Farmer training

The project organizes field trainings and demonstrations as well as exhibitions either singly or in cooperation with other stakeholders. Project publicity is done through public meetings, "barazas", and by local print media and radio.

5. Challenges and strengths of the project

The project has faced several challenges during its implementation: (a) Late pick up of the project during planning stages making many people impatient in the beginning; (b) High expectations in terms of inputs from donor after seeing big cars used in the project area; (c) Delays in the disbursement of funds from the GoK to match JICA funds; (d) Rough terrain and hence mobility difficulties; (e) Inadequate infrastructure including marketing; (f) Unreliable rainfall; (g) Political chaos of 2007; (h) Unpredicted out breaks animal diseases; and (i) Low group capacity.

CADSAL has developed the following strengthens and opportunities: (a) Strong DWG and DIT; (a) Good working relationships between the GoK and JICA counterparts; (b) Strong support from headquarters of both GoK and JICA; (c) Introduction of Community Initiated projects (CIPs); (d) Cost sharing; and (e) Goodwill from local politicians

6. Conclusion

CADSAL has provided an opportunity for the people of Kerio Valley to improve their livelihoods through semi arid agriculture techniques by means of several activities such as maize and NERICA trials, camel rearing and farmer training. The two approaches adopted by CADSAL, i.e. CPTDPs and CIPs, have improved the farmer participation and hence sustainability of projects. The development of the synergies has not been easy but the project has continued to look for the best methods possible. Working together as development partners in a pluralistic manner is beneficial to the farmer since it avoids duplication of efforts as well as conflicting information to the farmer. Stakeholder fora developed by other projects within the MoA has proved to be a good opportunity where farmers and stakeholders can meet and share experiences and approach agriculture in a holistic manner. There is strong need to mainstream ASALs development into the national development through provision of adequate development opportunities, at par with the high potential areas.

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10.10. A gender perspective in the enhancement of rural communities' livelihoods in Merek and Honam, Iran

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Abstract

Sources of livelihoods in rural areas are the product of activities performed by the household members in crop and livestock production in addition of any income from add-value production, or migration remittances. This article analyzes the different ways of enhancing livelihoods in two poor watersheds in rural Iran, paying a special attention to the related gender relationships. The research builds on both qualitative and quantitative data covering a sample of 261 households from eight villages with contrasting biophysical and socioeconomic conditions in two research watersheds (Merek and Honam). The sample represents 63% of the population in these villages. The aim was to analyze the households' livelihoods and the management over resources, and to identify innovations needed to increase productivity and market value of the local products and enhance livelihoods. Results show that women's contribution in household's livelihood from livestock production is higher than men (68.2% versus 31.8%), contrarily to their lower contribution from crop production (28% versus 72%). Heavy involvement in dairy production makes women control about 75% of the income from dairy production, which is mainly invested in children's education and better nutrition of the household members. The results could contribute in better targeting development initiatives and interventions and provide some insights into the feasibility of gender-specific improvements in agricultural production and the management of natural resources.

1. Introduction

ICARDA has adopted the approach of benchmark sites for its integrated natural resources management research. One objective of the benchmark approach is to improve research relevance and ultimately improve the livelihoods of the rural people and protect the environment. The present research was conducted at the benchmark sites established within the Challenge Program on Water and Food in the Karkheh River Basin in Iran. These are Honam and Merek with contrasting characteristics. Among others, the objectives of the research at the benchmark site was to identify interventions to improve livelihoods resilience of the communities while ensuring environmental sustainability at the river basin. The livelihood analysis is now carried out as an integral component of the benchmark model in different agro-ecological and resource endowment conditions for drawing global lessons for dry areas development (see Aw-Hassan et al. 2002, 2003; Buerli and Aw-Hassan 2004; Abdelali-Martini and Aw-Hassan 2006).

Women's participation in the enhancement of rural livelihoods has long been central to research on gender relationships and inequalities (Gonsalves et al. 2005). On the same line as Boserup (1970), many scholars have indicated the cross-cultural differences in the social value placed on women, and on their bargaining power within the households.

Like in neighboring countries, population growth is increasing rapidly in Iran and consequently affecting the available resources. The rainfed agricultural production in the Karkheh River Basin (KRB) is low, the irrigation systems have a high potential for improvement, and therefore livelihoods and development initiatives are increasingly becoming essential for an integrated and well designed improvement of the lives of rural communities. As a first priority for Iran, water productivity improvement can be well designed only when it is within the framework of livelihood improvement where rural people strategies are taken into account. For this reason the present paper looks at the women's concerns within the framework of the households' priorities and strategies in line with the project aims of helping resource-poor communities in the basin to sustainably improve their income and livelihoods (Oweis et al. 2008). Since the management of resources is done by the communities, it became of great importance to understand the extent of their strategies and their priorities in order to better consider the development initiatives. Do the ways in which household members make a living affect gender relationships and relations of power within the household? How do these gender relationships affect the ways in which resources are used? Whose responsibility is to find/earn money for the household needs? How is this translated in terms of the way it is organized and how the money is spent? Many dimensions interrelate, at the economic, ideological and political levels. It is also important to identify some ways for sustainable development options to improve livelihoods and reduce poverty in these marginal drylands.

There are many commonalities between Iran country side and its neighboring countries in terms of agricultural labor responsibilities, decision-making, illiteracy, and customs. The studies in the region show the importance of the division of labor, income and responsibilities. They provide a base for exploring and comparing the relationships and open up some questions such as in which type of households and area, the access over resources and decision-making impacts livelihoods and in which way? How do gender relationships shape the household livelihoods? How and why some changes in the household livelihoods are likely to change the relationships between the household members? A study conducted in Mazandaran province of Iran showed that women's share in economic and productive activities is strongly correlated with her involvement in decision-making in family affairs (Effati 1997). A study conducted in the provinces of Kohgiloyeh va Boyerahmad, Kermanshah, and Golestan on male out-migration in Iran and its impact on women's responsibilities and activities concluded that this situation led to increasing women's responsibilities within the household and their work outside the household boundaries (Effati 2003).

Concerning the effectiveness of structures that facilitates the participation of rural women in development initiatives, Azadi and Karami (1997) found that factors and indexes such as the availability of an appropriate technology to rural women, their organization through training, the traditional attitudes towards women, the financial needs, and the consideration of women's role in development initiatives are positively related to women's participation in economic and development activities.

Another research found that socially, the lack of participation of girls in the different development activities, results from a number of factors such as the prevailing culture of rural society (gender bias and cliché imaginations toward girls), wrong attitudes governing families, such as male chauvinism, son preference, girls' unawareness of their social rights, and their lack of self-confidence in their own abilities. However, the study suggests that girls might be induced to participate in social activities through applying certain mechanisms such as mass media, compulsory education and schooling, employing female teachers and extension workers, and establishing and developing rural social formations (Gholamrezaei 1997).

The objectives of this study are to:

- Analyze the role of the gender relationships in enhancing rural livelihoods in Merek and Honam
- Discuss the extent women's involvement in agricultural production, and how it translates in the improvement of the household's livelihoods
- Identify some recommendations for sustainable development options to improve livelihoods and reduce poverty in similar marginal drylands

2. Methodology

In order to tackle these critical issues, a number of methodological steps have been followed. We started by conducting a review of secondary information, with a focus on what has been done in Iran. This was followed by some informal surveys in the study area where qualitative information was collected using a checklist of questions, and finally a formal survey was conducted in the integrated benchmark research sites using a stratified sampling procedure, and following a purposive selection of villages with contrasting biophysical and socioeconomic conditions.

The research sites of Merek and Honam were selected by the project. The selection of the households sample was a multistage selection procedure. A review of secondary data, a rapid appraisal conducted (RRA) in Merek catchment, and intensive discussions with local research staff and extension agents showed that the sources of income (such as livestock, horticulture, crops and off-farm employment), as well as access to water, rangeland, market and services differ in different villages. Therefore, the study adopted a stratified sampling procedure that aimed at ensuring that most representative conditions of the villages in the catchments are included. Because of the heterogeneity between the villages, the objective of representativeness is achieved by purposively selecting few villages with contrasting biophysical and socioeconomic conditions. The following steps were followed for the selection. The communities in Merek catchment were first subdivided into three different groups based on their geographical location, natural resources and production system. These groups were villages along the valley, villages near the forest and villages near rangeland areas. The valley region has more irrigated areas and the highest concentration of population with 23 villages. One village was selected from each group, in addition to a fourth village from the valley to increase the representation of the greater systems diversity prevailing there due to the different level of water availability along the valley. The villages selected were Boghe Karambag near the forests, Sekhere Olya near the rangelands, and Mahdiabad Sofla and Kolehjoob from the valley.

The communities of Honam catchment were divided into three groups; upper, middle and down stream as they are generally different in terms of importance of livestock and water availability. The upstream villages have more livestock, horticulture and dry land crops, the midstream villages have more mixture of rainfed and irrigated crops as well as livestock, mainly cattle, and the downstream villages have good access to water and have mainly irrigated crops and dairy cows. Four villages were selected: Peresk Olya, Chahar Takhteh, Siyahpoosh and Bardbal. Peresk olya is located in the upper, Chahar Takhteh in the middle and Siyahpoosh and Bardbal in downstream part of Honam catchment.

The selected villages comprise of at least 40 households. They were visited and a RRA was conducted during the summer of 2007 in which basic village information including village size, production patterns, importance of different activities in livelihoods, resources, services, constraints and perceived community potentials was collected.

Gender disaggregation of data is a critical component of any sound research methodology, as it facilitates comparative/gender analysis of difference (IDRC 1998). Gender refers to the social construction of the roles of women and men in a given society, not to their biological differences. It is the society which assigns different roles to women and men according to the rules and sanctions of that society. These roles differ from one society to another, which explains the importance of such a process, and gender analysis is used to understand these roles (Abdelali-Martini et al. 2008).

The main research questions addressed in this study are: how much do women participate in household livelihoods as compared to men’s participation? what needs to be done in order to better target development initiatives and reduce poverty in Iran?

The total number of households selected (261) represents 63% of the total number of households (413) in the two sites; 160 households from 4 villages in Merek, and 101 households from 4 villages in Honam (Table 1).The survey was conducted during the period November 2007 to May 2008. As part of a larger study on livelihoods, this piece was intended to focus particularly on women and their specific concerns and needs. Therefore, the interviews were mainly addressed to women from these households, though addressing questions about all members of the households.

Table 1. Sample size and its representativeness in the research sites

Sites	Villages	Total number of households	Sample size	% of total population
Merek	Boghe Karembek	42	30	71
	Upper Sakher	53	36	68
	Kolah Joop	80	63	79
	Mehdi Abad Sofla	44	31	70
	Total	219	160	73
Honam	Bardbal	27	16	59
	Siahpouch	52	22	42
	Upper Peresk	90	51	57
	Shahar Takhteh	22	12	55
	Total	194	101	52
Overall total		413	**261**	**63**

3. Results

Preliminary results from this research provide some insights about the potential for livelihood improvement through the contribution of women to the household livelihoods. Women were asked about their perceptions about the status of their households in terms of poverty. Their answers indicated that 33 households in Honam and 48 in Merek considered themselves as poor, 63 and 109 respectively as medium, and none and three respectively as relatively rich. The following sections will illustrate who does what in these environments.

3.1. Land use patterns in the study area

Table 2 shows the way the study area is used in 2007. The main crops grown in the research area are cereals, legumes and forage crops, some of which were irrigated. Although the earlier rapid rural appraisal showed some limited areas (due to lack of irrigation) of cash crops such as sugar beet in Boghe Karambek village, these were not reported by the women of these villages during the formal survey, cereals and legumes remaining as the main food crops in addition to forages. Vegetables are also produced in home gardens and in some fields mainly for home consumption.

Table 2. Land use patterns in the study area

Sites	Cereals		Legumes		Forages	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Honam (N= 101)	1.33	1.84	0.13	0.44	0.44	0
Merek (N= 160)	1.22	2.68	0.07	0.61	0.07	NS
Sig.			***		***	

*** Significant at < 0.01

3.2. Contribution of women to agricultural production

Results show that men are more involved than women in cultivation (90% vs. 10%)), and in crop management (69% versus 31%). However, in harvesting activities, men have a higher participation overall especially with combine, while women are more involved in manual harvest (61% of women with only 39% of men). Post harvest activities are also shared between men and women with higher rates of women in cutting the tops of sugar beet and bagging (Table 3). This shows that women's contribution to crop production is lower than that of men in general. There are no significant differences between villages in terms of production of cereals and legumes, but there are significant differences in vegetable production as well as in activities of women related to animal feeding in the different villages.

Women encounter some difficulties in performing their work: 1) do manual harvest without hand protection (such as gloves); 2) have to take their children along when they work outside their homes because of lack of assistance; as a result, they work with one hand and carry the child with the other; 3) lack of hired labor in the village. The work is all performed by family labor in addition to some exchange of labor between households.

3.3. Importance of livestock and dairy production

Livestock production is important in the two communities, with significant differences concerning sheep and goats. It represents an important potential for livelihood improvement. There are important differences between the two sites, which should also be reflected in the development interventions. About 30% of the households from the total sample do not own livestock (24 households in Honam and 52 in Merek); about 37% own only cows (27 and 59 households, respectively), this number being more important in Merek. Households with sheep and goats are also significantly different between the two sites (38 and 19, respectively), and more important in Honam that is characterized by slopes as compared with the plains of Merek. Finally about 13% of the households (15 and 20, respectively) own all types of livestock. This suggests that livestock interventions can be directed to both sites with some differences between the different villages.

Results show that women are heavily involved in livestock production activities. Among the activities they performed for cattle production are the collection of fodder (69%) and feed preparation (79%), feeding (85%), watering (83%), milking (97%), cleaning (88%), carrying manure to the fields (59%), delivery of animal kids (70%) and processing dairy products (96%). However, they share most of these activities with their male relatives. Overall, they participate more in cow related activities (72%), and a bit less in sheep and goat activities (55%), and more than 96% in poultry related activities (Table 4). Marketing livestock and dairy products is mainly the responsibility of men, unless some of these products are sold by women to hawker merchants who come at their door, or when women sell the milk to the dairy production factory collectors, and control that income. Results indicate that cows and sheep and goat production is more important in Merek (72% and 64% respectively) than Honam, which suggests need for directing technology options related to livestock production in Merek more than in Honam (Table 5).

Dairy production is important in the two sites. Products include milk, yogurt, cheese, ghee, whey, chiraz, and butter. Ghee and thick and liquid yogurt are produced in the two sites almost equally, but there is a significant difference for whey production, and some in cheese production (Table 6). Women are responsible for almost all the processing activities. In a few cases men do help them but do not mention it in front of other men in the village, because this is considered as a negative behavior. A modified washing machine is used by most villagers to turn the dairy product into butter.

Table 3. Agricultural operations and tasks by gender in the research sites.

Activities		Women %	Men %	Total
Cultivation	Ploughing	6.46	93.54	100
	Levering	10.5	89.95	100
	Planting/ Seeding	13.56	86.44	100
Total participation in cultivation		10.0	90.0	100
Crop management	Fertilizer application	19.70	80.30	100
	Weeding	**69.41**	30.59	100
	Herbicide application	16.86	83.14	100
	Irrigation	14.55	85.45	100
	Look after the fields	35.50	64.50	100
Total participation in crop management		31.2	68.8	100
Harvesting	Harvesting combine	3.71	96.29	100
	Harvesting manually	**60.59**	39.41	100
	Collect. harvested products	40.23	59.77	100
Total participation in harvesting		34.8	65.2	100
Post harvest Activities	Carrying harvested product for threshing	36.17	63.83	100
	Threshing	32.90	67.10	100
	Transporting products manually	39.38	60.62	100
	Cutting chops of sugar beet	**53.97**	46.03	100
	Bagging	**51.08**	48.92	100
	Storage	30.12	69.88	100
	Loading on truck	17.15	82.85	100
	Transporting by truck	8.79	91.21	100
Total participation in post harvest		33.7	66.3	100
Marketing	Marketing	2.50	97.50	100
Total participation in crop production		**28.0**	**72.0**	100

Table 4. Livestock related operations and tasks performed by gender in the research sites

Activities		Women Participation %	Men participation %	Total
Cows	Feed collection	68.9	31.1	100
	Feed preparation	78.8	21.2	100
	Feeding	85.2	14.8	100
	Watering	83.4	16.6	100
	Milking	96.9	3.1	100
	Cleaning	88	12	100
	Carrying manure to the fields	58.7	41.3	100
	Herding	58.1	41.9	100
	Care of sick animals	42.3	57.7	100
	Delivery of animal kids	70.5	29.5	100
	Dairy processing	95.8	4.2	100
	Marketing	35.9	64.1	100
Total participation of cow activities		71.9	28.1	100
Sheep& Goats	Feed collection	49.3	50.7	100
	Feed preparation	62.4	37.6	100
	Feeding	64.6	35.4	100
	Watering	70.5	29.5	100
	Milking	99.1	0.9	100
	Cleaning	80.4	19.6	100
	Carrying manure to the fields	22.8	77.2	100
	Herding	18	82	100
	Care of sick animals	37	63	100
	Delivery of animal kids	52.1	47.9	100
	Dairy processing	98.7	1.3	100
	Marketing	10.2	89.8	100
Total participation of sheep and goats activities		55.4	44.6	100
Poultry (chicken, ducks and Turkey)	Feeding	55.9	44.1	100
	Collecting eggs	97.7	2.3	100
	Taking care of management of chicks	98.1	1.9	100
	Marketing	93.6	6.4	100
Total participation of poultry activities		96.5	3.5	100
Total participation of animal activities		68.2	31.8	100

Table 5. Participation of women (%) in livestock production activities by region

Activities	Honam	Merek	Mean	Sig.
Cows	68.0	72.0	70.3	NS
Sheep and Goat	48.1	64.3	54.3	***
Poultry activities	95.7	97.2	96.8	NS

*** Significant at < 0.01

Table 6. Quantity (kg) of dairy products produced per year in Merek and Honam

Products	Honam	Merek	Mean	Sig.
Cheese	20.40	5.71	11.15	**
Whey	1.41	8.93	6.25	***
Ghee	7.05	11.73	10.0	
Thick yogurt	180.48	150.56	161.65	
Liquid yogurt	275.83	554.20	451.19	
Butter	14.57	48.03	35.65	*
Chiraz	0.00	6.36	4.01	*

*** Significant at < 0.

4. Discussions

Women’s participation in crop production is lower than that of men (28% versus 72%). Men are more involved in irrigation (85% versus 15%) which indicates that irrigation interventions ought to be directed more to men in the area. However, women are still important users of water for home and livestock consumption, a fact that requires special attention. On the other side, women’s participation is higher in livestock production as compared to that of men (68.2 versus 31.8), and technology interventions directed to women are to be concentrated in this area as well as in dairy production where women’s participation is higher than that of men. The preliminary results show that the income of dairy products is managed by women (75%), but this requires additional analysis of the available data from our survey, especially that decision-making in the village is lower for women as compared to men (19% versus 81%), and the property rights of land and livestock are mainly to men (97% and 77% respectively). This results in more decision-making about land by men (65% for men and only 8.5% for women). The same applies to livestock where more men control livestock (62% for men 28% for women) but in some cases, it is shared. The illiteracy rates including primary school level are high in the area especially among women (88%), a fact that aggravates the livelihood situation and limits the options of women. In addition, the work of extension agents is generally weak in the research sites. Handicrafts are only by women (100% for carpets, galim, rasanbafi, chitbafi, mashteh, chador, baftani, and moj bafi), except doc risi where men contribute by 4%, and this represents an important potential for income generation to rural households if the state could help them in accessing the market.

5. Recommendations and conclusion

This study has analyzed the gender dimension in the rural livelihoods in two watersheds in Iran. It has analyzed the division of labor in agricultural activities in selected target areas in the country. It analyzed gender involvement in the processing of dairy products and their characteristics. The results indicate that both women and men have distinct responsibilities in agricultural operations, with men more involved in crop production and women more involved in livestock and dairy production. However, further investigation in the country would be necessary to analyze income from these activities on the basis of gender differences.

Findings from the study have indicated that local knowledge of dairy production and processing, as well as handicrafts are important especially among women, including some children. The livelihood resilience project implemented in the research sites has contributed in raising the awareness about the possibility to develop technologies in a participatory manner with the concerned communities. The governments of Iran can take advantage of the local knowledge of women to plan suitable development interventions.

The provision of some additional training on the improvement of the quality of locally processed agricultural products and alternative sources of income will enable the communities in the project sites to improve their on-farm and off-farm incomes. A first priority for the improvement of rural livelihoods is the improvement of the traditional equipment of dairy production and the technologies with respect to hygiene, storage conditions, and processing. However, the positive impact of these improvements can be tremendous if they are accompanied by better market access. Results show a strong willingness to develop this line of production, especially that indigenous knowledge about dairy production and processing exists, and this can be considered as a starting point for livelihood improvement. Also, buyers of dairy production actually go to the different villages to buy milk and some other products, and the related income is 75% controlled by women. However, in this case, the buyers impose their prices which are lower than those of the market. In case the access to markets is facilitated, and/or milk plants created in rural areas women can sell their products, or work within the milk plant and interact with other producers and exchange information and knowledge about their products. The second area where improvement is needed is handicrafts (making of carpets, Galim, Rasanbafi, Chitbafi, Doc risi, Mashteh, Chador, Baftani, and Moj bafi) which are only performed by women. However they lack access to market for these products, and as transaction costs would be high for each individual to manage, a production unit at the village level could take the lead in marketing these products which constitute an important potential for income generation for rural households. The third area would be training women in fattening sheep and cows and giving access to credits for these activities. The forth area would be improving legume harvest conditions. Exchange of knowledge through traveling workshops of women to improve their work in dairy production and other products would also be of advantage.

The role of women as a driving force in these important activities should be recognized and enhanced; the welfare of women can influence economic growth. Important differences exist between the villages under study in terms of responsibilities of women and men and their aspirations. The Government needs to pay attention to policies related to improved extension services for women's work, education and encourage the participatory development of specific technologies in rural areas.

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10.11. Feasibility of protected agriculture techniques for cash crop production in Balochistan Province, Pakistan

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Abstract

Production techniques for cash crops under simple green house (GH) structures were introduced to Balochistan growers through the USAID-funded Food Security/Poverty Alleviation in Arid Agriculture in Balochistan Project in 2006. The project established three GHs in Integrated Research Sites to increase and diversify income of the local communities. A recent feasibility study clearly indicated the potential and profitability of protected agriculture (PA). In the first year, the net return of GH-produced cucumbers was US$117 in one community, compared with US$12 from wheat in open fields using the same amount of water. Net return per m^3 of water under PA was estimated at US$3.31. The Net Present Value was US$954, which was higher than the initial annual investment cost of US$474.50. The Internal Rate of Return was 27%, which was higher than the 7% interest rate in Pakistan. Sensitivity analysis using different electricity rates and marketing prices confirmed the economic feasibility of PA under different scenarios of water charges and crop prices. It is expected that the production will increase as farmers gain experience and become familiar with the new techniques and management practices.

1. Introduction

Balochistan is one of four provinces in southwest Pakistan, bordered by Afghanistan and Iran. The population of Balochistan is 6.6 million, which is 5% of Pakistan's population (Population Census Organization 1998). About 75% of Balochistan's population lives in rural areas. Of 34.7 million ha of the total geographical area 2 million ha is cultivated. The climate is typically arid and semi arid with frequent drought and dry spells; the northern highlands are characterized by cold winters and mild summers. Most of the annual precipitation (250–350 mm) is received during winter. Within the last decade, for 4–5 years the mean annual rainfall in highland Balochistan was 60–150 mm. About 47% of the cultivated area is irrigated, while the rest is under *Sailaba* (floodwater) and *Khushkaba* (rainfall and localized runoff) farming systems.

Irrigated crop production dominates the agriculture-based economy of Balochistan. The province provides 35–85% of the deciduous fruit (apple, plum, pear, peaches, apricot and pomegranate) production of Pakistan. High value vegetable crops including onion, tomato, carrots, peas and cauliflower are irrigated. The fruit and vegetables produced are sold in distant markets of other provinces. The conventional sources of water in the province are shallow wells, kareze (a traditional irrigation water source, consisting of hand-dug horizontal canal) and springs. The tremendous increase and unplanned installation of tube wells has lowered water tables and depleted many wells, kareze and springs. This of course had a negative effect on the cultivated area and production in general.

Improved water use efficiency is one of the major goals of the USAID-funded project on Food Security and Poverty Alleviation in Arid Agriculture – Balochistan. The project consists of a development component managed by Food and Agriculture Organization (FAO) and an applied research component managed by the International Center for Agricultural Research in the Dry Areas (ICARDA). Both organizations are working closely to achieve the project goals. Introduction of protected agriculture (PA) to all growers using a simple and affordable greenhouse (GH) was one of the project activities. The main objective of this activity was to evaluate PA techniques utilizing marginal land and limited water supply to produce high value crops for Balochistan markets. Potential is indicated by results such as cucumber yield response to different irrigation levels in plastic houses, giving maximum yield of 946 t/ha with 223 mm of water transpired (Oweis 1990).

PA has the potential to significantly contribute to both development of rural communities and to developing sound water policy for producing high value crops in Balochistan. It can be important in supplying local markets with fresh produce that could not be grown otherwise, and in creating employment within rural communities and productive opportunities for the disadvantaged, particularly women. It also offers potential for development of a private sector to provide services in the construction and supply of PA equipment and inputs including seeds and fertilizers. Ultimately, high yielding quality produce from PA could be expanded to serve the export market and generate valuable foreign exchange.

Presently, in Balochistan, PA is used in the form of low tunnels (30–50 cm in height) to provide protection for open-field tomatoes at early stages of growth; the system is also used for production of seedlings of different vegetable crops for early planting. Such low tunnels are commonly used in the Nowshera area of North West Frontier Province (NWFP) of Pakistan to grow early season cucumber and squashes. The cost of polyethylene (PE) covering sheets and the simple metal structure for the low tunnels is estimated at US$208/ha (Ishaq et al. 2003; Adnan 2006). The average cucumber yield under low tunnels is 3.7 kg/m^2, while the total cost is US$0.32/m^2. The average net benefit is US$0.23/m^2 in farmers' fields in Nowshera (Adnan 2006). Low tunnels are used for only one production cycle/year.

Ordinary single span GHs (2–3.5 m in height) were used in the research aimed at intensifying production and increasing the number of production cycles of cucumber, tomato and sweet peppers. Chaudhery et al. (2003) tested 11 cucumber hybrids grown in tunnels during winter in rainfed Pothwar in northern Pakistan The use of high tunnels either made with local materials (e.g. bamboo sticks) or steel pipes and PE covers is increasingly popular in Punjab Province. Use of single or multi-span GH is rare and limited to research stations or seed importing companies to test new hybrids and demonstrate commercial production of high value off-season vegetable crops.

The basic function of PA is to protect plants from severe climatic conditions and provide a favorable environment for optimal crop production (SMEDA 2007). PA is an intensive form of crop production in which both the growth environment and timing can be controlled, and yield and water-use efficiency can be substantially improved (Moustafa et al. 2006). The water efficient techniques of protected agriculture have been successfully introduced by ICARDA to smallholders in the rain fed mountain terraces of Yemen (Moustafa et al. 2003) and Afghanistan (Moustafa 2007), and the experience gained there was transferred to Balochistan. The strategic focus of the current government plans is to augment and promote efficient use of limited water resources. The PA initiative was considered in this project to examine the efficiency of water use for the production of high value crops.

The objective of this study was to estimate the economic feasibility of vegetable production under PA condition in farmers' fields.

2. Material and methods

2.1. Setting up of green houses and cucumber production

Simple green houses (GH), 9 m × 30 m in size and consisting of a galvanized structure with a PE covering, were installed at three integrated research sites. The GH were equipped with a drip irrigation system (t-tape) and fitted with a fertigation system where soluble NPK fertilizers were supplied according to a set program. A water tank was placed near the GH at 2–3 m above the ground and connected to the irrigation system. The tank was fed regularly with fresh water from a nearby well by an electric pump. An inline water meter was fitted to measure the quantity of irrigation water. Pilot farmers were selected by the project team according to specific criteria, namely the interest and willingness to try the technology, availability and access to good quality water, availability of land space to accommodate the GH structure, acceptance to follow recommendations and to participate in different training and extension events. Two GHs were constructed in May 2006 in Saddigabad, Mastung District and in Lalbaig, Loralai District, and a third GH was constructed in March 2007 in Alozai, Qilla Saifullah District.

At the beginning of this activity cucumber seeds were sown in June 2006 under the hot and dry summer conditions of Saddigabad. There were 548 plants, planted in four double-rows. The temperature at sowing time was around 40°C and humidity 30%. The GH was shaded by limestone sprayed over the PE cover to reduce the heat penetration during daytime. The total duration of the crop was around 90 d (16 June to 12 October). Temperature, humidity, water and fertilizer consumption, yield and sale price data were recorded regularly during the growth, development and production stages.

2.2. Costs

All costs including GH structure and cover materials, irrigation system, installation and preparation, seeds, production materials and other fixed costs were accounted for in the analysis. In addition to fixed costs, a 7% interest rate on total initial investment cost was included. The initial investment cost was calculated by dividing the annual fixed cost by three to represent the crop production period (four months) and interest on total variable cost (7%). Variable costs included soil preparation, seed, and fertilizer, pesticide, labor, packing and marketing costs. Administrative costs were estimated to cover production operations and marketing. GH depreciation was estimated by the straight-line method. Assets were divided by their useful life expectancies to determine annual depreciation cost. Land rent was ignored in this study. The total production cost of cucumbers was the summation of fixed and variable costs. The net returns were estimated by subtracting total costs from the gross revenue of cucumbers produced and sold at different prices during the whole production cycle. Monthly average weighted prices were used to estimate gross returns from the total production.

2.3. Net present value (NPV)

The NPV of the cucumber enterprise was calculated as the sum of the present value of the annual cash flows minus the initial investment. The annual cash flows were the net benefits generated from the investment during the production seasons. NPV is one of the most robust financial evaluation tools to estimate the value of an investment (Baker 2000).

2.4. Internal rate of return (IRR)

The internal rate of return (IRR) is a capital budgeting method used to decide whether producers make long-term investments. A project is a good investment proposition if IRR is greater than the rate of return that could be earned by alternative investments. Mathematically, IRR is defined as any discount rate that results in a NPV of zero of series of cash flows. In other words the internal rate of return is the discount rate that makes the present value of the investment's costs and payoffs add up to 0.

2.5. Sensitivity analysis

Sensitivity analysis is the study of how the variation (uncertainty) in the output of a mathematical model can be apportioned, qualitatively or quantitatively, to different sources of variation in the input of a model. It is one of the better alternatives to understand uncertainty in any financial model. It changes each precedent variable at a time and then notes the changes of the resulting variable. For example, precedent variables can be the inputs to the NPV calculation such as revenues and costs, while the resulting variable is the NPV value. The objective of a sensitivity analysis is to identify critical inputs of the financial model and how their variability impacts the result. A scenario analysis is a special case of a sensitivity analysis where a pre-determined set of possible outcomes is identified. The pre-determined case scenarios are usually labeled according to their expected value from best to worst.

3. Results and discussion

3.1. Yield of cucumber

Cucumber production started after 42 days of vegetative growth. Total yield was 1100 kg for the first production cycle in 2006 in Saddigabad. Total yield in 2007 in two seasons was 1800, 2200 and 2500 kg from Saddigabad, Lalbaig and Alozai, respectively, from 270-m^2 GHs. The average yield was 4 kg/m^2/season. This was lower as compared with the yields (5.3 kg/m^2) in Afghanistan PA tunnels established by ICARDA in 2005 (Amegbeto 2005; Moustafa et al. 2006). In Afghanistan farmers were trained through Farmer Field Schools, while in Balochistan they started the business with limited technical knowledge of GH production of cucumber.

3.2. Investment and variable Costs

The initial investment costs came out to were US$2792 for a 270-$m^2$ tunnel or US$10.30/$m^2$ (Table 1). About 75% of initial investment costs were the galvanized frame, plastic covering and insect-proof net. Taking into consideration the life expectancy of each material used the initial investment cost per year was US$475. Two crops were assumed to be grown by the farmers under prevailing conditions during a production year. Therefore, the investment cost was estimated as US$238 per 270$m^2$ PA tunnel for growing cucumber in summer.

Table 1. Initial investment for PA tunnel construction

Item	Initial cost (US$)	%	Useful life (y)	Annual cost (US$)	%
GH galvanized frame	1471.40	53	15	98.10	21
PE cover	367.80	13	2	183.90	39
Insect-proof net	313.40	11	3	104.50	22
Black plastic mulch	46.30	2	2	23.20	5
Irrigation fittings	118.20	4	10	11.80	2
Irrigation lines	108.10	4	10	10.80	2
Water tank	133.30	5	10	13.30	3
Water pump	100.00	4	5	20.00	4
GH site preparation	50.00	2	15	3.30	1
GH assembly	83.30	3	15	5.60	1
Total	2792	100		474.50	100
Per m^2	10.30			1.80	

The variable costs of cucumber production during summer are shown in Table 2. Total variable costs were estimated at US$163.50 per 270-$m^2$ tunnel. Variable cost per m^2 was < US$1. Seed cost was 33% of total variable cost. Fertilizer and irrigation labor costs were 15% each. Pumping of water from tube wells is highly subsidized in Balochistan; therefore, cost of 39 m^3 of water used during the whole production season was only US$13. Packing cost was minimal because the same two plastic crates were used during the whole production cycle. The labor costs accounted for irrigation, picking, packing and marketing and were substantial, with important implications for adopting of labour-intensive high value crops production in PA tunnels (Elahi et al.

1983). The project area has a severe winter and temperatures can drop to –10ºC and so there is no production during winter. Heating is very expensive and fresh vegetables can be imported from other provinces (e.g. Punjab) and vegetables with high production cost cannot compete in the market.

The total cost associated with GH production of cucumber during summer is summarized in Table 3. The annual initial cost was divided by two, because the cropping season duration is four months. Total cost of production was US$411, with total cost per m^2 of US$1.50. The share of variable and fixed costs was 40 and 60%, respectively. About 1100 kg of cucumbers were produced. The cost incurred per kg of cucumber produced from GH was around US$0.40.

Table 2. Variable cost for cucumber production in PA tunnels

	Rate	Amount	Total cost (US$)	%
Tractor ploughing	5.00 US$/h	2.0 h	10.00	6.12
Ridge making	3.30US$/man-day	1.0 man-day	3.30	2.02
Seed	0.10US$/one seed	595 seeds	59.50	36.39
Fertilizer	0.80 US$/kg	28.4 kg	22.70	13.90
Irrigation labor	1.70US$/man-day	13.3 man-day	22.60	13.83
Electricity charges	0.40 US$/$m^3$	39.0 m^3	15.60	9.54
Picking labor	1.70US$/man-day	4.1 man-day	7.00	4.26
Pesticide	1.00 US$/L	6.7 L	6.70	4.10
Micro-nutrients	1.00 US$/L	3.1 L	3.10	1.90
Transport	1.00 US$/crate	11.0 crates	11.00	6.73
Packing cost	0.40 US$/crate	5.0 crates (box)	2.00	1.22
Total			163.50	
Per m^2			0.61	

Table 3. Total cost of cucumber production in PA per season (two cropping seasons/year)

	Total Cost (US$)	%
Variable cost	163.50	40
Fixed Cost		
Interest on total initial investment	5.60	
Initial investment cost for one crop	238	
Interest on total variable cost	3.80	
Total fixed cost	247.40	60
Total cost	410.90	100
Per m^2	1.50	

3.3. Marketing of the produce

Cucumbers were marketed in the nearby town of Mastung. They were transported in plastic crates immediately after harvest. The cucumbers produced from PA were clearly distinguishable from those produced in open fields; therefore, marketing was easy even in the small local market. The produce was easily distinguished by the buyers and was sold at premium prices during the whole production cycle. The prices in the local market were negotiated on per crate basis (one crate contained 18 kg). The average premium received per crate was around US$2 (30–40% higher prices than for open-field produce). During peak supply periods of August, prices received were lower due to the large supply from other areas of Pakistan. Prices increased significantly during September and October, when supply declined, which offers a good opportunity for PA growers. Average prices received in September and October 2006 were US$0.40/kg and US$0.46/kg, respectively. In the first season of 2007 (March–June) the price of cucumber was US$0.33/kg. The price was low mainly due to the large supply of cucumbers from open fields in this period of the year. The GH-produced cucumbers were highly accepted in the local market and buyers were willing to pay a premium price for such high quality cucumbers.

3.4. Sensitivity analysis of minimum yield to achieve break-even

For successful GH production it is important that the produce price covers at least the unit production cost. Based on current production costs inside a 270-m^2 greenhouse and because growers cannot influence the market price, a sensitivity analysis was conducted to indicate the minimum yield required at a given market price to cover production costs. The results showed that cucumber producers should target yields of more than 1177 kg for summer sales when prices could be as low as US$0.35/kg. In winter, yield should be more than 982 kg when the price is expected to be > US$0.42 (Fig. 1). Beyond these threshold yields and at specified price levels, they move into a profitable range and generate positive net incomes.

Water is a main factor in greenhouse production. In Balochistan underground water is pumped using electricity; and for agricultural purposes electricity is highly subsidized by government. In the sensitivity analysis we used different scenarios of electricity rates for pumping one cubic meter of water, the actual rate being US$0.40/$m^3$. We used US$0.50, US$0.60 and US$1.00 for the analysis. The analysis indicated that removing subsidies for electricity power will increase production costs and dramatically reduce incomes of the communities (Table 4).

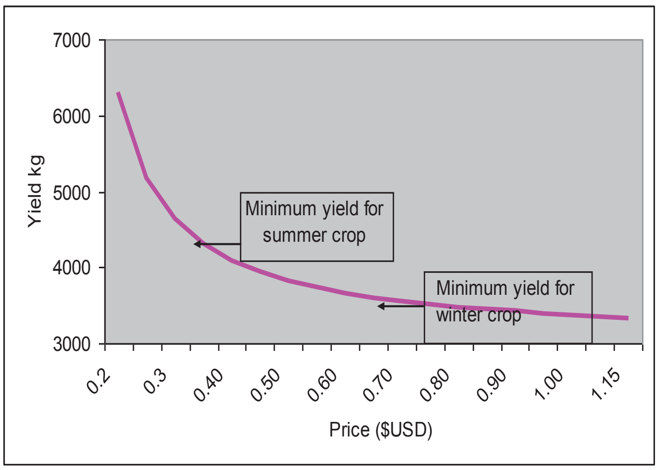

Figure 1. Minimum yield for given prices to break-even in cucumber production in GHs.

Table 4. Effect of different scenarios of electricity rates on revenue in PA cucumber production

Electricity rate scenario (US$/m^3)	Total cost (US$/tunnel)	% of electricity cost of total cost	Cost per m^2 (US$/m^2)	Gross revenue (US$/m^2)
0.4 (Benchmark)	543.90	2.9	2.01	2.3
0.5	546.83	3.6	2.03	2.29
0.6	550.73	4.2	2.04	2.27
1.0	566.33	6.9	2.10	1.30

We performed different output price scenarios analyses, US$0.50, US$0.60 and US$0.70, which were reasonable and can be reached during winter (Table 5). The gross revenue was calculated based on recent production, which is very low and we expect that yields will increase when farmers become familiar and gain experience with managing the system.

Table 5. Effect of different scenarios of cucumber sale price on revenue in PA cucumber production

Price scenario (US$/kg)	Total gross revenue (US$/tunnel)	Gross revenue (US$/m^2)
0.50	792	2.9
0.60	950	3.5
0.70	1108	4.1

3.5. Gross revenue and net returns

Total gross revenue earned from producing cucumber under PA was US$462 in Saddigabad in 2006 (Table 6). In 2007, the total production in two seasons reached only US$684 due to crop damage from extreme cold in March. In Lalbaig the gross revenue was US$834 from two cropping seasons in 2007 (Table 6). In Alozai the gross revenue was US$951 (Table 6) in two cropping seasons of 2007 and the net return was US$117.10, after deducting the cost of production of US$821.80. This would result in US$0.48 of return per m^2 of land and US$3.31 net return per m^3 of water.

Table 6. Net returns obtained from cucumber production from PA

Items (US$)	Saddigabad 2006 (one season)	Saddigabad 2007 (two seasons)	Alozai 2007 (two seasons)	Lalbaig 2007 (two seasons)
Total gross revenue	462	684	834	951
Variable cost	163.50	327.00	327.00	327.00
Fixed costs	247.40	494.80	494.80	494.80
Total costs	410.90	821.80	821.80	821.80
Net returns	51.10	–137.80	12.20	129.20
Net return per m^2	0.19	–0.51	0.05	0.48
Net return per m^3 water	1.31	–3.53	0.31	3.31

Total irrigation water resources used to produce 1583 kg cucumber was $39m^3$. The same amount of water can be used to irrigate 312 m^2 of wheat in the same land and soil type. The comparison was done between wheat and PA production of the same farmer in the same field. One hectare of wheat (10000 m^2) gave $396 US Dollars, 312 m^2 can give US $12 as a gross return comparing with US $117 as net return from cucumber production in PA condition using the same amount of water.

3.6. NPV results

Using the initial annual investment cost of US$474.50, the NPV was US$954. This means that the project is profitable because it gave US$954 after 10 years instead of US$474.50 from the first cropping year. As we mentioned earlier, farmers in the first year managed the crop production under PA conditions without previous experience. We expect that production will increase in the subsequent years and also that farmers will diversify crop production by introducing tomato, green pepper and other vegetables according to market demand.

3.7. IRR results

IRR was calculated for 15 years (the expected life duration of the PA tunnels) of cash flow in Saddigabad. IRR was 27%, which was significantly higher than the 7% interest rate in Pakistan, thus investing in PA is more profitable than depositing the money in a bank or purchasing bonds.

4. Conclusions and recommendations

Cucumber production under PA showed high potential to increase incomes by high-value produce. The economic analysis clearly indicated the profitability of the enterprise. It is expected that the productivity will further increase when farmers gain more experience. The water use efficiency under PA was higher compared to wheat production in field. It is recommended that farmers should therefore adopt PA and diversify the production by introducing other crops such as tomato, green peas and peppers.

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10.12. Potential of the ecosystem natural resources of the Red Sea region, Egypt

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Abstract

Although the southern part of the Egyptian Red sea region (about 18,000 sq. km) is suffering from some natural constraints (low and erratic rainfall, high temperature, wind erosion, etc.), it is relatively rich in flora and fauna. The information about its ecosystems is rather limited. Realistic evaluation of the status and potential of this ecosystem is essential for launching any development program in the region. The article sheds some light on the constraints of the natural resources in the region and their potential for proposed development. The region suffers from lack of fresh drinking water, and medical and veterinary services. It has been subjected to improper land and water management, overgrazing, over collection of medicinal and ornamental plant species, and tree-cutting for fuel and charcoal production. Most of rangelands have deteriorated and are exposed to land degradation and desertification, which are seriously reducing their productivity and biodiversity, and adversely affecting livestock production and rural livelihoods. The total area suitable for agricultural utilization is estimated to be over 600 thousand acres, but it has not been exploited as yet. Irrigated agriculture was rarely practiced in the past due to deficiency of suitable irrigation water. Utilization of underground water resources for growing some field crops and rangelands rehabilitation is recently started. More than 75 % of the population has nomadic or semi-nomadic life with livestock as the main source of income. The major objective of the Government is to improve the livelihood of the existing Bedouins population through proper utilization of the available nature resources to produce enough feed, food and other necessities for the socio-economic situation of local inhabitants in the region.

1. Introduction

The Red Sea region is the eastern gate of Egypt with its coast line extending to over 1080 Km. The region is bordered by the Red Sea in the east, Suez governorate in the north, Beni Souif, El Menia, Assout, Sohag, Kina and Aswan governorates in the west and Sudan in the south. The southern part of the Egyptian Red sea region (Shalateen–Halaib–Abou Ramad sector, SHAS) is triangle-shaped with the bottom side of about 300 Km coincident with the 22^o North parallel and the apex at the Red Sea. The total area of this sector is about 18,000 km^2 and is bounded by the longitudes 35^o and 37^o E and the latitudes 22^o and 24^o N. It includes the area along the Red Sea coast extending from Bernis to the international political border with the Sudan. This sector has an important economic and strategic situation in Egypt (Kassas and Girgis 1969). Elba

Mountains in the sector are very conspicuous and have great potential in terms of plant, animal, wild life and, to some extent, water resources. Elba area is considered botanically one of the main phyto-geographical regions in Egypt (Tammam 1999).

The land adjacent to the Red Sea in Egypt is generally mountainous, flanked on the western side by the range of coastal mountains. There are two main seasons: cool and hot. Rainfall is very low; the mean annual being about 3 mm whereas in the Sudan and Eritrea it reaches about 156 mm (Sheded 1992). Scarce water resources and their inefficient management largely limit the sustainable development for increased quality of life. The utilization of groundwater resources has not been fully exploited in the region. Of the total rangeland area of Egypt (about 4 million ha), around 0.6 million ha is in SHAS. These rangelands are constrained by extreme aridity, low productivity, and limited water availability. Although they constitute the main feed resource in the region all year round, approximately 45% of these rangeland areas are severely degraded. The general current trend is shrinkage of range areas and decline in quantity and quality of forage production due to the prolonged drought, annual erratic and low rainfall beside other climatic, edaphic and human factors that affect their growth, coverage, fresh and dry atter yield, and nutritive value (Zahran 1982; El Shaer 2004). In addition, the combined effects of overgrazing, over collection of medicinal and ornamental plant species, and tree-cutting for fuel and charcoal production have accentuated the decline in the forage production and the deterioration of good native forage species gene pool, thus threaten biodiversity. This review aims at highlighting the current status of the natural resources in SHAS and the potential for future development of the region.

2. The physical environment

The land adjacent to the Red Sea in Egypt is generally mountainous, flanked on the western side by the range of coastal mountains (1705 – 2187 m above sea level). Between the shoreline and the mountains extends a gently sloping sand plain, varied in width and dissected by series of wadis running eastward to drain their waters into the sea. There are two main seasons: cool and hot seasons. Winter usually extends from mid-October to mid-April and rest of the year has summer season. Rainfall is erratic and generally.

Two main groups of habitat are described (Zahran, 1982) in the region: one with saline soils, and the second with non-saline soils. Habitat with saline soils include the mangrove swamps, the reed swamps and the littoral salt marshes. The usual habitat of the mangrove swamps is along the shoreline especially in the lagoons, bays, coral or sand bars parallel to the shoreline. The habitat of reed swamps is not wide spread along the Red Sea coast as it occurs in scattered patches usually in the downstream parts of certain wadis. Habitat of littoral salt marshes comprises the maritime belt within the land bordering the shoreline. Habitat with non-saline soils includes the desert plains, wadis and mountains. The coastal desert plain and wadis occupy the areas between the littoral salt marshes on the seaward side and the coastal mountains on the island side. Continuous range of hills and mountains bound the inland side of the Red Sea coastal desert with various heights.

3. Land and water resources

Twelve landforms have been described in SHAS, of which the mountains, isolated hills, alluvial fans, piedmont plain, coastal plain and desert wadis are the most prominent (Sheded 1992). Among these, the piedmont plain covers a large portion of elevated lands; alluvial fans are located mainly at the outlet of desert wadis and extend to large distances towards the Red Sea to cover most of the piedmont and coastal plains. The coastal plain occupies relatively small area parallel to the seashore line and includes sandy shores, coastal sand dunes, sand sheets, sabkhas, islands, coral reef and mangrove (Kassas and Girgis 1969; Zahran 1982). Hydrographically, the area is dissected by numerous wadis and their tributaries. The total area that may be considered suitable for agricultural utilization (irrespective of water availability) approaches more than 600 thousand acres. This includes the soils formed in the desert alluvial plains, deltaic plains and desert wadis with considerable agriculture potential and soil characteristics to sustain productivity under the prevailing natural ecological conditions.

Scarce water resources and their inefficient management largely limit the sustainable development for increased quality of life. Surface and groundwater represent the main source of water supplies for local inhabitants. Therefore, the development of groundwater resources has a vital importance for drinking, agriculture and mining activities. The groundwater conditions are mainly controlled by climatic, regional, morphological, structural and hydrologic properties of water-bearing formations in such area. The groundwater recharge is mainly from runoff infiltration and the water is extracted from both hand-dug and shallow drilled wells.

4. Natural plants resources

The natural plant resources of the Red Sea coastal desert are characterized by six vegetation types named after their habitat: mangrove, reed swamp, littoral salt marshes, coastal desert plan and wadis and mountains (Kassas and Girgis 1969; Zahran 1982; Springuel and Sheded 1991). A short account of each type follows**.**

***Mangrove vegetation*:**Two mangrove species have been recorded, *Avicennia marina and Rhizophora mucronata* (Khahlifa 1996). The first one is widespread along the whole stretch of the Egyptian coas while *Rhizophora mucronata* is mainly in a limited area in the most southern sector, between Mersa El-Madfa (Lat. 23^{o}N) till Marsa Hablib (Lat. 22^{o}N). Both species are moderately palatable to livestock, particularly camels.

***Reed swamp vegetation*:** It occurs in channels and creeks at the mouth of big wadis and areas which represent the combined influences of the brackish-water springs. Two communities are recognized; the first is dominated by *Phragmites australis* and the second by *Typha domingenis.* Both species are palatable to livestock.

***Littoral salt marsh vegetation*:** The vegetation comprises 16 main community types in addition to two less common communities. The main communities are dominated by *Aeluropust* spp.*, Arthrocnemum macrostachyum, Halocnemum strobilaceum, Halopeplis perfoliata, Juncus rigidus, Limonium pruinosum, L. axillare, Nitraria* *retusa, Salicornia fruticosa, Sporobolus spicatus, Suaeda fruticosa, S. monoica, S. vermiculata, Tamarix nilotica, T. passerinoides and Zygoplylum album.*

Vegetation of the coastal plains and wadis: Two vegetation types are recognized: ephemeral vegetation type and perennial vegetation type. The appearance of local patches of ephemeral vegetation soon attracts herds of camels, goats and gazelles for grazing. Three types of ephemeral vegetation are seen: (i) succulent plants such as *Aizoon canariense, Trianthema crystalline* and *Tribulus pentandrus,* (ii) grasses such as *Aristida, Bromus, Cenchrus, Eragrostis, Schismus, Stipagrostis* etc., and (iii) herbaceous plants such as: *Arnebia hispidissima, Asphodelus tenuifolius,* Atragalus spp*., Filago spathulata, Malva parviflora, Neurada procumbens, Plantago ciliata, Schouwia thebiaces, Senecio desfontainei, Tribulus* spp. etc. Most of these ephemeral herbs and grasses are highly palatable to livestock and are of special importance for the nomadic herdsmen (Zahran 1982; Khahlifa 1996). The perennial vegetation type may be categorized under two main groups: (1) Under-shrubs (half - shrubs) like *Zygophyllum coccineum, Salsola baryosma and Hammada elegans* as succulent, *Panicum turgidium, Pennisetum dichotomum* and *Lasiurus hirsutus* as grasses and *Zilla spinosa, Launaea spinosa, Cleome droserifolia, Sphaerocoma hookeri* subsp. *intermedia, Iphiona mucronata, Artemisia judaica, Pituranthos tortuosus* and *Calligonum comosum* as woody species; (2) Shrubs and trees such as *Lycium shawii, Acacia tortilis, Tamarix aphylla, Acacia ehrenbergiana, Leptadenia pyrotechnica, Salvadora persica* and *Balanites aegyptiaca.* Great numbers of the dominant and associate perennial species are highly palatable to livestock.

Vegetation of the coastal mountains: These plant resources can also be grouped under two main types:, ephemeral and prennial vegetation. The species common in both wadis and mountains include: *Acacia raddiana, Anabasis articulata, Artemisia judaica, Hammada elegans, Launaea spinosa, Leptadenia pyrotchnica, Lygos raetam, Panicun turgidum, Zilla spinosa* and *Zygophyilum coccineum*. Camels are usually seen browsing soft parts of the branches of some mountainous trees and shrubs growing in the low levels of the mountains. On the other hand, goats may climb the slops for browsing and grazing (El Shaer 2002).

5. Range resources and their forage potential

The main range types of the SHAS are swampy and salt marshes type, desert sandy plains type, Wadis type.

Longitudinal narrow and shallow lagoons and bays are dominated by *Avicennia marina* and a few individual trees of *Rhizophora mucronata*. Wet salt marshes are dominated by halophytic vegetation (Zahran 1982; Khahlifa 1996). Data on chemical composition of the dominant salt marsh species (El Shaer 2002), presented in Table 1, revealed that these halophytes were characterized by high ash content and reasonable levels of fiber (averaged 15.9%). *A. marina* and *S. monaica* attained moderate levels of crude protein (10.5 and 9.40%, respectively) which appeared to be enough to cover the protein requirements of animals (Kearl 1982). *Avicennia marina* was sometimes overgrazed by camels, in particular during summer and autumn seasons when palatable shrubs were not available.

Table 1. Chemical constituents (% on DM basis) of common plant species in the coastal salt mashes area (El Shaer 2002)

Plant species	DM	CP	CF	EE	Ash	NFE
Avicennia marina	33.2	10.5	13.9	3.30	25.9	46.40
Arthrocnemom glaucum	39.1	6.33	17.3	1.98	39.7	34.69
Sueada fruticosa	38.5	11.7	19.7	3.55	29.0	36.05
Sueada monaica	40.2	9.40	16.7	3.00	30.3	40.60

Desert sandy plains type range extends between the coastal salt marshes in the east and the coastal hills and mountains westwards. The area includes several valleys such as Houdean, Sheab, Ebeb and Hederbah valleys which contain great varieties of annual and perennial shrub species. The area comprises non saline leveled and/or undulating plains confined to the drainage system, but far of the tidal sea water. The dominant plant species are *Anabasis setifera*; companion species are *Cassia senna, Crotolaria egyptiaca, Panicum turgidum, Salsola tetrandra, Acacia tortilis* and *Salsola baryosma* community types. *Lycium shawii, Maerua crassifolia, Acacia tortilis* and *Acacia albida* are the most important palatable fodders for all animal species all round year (El Shaer 2002). Mean values of chemical composition of main dominant plant species grown in Hederbah Valley are summarized in Table 2. *Acacia albida* and *Lycium shawii* followed by *Maerua crassifolic* and *Acacia tortilis* contain reasonable levels of crude protein which would cover the nutritional requirements of camel, sheep and goats (Kearl 1982). Such plant species should be protected as they are overgrazed and Bedouins tend to cut and collect wood from these trees for coal making.

Table 2. Chemical constituents (% on DM basis) for dominant species in HederbahValleys (El Shaer 2002)

Plant species	DM	CP	EE	CF	Ash	NFE
Acacia albida	5.13	13.2	2.66	27.9	9.59	46.65
Acacia tortilis	71.3	10.3	2.11	30.2	6.60	50.79
Zepharis ciliaris	56.9	8.72	1.53	23.3	3.6	52.85
Lycium shawii	39.8	12.5	1.17	34.9	8.65	42.78
Maerua crassifolia	60.8	11.5	1.98	30.7	10.2	45.62
Panicum turgidum	57.2	5.99	4.56	34.1	6.25	49.1

The dominant plant communities within wadis ecosystem, constituting the permanent backbone of vegetation, are: *Acacia tortilis - Zilla spinosa; Acacia ehrenbergiana - Indigofera argentea; Acacia tortilis - Depterygium glaucu; Acacia tortilis – Aerva javanica; Balanites aeyptiaca- Leptadenia pyrotechina; Maerua crassifolia - Panicum turgid; and Tamarix nilotica - Salsola imbricata.* Data on chemical constituents of the dominant plant species in Metab valley (as an example) are summarized in Table 3. As reported by El Shaer (2002), *Acacia tortilis, Capparis deciduca, Farsetia egyptiaca, Lycium shawii, Maerua crassifolia* and *Panicum turgidum* constitute the principal feed resources in the wadies dissecting mountainous zone judging from their palatability for all animal species , their coverage, intensity and high dry yield. Protein content ranged from 5.43 % (*Panicum turgidum)* to 13.8 % *(Farsetia aegyptiaca). Maerua crassifolia,* and *L. shawii* are highly palatable and nutritious for all animal species. *Panicum* *turgidum* represents the most important natural grass in the zone and provides a good feed resource during dry seasons (summer and autumn).

The most important annuals in the rainy seasons are: *Astraglus* sp*, Reseda* sp.*, Trigonella stellata, Euphorbia granulata, Launaea mucronata, Baronychia argentia* and *Cyperus rotundous.*

Table 3. Chemical constituents (% on DM basis) for dominant plant species in Metab wadis (El Shaer 2002)

Plant species	DM	CP	EE	CF	Ash	NEF
Acacia tortilis	63.70	10.2	2.07	30.4	6.25	51.08
Capparis deciduca	23.20	7.22	4.88	26.3	13.2	48.30
Farsetia aegyptiaca	35.80	13.8	3.51	21.1	18.8	42.79
Lycium shawii	40.80	11.8	2.09	35.6	9.46	41.05
Maerua crassifolia	59.60	11.1	2.08	28.4	11.1	47.32
Panicum turgidum	54.30	5.43	3.98	32.7	7.11	50.78

6. Range degradation

There is a general trend of the shrinkage in range areas and decline in quantity and quality of forage production. Adverse changes in range plant composition, i.e. more annuals, less palatable and more unpalatable and noxious species, are reported for most areas (Kassas and Girgis 1969; Khahlifa 1996; El Shaer 2004). The combined effects of overgrazing, over harvesting of medicinal plants and uprooting of woody plants have accentuated the decline in native forage production and the deterioration of good native forage species gene pool , thus threaten biodiversity. However, slight desertification status could be reversed by changing rangeland management practices (i.e. providing rest periods from grazing, slight reduction of stocking rate, changing season of use, initiation of special grazing systems, manipulation of the composition of grazing herds and /or improving the distribution of grazing animals).

The main reasons for rangelands degradation could be summarized as follows: (a) Low and erratic rainfall and long drought periods; drought not only diminishes rangeland productivity but also adversely affects feed species diversity and the composition and size of grazing herds. (b) Increasing uprooting of trees and woody shrubs for fuel; (c) Continuous overgrazing due to the rapid increase in the population of small ruminants which was encouraged by availability of subsidized feed; and (d) Increased development of stock watering points for grazing herds allowing for the extended use of rangelands where grazing in the past was only possible during the rainy season. This increased the proportion of degraded areas around water points; (e) Increasing use of trucks and water tanker for transporting grazing herds and water to far range areas; (f) Disruption of the traditional grazing system as a result of the reduction of common grazing areas due to desert encroachment. The present policy of rangeland management and utilization is the main cause of deterioration of rangelands. However, utilization of rangelands as common open free access ranges (without any restrictions on livestock population, animal movement, grazing seasons and duration) does not permit for any sustainable conservation and development of rangeland resources.

There are several signs of degradation of rangelands in the region: (a) Decreasing total vegetation cover percentage; (b) Increasing ratio of invaders, noxious and harmful species, and plants of low forage value; (c) Decline in the proportion of most high and medium palatable species and total disappearance of others; good perennial palatable species are either extinct or at the brink of extinction in their native habitats, with some shrubs remaining as hedges; (d) Decrease and / or disappearance of many good annuals of high forage value; (e) Marked decrease in the quantity and quality of forage production coupled by marked decline of livestock production; and (f) Increasing proportions of bare areas.

7. Range utilization

The Red Sea region has great potential as natural range resource in Egypt. There are several common usages of the indigenous plant species as given below(Springuel and Sheded 1991; Batanouny 1993**):**

Medicinal plants: There are numerous plant species used as medicinal resources. *Cymbopogon proximu* is used for treating cold and kidney stones, *Olea chrysophlla* is used for cold and rheumatic treatments, *Balanites aegyptiaca* and *Cleome drosenifolia* are used for diabetic treatment and *Convoluulus hystix* is used for internal parasite treatment.

Rope making: The plant species used for making ropes include *Colotropis procera, Cocculus pendulus* and *Dracena ombet.*

Plant leaves as food: There are many plant species that can be used as food materials such as *Glossonema nubicum, Launaea capitat, Malvua parviflora and Rumex vesiarius*

As feed resources for wild and domestic animals: As discussed previously, the native rangelands constitute the only feed resources in the SHAS region all the year round. The region is also relatively rich in natural fauna, which are adapted to the variety of habitats present in the region. Tamam (1999, in one visit in winter, described the following species to be present: one amphibian, 12 reptile, 29 avian and 10 mammalian species. Concerning the domestic livestock, several sheep breeds are raised in the region, three of which are more dominant. All goats in the region are of the common black desert type. They are small in size and the dominant color is black. Camels play an important role in the social and economic life of the nomadic pastoralists.

The official statistics released by the Agricultural Department of the Red Sea Governorate in 2003 revealed that the total number of livestock were about 261 thousand heads of which 52.4% were sheep, 21.5% goats and 26.1% camels. Sheep outnumber both goats and camels. They have a unique adaptability to the harsh arid conditions of the region, including high temperature, poor range and shortage of good quality drinking water (El Shaer 2004). Information on plant species, their palatability, grazing and nutritive value and their yield are of great importance in the region (E1 Shaer 2002).

Table 4 shows the most common plant species in the region and their palatability index to sheep, goats and camels according to several field observations. Some of these shrubs are highly palatable for all animal species and are therefore often overgrazed. However, palatability of such plants may vary from season to season and from location to another depending on several factors, i.e. climatic factors, plant associations and communities and animal species (El Shaer 1996). *Lycium shwli, Taverniera aegyptiaca, Mearua crassifolia and Farsetia aegyptiaca* were the most palatable species all the year round for sheep, goats and camels in many locations. Such shrubs should be protected from overgrazing for further propagation and reseeding should be done to provide more feed resources for the wild and domestic animal resources in the region. Providing enough fresh water points and rehabilitation of degraded ranges, particularly the palatable ones, by different means including giving irrigation using any sources of water harvested are strongly recommended and should be at the top of the Governmental strategies.

Table 4. Common natural ranges and their palatability index (Highly palatable (HP), Fairly palatable (FP), Poorly palatable (PP), Non palatable (NP) for sheep, goats and camels (El Shaer 2002)

Plant species	Goat	Camel	Sheep
Acacia alibida	PP	HP	PP
Acacia ethaica	PP	HP	PP
Acacia reddiana	PP	HP	PP
Acacia tortilis	HP	HP	FP
Arocnemom glaucum	NP	PP	NP
Avicennia marina	NP	HP	NP
Cadaba farinose	HP	HP	HP
Convolvulus hystrix	PP	HP	HP
Farsetia aegyptiaca	PP	HP	HP
Halopeplis perfaliala	PP	PP	NP
Indigofera argente	FP	HP	HP
Lycium shawii	HP	HP	HP
Maerua crassifolia	HP	HP	HP
Panicum turgidum	HP	HP	HP
Plantago ciliata	PP	HP	FP
Salsola baryosma	PP	PP	NP
Salsola tetrandra	FP	HP	PP
Suaeda fruticosa	HP	HP	HP
Suaeda monaica	NP	HP	HP
Taverniera aegyptiaca	NP	PP	NP
Zygophyllum coccineum	PP	NP	NP

8. Conclusion

The Red Sea region of Egypt has a strategic location for the country. It has a great biodiversity of all natural resources. It is necessary to make better use of the natural resources in the region. The combined effects of natural constraints and human and animal factors have accentuated the decline in native forage production and the deterioration of good native forage species gene pool, thus threatening biodiversity. Programs for rehabilitation, conservation and sustainable use of range resources should be a top priority of the Government of Egypt to arrest degradation of the rangelands and to maximize sustainable production from rangelands.

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10.13. Low cost sewage wastewater treatment station for villages and remote communities

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Abstract

Subterra constructed wetland is a natural system for wastewater treatment which employs the existing microorganisms and reed plants in sewage treatment. This paper presents the application of Subterra in Luxor, Egypt, as a suitable solution for Nile cruise wastewater treatment since it is easy to operate and maintain, with reliable efficiency in BOD and COD reduction regardless of the seasonal variations. Luxor Station serves 1000 persons daily. Four Subterra stations were also constructed at Agrotech Farm in Giza Governorate, serving about 700 persons daily besides handling the post-harvest facility wastewater. The effluent always has a better quality than required by usual legislation allowing its re-use in agricultural irrigation purposes. The system has the advantage of using local resources for construction resulting in a more economic solution. The lifetime of Subterra stations extends to 40 years and it requires little sludge removal compared with other systems. The stations are powered by one kWh electric motor pumps, and the total power consumed per day is 8 kWh.

1. Introduction

Reclaiming municipal wastewater for agriculture reuse is increasingly recognized as an essential management strategy in areas where water is in short supply. Wastewater reuse improves the environment because it reduces the amount of waste (treated or untreated) discharged into water courses, and it conserves water resources by lowering the demand for freshwater abstraction. In the process, reuse has potential to reduce the cost of both wastewater disposal and provision of irrigation water, mainly around cities and towns with sewers. There is also increase in productivity per unit area as well as an increase in total agricultural production because the reuse of treated wastewater permits expansion of irrigated area and opens the possibility of multiple planting seasons (Bartone 1986).

In the arid and semi-arid regions, the potential reuse of reclaimed wastewater for irrigation is still limited. The reason for that could be: i) the unrestricted discharge of industrial waste into sewers making wastewater unsuitable for irrigation; ii) the problems arising from inadequate water resource and the inability to control the effluent quality, the site chosen for reuse and the methods of effluent application; and iii) limitations imposed by climate and geography (Hamdy 1999).

Agencies utilizing wastewater for agriculture or planning the implementation of reuse system should consider the development of national standards and codes of practice for reuse, by adopting the WHO guidelines and taking into account their technical, economic, social, cultural and political characteristics and constraints (Hespanhol and Prost 1994). It is well known that the use of raw wastewater for irrigation has been associated with the prevalence of many diseases such as ascariasis, typhoid fever and cholera (Shuval et al. 1986).

Reed-bed purification systems are one of the oldest and most natural means of purifying sewage. In nature, water seeps into the soil, flows along roots, passes through natural filters of various sand- and gravel-layers and becomes purified through micro-organisms. Similarly, the 'Subterra' reed-bed purification system uses a combination of mechanical and biological mechanisms to treat wastewater. This paper outlines the case study of applying a Subterra system in treating Nile Cruise waste water in Luxor, Egypt. The main aim of this project was to demonstrate natural wastewater treatment efficiency and how it can be adapted to suit local conditions, making use of local construction materials. The project constructed a sewage treatment plant with a capacity of 250 person equivalent (p.e.) and total daily wastewater discharge of $40m^3$. This system allows the reuse of treated water in irrigation at tourist installations. Another aim of the pilot project was to educate and inform the construction industry in Egypt and surrounding countries about natural treatment system and its advantages including the protection of the environment as well as water saving.

2. Subterra reed bed purification system

The Subterra reed bed purification system is a vertical filter system with a subterranean irrigation tube system (Fig.1). The treatment process starts with the mechanical treatment phase where the wastewater goes into multi-chambered pretreatment pit. The size of the chambers depends on the size of the installation and quantity of sewage. Solid and light suspended materials are precipitated as a first step in the pretreatment chambers, which are treated at regular intervals. The second phase is the biological treatment, where the pre-treated sewage is pumped into the Subterra reed beds through special pressure piping system. The size of these beds is calculated on the basis of 50 to 150 liters water consumption per person per day. A special pressure piping system, Subterra pipes, embedded in the reed beds, is used guaranteeing the even distribution of effluent over the highly effective filter of various micro-organisms as well as the aeration of the sewage through a spray-effect of these special perforated Subterra pipes. Here, the biological purification takes place.

The Subterra reed bed is lined with polyethylene liner to protect the underlying soils and groundwater from any possible contamination. The bed consists of different layers of sand and gravel and is planted mainly with reed plants. The root system of the plants allows a constant aeration of the soil ensuring a continuous hydraulic flow on a long-term basis. The layer of micro-organisms formed on the roots allows nitrifiers and denitrifiers to break down organic compounds to such an extent that even benzyls and phenols are decomposed. Finally, the purified water is collected in a pipe and is led to a control pit, where it can be examined and discharged into a pond, river or the ground through an irrigation network system. The treated waste water can also be used as recycled water in households, in the same way as rain water is used.

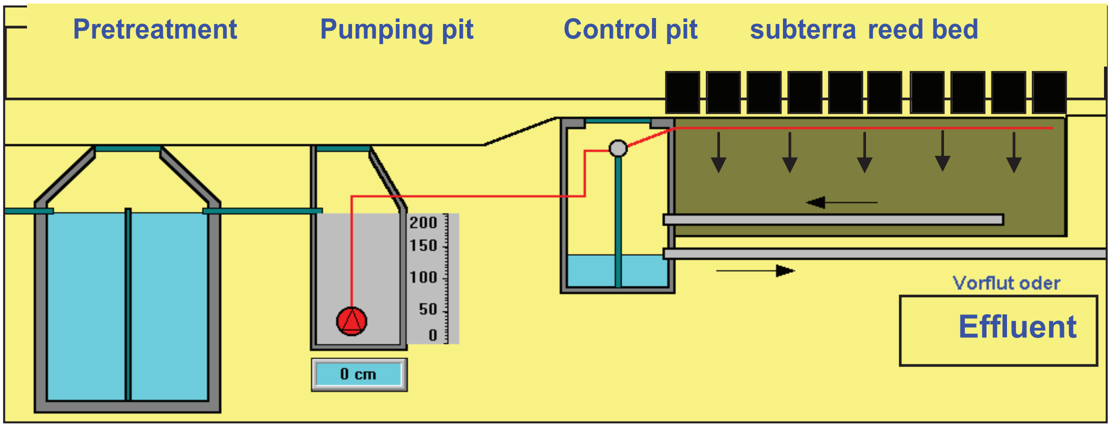

Figure 1: Flow chart of a typical Subterra-station

3. Project information

A Subterra station with a capacity of 250 p.e. with a total daily sewage quantity of 40 m³ from the Nile Cruise sewage municipal waste water was developed in Luxor in 2004 (Fig. 2). The pre-treatment tank size was 200 m³, total surface area for Subterra bed was 750 m². The outcoming effluent was re-used for irrigation purposes. It is important to note that 80% of the materials used in the construction were locally procured from the Egyptian market. The reed plants are available in abundance along the Nile and are characterized by being resistant to chemicals which prevent the systems from having any problems in case any chemicals entered into the system through the wastewater.

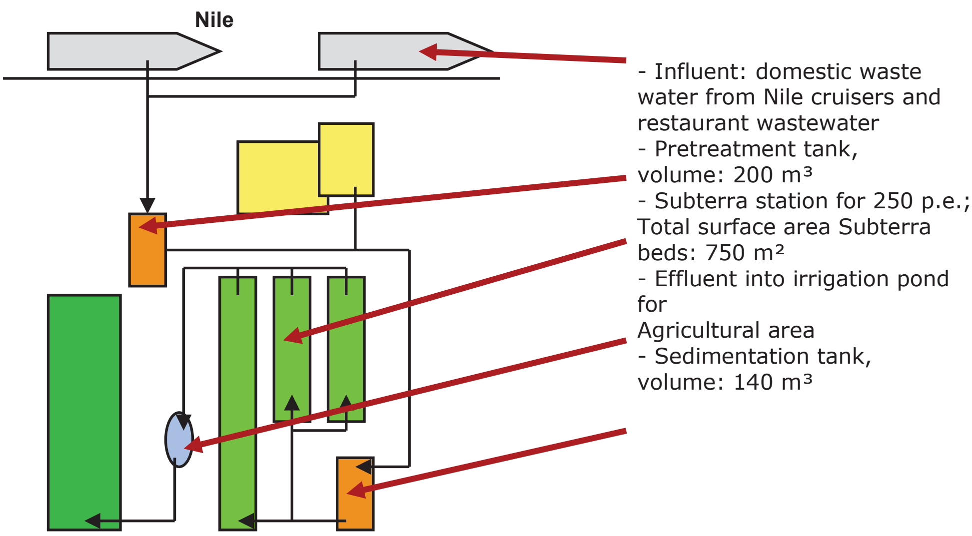

Figure 2. Schematic diagram of Luxor Station

Solar energy was used to operate the pumps, saving electricity and reducing operational cost. Seasonal fluctuations in the supply of wastewater, attributed to tourism industry, had minimal effect on the treatment process.

4. Results and discussion

4.1. Operation and maintenance

The Subterra station is easy to operate and maintain, requiring only average-level skilled staff. The most common problems occurring during operation are pump failure or switch replacement. Occasionally, the Subterra pipes may require replacement due to bursting as a result of mis-operation or high pressure pumping. However, even the pipe replacement requires a simple procedure. The way Subterra beds are planned, using multi control and distribution pits, enables maintenance of part of the Subterra bed without the need of stopping the operation of the whole system.

4.2. Treatment performance

Subterra stations have been constructed since more 10 years in different parts of the world. They have been performing with high efficiency even during extreme weather conditions. More than 220 stations have been installed with a varying capacity between 4 and 2500 p.e. for different purposes such as tourism developments, residential compounds, camping sites, highway stops and gas stations. Luxor station was a pilot station in Egypt. Table 1 gives the information about the quality of treated water from this station. It is clear that the BOD could be reduced by 94 to 98% and COD by 90 to 94% by treatment of wastewater in this system and the quality of water meets the standards set for irrigation by the ministerial decree in Egypt (Abou-Zeid 1998). The amount of nitrate produced from organic material was sufficient to fertilize 10 ha of agricultural land through the use of treated water in irrigation.

Table 1. The performance results of Luxor Station

Criteria	Influent values	Effluent values	Authorized limits
pH	7.1	7.5	6 – 9
COD	373 mg/l	15.3 mg/l	80 mg/l
BOD	226 mg/l	<3 mg/l	40 mg/l
Dissolved O_2	0 mg/l	4 mg/l	> 4
NH_4-N	21.8 mg/l	0.4-5mg/l	--
NO_3-N	--	40-70mg/l	--
E.Coli / 100 cm^3	1,500,000	3500	5000
Coli form	$2.06x10^4$	10^2-10^4	
Total Solids	914 mg/l	818 mg/l	2000 mg/l
Total Suspended Solids	856 mg/l	14 mg/l	40 mg/l

4.3. Economical analysis

The price of constructing a Subterra station is highly affected by two items, sand and gravel. If the sand and gravel were available in the area of the station, the costs would be rather low. In our case study, the construction cost for Luxor station amounted to 280 Euro/p.e. However, this cost is not a true reflection of the actual cost since Luxor station was developed as a pilot project. For the future stations the price could be as low as half, depending on the location of the station. As for the operation and maintenance costs, they are extremely low due to the simplicity of the process. For example, the energy consumption at Luxor station is approximately4 kWh/d.

The growers wanting to export agriculture products from Egypt to Europe are required to meet several 'Euro gap restricted rules'. One of these rules is related to the environment protection such as sewage wastewater treatment. The growers intend to fulfill this rules. For example, Agrotech Co. Farm cultivates fresh vegetables for export. The Company farm employs about 700 persons daily. It requested Subterra Co. to install four Subterra sewage treatment stations at the farm, to treat 20 cubic meter of sewage water daily for irrigation use. The farm used to transport the sewage wastewater in sewage tanks by trucks to a desert area and dump it. The quantity of sewage wastewater transported was 20 cubic meter, needing an allocation of L.E.7200 per year for transport. Besides, the sewage water was discharged on desert surface area, causing environment pollution, while the farm used fresh water drawn from deep well to irrigate wood trees and landscape greenery with a total cost of L.E.5400 per year. After, the farm had constructed Subterra system, it saved under ground water by using treated sewage water for tree woods and landscape irrigation. The total saving was L.E.12600 per year. The economic and technical analysis indicated that the station depreciation period could range from 20 to 40 years. The cost of treating one cubic meter of sewage water by Subterra system came out to be L.E 1.77 on 40 years depreciation period, L.E 2.13 on 30 years depreciation period, and L.E 2.85 on 20 years depreciation period.

4.4. Economical use of treated sewage wastewater

The use of sewage wastewater after treatment in Egypt can only be done on a non-food crop. Most of the sewage wastewater stations are built on desert land. The treated sewage water should be utilized for cultivation of wood trees (Braatz and Kandiah 2006; Christersson and Verma 2006) for furniture, paper pulp, oil trees for bio-fuel needs, trees to form shelterbelts to protect farm from desertification, and trees to increase green areas in order to reduce atmospheric carbon dioxide levels and thus global warming for environment protection. Recycled treated wastewater is important to save water resources and save fresh water for other uses. The aim of this research was to highlight the benefit of sewage waste water recycled and conserved for irrigating wood lots (forest trees) such as *Casuarina glauca*, *Eucolyptus camaldulensis* for wood production and *Jatropha curcass* for bio-fuel production for sale in the local markets and also to provide environmental services, recreation, and improved quality of life.

4.5. Amount of treated sewage wastewater

The daily amount of sewage water available from different governorates in Egypt is equivalent to 8.456 million m^3/day. The average amount of water lost during the treatment is 0.844 million m^3/day. Therefore, the remaining amount of treated sewage waste water is 7.615 million m^3 /day, which is mostly discharged to drainage canals. Egypt could recycle about 3.139 billions m^3 of treated sewage wastewater per year for irrigation.

5. Conclusion

Over the years, Subterra system has proved to be overwhelming more efficient than other exisiting systems for sewage treatment. Through the demonstration of Luxor station, as an example of applying Subterra station in Arab countries, the following advantages and benefits were noted: (a) The simple mechanical pretreatment is sufficient for separation of sludge; (b) There is homogeneous distribution of the wastewater; (c) Subterranean process avoids smell; (d) There is reduction in disease-causing germs; (e) The energy consumption is low; (f) Mmaintenance is easy and can be done by locally trained people; (g) Microbiological balance through "low loadings"allows no sludge production in the filter bed; (h) The system is suitable for remote sites, which have no access to the public sewage network; (i) It is highly economical, requires locally available material and can last up to 40 years; (j) Treated wastewater meets the Egyptian and international standards for irrigation (Abu-Zeid 1998); (k) The potential amount of treated wastewater per year in Egypt is about 3.139 billions m^3, part of which could be used for growing trees to protect the lands from desertification and for growing biofuel trees such as Jatropha.

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10. 14. Socio-economic norms affecting farmers' participation in some agricultural development projects in the northwest coast area of Egypt

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Abstract

This study aimed to determine the socio-economic norms which affect the participation of the farmers in some agricultural developmental projects in the zone of the northwest coast in Matroah governorate of Egypt. The data were collected from two groups, one participating in the studied agricultural developmental projects and the second not participating in any of these projects. The results showed that there was a positive correlation between the degree of participation of the studied farmers and their degree of their sticking to the following socio-economic norms: tribal affiliation, science consideration, planting local varieties, and leading life of Bedouins owning camels. There was no correlation between the studied farmers' participation in the developmental projects and their degree of holding to the following norms: saving water, restricting shepherding to women, fatalism, work partnership and respecting old age. There was significant contribution of the two norms of farmers (Bedouins owning camels and tribal affiliation) in explaining the degree of total variation in the extent of their participation in the studied projects.

1. Introduction

Most of the developing countries depend for their economy on the rural areas where agriculture plays a vital role in contributing to the general national income. Therefore, the governments of these countries must develop their rural areas and make them their main development target. The development process is multi-sided; increasing the production of a country for the purpose of increasing the income forces other sides of the development process such as improving and changing the socio-economic structures including the value system of the people and sustaining the equity, freedom, and high standard of living.

Rural development includes not only the economic development but also such considerations as the changes in the social and institutional relationships in the rural areas. Creating new job opportunities inside and outside the farms and carrying out justice in distributing the agriculture land and income and improving the nutrition, health conditions, and housing in rural areas is integral to the rural development. Providing formal education to children and informal education to adults to meet the human needs of the residents of rural areas is also important.

The process of development is an integrated one where people should share and participate in the developmental project in all the stages of planning, execution and management. Their participation will back up these projects and decrease the obstacles, get mutual benefits, and increase the success of the developmental programs and decrease the chances of failure. Abo-Zaid (1991) suggested that for developing the conditions for Bedouins, one should seek their opinion before the developmental projects are launched because they are familiar with their environment and the natural resources, especially the underground water. There is also a need to include the participation of all categories in the community such as women, youth, adults and sometimes children. People's participation plays a very important role, in both developed and developing nations. However, the size of this participation depends to a great extent on the culture in each country and the values and norms within each culture. The socio-economic norms in a culture in the rural areas can affect greatly the people's participation in the agriculture developmental projects. in each country.

When it comes to defining social norms, it is hard to find consensus on one general and comprehensive scientific definition. According to Omar (1992) social norms are the rules which describe what is or is not acceptable socially. Hakie (1983) defines social norms as a scale or a ruler to measure the correctness of the behavior. According to Hegazie (1982) social norms are expectations and social determination to the possible actions.

Any developmental project aims at achieving desirable socio–economic changes which would require making full use of the available resources and organizing the societal and environmental structure. In any society and particularly the Bedouin ones, the socio-economic norms control to a great extent the people's behavior and motivate them to work with the governmental efforts to achieve the targets of the developmental projects. In this study, we determined the socio-economic norms which affect the participation of the farmers in some agricultural developmental projects in the zone of the northwest coast in Matroah governorate of Egypt.

2. Objectives

The objectives of the study were to: (a) Determine the extent to which the farmers recognize the current agricultural developmental projects in the studied villages; (b) Determine the degree of participation of the studied farmers in the current agricultural developmental projects; (c) Determine the degree of adherence to various socio-economic norms by farmers in the studied villages; (d) Test the differences between the farmers participating and not participating in the agricultural developmental projects in their degree of adherence to the studied socio-economic norms; and (e) Study the relationship between the degree of adherence to norms with the degree of participation in the agricultural developmental projects.

3. Methodology

This study was conducted in the Matrouh district of the northwest coast in Egypt. Three villages were chosen, El-Matania, El-Negeela and Sidi Barrany where some development projects had been conducted such as the project on collecting and delivering seeds, improving areas of shepherding, and on developing the shepherding areas (provision of feed). The projects were implemented by some governmental institutions for development and also by some foreign developmental organizations. The data were collected from two groups. The first one was participating in the developmental projects and the second group was not participating in any of these projects.

Fifty seven participants were taken from the project seeds. This is nearly half of all the participants (113 farmers) in this project in the three villages. They were selected by systematic random sampling. All the 25 participants in the project on developing shepherding area in the three villages were selected. From the third project (developing the shepherding areas feed provision) 100 participants were taken by systematic random sampling, which represented about 11% of the total participants in this project (878 farmers). A number of non–participants were taken from the records of the farm land owners listed in the agricultural cooperative societies with the condition that they had heard about the above mentioned agricultural developmental projects. Systematic random sampling was used to select 182 participants. Thus, the total sample amounted to 364 respondents, 182 participants and 182 non-participants.

A questionnaire was designed and used to collect the data through face-to-face interviews. Tabulations, averages and percentages were used to display the results of the study. Other statistical methods were used such as Chi-square, simple correlation as well as multiple correlation and regression analyses.

Following socio-economic norms were considered: 1- Saving water; 2- Restricting shepherd activities to women; 3- Tribal affiliation; 4- Respecting old-aged ones; 5- Science consideration; 6- Fatalism; 7- Work partnership; 8- Planting local varieties of crops; 9- Ownership of a camel. These nine socio-economic norms were measured through various positive and negative items on 3-point scales. For the positive items, 3 points were given to the answer 'agree,' 2 points to 'neutral,' and 1 point to 'disagree,' and vice versa for the reversed (or negative) items. An accumulative score was given to each respondent according to the answers given to indicate the degree of adherence to these socio-economic norms. For the other methods of measuring and weighing the responses, suitable scales were designed to deal with each question and answer according to their nature. The independent variables were: age, education, marital status, family size, farm size, animal ownership, agricultural machine ownership, mass exposure, frequency of visit to agricultural service centers, degree of membership in local organizations, and knowledge of agricultural development projects and its source.

4. Results

4.1. Personal characteristics

Around one-third of the participants in the studied agricultural development projects were 30 to less than 40 years of age. The non-participants were slightly more than one-third (34.6%) in this age range. Around half of the participants (50.5%) and 78.0% of the non-participants were illiterate. Most of both participants (97.8%) and non-participants (94.5%) were married. Close to half of each group, participants (47.80%)

and non–participants (45%), had an average family size (9-13 individuals). Around 53.3% of the participants and 60.4% the non-participants owned less than 50 feddans of land each. Thus, the participants had low percentage of illiteracy, smaller family size, and larger land holdings than the nonparticipants. The non-participants owned more animals on the average.

Nearly half in each group lacked machinery, but more participants owned tractors. Participants also had more exposure to media than nonparticipants. The frequency of visits to the agricultural service centers was same. The majority in the non-participant group did not have membership in the local organizations (89.0%) as against less than half of the participants (42.9%) who were not members.

4.2. Source of information about agricultural development projects

The sources of knowledge were meetings, people, agricultural cooperative society, mosque, relatives, and neighbors. About 88.6% of participants heard about the seeds project through the agricultural cooperative society. Depending on the same source, a good majority (82.41%) of the participants heard about improving shepherding area project. An overwhelming majority (98.35%) of the participants also heard about the project ‘developing shepherding areas’ through the agricultural cooperatives. In contrast, a smaller percentage of non-participants depended on the same source of knowledge about projects #1 and #3 (71.43% and 87.70%, respectively) but a larger majority (92.31%) about project #2. These results reflect the great importance of the agricultural cooperative society as a source of knowledge to both groups. The farmers get most of the needed services for their farms from the cooperative society, which also makes the link between farmers and various agriculture-related institutions which can provide some financial and material support.

4.3. Degree of participation in agricultural development projects

About 82.5% of the participants had a medium degree of participation (2 points average) on project #1 (collecting and delivering seeds), while 76% of them had a high degree of participation (3 points) on projects #2 (developing the shepherding areas-feed provision) and 68% of them participants also had a high degree of participation (3 points) on project #3 (improving shepherding areas). In general, there was a gradual increase in the degree of participation of the studied farmers in these development projects due to high incentives and rewards they got.

4.4. The relationship between the degree of adherence to various norms by farmers and their participation in developmental projects

Data showed that norm #7 (work partnership) came first with the highest degree of adherence by the studied farmers. Norm # 2 (restricting shepherding activities to women) came first with the lowest degree of adherence to the contents of the statement representing that norm.

There were differences between the participants and the non-participants with respect to norms #3 (tribal affiliation), #5 (science consideration), #8 (planting of local varieties) , and #9 (Bedouin's ownership of camels). The differences were significant based on Chi-square test. There were no differences between the two groups regarding the norm #7 (work partnership), #6 (fatalism), #1 (saving water), #4 (respecting old age) and #2 (restricting shepherding activities to women).

Table 1. Simple correlation coefficient of participants' norms holding degrees and project participation degrees

Socio-economic norms	Correlation coefficient
Saving water	0.065
Restricting shepherding to women	0.071
Tribal affiliation	0.328*
Respecting old age	0.093
Science consideration	0.149*
Fatalism	0.021
Work partnership	0.076
Planting local varieties	0.202*
Bedouins ownership of camel	0.555*

*Significant at p <0.05 level

To further examine the above relationship, data were analyzed through simple correlation. The results are as shown in Table 1. The correlation coefficient was 0.328 between the two variables and significant at P<0.05 with respect to the norm 'the tribal affiliation'. Similar correlation was found for the norm 'science consideration' (r = 0.149), the norm 'planting local varieties' (r = 0.202), and the norm 'Bedouins owning camels' (r = 0.555).

Table 2. Multiple correlation and regression analyses (stepwise) for the relationship between respondents' degree of adherence to norm and their participation in the developmental projects

Analyses steps	Variables	Multiple corr. coefficient	Accumulative variance of dep. var.	% variance of dep. var.	Regression coefficient	Calculated "f"
Step one	Bedouins own camel	0.555	30.9	30.9	0.235	80.45
Step two	Tribal affiliation	0.328	34.6	3.7	0.150	47.40

Table "f" at 0.05 level = 3.84

To estimate how much the variation of each positively correlated norm could explain the degree of participation in the studied projects, multiple correlation and regression analyses (stepwise) were performed. Results are shown in Table 2. Four norms were analyzed: tribal affiliation, science consideration, planting local varieties and Bedouins own camels. Results in indicated that only two norms, Bedouins own camels and tribal affiliation, contributed significantly in explaining the total variation in the degree of participation of the studied farmers in the projects. The first of these norms contributed 30.9% and the second 3.7%. Jointly, the two contributed to 34.6% in explaining the total variation in the degree of participation. The relationship was significant at $p<0.05$.

5. Conclusion

There is a positive correlation between the degree of participation of the studied farmers in the three studied development projects and the degree of their adherence to the socio-economic norms 'tribal affiliation', ' science consideration', 'planting local varieties', and 'Bedouins owning camels'. The norms 'saving water', 'restricting shepherding to women', 'fatalism', 'work partnership' and 'respecting old age' showed no such relationship. There was significant contribution of norms 'Bedouins owning camels' and 'tribal affiliation' in explaining the total variation in the degree of farmers' participation in the studied projects. This highlights the importance of understanding specific socioeconomic norms in enlisting participation of farmers in a development project.

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10.15. Attitude of rural youth towards working in agriculture in Egypt

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Abstract

Paying attention to agriculture sector is vital for providing food security, realizing sustained development and supporting agro-industries in Egypt. The rural youth, with vigor and energy, is the most important component of society for engaging in and making success out of agriculture. The main objective of this study was to determine, through survey, the attitude of rural youth of both sexes, in Buhaira and Menia governorates of Egypt, towards working in agriculture and making the agriculture as one of their first work choices in the newly reclaimed lands. The result showed that majority of the surveyed youth, both male and female, were neutral about taking up agriculture as profession and only few had either positive or negative attitude for working in this vocation. Problems associated with agriculture were the major factor for lack of enthusiasm among the youth for agriculture. The paper analyses these problems segregated by gender and proposes solutions to ensure harnessing this valuable human resource for agricultural development in the newly reclaimed lands in Egypt.

1. Introduction

Agriculture remains one of the most promising instruments for reducing world poverty. It can also be the leading sector for growth in the agriculture-based countries. The developing world's 1.3 billion young people, in the age group 12-24 years, constitute the major economic and social actors in the new generation (World Bank 2006). In Egypt, rural population represents 56.5% of the total population, and youth represent 41% of rural population (50.6% male and 49.4% female) in the age group of 15-35 years. Rural youth represent 81% of the Egyptian youth (CAMPAS 2003). Making sure that they are well prepared for their future roles as workers, entrepreneurs, parents, citizens and community leaders is enormously important.

Agricultural plays an important part in the national economy of Egypt, as its contribution to the total domestic product is around 15.6% (World Bank 2008), and also the exports of agricultural products contributes to 20% of the foreign trade. The agricultural sector employs 34% of the total work force in Egypt.
Agricultural activities in Egyptian villages have undergone great changes which are worth studying. For instance, the vocational engagement outside agriculture has increased; some 38.5% of the rural work force is engaged in non agricultural professions. Some 63.5% owners of the holdings under 5 *feddan* (1 *feddan* = 0.4 ha), which represent 95% of the total holdings in Egypt, get more than half of their revenues from non agricultural sector. There has been a decline in the percentage of the workers

in agricultural sector from 11.2 in 1976 to 7.3% in 2003. There has also been an increase in the average age of the workers in agriculture, as 65 to 85% of the samples of this study were of 40 years and above, whereas young people of 20 to 40 years age-group were 2 to 30%. These are alarming figures for the future of the Egyptian agriculture. Despite the great homogeneity in many characteristics of youth there is also a great degree of difference among the youth, based on sex, and economic, social and cultural status. Youth represent a great human resource, and an energy that must be well utilized and oriented towards the agriculture sector.

The Egyptian society is considered as one of the young societies as the proportion of the 15 to 35 years old youth amounts to 41% of the total population of the State. The rural youth account for 41% of the rural population, and 81% of the total of Egyptian youth. The youth need a role model for motivation to exert their full energy and knowledge to the public issues. Their view of the society is defined at the stage of schooling and when they start their career and are exposed to a new world strange to them, to which they may or may not adapt. In the later case, they would face conflicts and may eventually become introvert. Thus, getting acquainted with attitude of youth towards different issues would help in sustained development. The attitudes would determine how the individuals would respond to the situations they go through. The information would also enable us to draw the limits of relationship between the general values of the society and the specific individual attitudes, and provide an indicator of the relative stability in individuals' behavior.

Attitude can be defined as a state of nervous mental alertness and preparedness that organizes and directs the individual’s response towards the environment elements. Most researchers deal with the attitude as a dynamic order of four components - cognitive, knowledge, emotional and behavioral. Psychological attitude measurement means transforming it from its descriptive form to a quantitative form based upon which it may be possible to compare between individuals and groups. Attitude measurement methods aim at placement of a person in light of the response, stretching from perfect acceptance to decisive rejection, with a neutral attitude in the middle. Researches have developed many ways of measurement of attitudes. These include: 1) self assessment scales, 2) scales based on observation of the actual behavior through interviews, and 3) projection method based on the individual's interpretation of vague stimuli presented to him. Attitudes are changeable; although they are generally characterized by relative stability and continuity. Theoretically, changing the attitude would require efforts that would either support the new attitude or reduce it.

2. Objectives

This study aimed at getting acquainted with the attitudes of youth towards contemporary issues in some selected governorates in Egypt where there is opportunity for them to take up agriculture on newly reclaimed lands as a vocation. As the attitude study is important generally for predicting behavior, the study of attitude of rural youth towards work in agriculture is of special importance for the future of Egyptian agriculture. It would also help the concerned officials of the Ministry of Agriculture and Land Reclamation and private sector to supply the youth with information and training to enhance their skill in the practice of agriculture, as most of the youth have little experience of the agricultural work. The study was done by undertaking survey of a sample of male and female youth in Buhaira and Menia governorates.

3. Results and discussion

Response in Bahaira governorate, based on the survey of 55 male and 45 females, indicated that the highest proportion of the youth (72%) had the neutral attitude towards work in agriculture, as it amounted to 73% of young men and 71 % of young women, whereas only the 14 % youth had positive attitude. This is attributed to a number of problems associated with agriculture. The most important of such problems were the high costs of agricultural production and shortage of the production inputs. It can be inferred from these results that although the attitude of youths towards agricultural work was neutral in general, if the availability of the agricultural production inputs was ensured at adequate price level, the attitude could be turned to become positive towards agricultural work for the youth of both sexes.

The survey of the attitude of rural youth of the two sexes (50 individuals each) towards agricultural work in Menia governorate indicated that only 26% males and 10% had positive attitude while 66% of male and 69% of female had a neutral attitude, 8 and 18% negative attitude and 26 and 10% had positive attitude. This gender difference might be due to a number of inherited traditions and customs that discourage females to work, particularly in agriculture field. The low percentage of youth with positive attitude might be due to the fact that the most of the study sample comprised of youth with a high school education, which would have motivated them to take up jobs other than agriculture. Besides that, the problems related to work in agriculture as mentioned before might have further contributed to a neutral or negative attitude (Table 1). It is apparent from Table 1 that the high price of production in puts was the most important reason for the reluctance of youth to work in agriculture in Buhaira governorate, whereas the non availability of financing sources was the first dominant cause in Menia governorate. This means that there is an urgent need to remedy the situation by removing these constraints by the authorities responsible for developing agriculture in the region. If the agricultural work was made more remunerative, youth would engage in it no matter how difficult it was.

Suggestions were invited from the youths for the promotion of agricultural work in both the governorates. The results are summarized in Table 2. In Buhaira governorate, the most frequent suggestion was to ensure availability of production requirements at affordable prices. Regarding the second suggestion, opinion differed between males and females. Males suggested that a specialized TV channel should be established for presenting agricultural information, which reflects the male youth awareness of the importance of the information in agricultural work. Same suggestion had also come at the third place from the females. Land reclamation and its distribution to youth in good productive condition was the second most important suggestion from the females. In Menia governorate, male youth considered it as highest priority to have access to low interest loans, followed by providing production requirements at suitable prices, land reclamation and distribution of good quality land to the youth (Table 2). For female youth, land reclamation was the first priority, followed by low interest loans, and provision of production requirements at affordable prices. Such suggestions from both male and female youth in both the governorates reflect their awareness of the most important conditions necessary for the success of agricultural work in these governorates.

Table 1. Reasons for the reluctance of youth to work in agriculture

Reasons	Buhaira governorate				Menia governorate			
	Males		Females		Males		Females	
	No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	%
High prices of production inputs	41	40	44	48	35	26	27	2
Low product prices and difficulty in marketing	25	25	14	15	18	13	19	14
Non availability of continuous water supply for irrigation	18	18	12	13	15	11	8	6
Insufficient financing resources	10	9	7	8	53	39	51	40
Scarce and expensive manpower	4	4	7	8	8	6	11	8
Agricultural work was hard	4	4	7	8	6	4	16	12
Total	102	100	91	100	135	100	132	100

Table 2. Suggestions provided by surveyed youth for the promotion of agricultural work in the studied governorates

Proposals for promoting agricultural work	Buhaira governorate				Menia governorate			
	Males		Females		Males		Females	
	No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Land reclamation and distribution in good land	15	13	21	20	33	19	42	30
Providing agricultural production requirinputs at suitable prices.	32	28	35	33	36	20	26	18
Providing irrigation water round the year	10	8	8	8	16	10	11	8
Providing low interest loans	12	10	9	9	40	22	34	24
Providing outlets for selling product at good price	14	12	7	7	17	10	9	6
Holding training courses to enhance skill	12	10	11	10	12	6	8	6
Specialized TV channels for providing information	23	19	15	13	24	13	11	8
Total	118	100	106	100	178	100	141	100

Investigation of the reasons for the youth to accept non agricultural work in both the governorates revealed that this was done primarily to improve family income. The second important reason was that the youth, particularly female, considered agriculture as a hard and non remunerative profession. The last, relatively less important reason was to get funds to buy agricultural in puts.

Every society strives to see a bright future and accordingly plans for it based on the identification of constraints and opportunities. It is worth mentioning that the problems the youth face in the contemporary society do not limit only to the career in the immediate future, but extend well beyond affecting all the aspects of their life. Because the youth represent a faction seeking to create a new future, the sound social body would be the one in which the opportunity may be available for such force to bring out its full potential and to contribute to the advancement of the society. Hence, dealing with the concerns expressed by youth in taking up agricultural work should form a basic part of our future strategies for offering assistance to the youth for the agriculture sector, and harnessing this human capital for sustainable development. Understanding the attitudinal differences based on gender is important for developing effective strategies.

4. Recommendations

In light of the above, the study recommends that for encouraging youth to take up agriculture as profession in the newly reclaimed lands there is a need to provide agricultural production in puts at affordable prices, low interest loans, information through media and training courses, transportation and other infrastructural services. Activating the rural institutions for resolving the young farmers' problems will help and encourage them to work in agriculture. Activating the media to provide agricultural information regularly will also be important.

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Appendix 1

Minutes of the Meeting of the Board of International Commission on Dryland Development (ICDD) held on 9th November 2008 at Bibliotheca Alexandrina, Alexandria, Egypt

Present:

1. **Prof. Dr Adel el-Beltagy,** *Chair of ICDD*
2. **Prof. Dr Gareth Wyn Jones,** *Secretary General of ICDD*
3. **Academician Djhamin Akimaliev,** *Member of Executive Board of ICDD*
4. **Prof. Dr Iwao Kobori,** *Member of Executive Board of ICDD*
5. **Prof. Dr Shinobu Inanaga,** *Member of Executive Board of ICDD*
6. **Dr K.P.R. Vittal,** *Member of Executive Board of ICDD*
7. **Prof. Dr Mohan C. Saxena,** *Executive Secretary of ICDD*

Summary of Discussion:

1. The Chairperson, Prof El-Beltagy welcomed the members of the Board and briefly introduced the agenda for the meeting. He invited comments from the Members about the organization and deliberations of the 9th International Dryland Development Conference (IDDC) and asked for suggestions for further improvement.

2. Acad. Akimaliev said the Conference was well organized and the level of participation was very good. He however felt there were too many presentations and the quality of some of them was not as good as was expected.

3. Prof. Kobori was of the view that the participation from distant countries was rather low, although from Egypt it was very good. He particularly felt that Europe was not much represented. Regional papers were rather repetitive and talked mainly of the recommendations of IPCC. The session on renewable energy was rather weak as there were only a few presentations.

4. Prof. Wyn Jones was of the view that the Conference was highly successful because of very good attendance, great enthusiasm and quality of presentation. The program was however very crowded which made time management difficult and permitted no discussion in the plenary sessions. This led to some degree of frustration. In this background it will be desirable to reflect on how we structure future Conferences. More emphasis on renewable energy must be given, and the crucial role of indigenous knowledge including indigenous architecture in reducing energy use should be highlighted. There was a certain level of repetition in the papers. Hence in the future we should assign topics to the invited speakers rather than accepting the topics volunteered by them. Prof. Wyn Jones welcomed the announcement by the Chair that the Commission now had an official base at the Bibliotheca Alexandrina. This should offer new opportunities for organizing diverse activities of the Commission. He also alluded to the need for developing some kind of formal, non-governmental organization that links land and water use for sustainable development of the dry areas, and with the new base of the Commission at the Bibliotheca Alexandrina, this possibility should be explored.

5. Prof. Inanaga said this Conference was far better than the last one in terms of participation, and the scientific quality of presentations. There were much lesser cancellations of presentations. He however felt that the number of invited plenary presentations was rather too high which made the program very crowded and left little room for discussion. He particularly appreciated the enthusiastic participation of young scientists in this Conference. He felt, field trip was very important component of the Program for meeting the objectives of the ICDD and hence this should be given due importance and should be very carefully organized so that the participants could benefit by exchange of information and interaction. The time had now come for the Commission to reconsider its role, based on its comparative advantage.

6. Dr. Vittal, who was attending the meeting for the first time, thanked the Chair for inviting him to join the Board after his predecessor, Dr Pratap Narain, retired. He felt the meeting was very well organized, presentations were good, and the platform was well utilized by the participants to send out the message. The duration of three days was rather short for such a meeting; at least four days were needed for presentations with one day in between for filed visit. Alternatively, the Commission could consider organizing the meetings of regional Chapters and then hold a plenary to get all the recommendations from the regional Chapters.

7. The Executive Secretary clarified that the participation in this Conference was much larger than in the past. There were more than 400 participants coming from more than 50 countries including those coming from 20 international and regional organizations. The European countries present included France, Finland, Germany, Italy, Malta, Norway, Portugal, Spain and UK. The maximum participation was however from Egypt, followed by Japan, Iran and USA. Amongst the international organizations, ICARDA's participation was the highest. The topic of renewable energy was reasonably well covered in one concurrent session with the emphasis as to how the greenhouse gas emissions could be reduced. There was even a presentation on the greening of roofs in the cities to reduce energy consumption and capture solar energy for food and feed. Yet, there was much larger scope and our request for additional participation did not get commensurate response. We will have to work harder on this in the future and the support of the Board members in identifying the potential resource persons will be very important.

8. Prof. Wyn Jones appreciated the fact that, besides the scientific community, people of very high rank had come and participated, including the Minister of Higher Education and Science Minister of Agriculture and Land Reclamation, and the representative of the Minister of Energy of the Government of Egyptian, the President of the Bibliotheca Alexandrina, the President of OPEC Fund for International Development (OFID), the Vice President of IFAD, the Secretary General of the WMO, the ADG of FAO, the Head of Sustainable Development of Agriculture in the World Bank, and the representative of the Chief Executive of the World Food Program.

9. The Chair then sought the opinion of the Members about the frequency and the nature of future Conferences and possible topic/theme.

10. Acad. Akimaliev felt that once in three years for the main Conference was an optimal frequency. He felt three days were adequate, but there should be careful selection of keynote speakers in the plenary. A meeting should be held of the Board before the main Conference

to decide on the Program. Although this would have financial implications, the cost would be justified.

11. Prof. Kobori said electronic communication with the members of the Board in developing the Program was adequate as was done this time. Formal meeting of the Board just to discuss program would be expensive in terms of time and cost. The Commission does not have that kind of resources. It was started by a group of individuals interested in and concerned about the sustainable development of the drylands, and it is very fortunate that with its present leadership it has grown step by step in strength in achieving its objectives. As there is no international society on desertification and dry areas, there is a scope for the Commission to expand its role in this regard. The orientation of the Commission in the past has been more towards agriculture and hard science, thus limiting the scope of coverage in the Conference. It would be desirable to have more broad coverage of topics and larger inclusion of social sciences and humanities and case studies that depict how the resilience of the dry areas could be further enhanced. In this regard, renewed efforts should be made to enlist collaboration with UNESCO. Other institutions should also be invited.

12. Regarding the future Conference, Prof. Inanaga suggested that the Commission should adopt a participatory approach and ask the participants of this Conference for their views by sending out a questionnaire. We should ask them why they attended this Conference; particularly the motivation of the young scientists to participate in this Conference should be investigated. We should ask them about the frequency, nature and theme of the future Conferences. Prof. Wyn Jones strongly supported the suggestion and said we should also ask them whether the Commission should engage with the policy makers. As this was unanimously accepted by the Members, the Chair agreed for its immediate implementation. He said four to five well framed questions should be sent out for a quick feed back.

13. Dr Vittal said that the success of the Commission will be rated by the acceptance of its recommendations by the Policy Makers. The Chair agreed and suggested that the Commission should come up with very clear recommendations and ensure that they reach the Policy Makers and are implemented.

14. The Chair then suggested that the Commission might hold a small workshop some where midway between now and the 10th International Conference. The timing, theme and venue could be decided by electronic consultation. The members agreed.

15. Regarding the venue for the 10th ICDD, the Chair said that he has not received any formal official invitation so far, although feelers have come from Kazakhstan, through the DG of ICARDA, and from India, Jordan and Oman. Once the formal request for holding the meeting is received, the Chair will consult the Board to arrive at a decision. In the interim, the Chair asked the Members if they had any preferences at this stage about the place of the next Conference. Dr Vittal said he would like the Conference to be held in Jodhpur, India at the Central Arid Zone Research Institute (CAZRI), where adequate infrastructural support would be available and the town has the needed hotel accommodation. He will arrange to send the Official invitation from the Chair of the Indian Council of Agricultural Research (ICAR) for hosting the Conference.

16. The Chair informed the Members on the arrangements made with the Bibliotheca Alexandrina for hosting the Commission.

The agreement signed by the Commission with the Library will be shared with the Members by e-mail. Giving the past history of the office of the Commission, the Chair said, it was first at the American University of Cairo, the organization where the founding members established the Commission. It then moved to the Egyptian National Program and from there to ICARDA. It will now be permanently be at the Bibliotheca Alexandrina that also hosts other similar international institutions and organizations..

17. Commenting on the support to the Commission, the Chair expressed his appreciation of the ARC- Egypt, the Arid Land Research Center of the Tottori University, Japan, ICARDA, JIRCAS, and JICA. He also appreciated the partial funding provided by the AAAID and OFID, which supplemented the funds received as the registration fee. Dialogue was on with IFAD and GFAR for additional support, but the possible outcome was unknown. The funds were kept in the past in a special account for the Commission held at ICARDA Cairo, for which the Commission was indebted to ICARDA. Now that a formal agreement has been signed between the Commission and the Bibliotheca Alexandrina, the funds will eventually be held in the Library and the accounts will regularly audited by the auditors of the Library in the usual course. The Executive Secretary requested the Members to help the Commission in augmenting resources for the Commission for enhancing the sustainability of the Commission.

18. Prof. Inanga expressed his delight at the Commission moving out of 'nomadism' and getting settled at the Bibliotheca Alexandrina. He suggested that we could hold the next Conference here again. Prof. Wyn Jones suggested that the workshop could be held here while the 10th Conference could be held at some other venue based on the invitations expected from different prospective hosts. The Chair sensing a consensus agreed that this would be the right strategy.

19. The Chair initiated some discussion on the theme of the proposed Workshop. One of the topics of concern for the national programs was to assess the impact of climate change at the local level. For this, there was need for developing suitable indicators. There was a need to go at the level of the communities to assess impact and develop options as well as "What if?" scenarios. Dr Wyn Jones agreed. He added that there was a need to educate the policy makers about the uncertainties associated with the current assessments and future scenarios, and that we should not let them be misled. Prof. Kobori asked about the size of the Workshop. Prof. Wyn Jones suggested a Bellagio-style Workshop, with very specific objective and focus, in a brain-storming mode, and the participation not exceeding 30 including investors. Acad. Akemaliev and Dr Vittal suggested that to be effective, the number should not exceed 20 to 25 participants. The Chair suggested that 70 to 80 could be an intermediate number. Prof. Inanaga suggested that we should first decide on the objectives of the Workshop and then think of the structure. The Members agreed.

20. The Chair said that there were some vacancies in the Board because of non attendance by a couple of Members consecutive three meetings of the Board. He suggested that he would come up with the proposals and seek the opinion of the Members for new membership. He also invited Members to send him their suggestions of any outstanding person who could bring new expertise and experience on the Board.

21. The meeting ended with a vote of thanks to the Chair and the Executive Secretary.

Appendix 2

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Appendix 3

Conferences organized by The International Dryland Development Commission

1. First International Conference on Desert Development: *Application of Science and Technology for Desert Development*, **Cairo**, Egypt, 1978.

2. Second International Conference on Desert Development: *Desert Development Systems – Technologies for Desert Agriculture, Energy and Desert Communities*, **Cairo**, Egypt, 1987.

3. Third International Conference on Desert Development, **Beijing**, China.

4. Fourth International Conference on Desert Development: *Sustainable Development for our Common Future*, Mexico City, **Mexico,** 1993.

5. Fifth International Conference on Desert Development: *Desert Development – The Endless Frontier*, Lubbock, **Texas**, 1996.

6. Sixth International Conference on Dryland Development: *Desert Development – Challenges in the New Millennium*, **Cairo**, Egypt, 1999.

7. Seventh International Conference on Dryland Development: *Sustainable Development of Drylands in the 21st Century*, **Tehran**, Iran, 2003.

8. Eighth International Conference on Dryland Development: *Human and Nature working together for Sustainable Development of Drylands*, **Beijing**, China, 2006.

9. Ninth International Conference on Dryland Development: *Meeting the Challenge of Global Climate Change,* **Alexandria**, Egypt, 2008.

About International Dryland Development Commission

The International Dryland Development Commission (IDDC) is a nongovernmental organization established in 1987 by concerned scientists/experts and institutions interested in the sustainable development of dryland areas. The vision of IDDC is: improved livelihood of the people in the dry areas through environmentally and economically sustainable development and halting and reversing the trends in desertification. The objective is to encourage all aspects of dryland studies to promote sustainable development by fostering cooperation and networking between various international, regional and national organizations. The modus operandi is to: (a) provide forum for scientific dialogue and debate on issues constraining the development of dry areas and enhancing the exchange of information amongst researchers engaged in multi-disciplinary research on developing environmentally, economically and socially acceptable solutions for improving the livelihood of the people living in dry areas and desert communities; (b) encourage networking by holding a major scientific conference - International Conference on Dryland Development (ICDD) - every three years to provide opportunity to participants from around the world to exchange research results and experiences in dryland development and combating desertification; (c) publish proceedings of the conferences and other scientific publications and disseminating them amongst all the stakeholders; and (d) contribute to the objectives of various global conventions that affect sustainable development of the dry areas. In November 2008, the IDDC signed a twining agreement with the Bibliotheca Alexandrina under which the office of the Commission is now based at the Library in Alexandria, Egypt. The website of IDDC is therefore hosted by the Bibliotheca Alexandrina. The URL for the website is http://www.bibalex.org/ICDD .