Biogas for Better Life

An African Initiative

Domestic biogas in Africa; a first assessment of the potential and need

Draft / Discussion Paper

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Domestic biogas in Africa; a first assessment of the potential and need.

Abstract.

To estimate the technical potential of domestic biogas in Africa, two main indicators have been used, the number of households with access to water and the number of domestic cattle per household. Land-use and cattle-type information has been used to correct for pastoral farming practices. With this methodology, the technical potential for domestic biogas for Africa turns out to be 18.5 million installations. At country level, this calculation matches the lower estimates for Ethiopia and Rwanda but overstates the estimates for Senegal, for which more detailed recent feasibility studies are available.

This technical potential value on its own provides an incomplete picture on the feasibility of large(r) scale biogas dissemination initiatives. To improve the accuracy, and thus the reliability, four supporting “aspect areas” –development, energy, health & sanitation and environment- have been assessed from a biogas perspective. For each of these aspect areas, a “Biogas Feasibility Index” is suggested, providing an indication of the situation of the aspect area relative to domestic biogas.

Introduction.

Global understanding on sustainable energy supply as a critical factor for development is steadily increasing. For farming households in developing countries domestic biogas could contribute in a modest but significant manner, providing multiple benefits, beyond energy, in the areas of health, nutrition and environmental sustainability.

Fig 1:

Fixed dome domestic biogas installation

Production of biogas through anaerobic digestion is a relative simple technology that can be implemented at industrial, village and household scale *(fig 1)*. At domestic level, the controlled management of animal dung and other organic waste allows for the safe production of gas for cooking and lighting and improves the sanitary situation of the farm yard. In addition the fermented bio-slurry provides an extremely valuable organic fertilizer. Replacing traditional biomass fuels and inefficient stoves, biogas virtually eliminates indoor air pollution and reduces the workload –mostly for women and children- related to food preparation significantly.

In Asia, the potential of domestic biogas is well exploited. By the end of 2004, over 15 million households in China were using biogas, the government aiming to increase this number to 27 million by 2010. India registered 3.67 million domestic biogas installations at that time[1]. National programmes for domestic biogas have also been established in Nepal[i],[2] and Vietnam[ii] and, more recently in Cambodia and Bangladesh.

Africa has not seen such propagation of domestic biogas. Despite several biogas dissemination initiatives the number of constructed installations for the continent as a whole is rather in the order of thousands[3,4] and a large share of them has fallen into disrepair or disuse [World Energy Council and FAO, 1999].

At the same time, however, many households in Africa are facing problems with energy supply. Traditional biomass covers 70-90% of the primary energy supply and up to 95% of the total energy consumed [World Energy Council, 2005]. The availability of traditional cooking fuels such as wood, agricultural residue, dried dung and charcoal is declining, while commercial fuels often are too expensive and their availability unreliable. Collection of traditional fuels is time intensive, preventing -in particular women and children- from engaging in education or productive activities. Burning biomass fuels exposes family members to indoor air pollution, causing respiratory diseases and eye ailments [Rehfuess, 2006][iii]. Often the same households face the consequences of lacking hygiene and sanitation, resulting in waterborne diseases. Studies from the WHO[5] and Winrock indicate that the benefits from latrines and improved hygiene far outweigh the costs. At many places, the collection of traditional fuels and the production of charcoal exhausts natural resources and damages the very environment on which people heavily rely.

There is, in short, an urgent need in Africa for alternative more sustainable energy sources and improved sanitation.

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[i] The Biogas Sector Partnership / Nepal, established in 1992, supported construction by the end of 2006 165,000 installations

[ii] The Vietnam Biogas Programme, established in 2003, supported construction by the end of 2006 over 26,000 installations

[iii] It is estimated that several hundred thousands of women and children die annually as a result of traditional fuel burning

Technical potential[6]**.**

For this paper, "technical potential" is defined as the number of households that can meet the two basic requirements –sufficient availability of dung and water- to run a biogas installation.

Although biogas can be generated by a score of organic material, cattle dung[i] is arguably best suited as a substrate for small installations; the digestion process is robust and the material is abundantly available on many farmyards. For a biogas plant to be attractive to a family, it should be able to provide at least 0.8 to 1 m^3 biogas daily[ii]. To generate this amount of biogas, the household should have 20 to 30 kg of fresh dung available at a daily basis. Theoretically, two healthy mature cattle would be able to produce this amount of dung, but as for large parts of Africa zero-grazing is not common and cattle are generally small and undernourished, most African households would rather need at least 3 or 4 night-stabled heads of cattle[iii].

To enable both the installation's micro-biological process as well as the hydraulic functioning, the feeding material, dung, has to be mixed with equal amounts of water. This process water does not have to be of "drinking water" quality, but –in view of the significant amount needed on a daily basis, should be available in the vicinity[iv] of the installation.

For the process to run in a relatively simple, domestic installation, the ambient temperatures should remain over 15^{O}C. At continental level the temperature will not be a limiting factor *(map 1a)*[v].

Agricultural households with access to water.

Freshwater withdrawal for domestic and agricultural use in Africa rank amongst the lowest in the world *(fig 2)*. Also, Africa features the lowest share of cultivated land being irrigated (5.9% in 2003)[7]. Although these numbers do not indicate actual domestic or agricultural water consumption, and even less the geographical and seasonal distribution of water availability, clearly (domestic) water comes at a premium in Africa.

In absence of detailed data on water proximity and availability to households, "access to safe water sources" is used as a proxy. Out of a total population of just over 837 million, Africa has an agricultural population of 455 million persons. Assuming an average family size of 6 persons, this equals about 76 million agricultural households.

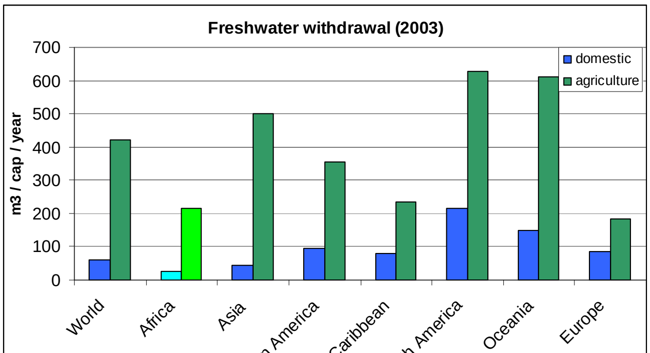

Fig 2

Of the total urban population, 85% has access to safe water, a claim that can only be made by 50% of the rural population. Assuming that 80% of the agricultural households are living in rural areas, **43 million agricultural households** can be expected to have access to safe water *(map 1b)*.

Domestic cattle population.

The total cattle population of Africa amounts to 277 million heads [FAO 2006]. Lacking official data on the share of the total cattle population that is –at least- night stabled, it is assumed that domestic cattle[vi] is equal to all dairy cattle (46 million heads) plus a share of the non-dairy cattle (draft animals, local grazing).

For an approximation of the share of non-dairy cattle that is night-stabled, the land-use factor *(box 1)* based on the ratio arable / pastoral land area is proposed. With this land-use factor, 122 million heads of non-dairy cattle (53% of the total non-dairy cattle herd of Africa) are expected "domestic". Based on these assumptions, Africa is estimated to have some **168 million heads of domestic cattle** *(map 1c)*.

Box 1:

Domestic cattle:

milk cattle + (*land-use factor* x non-milk cattle)

Land Use Factor:

arable land / (arable land + 20% pastoral land)

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[i] Pig manure and poultry litter make a good anaerobic substrate as well, but densities of these animals in most countries of rural Africa may not justify a larger dissemination programme.

[ii] Such amount of biogas would provide about 2 to 3 "stove hours"; sufficient to prepare at least one family meal.

[iii] To properly assess the availability of dung, the actual collected amount over a longer period (1 week) should be measured.

[iv] Biogas programmes in Nepal and Vietnam use the criterion that a suitable water source shall be within 20 minutes walking.

[v] Main maps are inserted in the document. Supporting maps, indicated with a suffix, are combined in the annex.

[vi] Domestic cattle is in this paper defined as cattle that is al least kept stabled at the farmyard during the night

Technical potential for domestic biogas.

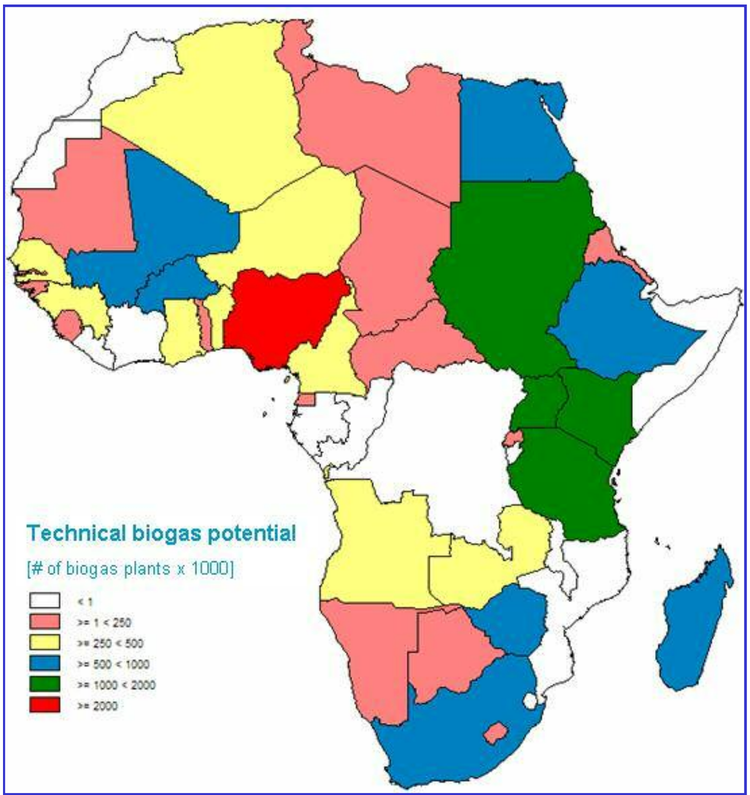
As argued earlier, for a domestic biogas plant to work satisfactorily, a household would need at least 3 heads of domestic cattle and good access to water. On average an African agricultural household with access to water has **4.15 heads of cattle** *(map 1d)*.

> ***Box 2:***
>
> **Technical potential:**
>
> Agric hh with water x cattle holding factor
>
> ***Cattle holding factor:***
>
> 0.75 if cattle holding /ah > 3
>
> 0.50 if cattle holding / ah >2 and < 3
>
> 0.25 if cattle holding / ah >1 and < 2
>
> 0.00 if cattle holding / ah <1

However, even at country level, this would be a very rough indication of the technical potential of domestic biogas. To arrive at a more precise estimate of the technical potential, the number of agricultural households with access to water is multiplied with a cattle-holding factor *(box 2)*, correcting the technical potential downwards for countries with a lower average cattle holding per agricultural household. Also, to justify a large-scale dissemination programme in any country, a certain minimum potential (for the calculations set at 30,000 households) should be available. Following this, the technical potential market for domestic biogas in Africa is estimated at **18.5 million households**[i] ***(map 1)***.

In absolute figures, most East African countries except Somalia and Djibouti show a substantial potential. In Southern Africa, Zimbabwe and South Africa stand out, but also Lesotho would have a significant scope. Nigeria, and to a lesser extent Mali and Burkina Faso, seem to qualify for large-scale biogas dissemination programmes.

Map 1
Technical potential



Equally important would be the share of potential biogas households out of the total number of agricultural households in a country. This biogas potential density works out at 24% for the continent as a whole *(map 1e)*.

Validation.

Lacking more detailed information on technical potential parameters at regional, country or district level, the estimates are based on macro-level data and thus unavoidably coarse.

Box 3:	**Feasibility study**	**Potential & need assessment**
Rwanda	110,000	140,000
Ethiopia	1,100,000	916,000
Senegal	200,000	439,000

For Rwanda[8] and Ethiopia[9], SNV-the Netherlands Development Organization recently performed more detailed feasibility studies *(box 3)*. The estimates for the technical potential of Rwanda -110,000 installations and Ethiopia (4 regions) -1.1 million installations are in the same order of magnitude as the results of this paper (140,000 and 916,000 installations respectively).

More detailed information obtained from Winrock International on zero and semi-zero grazing practices of 8 districts in south west Kenya indicate a technical potential of over 320,000 households against an estimated potential in this paper of 1.26 million for the country as a whole.

A recent feasibility study in Senegal[10] estimates the technical potential at some 200,000 installations, against an estimate in this paper of 439,000.

[i] A table with supporting data for the technical potential calculations is provided in Annex 1.

The Biogas Feasibility Index.

Technical potential of domestic biogas is not the sole indicator for successful large scale introduction of the technology. As biogas has an impact on aspects of energy, environment, agricultural production, socio-economic development and health & sanitation, (proxy-) indicators of these aspect areas should be assessed as well.

> ***Box 4:***
> **Biogas Feasibility Index** (BFI)**:**
> ([x-value] – [min value]) / ([max value – min value])

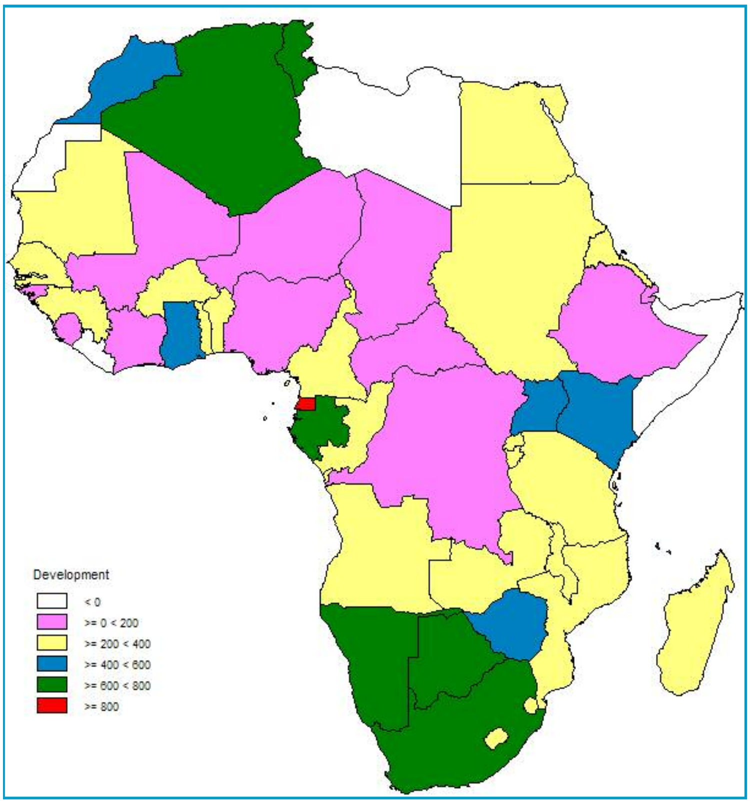
To be able to compare indicators of such different areas, the "Biogas Feasibility Index" is proposed *(box 4)*. This index assesses values within an aspect area relative to each other, not unlike the calculation method of the human development index.

Development[11]**.**

The indicators selected to arrive at the development BFI are: Human Development Index [HDR[i] value]; Gross Domestic Product (ppp) per Capita [US$$_{ppp}$/cap]; Gender Development Index [HDR value]; and; Female / male Income Earning Ratio [HDR value].

The Human Development Index (HDI) *(map 2a)* indicates the general level of development of a population, based on a range of economic and social indicators. For biogas the HDI is relevant in two ways: Countries with a very high HDI value (North-African countries, South Africa, Namibia and Gabon) and a significant biogas potential can be expected to embark up on domestic biogas on their own strength, and dissemination may pick-up quickly. Countries with a very low HDI value (e.g. the Sahel countries and Ethiopia), despite a high biogas potential, may be slow in accepting the new technology both for social as well as economic reasons.

Map 2
Development BFI



Although the Gross Domestic Product per Capita (GDP$_{ppp}$/cap) *(map 2b)* is also included in the HDI indicator, the GDP$_{ppp}$/cap indicator on its own more precisely indicates the financial capacity of the population to bear the investment costs of a domestic biogas installation. In addition, higher GDP rates may point towards better financial infrastructure, possibly including rural (micro) credit.

The Gender Development Index (GDI) *(map 2c)* measures the extent to which women play an equal role in society. As women often are the main biogas plant operators and reap an important share of the benefits of an installation, the GDI provides an impression on the role women can be expected to play in the investment decision, plant operation and promotion of the technology.

The Female/Male Income Earning Ratio (FMIE) *(map 2d)* approaches gender equality from a more economic perspective.

The Development BFI ***(map 2)***, calculated with these four indicators, point at South Africa, Zimbabwe, Uganda, Tanzania, Gabon and Equatorial Guinea, combining a high technical potential for domestic biogas with a high "Development BFI".

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[i] HDR: Human Development Report

Energy[12]**.**

The two indicators used to arrive at the Energy BFI are Traditional energy use as share of total energy use [%] and Forest area as share of total land area [%].

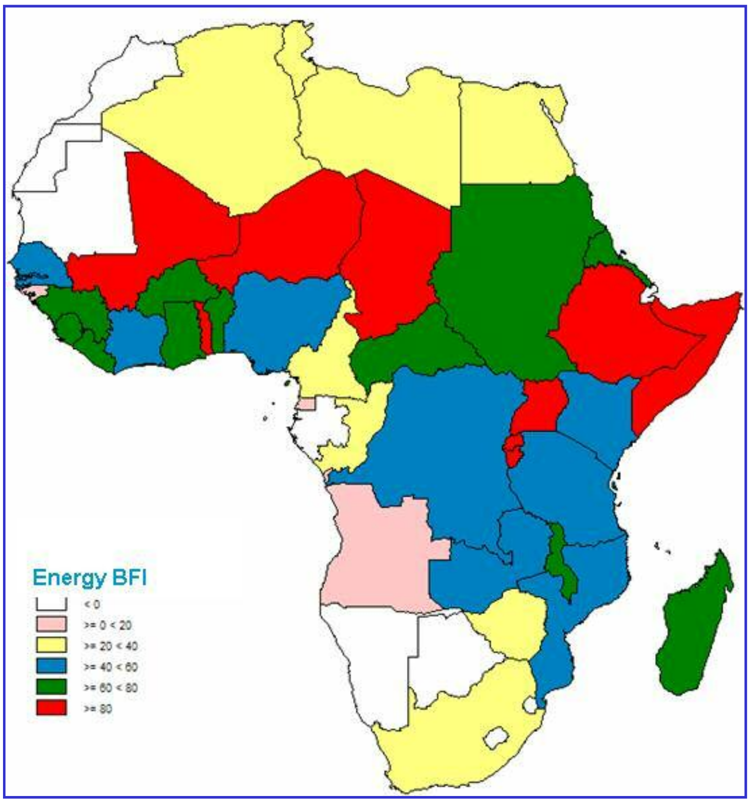
The lion share of Africa's domestic energy consumption is (in-) directly sourced from biomass: fuelwood, agricultural residue and dung *(map 3a)*. Typically, the common biomass combustion devices are characterised by a very low efficiency[13] and high emission rates of toxic / harmful exhaust gasses[14]. Whereas traditional energy used to be a commodity in the in-formal domain of the economy, increasing demand (population growth and consumption per capita) have commercialized the trade in fuelwood, agricultural residue and dung cake. This development causes severe "energy poverty", to the extent that cooked meals are becoming a luxury for many rural African households. Biogas (partly) substitutes traditional fuel, offering at least a partial solution for the domestic energy crisis and easing the environmental pressure resulting from fuelwood and dung burning.

Although biogas offers multiple benefits, for many households the initial prime attraction of biogas is the substitution of fuelwood. In areas with high forest coverage, fuelwood is often easily available and free of (financial) costs. On the other hand, low forest coverage –particularly in combination with a high share of traditional energy use- is an indicator for commercialization of fuelwood, dung and even agricultural waste. Biogas programmes, hence, can be expected to be more successful in countries with low forest coverage *(map 3b)*.

The main use of electricity for households is for lighting and running small electric equipment. Especially domestic illumination is a highly valued commodity for rural households. Although biogas lighting, using mantle lamps similar to kerosene pressure lamps, cannot compete with the comfort of electric lighting, they may offer the best option in areas that are not connected to the grid. This would suggest an inversed relation between the electricity consumption and the attractiveness of biogas, an assumption that is supported by programme experiences in remoter areas. At the same time, however, experiences in the Nepal and Vietnam programmes indicate a positive correlation between biogas penetration and electric grid connection; electricity is rarely used as cooking energy and grid connection might here be an indicator for improved accessibility / development opportunities of rural areas, supporting - amongst a score of other things- biogas dissemination. Electricity consumption thus seems to indicate two different issues, one addressing need (for illumination) and one related to accessibility aspects of information and promotion. Although a map is provided *(map 3c)*, for its ambiguous nature the indicator is not included in the Energy BFI calculation.

The energy BFI, combining traditional energy and forest coverage indicators, provides an insight in the location of areas that share a high demand with low supply of traditional energy ***(map 3)***. Roughly the entire central band of African countries is facing a serious domestic energy crisis. In view of the technical potential of domestic biogas in most of these countries, the technology could assist in (partly) alleviating this problem.

Map 3
Energy BFI



Health & sanitation.

Indicators used to arrive at the Health & sanitation BFI are: Population undernourished [%]; Access to improved sanitation [%]; Access to improved water source [%]; Mortality children <5 diarrhoea [%]; Traditional energy use [%], and; Mortality children <5 pneumonia [%].

Proper nutrition is a sine qua non for health and development. As shown in the map *(map 4a)*, large parts of sub-Saharan Africa do not meet this condition. Biogas can improve the nutrition of families only indirectly, as far as the application of bio-slurry as organic fertilizer improves agricultural yield. As manure is used and traded as an energy source in many countries, biogas provides the added value of providing both energy and plant nutrients.

A considerable share of Africa's public health problems can be attributed to the poor sanitary situation *(map 4b)* of many households. Domestic biogas installations can be connected to a toilet at very little extra costs. In this way the sanitary situation of the farmyard and its immediate environment improves significantly.

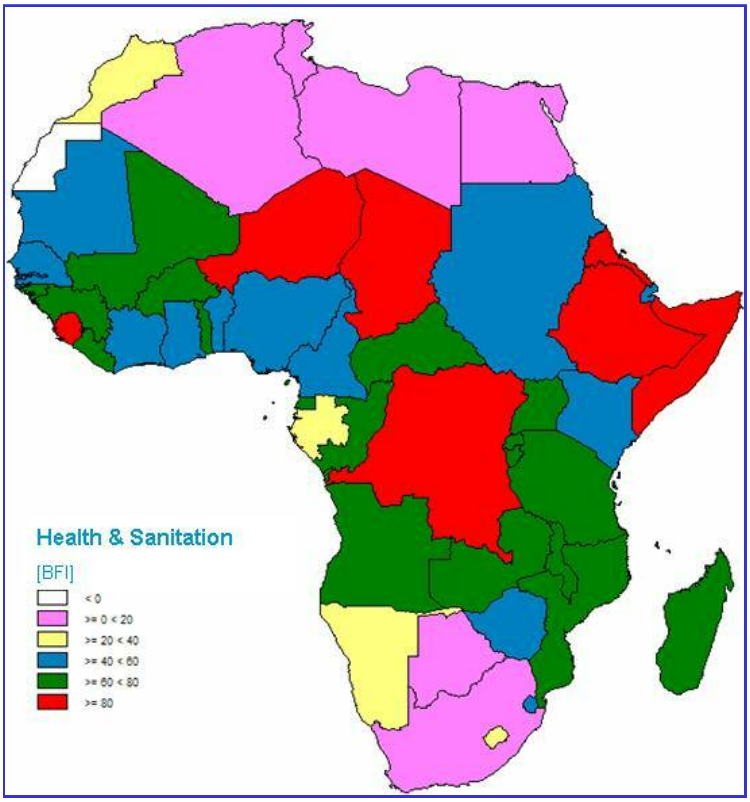
Access to an improved water source *(map 4c)* –or any water source for that matter- is not a commodity in Africa and contaminated or polluted water sources harbour a major health risk. Biogas does not improve the access to water, rather is access to water a condition for sedentary agriculture and livestock keeping, improved sanitation and the proper operation of a biogas plant.

Diarrhoea *(map 4d)* is closely related to polluted water sources and poor sanitation practices. For African children diarrhoea is a very serious health threat.

Indoor air pollution[15] is another major health risk, linked directly with the use of traditional fuel (*map 3a)* and simple stoves in poorly ventilated kitchens. Indoor air pollution is related to the incidence of pneumonia *(map 4e)* although the disease has many other causes as well [Ezattie and Kammen, 2001].

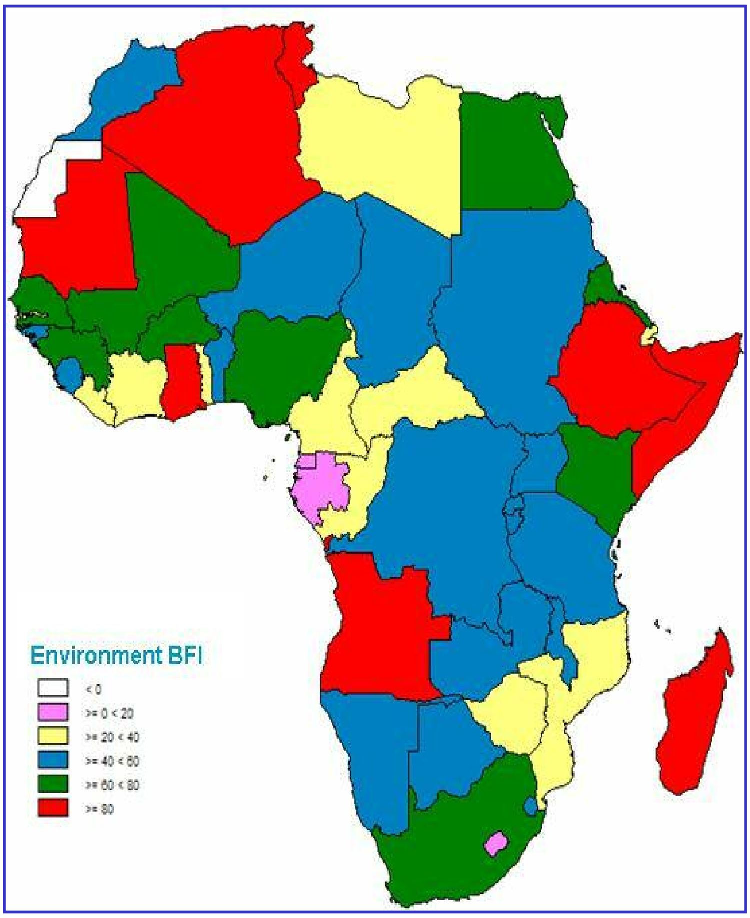
All countries in the central east-west band of Africa suffer major health & sanitation problems ***(map 4)***. Many of these countries have a reasonable potential for domestic biogas, the technology can improve this situation.

Map 4
Health & Sanitation BFI



Environment[16].
Indicators used for the Environment BFI are: Soil degradation and erosion; Deforestation; Desertification; Overgrazing; Water shortage, and; Water pollution (organic).

Map 5
Environment BFI



Soil degradation and erosion is an indicator for the level of sustainability of agricultural practices. The CIA fact book mentions degradation and erosion as an environmental issue for most of the African countries *(map 5a)*. Their assessment is supported in a more quantitative way by Henon[17] (*map 5b*). Many agricultural systems in Africa deplete nutrients and further degrade soils. Domestic biogas prevents valuable manure and its nutrients from being wasted through evaporation, leakage and burning. Proper application of bio-slurry will improve nutrient cycling at a local level, improving the quality of agricultural soils.

Forest resources in Africa are dwindling; some countries report an annual decline of forested area at a rate of 4% p.a. between 1990 and 2000. Main causes of deforestation *(map 5c)* include increasing population pressure; poor forest management practices; conflict; extension of agricultural land, and; the increasing need for (domestic) energy. Biogas contributes to combating deforestation; directly, as biogas substitutes fuelwood, and; indirectly as bio-slurry improves soil-fertility and thus reduces the requirement for new agricultural land.

Desertification *(map 5d)*, possibly even more than deforestation, is an indicator for unsustainable land use (livestock) and a high demand for domestic fuel, often triggered by periodically declining rainfall patterns[18] *(map 5e)*. Biogas will, at best, only marginally contribute to reducing desertification, and the implied water shortage in these areas will hamper implementation of large scale programmes

Linked with the above is overgrazing *(map 5f)*; in large parts of Africa the traditional way of livestock keeping with large free-roaming herds for centuries was a symbol of well-being. In combination with the increasing population pressure, however, pasture land is reducing and increasingly overgrazed. Although livestock for many rural families is the cornerstone for survival, many countries (e.g. Ethiopia, Kenya Rwanda) are contemplating on far-reaching measures (from promoting “cut and carry” practices to penalties on free roaming cattle) to drive back this practice.

The availability of water *(map 5g)* for domestic or agricultural use cannot be taken for granted for the majority of Africa’s rural population. For domestic biogas to function properly however, process water (not necessarily of drinking water quality) is required in roughly equal quantity as the amount of manure fed to the installation. For practical purposes, in view of the significant amounts of water needed, water should be within a distance of –say- 20 to 30 minutes from the installation.

Water sources –particularly in (peri)urban areas- are often polluted with organic matter *(map 5h)* as a result of poor sewage and sanitation practices. Domestic biogas, especially where toilets are connected to installations, controls the pollution of water sources and reduces the biological oxygen demand for the subsequent final decomposition.

From an environmental perspective it would be more correct to speak of necessity rather than feasibility. The cause of Africa’s high environmental pressure ***(map 5)*** is complex and multi-facetted. Domestic biogas can only play a modest supporting role in bettering this situation, and than only in combination with other measures.

Conclusions.

This assessment is based entirely on macro-level data whereby some of the information had to be "manipulated" to arrive at –for biogas- meaningful indicators. Hence, this assessment cannot be a substitute for detailed research at country level. Nevertheless, the results of this assessment are in the same order of magnitude as some of these recent feasibility studies.

The technical potential for domestic biogas in Africa appears to be significant; 1 in 4 agricultural households on the continent would qualify, translating in a total potential of some 18.5 million installations. With the current –UN Millennium Development Goals and UN Millennium Ecosystem Assessment induced- activities aiming to improve livestock holding practices, water accessibility and the environment in general, the technical potential for domestic biogas is likely to increase over the coming decade. In addition, the growing scarcity of traditional and fossil energy sources as well as the high costs of modern energy sources (electricity, LNG) in most rural areas will likely improve the economy of investment in a biogas installation over time.

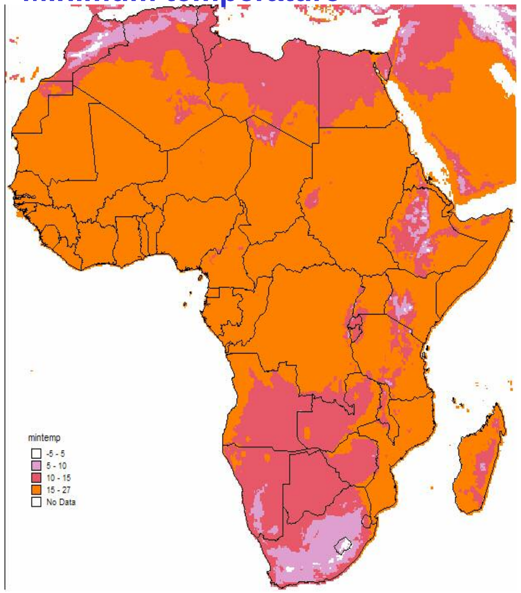
The need for biogas, in terms of its potential contribution to development, energy, health & sanitation and environment, seems even larger than its potential demand; Africa's status on these aspects is alarming. In this respect the BFIs provide an indication of "low hanging fruit" for starting large-scale biogas programmes, but are by no means a guarantee for success.

Annex 1
Main data for technical potential calculation

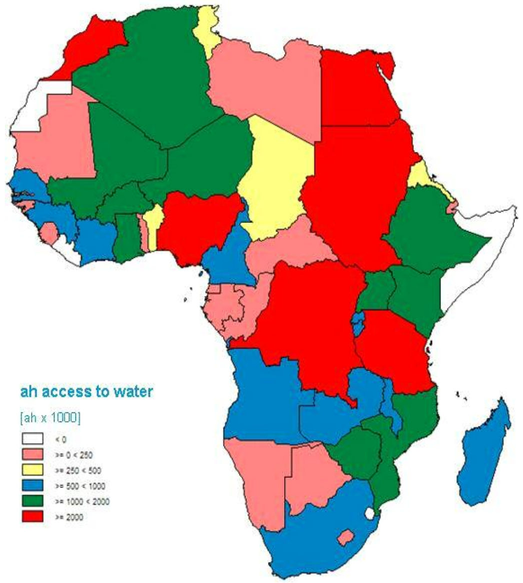
COUNTRY	agricultural households [hh x 1000] ah_tot	agric hh with access to water [hh x 1000] ah_wat	non-milk cattle [# of heads x 1000] cattle_nonmilk	landuse factor arable vs pastoral land [arable / arable + 20% pastoral land] arab/past	calculated non-milk domestic cattle [# of heads x 1000] lomcat_nonmilk	milk cattle [# of heads x 1000] domcattle_milk	total domestic cattle [# of heads x 1000] domcat_tot	cattle holding per agricultural household [heads of cattle/agric hh] domcat/ah_wat	75% of agric hh for avg holding >3 [biogas plant potential x 1000] bio_ah>3	50% of agric hh for avg holding >2 but <3 [biogas plant potential x 1000] bio_ah>2	25% of agric hh for avg holding >1 but <2 [biogas plant potential x 1000] bio_ah>1	[biogas plant potential x 1000] bio_ahtot	›io_ahprogto
ALGERIA	1234	1111	1560	0.55	853	1003	1856	1.67	0	0	278	**278**	278
ANGOLA	1660	644	4150	0.22	902	404	1306	2.03	0	322		**322**	322
BENIN	577	339	1745	0.96	1673	210	1882	5.55	254			**254**	254
BOTSWANA	131	121	1700	0.07	115	290	405	3.34	91			**91**	91
BURKINA FASO	2058	1169	5200	0.78	4075	1040	5115	4.38	876			**876**	876
BURUNDI	1057	736	325	0.83	271	55	326	0.44	0	0	0	**0**	0
CAMEROON	1301	651	5950	0.94	5576	260	5836	8.97	488			**488**	488
CAPE VERDE	16	13	23	0.89	20	9	29	2.13	0	7		**7**	0
CENTRAL AFRICAN REPUBLIC	451	238	3423	0.76	2586	246	2832	11.89	179			**179**	179
CHAD	1053	284	6400	0.29	1829	248	2077	7.30	213			**213**	213
COMOROS, THE	95	91	50	0.96	48	9	57	0.63	0	0	0	**0**	0
CONGO, THE	238	66	123	0.09	11	2	13	0.19	0	0	0	**0**	0
DJIBOUTI	91	91	297	0.00	1	23	24	0.26	0	0	0	**0**	0
EGYPT	4155	3922	3900	0.50	1950	2050	4000	1.02	0	0	980	**980**	980
EQUATORIAL GUINEA	58	25	5	0.86	4	nd	nd	nd	19			**19**	0
ERITREA	546	252	1930	0.26	510	200	710	2.81	0	126		**126**	126
ETHIOPIA	4735	1222	35500	0.71	25311	7500	32811	26.86	916			**916**	916
GABON	74	43	35	0.26	9	6	15	0.35	0	0	0	**0**	0
GAMBIA, THE	189	111	328	0.73	240	44	284	2.56	0	55		**55**	55
GHANA	1967	1113	1365	0.71	975	273	1248	1.12	0	0	278	**278**	278
GUINEA	1183	511	3400	0.30	1007	442	1449	2.84	0	255		**255**	255
GUINEA-BISSAU	210	104	520	0.58	302	84	386	3.70	78			**78**	78
IVORY COAST, THE	1262	883	1111	0.54	604	197	801	0.91	0	0	0	**0**	0
KENYA	3979	1679	11500	0.52	5971	5500	11471	6.83	1259			**1259**	1259
LESOTHO	115	104	540	0.45	244	95	339	3.27	78			**78**	78
LIBERIA	381	nd	36	0.49	18	6	23	nd	nd	nd	nd	**0**	0
LIBYA	44	30	130	0.45	58	108	166	5.49	23			**23**	0
MADAGASCAR	2162	904	10500	0.38	3997	1900	5897	6.52	678			**678**	678
MALAWI	1547	838	750	0.86	646	76	722	0.86	0	0	0	**0**	0
MALI	1758	1118	7500	0.44	3279	750	4029	3.60	839			**839**	839
MAURITANIA	258	100	1500	0.06	88	345	433	4.33	75		25	**100**	100
MOROCCO	4833	3209	2689	0.67	1792	1380	3172	0.99	0	0	0	**0**	0
MOZAMBIQUE	2423	1265	1320	0.32	426	355	781	0.62	0	0	0	**0**	0
NAMIBIA	154	113	2500	0.10	242	260	502	4.45	85		28	**113**	113
NIGER	1797	1057	2260	0.65	1472	460	1932	1.83	0	0	264	**264**	264
NIGERIA	6305	2988	15200	0.79	12067	1800	13867	4.64	2241			**2241**	2241
RWANDA	1274	561	815	0.92	752	251	1003	1.79	0	0	140	**140**	140
SAO TOME AND PRINCIPE	17	nd	4	0.97	4	1	5	nd	nd	nd	nd	**0**	0
SENEGAL	1248	879	3100	0.69	2124	310	2434	2.77	0	439		**439**	439
SIERRA LEONE	517	152	400	0.55	219	85	304	2.00	0	76		**76**	76
SOMALIA	1192	nd	5350	0.11	580	1165	1745	nd	nd	nd	nd	**0**	0
SOUTH AFRICA	937	772	13600	0.47	6362	930	7292	9.45	579			**579**	579
SUDAN	3285	2378	38325	0.41	15677	6800	22477	9.45	1784			**1784**	1784
SWAZILAND	57	nd	580	0.43	247	130	377	nd	nd	nd	nd	**0**	0
TANZANIA	4788	2375	17800	0.36	6473	4828	11300	4.76	1781			**1781**	1781
TOGO	479	227	279	0.93	258	41	299	1.32	0	0	57	**57**	57
TUNISIA	383	259	760	0.74	563	575	1138	4.39	194			**194**	194
UGANDA	3422	1752	6100	0.83	5081	2000	7081	4.04	1314			**1314**	1314
WESTERN SAHARA	18	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	**0**	0
ZAIRE	5559	2146	765	0.69	528	6	534	0.25	0	0	0	**0**	0
ZAMBIA	1219	683	2600	0.47	1215	214	1429	2.09	0	341		**341**	341
ZIMBABWE	1298	1059	5760	0.48	2785	800	3585	3.39	794			**794**	794
	75785	**40387**	**231702**		**122039**	**45764**	**167799**	4.15	**14838**	**1622**	**2051**	**18511**	**18463**

Annex 2
Supporting maps for “Technical Potential”

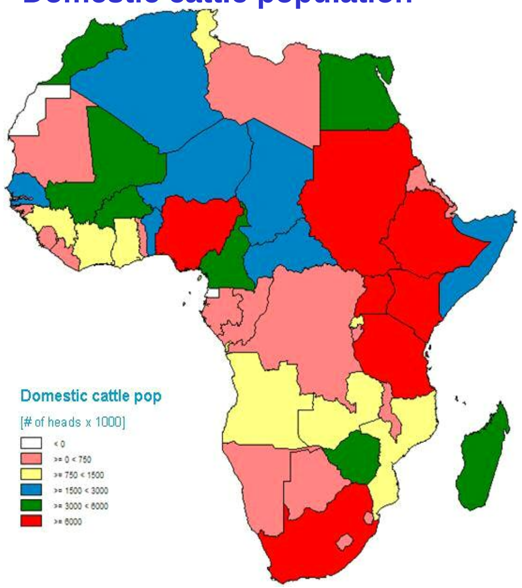
Map 1a
Minimum temperature



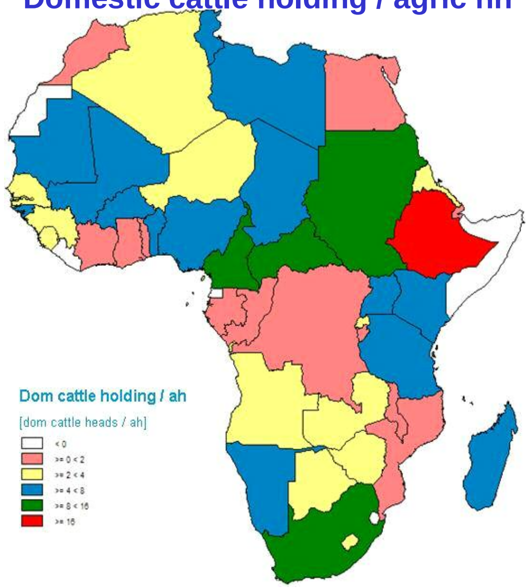
Map 1b
Agric hh with access to water



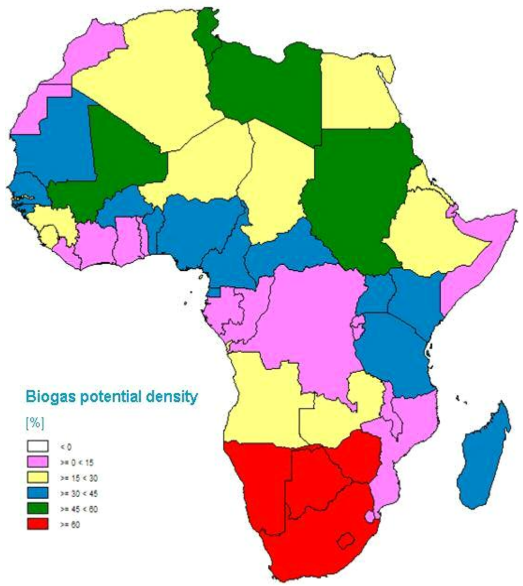
Map 1c
Domestic cattle population



Map 1d
Domestic cattle holding / agric hh

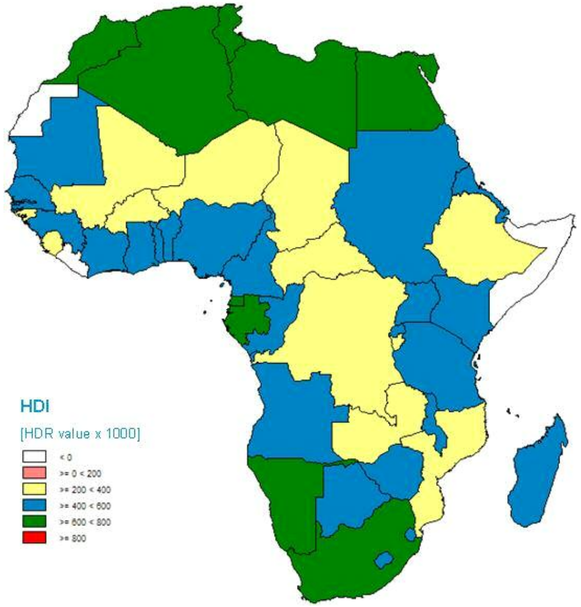


Map 1e
Biogas potential density

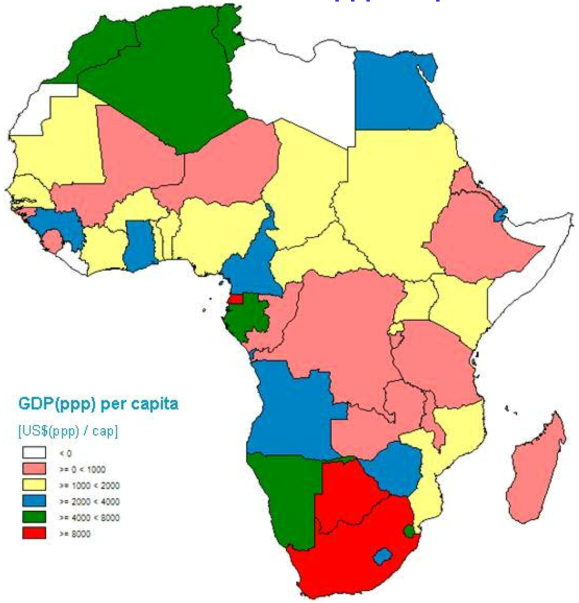


Annex 2
Supporting maps for "Development"

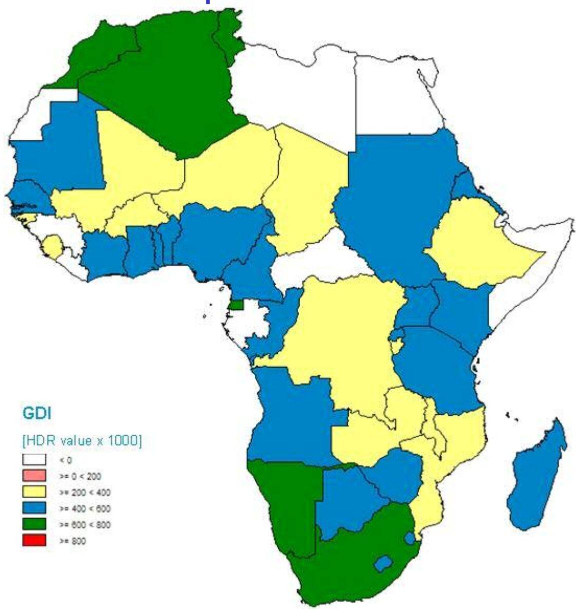
Map 2a
Human Development Index



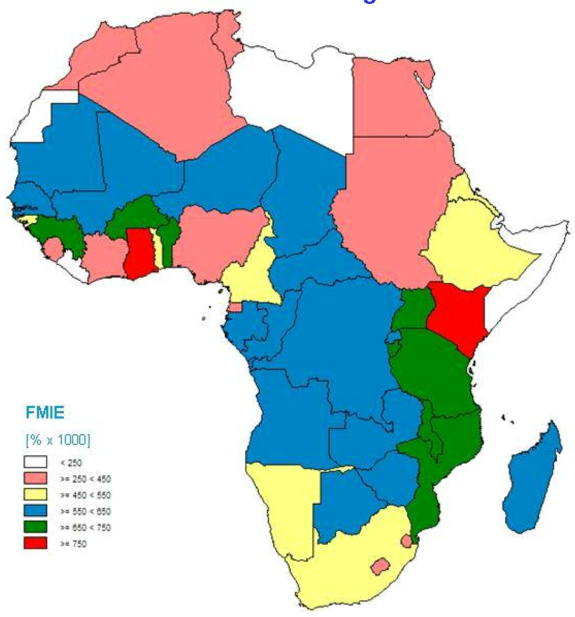
Map 2b
Gross Domestic Product ppp / Cap



Map 2c
Gender Development Index

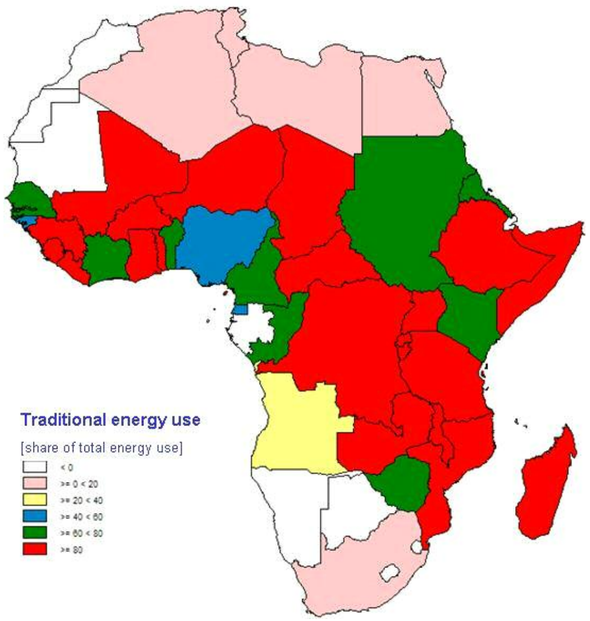


Map 2d
Female/male Income Earning Ratio

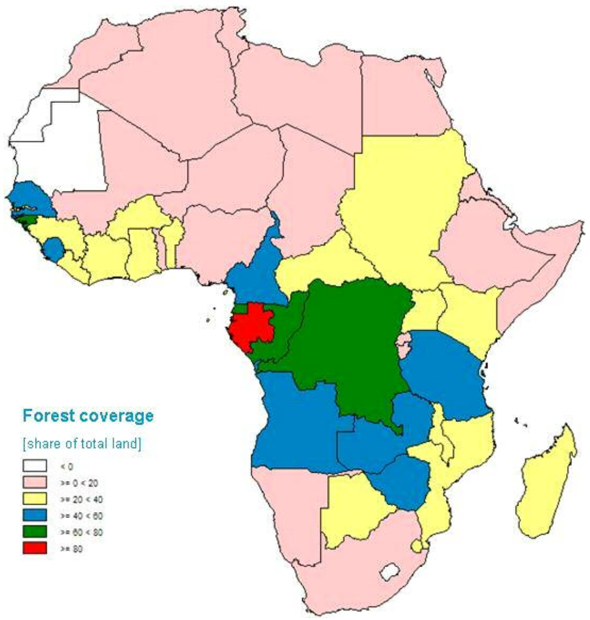


Annex 3
Supporting maps for “Energy”

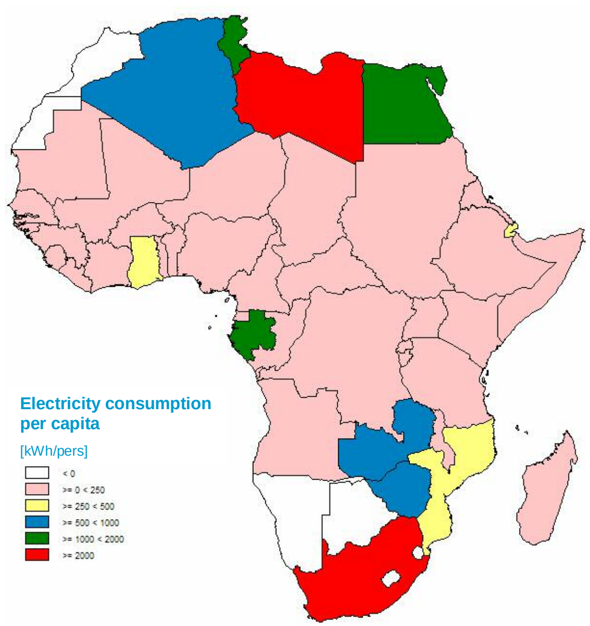
Map 3a
Traditional energy use



Map 3b
Forest coverage

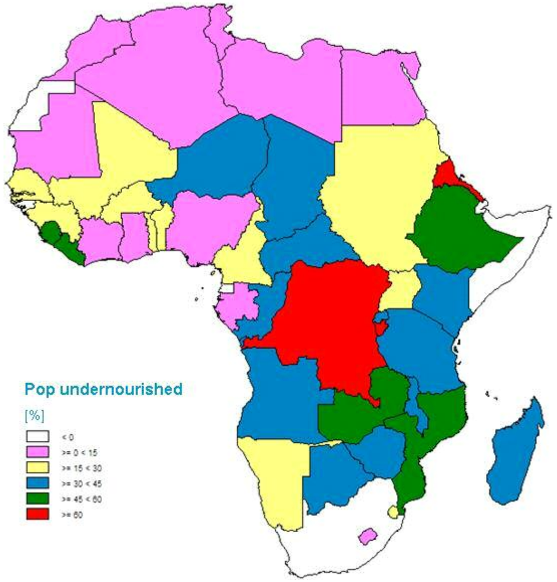


Map 3c
Electricity consumption

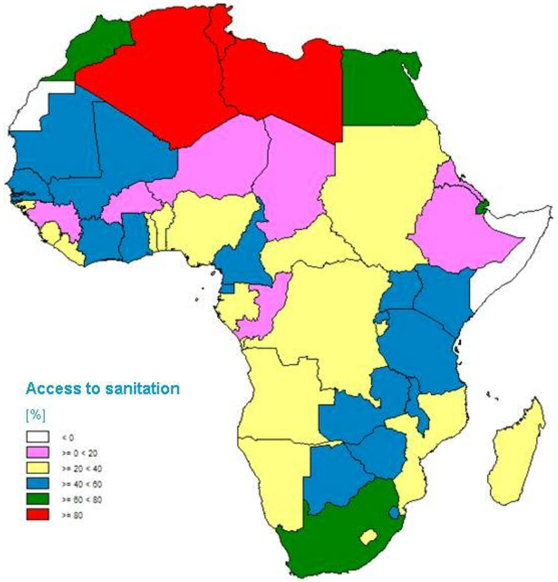


Annex 4
Supporting maps for "health & sanitation"

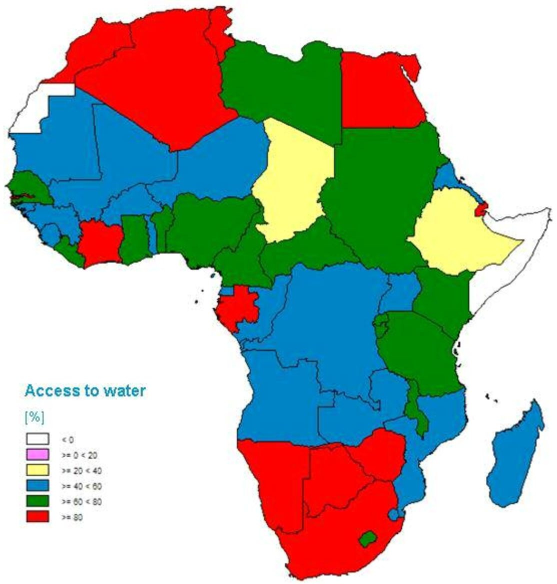
Map 4a
Population undernourished



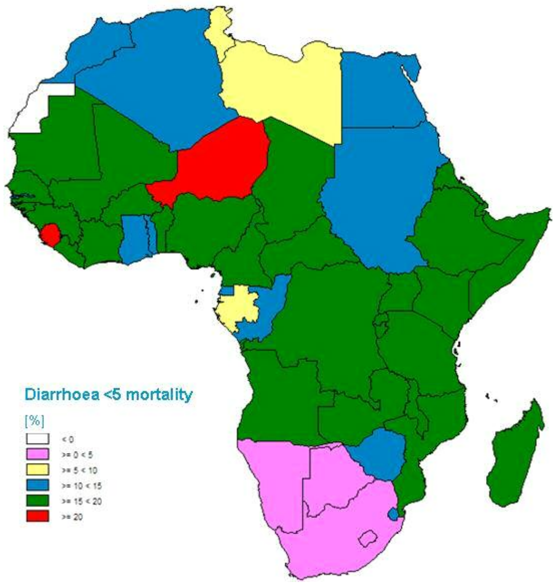
Map 4b
Access to improved sanitation



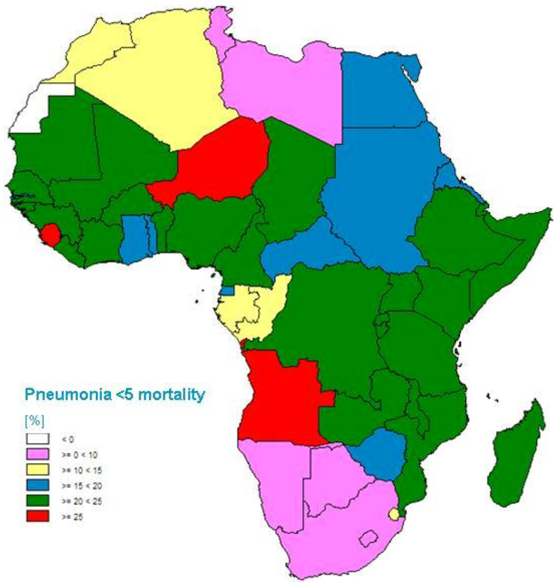
Map 4c
Access to improved water source



Map 4d
< 5 mortality diarrhoea



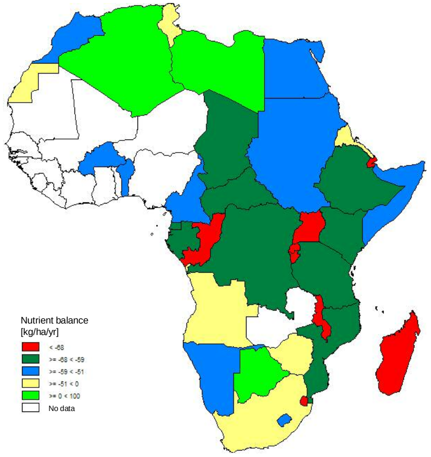
Map 4e
<5 mortality pneumonia



Annex 5
Supporting maps for “environment”

Map 5a
Soil degradation / erosion

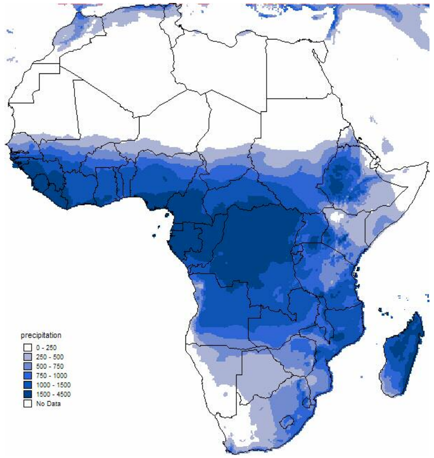
Map 5b
Nutrient balance



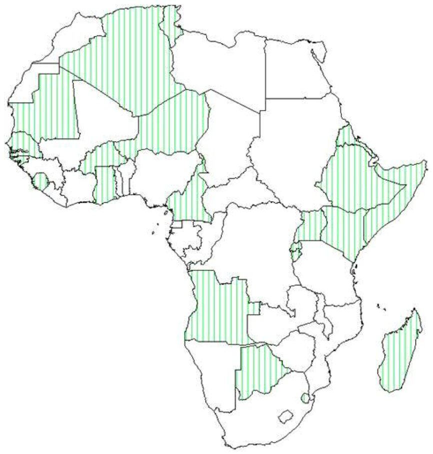
Map 5c
Deforestation

Map 5d
Desertification

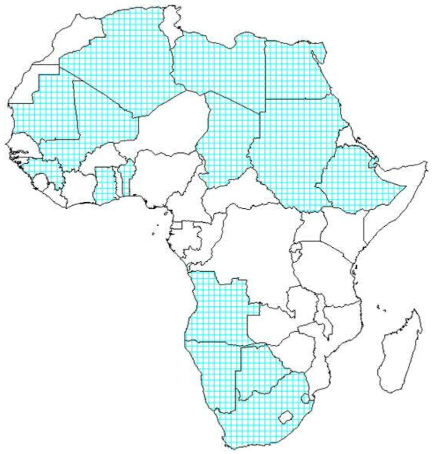
Map 5e
Precipitation



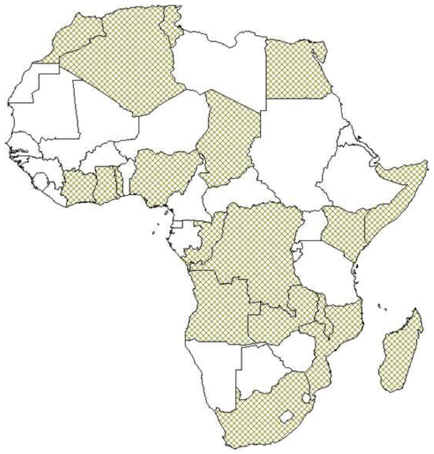
Map 5f
Overgrazing



Map 5g
Water shortage



Map 5h
Water pollution (organic)



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