A HEATH SYSTEM PERSPECTIVE ON MALARIA VECTOR CONTROL INTERVENTIONS IN ETHIOPIA

Mahlet Berhanu Kebede

Ethiopia

Master of Science in Public Health and Health Equity, 09 September 2024 – 29 August 2025

KIT Institute

Vrije Universiteit Amsterdam (VU)

A HEATH SYSTEM PERSPECTIVE ON MALARIA VECTOR CONTROL INTERVENTIONS IN ETHIOPIA

A thesis submitted in partial fulfilment of the requirement for the degree of

Master of Science in Public Health and Health Equity

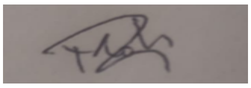
by

Mahlet Berhanu Kebede

Declaration:

Where other people’s work has been used (from either a printed or virtual source, or any other source), this has been carefully acknowledged and referenced in accordance with academic requirements.

The thesis “**A Heath System perspective on malaria vector control interventions in Ethiopia**” is my own work.

Signature: 

Master of Science in Public Health and Health Equity

09 September 2024 – 29 August 2025

KIT Institute/Vrije Universiteit Amsterdam

Amsterdam, The Netherlands

August 2025

Organised by:

KIT Institute

Amsterdam, The Netherlands

In cooperation with:

Vrije Universiteit Amsterdam (VU)

Amsterdam, The Netherlands

Abstract

Introduction: Malaria remains a major public health concern in Ethiopia, with approximately 75% of the country endemic to malaria. Despite the adoption of a national malaria elimination strategy, recent years have seen a resurgence in cases, underscoring the need for a critical review of existing interventions.

Objective: This study aims to assess malaria vector control interventions in Ethiopia from 2020 to 2025 through the lens of the World Health Organization's (WHO) health system building blocks and to draw lessons from selected African countries to inform national policy.

Methodology: A narrative literature review was conducted using structured search strategies across databases including PubMed and Google Scholar. The WHO's health system framework guided the synthesis and analysis of findings.

Results: The review revealed persistent gaps in Ethiopia's malaria vector control implementation, including limited nets and indoor residual spraying coverage, weak surveillance systems, and inadequate support for frontline workers. Centralized planning, limited district-level capacity, donor dependency and weak intersectoral collaboration hinder effective execution, especially for vulnerable groups. Despite political commitment and existing policies, implementation remains uneven and under-resourced. In contrast, countries like Rwanda, Algeria, and Cabo Verde demonstrate how strong domestic ownership, real-time surveillance and multisectoral coordination can accelerate malaria elimination.

conclusion: Ethiopia's vector control efforts require systemic reforms beyond scaling up existing interventions. It is therefore recommended to enhance surveillance and data use, ensure sustainable financing, integrate multisectoral engagement, support front line workers and implement true decentralization of operations.

Key words: Ethiopia, Malaria, Malaria elimination, Health System

Word count: 11,838

Table of Contents

List of Figures

List of Tables

Lists of abbreviations

Artemisinin-based combination therapies: ACTs

Bacillus thuringiensis israelensis: Bti

Community health workers: CHWs

Demographic and Health Survey: DHS

Dichloordifenyltrichloorethaan: DDT

District Health Information System 2: DHIS2

Entomological Surveillance Planning Tool: ESPT

Global Malaria Eradication Programme: GMEP

Global Technical Strategy: GTS

Global Technical Strategy for Malaria: GTSM

Gross domestic product: GDP

Health extension workers: HEWs

Indoor residual spraying: IRS

integrated vector management: IVM

Insecticide treated nets: ITN

Knockdown resistance: kdr

Long-lasting insecticide-treated nets: LLINs

Malaria Eradication Scientific Alliance: MESA

Millennium Development Goals: MDGs

Ministry of Health: MoH

National Malaria Elimination Program: NMEP

President's Malaria Initiative: PMI

Primary health care unit: PHCU

Rapid diagnostic tests: RDTs

United States Agency for International Development: USAID

World Health Organization: WHO

Glossary of Key terms

Malaria elimination: “Interruption of local transmission (reduction to zero incidence of indigenous cases) of a specified malaria parasite in a defined geographical area as a result of deliberate activities.” (1)

Malaria control: “Reduction of disease incidence, prevalence, morbidity or mortality to a locally acceptable level as a result of deliberate efforts.” (1)

Malaria free: “Describes an area in which there is no continuing local mosquito borne malaria transmission and the risk for acquiring malaria is limited to infection from introduced cases.” (1)

Integrated vector management: “Rational decision-making for optimal use of resources for vector control.” (1)

Insecticide treated nets: “Mosquito net that repels, disables or kills mosquitoes that come into contact with the insecticide on the netting material. Insecticide treated nets (ITNs) include those that require treatment and retreatment (often referred to as conventional nets) and those are “long-lasting”” (1)

Long lasting insecticide treated nets: “A factory-treated mosquito net made of material into which insecticide is incorporated or bound around the fibres. The net must retain its effective biological activity for at least 20 WHO standard washes under laboratory conditions and 3 years of recommended use under field conditions.” (1)

Indoor residual spraying: “Operational procedure and strategy for malaria vector control involving spraying interior surfaces of dwellings with a residual insecticide to kill or repel endophilic mosquitoes” (1)

Larval Source Management: “Management of aquatic habitats (water bodies) that are potential habitats for mosquito larvae, in order to prevent completion of development of the immature stages.” (1)

Residual malaria transmission: “Persistence of malaria transmission following the implementation in time and space of a widely effective malaria programme.” (1)

Malaria endemic area: “An area in which there is an ongoing, measurable incidence of malaria infection and mosquito-borne transmission over a succession of years.” (1)

Anthropophilic: “Description of mosquitoes that show a preference for feeding on humans, even when non-human hosts are available” (1)

Endophilc: “Tendency of mosquitoes to rest indoors.” (1)

Exophilic: “Tendency of mosquitoes to rest outdoors.” (1)

Exophagic: “Tendency of mosquitoes to feed outdoors.” (1)

Endophagic: “Tendency of mosquitoes to blood-feed indoors.” (1)

Insecticide treated nets utilization: “percentage of a given population group that slept under an ITN the night before the survey” (2)

Insecticide treated nets ownership: “percentage of households that owned at least one ITN” (2)

Insecticide treated nets access: "percentage of the population with access to an ITN within their household: assuming access is limited to one ITN for every two people. (2)

House wall modification: "the act of painting, plastering or covering the house wall before six months of indoor residual spraying" (3)

Introduction

Infectious disease has always been one of the areas that interested me. It's been part of my education and career background as I am trained as an internist. Malaria is one of the commonest infectious diseases I treated while working in different hospitals in Ethiopia. It shows up everywhere; be it urban or rural. If treated soon enough, the recovery of patients is quick. But I have also seen patients lose their lives because of it. I have seen people who came in too late to salvage.

When I decided to write my thesis on malaria, it was inspired by the recent spike in the incidence of the disease after Ethiopia had been doing quite well controlling malaria for almost 3 years. There are multiple factors contributing to this. Trained as a medical doctor and working in health care for the past 7 years, I know too well about the mishaps in malaria treatment and diagnosis. There are several factors that need to be addressed there. However, I wanted to put on a different pair of optics. Taking part in this Master of Public Health and Health Equity has given me a perspective shift where I believe investing on prevention at the the grass root level is equally important if not more than expanding just on diagnosis and treatment. Malaria vector control is the best option of prevention out there. I wanted to investigate the matter through a health system perspective and really examine the shortcomings.

Doing the literature search, I couldn't help but notice that the vector control has not been examined through the health system perspective widely. Though a cornerstone to the elimination process, there is a disconnect between vector control interventions and the treatment and diagnosis efforts, which are often examined through the health system perspective. This thesis does not merge the two or explore their connection. However, it uses the same lens used to examine one often, on the other to get a better insight and to possibly inform the policy improvement process.

Chapter 1: Background

1.1. General overview

Malaria is a life-threatening disease that is most prevalent in tropical countries. It has a higher risk of severe illness in children under 5 and pregnant women. However, it is preventable, treatable and curable.(4) Recently 2 vaccines have also been approved and recommended by World Health Organisation (WHO).(5,6) Malaria is transmitted through bites of infected female Anopheles mosquitoes. There are 5 parasite species that cause malaria, out of which 2 pose the greatest threat. These are *Plasmodium falciparum* and *Plasmodium vivax*. Plasmodium falciparum is the deadliest one. (4)

Even though the number of deaths from malaria showed some decline in the past decade worldwide, the disease burden has been on an increasing trend. In 2023, globally there were 263 million cases;11 million more cases when compared to 2022.(2) Africa bears the highest burden, accounting for 94% of cases and 95% of malaria-related deaths in 2023.(7) The five countries with the highest burden include Nigeria, the Democratic Republic of the Congo, Uganda, Ethiopia, and Mozambique.(4) In Ethiopia, 75% of the country has land mass that is considered malaria endemic. In 2024 there were 7.3 million cases and 1157 malaria related deaths in the country. (8)

1.2. Country's profile

Ethiopia is a landlocked country in Sub-Saharan Africa with a population of more than 130 million in 2024 and with annual population growth of 2.6%.(9) The poverty headcount ratio (population living on less than 3.20 U.S dollars per day) is 38.6%. The gross domestic product (GDP) per capita is 1272 dollars with annual GDP growth rate of 7.3%. Ethiopia is classified as a low-income country by the World Bank, with more than 75% of the population residing in rural areas. (9)

The country's climate varies significantly with altitude and can be broadly categorized into three zones: a cool zone (near freezing to 16 °C) above 2,600 meters, a temperate zone (16 °C to 30 °C) between 1,500 and 2,500 meters, and a hot zone (27 °C to 50 °C) comprising tropical and arid lowlands. Most of the population live in the temperate zone. The country experiences two rainy seasons (March to May and September to November) and two dry seasons (December to February and June to August), though the timing can vary annually.(10) Malaria transmission predominantly occurs below 2,000 meters, with intensity differing across ecological zones. Lowland areas experience high, year-round endemic transmission, while highland and semi-arid regions have low to hypo endemic seasonal transmission. (11)

In Ethiopia *plasmodium falciparum* accounts for more than 60% of the cases. From the vectors *Anopheles arabiensis* which is a member of *Anopheles gambiae* complex is the primary vector. Secondary vectors include *Anopheles funestus* and *Anopheles pharoensis*. A new vector, *Anopheles stephensi* has also recently emerged in the Eastern part of the country. (11)

Ethiopia's health system is structured into three tiers. The primary level consists of health posts, health centres, and primary hospitals, which focus on both preventive and curative services. The secondary level includes general hospitals providing comprehensive outpatient and inpatient care. The tertiary level comprises specialized hospitals that serve as referral centres and provide advanced medical services. (12) Malaria services are provided at all levels of the health system but most preventive services and vector control intervention operations are run by the health workforce at the primary level within the health extension programme (HEP).(13) The HEP is integrated to the primary tier of the Ethiopian health system, organized under the Primary Health Care Unit (PHCU). A PHCU typically consists of a primary hospital and a health centre for urban populations, and a health post for rural areas. Each health post or centre is staffed with two health Extension Workers (HEWs) who serve approximately 3,000 to 5,000 individuals. These HEWs are government employees trained to deliver a broad range of services, including family health, disease prevention and control, hygiene and sanitation, injury prevention, and referrals. They operate in close collaboration with unpaid Community Health Workers (CHWs), also known as health development army volunteers.(14)

Health financing has been one of the focuses of Ethiopia's health sector transformation strategy plan. With the aim of achieving universal health coverage, community-based health insurance (CBHI) was implemented.(15) According to the WHO report in 2021, Ethiopia's current health expenditure accounted for 3.21% of its GDP, with domestic general government health expenditure representing 5.68% of total government spending and 0.72% of GDP. (16) Despite the efforts, low health budget allocation, inefficiencies, absence of social health insurance and low coverage of CBHI remain financial challenges. (15) Notably, malaria prevention and treatment services have been provided free of charge since 2011.(17)

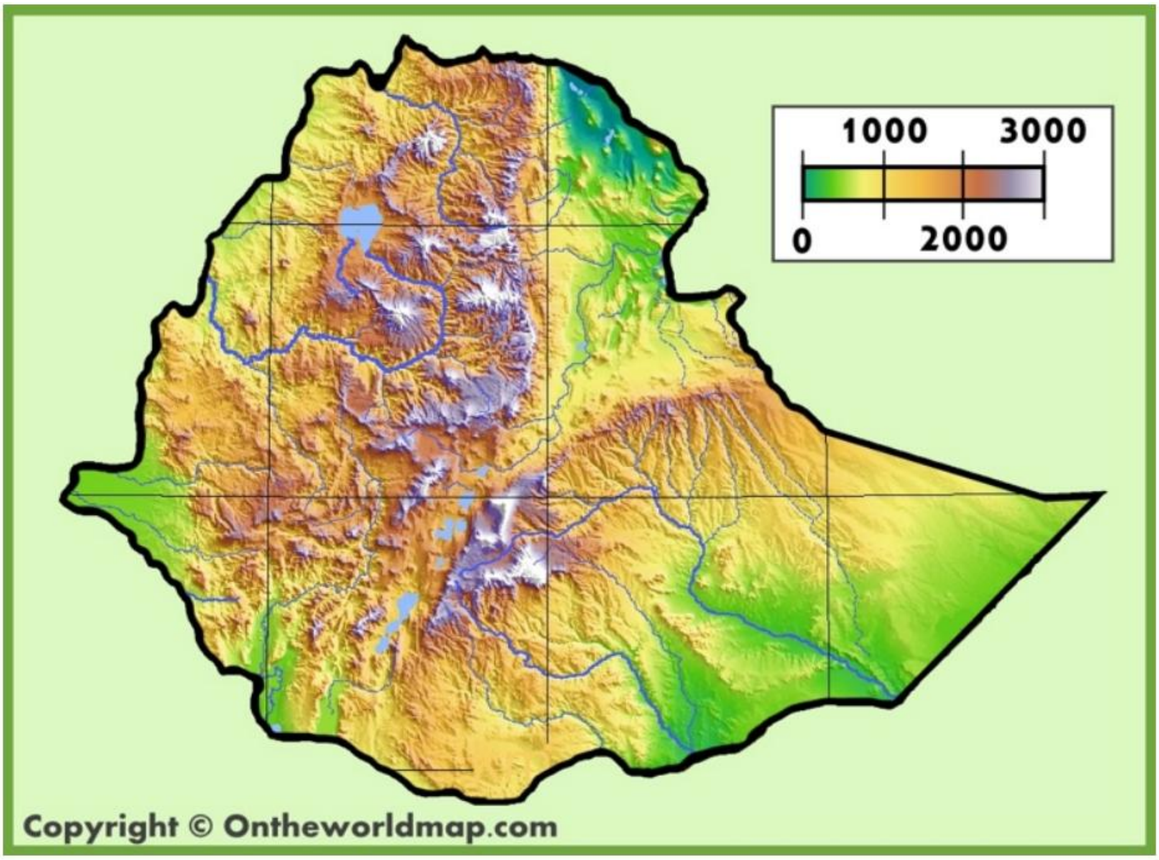


Figure 1: Ethiopia's physical map, 2025 (18)

1.3. Global efforts toward malaria control and elimination

Over the past few decades, the fight against malaria has evolved from fragmented, country-level control measures to a globally coordinated, multi-pronged campaign involving extensive investments. Since 1950 WHO has been organizing these efforts. The Global Malaria Eradication Programme (GMEP) was established in 1955. This program, which emphasized vector control through dichlorodiphenyltrichloroethane (DDT) spraying and long-lasting insecticides, struggled in regions with high, sustained transmission and was ultimately terminated in 1969 due to financial and operational challenges. Following a period of setbacks between 1970 and 1999, exacerbated by economic crises and emerging public health priorities like HIV/AIDS, the global fight was revitalized through the Roll Back Malaria (RBM) partnership in 1998 and the Millennium Development Goals (MDGs). By 2015, these efforts contributed to a 60% decrease in malaria mortality and a 37% reduction in incidence globally, although key targets, such as reducing preventable deaths to zero, were not fully met. Ethiopia, notably, achieved a 50–75% reduction in cases during this period. (5)

Despite these gains, challenges persist. The emergence and spread of artemisinin-resistant *Plasmodium falciparum*, widespread insecticide resistance undermining bed nets and indoor spraying, and the rapid expansion of *Anopheles stephensi* have all threatened progress. Further compounded by the diversion of resources during the COVID-19 pandemic, these issues jeopardize the Global Technical Strategy for Malaria (GTSM) 2013–2030 goals. Nonetheless, there have been promising advances, such as the development of malaria vaccines now recommended by WHO for high-burden areas, providing new hope for control and eventual elimination.(5,6) The GTSM strategy has emphasized on moving towards elimination of the disease irrespective of where countries are. It supports countries with tailored frameworks to accelerate the progress with the goal of having at least 35 counties eliminating malaria by 2030. (19)

1.4. Ethiopia's efforts towards eliminating malaria

Ethiopia has been actively engaged in global malaria elimination efforts. The country's first elimination plan was launched in 1966 with the aim of eliminating malaria by 1980, primarily through vector control and mass drug administration. However, this initiative was unsuccessful due to vector resistance to insecticides used in indoor residual spraying (IRS) and difficulties sustaining interventions in target areas. In response, a vertical national malaria control organization was established in 1976. (20) In 1993 the vertical malaria programme was integrated to the basic health services to ensure the realisation of malaria control strategy and followed by deployment of health extension workers at a large scale after a decade.(11)

Between 2003 and 2015, Ethiopia achieved significant reductions in malaria incidence and mortality, with especially notable declines from 2014 to 2016. These improvements were attributed to key policy and programmatic changes involving diagnosis, treatment and prevention of the disease. These include the introduction of artemisinin-based combination therapies (ACTs), the implementation of rapid diagnostic tests (RDT) at the health posts and microscopic examination of blood smears at health centre and hospitals, the implementation of test based treatment with anti-malaria, the introduction of long lasting insecticide-treated nets (LLINs) and the scale up with wide distribution free of charge, the replacement of DDT with pyrethroids for IRS and the use of larvicides for source reduction (17)

From 2016 to 2019, the success continued. In 2019 there were only 15,307 admissions due to malaria which is almost a 50 % drop from the previous year. Death was also reduced by 58%. However, beginning in 2020, malaria cases began to rise again. The COVID-19 pandemic and internal conflict contributed to the disruption of the previously established system. (20) The conflict has been taking place since November 2020 in different degrees, mostly in the Northern part of the country. It also contributed to further escalation of existing ethnic tensions in other parts of the country. (21) Due to this health care services have been disrupted in some part of the country contributing to the surge of malaria.(22) Despite these setbacks, Ethiopia has continued to pursue its goal of eliminating indigenous malaria cases by 2030.

Prior to 2017, the country had focused on malaria control. However, Ethiopia transitioned to elimination phase driven by the success in decreasing malaria incidence in prior years. Initiated formally with the 2017 Malaria Elimination Roadmap, the strategy involved targeted interventions in low-transmission districts, strengthened surveillance systems including case-based reporting, and stratification of malaria risk at the district level. (23)

In 2021 Ethiopia has issued a malaria elimination strategic plan that was to be executed between 2021 and 2025 with the goal of eliminating indigenous cases of malaria from the country by 2030. (11) The plan was built on the national malaria strategic plan that spanned from 2017 to 2020. It identified challenges during the implementation of the earlier plan. The recurring themes were gaps in diagnosis and treatment, vector control (using LLINs, IRS, and larval source management) and the surveillance system.(11)

The elimination strategic plan (2021-2025) was launched with the goal set to reduce malaria by 50 % from 2020 baseline and achieve zero indigenous malaria cases in low transmission areas (annual parasite incidence (API) of less than 10). In line with the previously identified gaps, interventions were devised that are in alignment with the Global Technical Strategy (GTS).(11) All the strategies are uprooted in addressing human rights and gender equity and strengthening collaboration with stakeholders. The plan recognises migrant labourers, internally displaced people and refuges as high risk population for malaria in addition to pregnant women and under 5 children. (11) The past 5 years have been selected as the study period of for this study to examine the vector control interventions within this elimination strategic plan.

Ethiopia’s selection of LLINs, IRS, and larval source management (LSM) as its primary malaria vector control interventions is guided by the country’s diverse ecological, epidemiological, and transmission contexts.(24) As the globally preferred intervention to halt transmission and as a corner stone for malaria control, vector control strategies have been implemented throughout the country.(25) One of the strategic plan is to have 100 % of the population at risk of malaria to be covered by at least one globally recommended malaria vector control intervention. (11) However, recent reports show the trend to be otherwise. (2)

Chapter 2: Problem statement, Justification, objectives and Methodology

2.1. Problem statement

Ethiopia made significant strides in malaria control between 2016 and 2019, achieving more than a 50% reduction in malaria-related deaths. However, starting in 2020/2021, malaria cases began to surge again, with 4.7 million cases reported nationwide in 2024. The western regions have been particularly affected. (8,26)

A 2023 systematic review assessing Ethiopia's progress toward malaria elimination by 2030 identified major challenges such as vector insecticide resistance and the spread of *Anopheles stephensi*.(20) Additionally, climate change has expanded suitable transmission zones by altering temperature and rainfall patterns.(27)

Vector control interventions, primarily insecticide treated nets (ITN) and IRS, have been central to Ethiopia's malaria elimination strategy. They are directed towards eliminating the most common types of malaria vectors that are assumed to be endophilic.(28) However, *Anopheles arabiensis*, which is the most common type of malaria vector was found to have a change in the biting pattern. It was also found to be resistant to pyrethroid insecticides in several areas. (11)

The recent spread of *Anopheles stephensi* adds a critical new dimension to these challenges. Unlike traditional rural vectors, it thrives in urban and peri-urban settings causing intense and localized outbreaks. (29) It also has the tendency to breed in man-made water containers, making it more difficult to control using conventional strategies. Its resistance to multiple insecticide classes further complicates control efforts and threatens to undermine progress toward malaria elimination.(30)

Insecticide resistance remains a major barrier to elimination efforts. Ethiopia first introduced DDT for IRS in 1959 and ITNs in 1995, with large-scale deployment since 2005. Following the detection of DDT resistance, multiple insecticide classes (pyrethroids, carbamates, organophosphates, and organochlorines) have been used, resulting in heterogeneous resistance patterns nationwide. (31) Piperonyl butoxide (PBO) has been introduced as a synergist in recent years to enhance efficacy. Pyrethroid-treated LLINs have been used extensively, with approximately 80 million units distributed between 2008 and 2019. While Ethiopia's strategy involves tactical insecticide rotation, cross-resistance remains a significant concern. (31)

These complex and evolving challenges underlines the urgent need to strengthen and adapt vector control strategies in Ethiopia to address both existing and emerging threats. Without innovative, targeted, and context-specific interventions, Ethiopia's goal of malaria elimination by 2030 remains at serious risk.

Examining malaria vector control interventions within the broader context of the health system is essential for identifying and addressing systemic challenges that may hinder their effectiveness. Although Ethiopia has documented the implementation of vector control strategies and community engagement efforts, there remains limited published evidence that examines these interventions through a complete health systems lens. Existing studies tend to focus narrowly on specific components, such as the role of health extension workers and service delivery mechanisms. As such, drawing on insights from a system effectiveness framework can help bridge this gap and provide valuable guidance on how Ethiopia might better integrate and strengthen vector control within its overall health system.

2.2. Justification

Although all three main pillars of malaria control strategies where Ethiopia has reported to have gaps in (diagnosis, treatment, and prevention of malaria) require attention, this study focuses on the three vector control interventions (LLINs, IRS and LSM) in Ethiopia. This choice is justified as vector control is the most suitable measure to stop transmission of malaria.(25) It is one of the primary drivers and cost-effective interventions in preventing malaria outbreaks. Indeed, a study reporting on the effect of such interventions in Africa between 2000 and 2015 showed 68% of cases were averted due to ITN use.(32)

Strengthening vector control interventions is crucial to curb recent malaria surges in Ethiopia. Additionally, vector control strategies must be tailored to diverse contexts within Ethiopia. The country has both high and lowlands that are endemic to malaria. Specific settings such as involvement of migrant workers, internally and externally displaced communities as well as growing irrigation sites need tailored vector control interventions. (33)

This study aims to examine the main vector control interventions implemented in Ethiopia (long lasting insecticide treated nets, indoor residual spraying and larval source management) over the past five years through a literature review from a health system perspective. Furthermore, by reviewing vector control practices from another African countries who are on track to eliminate or has already eliminated malaria, this study intends to generate evidence-based recommendations to inform national malaria control policy and guide future interventions. By compiling and synthesizing existing evidence, this review aims to help clarify current gaps and challenges in vector control efforts in Ethiopia from a health system perspective and provide insights that can support ongoing policy and program improvements.

This study adopts a health systems perspective to evaluate malaria vector control interventions from the provider's standpoint, with the aim of identifying opportunities for improved implementation. While it is well understood that the health system is shaped by multiple actors and contextual factors beyond the provider alone, much of the existing literature tends to focus on individual-level barriers to success. Although such analyses are valuable, this study extends the scope by emphasizing broader systemic factors that influence implementation.

2.3. Objectives

The main objective of this thesis is to examine malaria vector control interventions for the past 5 years (2020-2025) in Ethiopia from the health system perspective and identify lessons learned from selected African countries to provide recommendation to Ministry of Health (MoH) of Ethiopia and other key stakeholders.

The specific objectives are

1. To examine the implementation of malaria vector control interventions (LLINs, IRS, LSM) in Ethiopia from a health system perspective

2. To identify lessons that can be learned from selected African countries in malaria vector control interventions to inform the implementation of Ethiopia's vector control strategies.
3. To propose actionable recommendations to support MoH of Ethiopia and other key stakeholders in strengthening malaria vector control interventions

2.4. Methodology

2.4.1. Study design

This study employs a literature review design to examine vector control interventions implemented in Ethiopia over the past five years. It is based on evidence from peer-reviewed articles, grey literatures, official reports, national guidelines, and other relevant policy documents. Additionally, the review includes an analysis of vector control experiences from other African countries to generate evidence-based recommendations. The period from 2020 to 2025 was selected to align with Ethiopia's national malaria elimination strategic plan, which outlines key targets and activities aimed at achieving zero indigenous malaria cases by 2030. Although not a formal systematic review, a systematic approach was applied to ensure comprehensive and transparent evidence identification, selection, and synthesis. No new data involving human subjects were collected; therefore, ethical clearance was not required.

2.4.2. Search strategy

To address both objectives, literature searches were conducted using PubMed and Google Scholar. As the databases require different search strategies, a Boolean search method was used for PubMed and advanced search operators were applied for Google Scholar. To ensure accuracy and comprehensiveness, key terms were developed using PubMed's advanced Medical Subject Headings (MeSH) search tool.

In addition, official policy documents and guidelines from the WHO, the MoH of Ethiopia, and the Ethiopian Public Health Institute (EPHI) were reviewed to provide context on national vector control policies and strategic plans for objective 1.

For objective 2, to select countries for identifying malaria elimination/pre-elimination success stories, the WHO World Malaria Reports of 2023 and 2024 were reviewed. Based on these reports, countries showing notable reductions in malaria burden were considered. After further assessment of contextual factors such as geographical characteristics, climate, policy approaches, and economic alignment, Rwanda was selected for further exploration, despite its smaller size and population compared to Ethiopia. Rwanda's significant reduction in malaria cases, attributed in part to strengthened vector control strategies, provided a relevant case for comparison. Additionally, Cabo Verde and Algeria, the two African countries that were certified to be malaria free in the past decade are included. National strategic plans, program reports, and guidelines were reviewed from available sites including official government sites of the countries.

Websites of WHO and World bank were used to retrieve policy documents, articles, fact sheets and reports for both objectives. The search strings are summarised in table 1.

2.4.3. Inclusion and exclusion criteria

Separate inclusion and exclusion criteria were developed for each objective to reflect differences in focus and evidence sources. Table 2 summarises inclusion and exclusion criteria for both objectives.

Table 1: summary of search strategy

	Key issue		interventions		factors		Geography
		AND		AND		AND	
OR	Malaria		Vector control		Health system		Ethiopia
			Vector intervention		Service delivery		
	anopheles		Long lasting insecticide nets/ LLINs		Service provision		[compare] Rwanda
	Malaria elimination		Indoor residual spray / IRS		Service assessment		[compare] Algeria
	Malaria control		Larval source management/LSM		Health workforce		[compare] Cabo Verde
			larvicidal		Health extension workers/ community health workers		
			insecticides		Health facilities		
			Insecticide treated nets /ITN		Health information system		
					Surveillance		
					Medical supplies		
					Supply chain		
					procurement		
					distribution		
					Financing/funding/ grants/ donors		
					Governance		
					Policy/plan/ strategy		
					equity		
					Vulnerable population		

Table 2: inclusion and Exclusion criteria for literatures

Objective	Criteria type	Criteria
Objective 1	Inclusion	• Peer-reviewed articles published between 2020 and 2025 in English • Relevant literatures/guidelines/ policy briefs identified through snowballing from peer-reviewed articles • Grey literature on malaria elimination progress • Policy briefs, national strategies, and guidelines focused on malaria and Ethiopia
Objective 1	Exclusion	• General overviews on pathogenesis, clinical features, and treatment • Publications on general infectious disease topics (not specific to malaria) • Publications with inaccessible full text • Studies purely on advanced vector genetics without policy relevance • Articles focused on the parasite or clinical aspects of the disease • Trial registrations without results • publications in languages other than in English
Objective 2	Inclusion	• Publications describing effective or innovative malaria vector control practices in Rwanda, Cabo Verde and Algeria • Relevant literatures identified through snowballing from peer-reviewed articles • Articles on lessons learned toward elimination • Policy briefs, strategic plans, and guidelines on vector control
Objective 2	Exclusion	• Articles assessing only individual-level factors without relevance to national vector control strategies • publications in languages other than in English

2.4.4. Analytical framework

In this study, the **WHO health systems framework** (34) was selected as a guiding structure to organize and synthesize the evidence identified through the literature review.

This framework with six building blocks was launched in 2000 by WHO to promote common understanding of what a health system is made of and how to strengthen it. The health system building blocks outline the key capacities a system must have.(34) Service delivery, health workforce, information, medical products, financing and leadership and governance are the six building blocks. While the building blocks clarify essential functions, in practice, countries often face challenges that do not appear in neatly separated categories.(34) The framework is presented to be simplistic without the consideration of one building block closely affecting the other. In addition is criticized for not centring patients and the community.(35) These are clear limiting factors. Recognizing the WHO health system framework's limited focus on people-centred dimensions, this study mitigates that limitation by explicitly linking individual and social determinants with system-level factors, thereby allowing for a more holistic and context-sensitive analysis of implementation. A study on critical analysis of the framework suggests a similar approach for a better outcome. (35)

The WHO health system framework was used as an analytical guide to systematically classify and present the evidence identified in this review. Rather than serving as an evaluation tool to formally assess health system capacities, it provided a structured lens to organize findings across different system components relevant to malaria vector control. This approach allowed for a more comprehensive and coherent presentation of the diverse evidence, while avoiding restrictive judgments on the performance of each health system building block. After identifying and reviewing articles, the evidence was grouped under building blocks that match closely with the key issues discussed within the publications. The key issues that are included under each block of the framework are summarized in table 3.

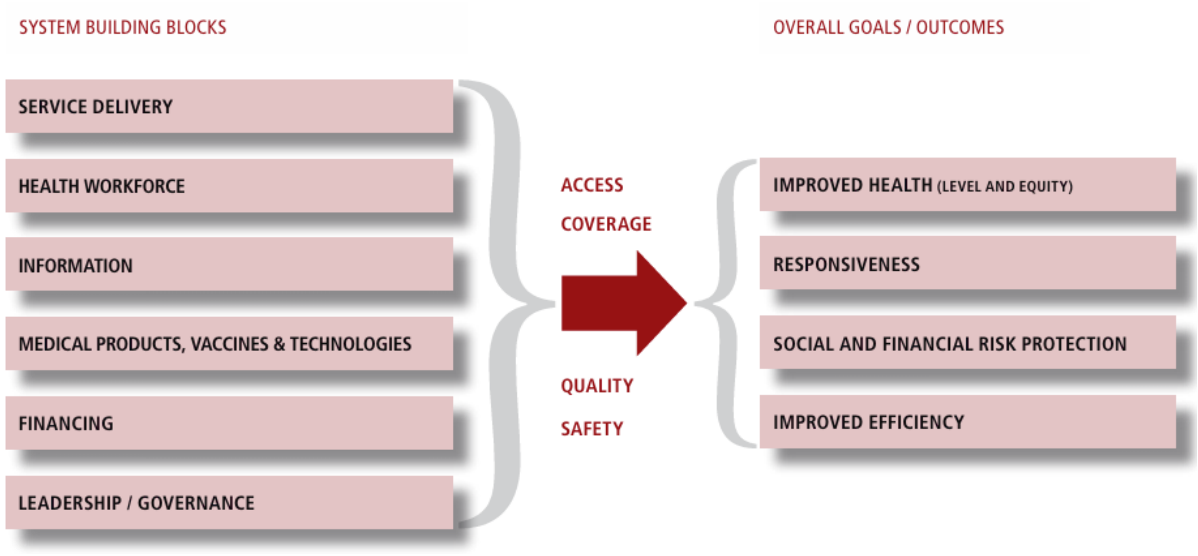


Figure 2: The WHO Health System Framework, 2007 (34)

2.1.1. Evidence extraction and analysis

A total of 638 records were initially identified through the search strategy conducted up to May 15th, 2025. After the removal of duplicates, titles and abstracts were screened based on predefined inclusion and exclusion criteria (outlined in Table 2). Subsequently, 91 articles were selected for full-text review. Additional sources were identified through snowball sampling from the reference lists of eligible studies. Grey literatures and policy documents found through snowballing are not restricted to only the ones published in the past 5 years. In total, 102 articles were included in the final synthesis. The extracted evidence was organized and analysed using the WHO health systems framework, with certain studies classified under multiple building blocks based on the breadth of issues they addressed.

A standardized data extraction template (developed in Excel) was used to systematically collect information on study objectives, methods, key findings, and relevance to malaria vector control strategies. Evidence was then mapped and synthesized under the six building blocks of the WHO health systems framework. It was then presented under each block. It is reported divided across the three vector interventions for service delivery and medical supplies blocks and organised into one narrative for the rest of the blocks.

Table 3: key issues included under the building blocks of the WHO framework

Framework (Building block) definitions(34)	**Key issues included**
Health service delivery: "safe, effective, and quality health services to those in need, at the right time and place." (34)	Coverage and utilization of vector control interventions
Health workforce: "sufficient, competent, fairly distributed, and responsive workforce to achieve health goals." (34)	Workforce capacity, availability, training, and distribution related to delivering vector control interventions.
Health information systems: "reliable, timely data on health determinants, system performance, and population health." (34)	surveillance systems in place and their use, data quality
Medical products & technologies: "equitable access to safe, effective, and affordable medical products, vaccines, and technologies." (34)	Availability, distribution, and quality of insecticides and other vector control tools; supply chain of the products
Health financing: "funds to provide needed services while protecting people from financial hardship." (34)	Costs of interventions, analyses of cost-effectiveness, resource allocation, affordability and funding sustainability.
Leadership & governance: "policies, oversight, regulation, collaboration and accountability to guide and strengthen the health system." (34)	Policy formulation, regulatory frameworks, coordination mechanisms across sectors, strategic planning, and equity considerations integrated into governance structures.

Chapter 3: Results

3.1. Ethiopia's vector control interventions through optics of health system

3.1.1. Service delivery

Long lasting insecticide nets

LLINs are distributed to achieve universal coverage in malaria-endemic regions, with comprehensive provision across low to high transmission zones, and partial coverage in very low transmission areas. Distribution primarily occurs through free mass campaigns every 2–3 years, supplemented by limited commercial distribution in urban settings. HEWs and CHWs are responsible for dissemination and community education to ensure proper use. The number of nets distributed per number of household member is depicted in table 4. (25)

Table 4: guide to determine the number of nets per household based on family size (25)

Family size	Number of LLINs to be supplied
1 to 2	1
3 to 4	2
5to 6	3
More than or equal to 7	4

As per the 2025 Malaria Elimination Strategic Plan, Ethiopia aimed for LLINs ownership of 85–100%, access of 65–100%, and utilization rates of 70–80% for 2022–2025. (11) Recent studies in Southwest Ethiopia (2024–2025) reported ownership at 89%. (36,37) . However, a longitudinal survey in the South showed a decline in ownership from 85% to 69% within 12 months of distribution. (38,39) Utilization rates remain inconsistent. A meta-analysis reported use ranging from 14% to 92% nationally, with subnational rates of 20.4% in the Southwest, 46.6% in West Shoa, and 69% in the Northwest and Western regions. These studies define ownership as having at least one LLINs within the household. (36,40–43) In the North, only 68% of users correctly hung their nets.(42) In contrast to mostly high LLIN ownership reports, WHO reports the population with access to LLINs to be only 28.5%. (44)

Low ownership and utilization are linked to factors such as limited malaria knowledge, low level of education, larger household size, poor housing infrastructure, and unsuitable space for net hanging.(36,38,41,42) Physical degradation of nets, including tearing and long-term use, further contribute to low usage.(45) A study in three pastoralist communities reported malaria prevention practices including net utilization at about 30%, with a strong correlation between knowledge and preventive behaviour. (46)

Qualitative research from Northwest Ethiopia noted insufficient ITN allocation per household, and barriers among pastoralist communities, including sleeping outdoors, which hinders net use.(47) Rural residence, traditional housing (huts), and preferences for specific net shapes also impacted usage.(36)(47) Repurposing the nets for other functions such as covering grains or carrying bags is also a common practice. (48)

Among pregnant women, net use remains suboptimal. In Northwestern Ethiopia, only 60% reported sleeping under a net, and only 58% hung them properly.(49) Two meta-analyses and additional studies showed usage between 47–60%.(50–53) Key determinants include absence of ANC follow-up, limited access, lower income and education, lack of awareness, net discomfort, and shape preferences.(49–52,54–56)

Similarly, LLIN use is low under 5 children. It is reported to be around 58.2%. (57) Among school-aged children, net ownership was 19.3% and access only 10.3%. Children in semi-urban areas were more likely to have access. (58) Among additional factors negatively affecting in reaching universal coverage of LLINs is the overlapping of campaigns with harvesting time. (59)

The internal conflict and displacement have further disrupted service delivery as well. (60) In 2023, out of the 222 high burden districts, 50 of them were only partially accessed for net distribution due to ongoing conflicts in the areas. (8) Notably, 30% of migrant workers lacked access to medical services and had low access and utilization of nets. Additional contributing barriers included overcrowding, unsuitable housing for ITN use, and limited access to LLINs and IRS due to logistical constraints. In Northern Ethiopia, malaria prevalence was 12% among migrant workers compared to 0.5% in locals. (61)

Indoor Residual spraying

IRS is implemented in three-year cycles, guided by malaria risk stratification in Ethiopia. It targets sleeping areas, with planning based on household data and structure types. Insecticide selection adheres to WHO guidelines, and community leaders are engaged to increase uptake.(25)

The strategic goal was to spray 94–98% of unit structures in targeted areas between 2023 and 2025.(11) Nonetheless, WHO reports indicate a reduction in coverage, from over 16 million individuals protected in 2015 to just 3.3 million in 2023, due to shrinking targeted zones.(44) In response, the U.S. President's Malaria Initiative (PMI) restructured 70% of IRS operations from district to community-based models and extended coverage to 10 refugee camps in Western Ethiopia. (62)

Community acceptance remains limited. A study in a malaria-endemic region found IRS acceptance at 56.7%. (63) In Southern Ethiopia, wall modifications post-spraying occurred in 30% of households, with 10% citing dislike of the insecticide's smell as the reason; most modifications were cosmetic. While 78% of the community received information about the operation from health extension workers, 55.7% lacked understanding of IRS's residual effects.(3) Another study reported a 41% modification rate. (64) Contributing factors included lack of pre-spray communication, poor supervision, and low IRS knowledge.(3,64)

Larval source management

LSM targets mosquito breeding habitats, disrupting larval development. It is considered a supplementary intervention, most effective in arid zones where breeding sites are few, fixed, and findable, per WHO guidelines. Community-led environmental management activities (e.g., canal draining, pit filling, planting of water-absorbing trees) are coordinated by health extension workers. Where environmental control is inadequate, larvicides are selectively applied due to high costs and the need for repeated dosing. Of the 5 types of larvicidal that are available worldwide (oils/surface agents, synthetic organic chemicals, bacterial larvicides, spinosyn, insect growth regulator) Ethiopia is using synthetic chemical (Temephos/Abate). It is an agent safe to use in drinking water but expensive because of the need for repeated application. Therefore, it is used only in limited breeding sites. (25)

3.1.2. Medical supplies

Long lasting insecticide nets

LLINs are procured with financial support from donors including the Global Fund and the U.S. PMI. (59) As depicted below in figure 2 LLINs are distributed throughout the country from Pharmaceuticals Fund and Supply Agency (PFSA). The process begins with bottom-up microplanning at the district (woreda) level, informing national procurement and distribution planning by the Federal Ministry of Health's National Malaria Control Program. LLINs are imported and received by the PFSA central warehouse, then distributed to regional hubs and subsequently to district (woreda) health offices. From there, nets are dispatched to health centres and health posts, where HEWs oversee final distribution to households. Information flows include performance reporting, forecasting, and procurement documentation, involving stakeholders across federal, regional, and community levels. The system emphasizes decentralized planning, structured logistics, and community-level execution to enhance coverage and accountability in vector control. (65)

Despite this structured system, stockouts and delays in LLIN distribution are frequently reported. (59,66) Health facilities such as health centres and health posts are designated to store and distribute LLINs for routine services and as replacements between campaigns. (65) According to the DHS Service Provision Assessment, just 19% of health facilities had ITNs available on the day of survey, and only 25% of antenatal care sites provided nets to pregnant women.(67) Supply challenges have been attributed to poor storage infrastructure in some facilities, logistical barriers to remote areas, and uneven distribution, with some sites receiving excess stock due to reporting and allocation issues. (59)

Two main LLIN types are distributed through national campaigns: pyrethroid-only nets, pyrethroid plus piperonyl butoxide (PBO) both primarily procured by the Global Fund. (68) The distributed LLINs have a life span of 3 years maintaining its biological activity without retreatment and national mass distribution campaigns follow this replacement cycle (11,69)

However, recent evidence raises concerns over net durability. One study found that only 13% of LLINs remained functional after three years, with decreased lifespan associated with rural settings, low transmission areas, and nets hung in kitchens, where exposure to smoke and heat likely accelerates degradation. (70,71)

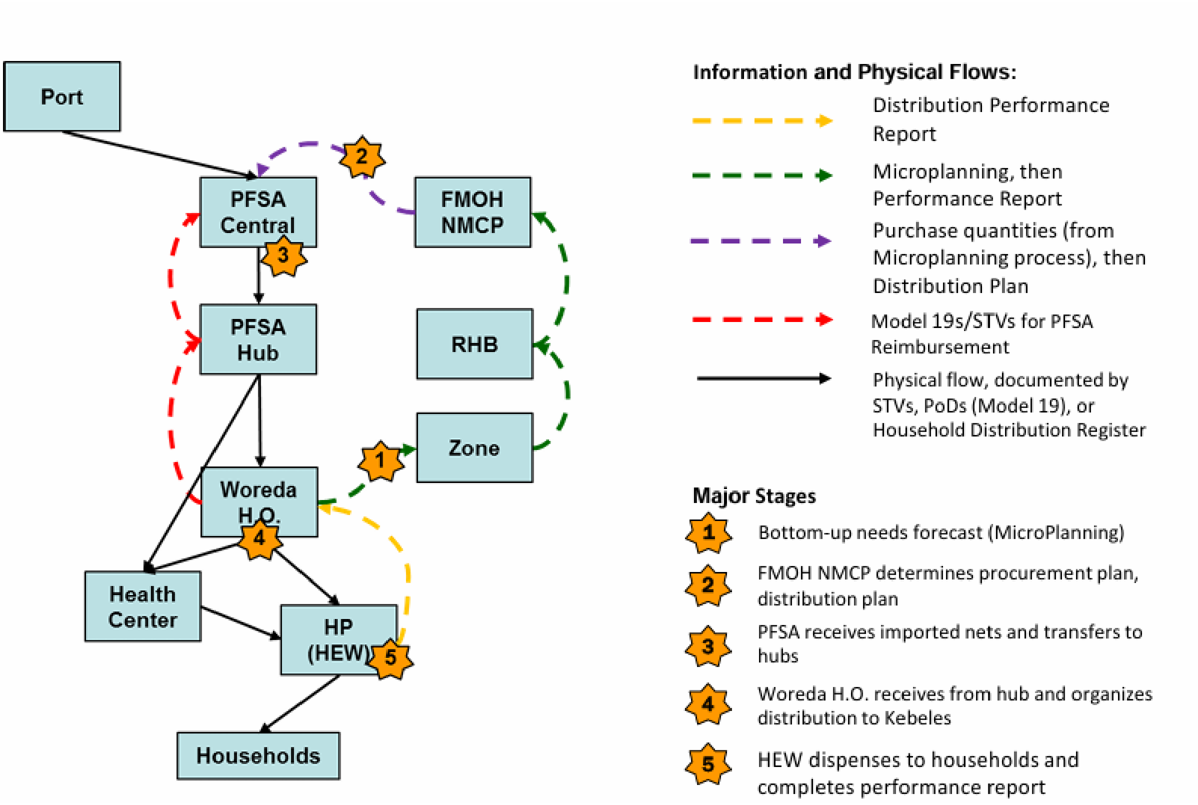


Figure 3: LLIN campaign system, 2007 (65)

Insecticide resistance is an emerging challenge. Pyrethroid resistance has been documented in several regions of Ethiopia, including the southwestern, the western and the northern (sugarcane irrigation) areas.(31,72–74)

Indoor residual spraying

Targeted, campaign-based IRS is a core component of Ethiopia's malaria elimination strategy.(11) While detailed descriptions of the IRS supply chain are lacking in the literature, the use of various insecticides has been well-documented.

Actellic 300CS, an organophosphate, remains the most commonly used compound; however, growing resistance has prompted investigation into alternative formulations. VECTRON T500, a meta-diamide recently endorsed by WHO, demonstrated longer residual efficacy across multiple wall types compared to Actellic 300CS. (75) A neonicotinoid compound maintained over 80% mosquito mortality for nine months post-application and outperformed Actellic in field trials. (76) A combined formulation of neonicotinoid and pyrethroid sustained >80% efficacy for 12 months on painted and dung walls, and for nine months on mud surfaces, making it the most effective IRS option.(77)

Evidence suggests that combining IRS with ITNs provides synergistic effects. PBO nets resulted in higher mosquito mortality compared to pyrethroid-only nets. (78) In areas with documented pyrethroid resistance, combining standard ITNs with non-pyrethroid IRS significantly reduced malaria incidence; however, this protective benefit waned in the second year for PBO nets. (79) These additive effects were also noted in low-transmission settings.(80)

Resistance in *Anopheles stephensi*, an invasive vector species, presents a further complication. Populations in eastern Ethiopia exhibited resistance to pyrethroids, carbamates, and organophosphates. While susceptibility to pyrethroids increased with PBO exposure, resistance was not linked to common knockdown resistance (kdr) mutations. Instead, metabolic resistance mechanisms such as elevated expression of esterase E4 and venom carboxylesterase-6 appear to be responsible. (81–83)

Larval source management

Despite encouraging results, larval source management (LSM) remains underutilized in Ethiopia, in part due to the high financial and operational costs associated with its implementation. In southwest Ethiopia, natural invertebrate predators—especially backswimmers (Notonectidae)—proved effective in consuming mosquito larvae. (84) The biological larvicide spinosad achieved 100% mortality of *An. stephensi* larvae within 24–48 hours. (85)

Among larvicidal products, SumiLarv 2MR demonstrated the longest-lasting efficacy under semi-field conditions, maintaining activity for up to 35 weeks. In comparison, SumiLarv 0.5G and Abate 1SG were effective for only 7–8 weeks. Integrated approaches have also shown promise: combining Bacillus thuringiensis israelensis (Bti) with LLINs and community mobilization significantly reduced malaria incidence in low-transmission areas. (86) Additionally, novel odour-based vector control strategies such as synthetic cattle urine mass trapping piloted in southern Ethiopia, demonstrated reductions in both mosquito density and malaria cases.(87)

.

3.1.3. Health workforce

Building the capacity of health workers is a central priority in Ethiopia's national malaria elimination plan. (11) Community-based malaria prevention and control services are strongly emphasized, with a heavy reliance on HEWs. These services are part of the broader HEP, which was launched in 2003 and has since demonstrated positive outcomes, including increased utilization of LLINs, improved malaria-related knowledge, and enhanced community satisfaction. (13,14)

The national vector control strategy relies primarily on mass distribution campaigns of LLINs. HEWs and CHWs are the key agents responsible for delivering nets at the community level. Nets are procured using funds from development partners and distributed to households based on family size in malaria-endemic areas. (88,89)

IRS was traditionally delivered through a district-based model, in which district health offices managed planning and implementation, with technical and logistical support from development partners. (90) Each spray team typically included a team leader, four squad leaders, porters, and 16–20 spray operators. These teams were deployed to operation sites for about 30 to 35 days, during which they conducted daily spraying in nearby villages. (90)

In recent years, a transition toward a community-based IRS model has occurred to increase efficiency and promote local ownership. (90) Under this approach, IRS is conducted over 1–2 months, led by trained HEWs. Only one of the two assigned HEWs participates in IRS activities to prevent disruption of routine care.(90) The HEWs supervise spray operators who are selected and trained from the local community, in consultation with community leaders. They are responsible for mobilizing the community, managing insecticide stocks, and overseeing data collection. (90) Areas that adopted the community-based approach reported a 2–3% increase in population coverage without compromising operational quality. However, initial compliance with standard procedures was lower compared to district-based IRS, though this improved in subsequent years. (90)

Environmental management activities under LSM, such as puddle drainage and landscaping, are coordinated by HEWs. These interventions aim to reduce mosquito breeding sites and are considered supplementary to other vector control methods.(25)

Despite their pivotal role, HEWs face numerous challenges. These include dissatisfaction with remuneration and incentives, limited recognition from supervisors and communities, insufficient training and support, and restricted opportunities for career advancement.(14)

Although HEWs form the core of the vector control workforce at the primary care level, limited data exist on the involvement of higher-level health professionals in vector control. Nonetheless, other cadres such as entomology technicians, environmental health officers, public health officers, and researchers play key roles in planning, training, and providing technical support to HEWs. (91)

3.1.4. Health information

Effective implementation of vector control interventions depends on accurate entomological and epidemiological data to determine the appropriate timing, location, and method of application. (11) In Ethiopia, *Anopheles arabiensis*, a member of the *Anopheles gambiae* complex, remains the primary malaria vector across most regions.(92) However, recent studies have revealed regional variations in vector composition, with secondary vectors such as *Anopheles demeilloni,* and *Anopheles pharoensis* becoming predominant in certain areas.(93,94) Vector behaviour including larval habitat preferences, biting patterns, and host selection also varies by context.(95) Agricultural expansion, particularly through irrigation schemes and dam construction, has led to increased vector density in irrigated areas, even during the dry season.(96–98) Moreover, *Anopheles arabiensis* has demonstrated behavioural shifts, including mixed feeding on both humans and animals, and a tendency toward exophagic and exophilic behaviours. (99)

Despite the critical role of surveillance in malaria control, the literature reveals substantial gaps in systematic reporting on Ethiopia's malaria surveillance systems particularly in relation to entomological surveillance. Most publications on malaria vector control focus heavily on vector biology (e.g., species composition, behaviour, and ecology), while offering limited insight into the infrastructure, routine processes, or effectiveness of the surveillance systems that inform control strategies.

A study in one of Ethiopia's federal city administrations (Dire Dawa) found health information systems (HIS) implementation at 80%, with data quality at 91.6%, information use at 70.3%, and 80% of facilities meeting infrastructure requirements. Yet, challenges persisted in workforce training of the information system and resource availability. (100) In Southern Ethiopia, the Health Management Monitoring Tool showed 79% data accuracy, 86% completeness, and 84% timeliness. Supportive supervision positively influenced performance, while lack of training and supervision reduced data quality. (101,102)

On the contrary, another study reported an overall HIS implementation score of 46.3%. To improve this, the Capacity-Building and Mentorship Partnership (CBMP) engaged university professionals in training initiatives, leading to an implementation increase to over 70% within three years.(103)

At the facility level, HIS reporting format varies, and data from health posts and centres are compiled and sent to district officers managing communicable disease control. There are no malaria-specific officers, and reports are aggregated across diseases. Discrepancies between the report and the counted incidents is usually evident. In one large region, only 30% of reported data matched observed malaria cases. Most reports focus on morbidity, mortality, and treatment outcomes. (104) In addition, these data is not efficiently used to forecast demand on the preventive malaria services.(66)

Several HIS initiatives have been implemented, including the District Health Information System 2 (DHIS2), electronic medical records, the Electronic Community Health Information System (eCHIS), and human resource information systems. However, challenges such as limited infrastructure, electricity, internet access, training, and support have hindered effective implementation. (103)

DHIS2, an open-source platform used for patient-based data collection both online and offline, faces operational inefficiencies in Ethiopia due to these constraints. To address this, a strategic national HIS plan was launched, though only 5% of health facilities reported sufficient workforce for implementation, and private sector involvement remains low (1%). (100) DHIS2 has also been critiqued for high costs and infrequent data collection, limiting its utility. (105)

CHIS is designed for use by HEWs and CHWs to manage data. It started out as paper based with family folder and health cards assigned to each household containing the health information of the members to enable the health workers to advise on preventive medical care which includes LLINs availability and use. (106) Despite this system being place a study showed only half of the HEWs have good data practice using it. (107) One of the intuitive to improve the quality was digitalizing the system. eCHIS came into the picture in 2018. It has brought a significant improvement in data quality. However, there are challenges regarding technical support/training and adequate funding. (108)

Sentinel surveillance systems have been piloted in high-burden regions, focusing on clinical outcomes. However, no routine, standalone national vector surveillance system exists. Entomological data are often embedded within operational programs, with weak documentation. While Ethiopia lacks a formal entomological surveillance tool, global initiatives like the genomic epidemiology network and the Entomological Surveillance Planning Tool (ESPT) at Malaria Eradication Scientific Alliance (MESA) offer technical support. (109,110)

3.1.5. Health financing

The national malaria programme in Ethiopia is financed through a combination of domestic funding and support from development partners. Approximately 40% of total expenditures in recent years were covered by external partners, primarily funding commodities such as LLINs, spray pumps, and diagnostic and treatment equipment. (11) Domestic sources predominantly covered recurrent costs, including salaries and training, along with selected commodities such as insecticides. Budget planning and execution follow a decentralized structure, with financial reporting cascading from districts to regions and subsequently to MoH, which consolidates reports for the Ministry of Finance.(11)

It's been shown that an increase investment in malaria can result in more efficiency. A cost-effectiveness analysis done in Ethiopia indicated that publicly financing a 10% coverage increase in four interventions; LLINs, IRS, ACT, and malaria vaccination could avert over USD 4 million in private health expenditures, with the majority of benefits accruing to the poorest households. (112)

The combined implementation of LLINs, IRS, and effective case management with ACTs has been shown to be among the most cost-effective malaria interventions.(113)

Ethiopia distributes LLINs primarily free of charge; however, limited commercial availability exists in urban areas. (25) In Northwest Ethiopia, 64% of respondents reported willingness to pay for LLINs, while a study in the Northeast found this figure to be as high as 96%. Those unwilling to pay cited economic constraints. Higher education, higher wealth index, and awareness of LLIN utility were associated with increased willingness to pay. (114) Community-based health insurance has also shown positive associations with preventive practices; for instance, pregnant women enrolled in the scheme were more likely to own and use LLINs.(49)

As outlined in the National Malaria Elimination Strategic Plan, cost-effectiveness and "value for money" are guiding principles. (11) However, significant financial gaps remain, and these are projected to widen due to the downscaling of global support. The 2025 reduction in donor commitments, including the United States Agency for International Development (USAID) contributions, has particularly impacted LLIN distribution, IRS activities, and health education campaigns.(111) Given the reliance on external financing, sustainability is a major concern. (11)

3.1.6. Governance

Ethiopia has demonstrated strong political commitment to malaria elimination, setting a national goal to eliminate the disease by 2030. In alignment with the GTS, the country developed a national roadmap emphasizing universal access to malaria services. (23) Policies supporting mass distribution of LLINs, targeted IRS, and LSM have been central to this approach. (23) Coordination, policy development, guideline formulation, monitoring and evaluation, and resource mobilization are led by the MoH, specifically through the National Malaria Elimination Program (NMEP), situated within the Disease Prevention and Control Directorate of MoH of Ethiopia. (115) Subnational NMEP units were established in 2017 to strengthen implementation at regional and district levels.(23)

Several studies have criticized the predominance of national-level planning, citing its tendency to result in a "one-size-fits-all" strategy that overlooks local transmission dynamics. Stakeholders have advocated for greater decentralization, with districts acting as the operational and planning hub. In this model, district health officers would coordinate closely with HEWs, who hold contextual knowledge of malaria transmission patterns. (116) HEWs have a strong mediating role in implementation of these policies. (117) Such an approach would require flexible donor funding and enhanced district-level decision-making authority, alongside technical and operational capacity at the local level.(116)

The governance framework also mandates intersectoral collaboration to address upstream drivers of malaria transmission. Key ministries such as agriculture, urban development, and transport are identified as essential partners. For instance, irrigation projects have been associated with increased mosquito breeding, and *Anopheles stephensi* has been implicated in urban spread. (96,118) A study in Jigjiga documented the first confirmed detection of *Anopheles stephensi* in Ethiopia in 2018. Construction sites, particularly water-filled pits, were found to be primary breeding habitats, maintaining vector populations even during the dry season. Breeding positivity in construction pits reached 62%, compared to 6% in cement-lined cisterns. (119)

Construction practices were further linked to governance gaps in vector control. One qualitative study highlighted that unregulated building activities such as open pits left during mud plastering created persistent breeding grounds. In newly developed areas, uninhabited houses were also found to contribute to increased mosquito density. (48)

The national elimination strategy explicitly identifies high-risk groups including pastoralists, migrant labourers, refugees, and internally displaced persons as critical to equitable malaria control. However, service delivery to these populations is hindered by logistical constraints. (11) To address these, policy adjustments have focused on identifying service gaps, enhancing delivery mechanisms, collaborating with industrial parks (to reach migrant workers), and partnering with humanitarian agencies. Improved monitoring systems are also planned. Yet, significant implementation challenges persist.(11)

Vulnerable and mobile populations have been underserved due to policy execution and governance limitations. A qualitative study found weak coordination among implementing partners hindered malaria control efforts in this group. (120) During the northern Ethiopia conflict, approximately 2.5 million people were displaced, severely weakening health infrastructure. Malaria outbreaks were exacerbated by poor intersectoral coordination and fragmented health systems during and after the conflict . (60)

3.2. Country Case Studies: Malaria vector control efforts in Africa

3.2.1. Rwanda

Rwanda, a landlocked East African country with a population of approximately 12.7 million, has demonstrated consistent and strategic efforts in combating malaria over the last two decades. Its varied geography, consisting of highland plateaus, mountainous regions, and lake-dense valleys results in a temperate climate with an average annual temperature of 18.5°C. These ecological conditions influence malaria transmission dynamics, which vary from year-round to periodic outbreaks during the rainy seasons of May–June and November–December. (121–123)

Malaria transmission in Rwanda is heterogeneous, with some districts experiencing high endemicity and others reporting very low or seasonal incidence. The principal malaria vectors are *Anopheles arabiensis* in IRS areas and *Anopheles gambiae s.s.* in non-IRS zones. Vulnerable populations include pregnant women, children under five, migrants, and prisoners. (123)

Following a malaria resurgence between 2012 and 2016, the government launched a new strategic plan focusing on scaling up LLINs, expanding IRS to high-burden districts, and promoting community-based case management. These interventions resulted in significant gains: LLIN access increased to 72%, and IRS was scaled from 5 to 10 districts.(123,124) Rwanda's current National Malaria Strategic Plan (2020–2024) aims to reduce malaria cases by 75% in line with the WHO GTS 2025 targets. It had implemented national IRS, carried out mass ITN campaigns and had 50-80% coverage of the population at risk with either ITN or IRS in 2023. It is recognised by the WHO as one of the countries that has made noteworthy progress towards decreasing the incidence of malaria. (2,123)

Rwanda adopted a blanket IRS approach in targeted districts, aiming to reach 98% of the population in high-transmission areas, including refugee camps, prisons, hotels, and schools. Focal IRS is now reserved for outbreak response. LLINs are distributed through routine services such as antenatal care and expanded program on immunization (EPI), in addition to mass campaigns. Non-IRS areas receive PBO nets, while standard LLINs are used in IRS-covered regions. (123,124)

The country is a continental leader in integrated vector management (IVM). Innovations include the use of biological larvicides (Bti), larvivores fish (*Clarias* species), spatial repellents, wall linings, and personal mosquito repellents. These are deployed based on entomological evidence and local context. (123) For example, Bti was piloted in rice farming areas, and the approach showed promising community engagement and willingness to co-finance the intervention. (125) Additionally, the use of drone-based larvicide delivery systems demonstrated effectiveness in reducing vector density and malaria incidence in Kigali. (126) This is seen as a step forward to possibly move away from the restrictive few-fixed-findable WHO larvicidal approach to a wider range of context. (127)

Rwanda's approach incorporates substantial community engagement. CHWs are instrumental in promoting net usage, advocating for personal protection methods, and supporting larval source management by guiding communities in planting mosquito-repellent plants and using essential oils.(122–124)

A novel "citizen science" model allows community members to report mosquito nuisance levels, which have shown correlation with entomological survey results. Hand-made traps were also piloted as part of this model, yielding comparable data to standard traps, and participants showed increased malaria knowledge post-intervention. (128–130)

Rwanda maintains a strong surveillance backbone through systems such as the Health Management Information System (HMIS), RapidSMS, and SISCom, achieving 98% reporting rates from public facilities. (123) Investments have since been made to train entomologists and enhance capacity for data-driven decision-making. (123,124)

Entomological surveillance is robust, with regular monitoring of insecticide resistance patterns. Resistance to pyrethroids, first documented in 2012, led to strategic shifts in insecticide classes and the introduction of dual-active ingredient LLINs. The integration of climatic and epidemiological data through forecasting platforms further enhances outbreak preparedness and response. (123,124,131)

Between 2008 and 2022, Rwanda distributed over 22 million LLINs, prioritizing pregnant women and children under 5 years old through ANC/EPI services and mass door-to-door campaigns. PBO nets, proven to reduce malaria incidence in resistant areas, are widely used in non-IRS zones. LLINs with dual active ingredients have also been piloted. Areas receiving PBO nets witnessed significant malaria reductions between 2020 and 2022. (122,132) After detecting insecticide resistance, the country implemented a rotation strategy, alternating carbamates and organophosphates every two years to prevent resistance build-up. (124)

Political commitment has been a cornerstone of Rwanda's malaria response. The Ministry of Health coordinates vector control interventions with other sectors, including the Ministry of Agriculture. Joint efforts have targeted irrigated rice fields using larviciding and water management to disrupt breeding sites. The country's universal health coverage (91% community-based health insurance enrolment) has supported equitable access to malaria services. (123,124)

Rwanda's vector control program is funded through a mix of domestic resources and international support, including the Global Fund, the President's Malaria Initiative (PMI), and Roll Back Malaria. Social marketing and public-private partnerships have been promoted to address funding gaps, particularly in LLIN distribution. (122,124)

3.2.2. Cabo Verde

Cabo Verde, an island nation located approximately 450 kilometres off the West African coast, west of Senegal, comprises ten islands forming an archipelago with diverse ecological zones. These range from arid and semi-arid to sub-humid and wetland environments, all situated below 1,000 meters in elevation. The climate is temperate, with average temperatures ranging between 18.4°C during the cooler seasons and 26.7°C during warmer periods, creating favourable yet varied conditions for vector-borne diseases, including malaria. (133)

The dominant malaria vector in Cabo Verde is *Anopheles gambiae*. The country's malaria control efforts culminated in its certification as malaria-free by the WHO in 2024. Cabo Verde had been part of the WHO's E-2020 initiative, which aimed to eliminate malaria in 21 countries by 2020. However, this goal was temporarily disrupted by an outbreak in 2017, primarily due to indigenous transmission on the islands of Santiago and Boavista. The resurgence prompted intensified interventions that eventually restored progress and eliminated local transmission by 2018. (134)

Cabo Verde's vector control strategy has been strongly integrated and adaptive. While LLINs are not distributed routinely, they are deployed during outbreaks. The cornerstone of the country's malaria prevention has been biannual IRS, using deltamethrin a pyrethroid insecticide as the primary agent. LSM has complemented IRS efforts through the use of temephos (Abate), a larvicide, and more localized application of larvivorous fish and petroleum derivatives. Vector control also extended to international entry points, with aircraft being treated with permethrin to prevent importation of infected vectors. (133)

A hallmark of Cabo Verde's success has been its robust surveillance infrastructure. The system allows for real-time geolocation of malaria cases, enabling rapid and targeted vector control responses. This case-based geolocalization was instrumental in containing the 2017 outbreak and has since served as a cornerstone for sustaining malaria-free status. Surveillance data are integrated with vector control operations to detect indigenous cases swiftly and to distinguish them from imported infections. This approach was especially crucial for Santiago and Boavista, the only islands to report indigenous cases in recent years. In contrast, other islands recorded only imported cases, mainly linked to air and maritime travel from mainland Africa. (134,135)

Cabo Verde also demonstrated strong cross-border and intersectoral collaboration to manage the threat of imported malaria. Surveillance and control mechanisms at ports and airports were intensified, including vector control measures and improved health checks. This was supported by a political commitment to malaria elimination that spanned multiple government sectors. Local authorities played a proactive role, particularly in Santiago and Boavista, where targeted investments in health infrastructure and human resources ensured a high standard of services. (135,136)

Throughout the pre-elimination and elimination phases, sustained domestic political commitment remained a driving force behind the country's success. While external technical assistance complemented national efforts, the emphasis on maintaining functional surveillance, environmental vector control, and public health responsiveness ultimately positioned the country to interrupt local transmission and attain WHO certification in 2024. (136)

3.2.3. Algeria

Algeria is the largest country in Africa, characterized by three distinct geographic and climatic zones: the Mediterranean coastal region in the north, the Tell and Saharan Atlas Mountains through the centre, and the Sahara Desert covering more than 80% of the country in the south. The northern coastal areas have a Mediterranean climate, with mild, wet winters and hot, dry summers. The highland and mountainous zones are cooler. In contrast, the southern Saharan zone is hyper-arid, with extreme temperatures. Historically, malaria transmission was confined to the northern and central zones, where seasonal rainfall, moderate temperatures, and suitable breeding sites supported *Anopheles* mosquitoes such as *Anopheles labranchiae* and *Anopheles sergentii*. The vast desert and cooler highlands limited malaria vector survival and parasite development, acting as natural barriers to transmission. (137–139)

Algeria's path to malaria elimination has been shaped by a long-standing national commitment, dating back to the late 19th century. The country experienced several cycles of progress and setbacks until the most recent efforts launched in the 2010s led to a significant reduction in incidence and, ultimately, certification of malaria-free status by the WHO in 2019. (140)

One of the defining features of Algeria's success was the absence of dependency on external donor funding. In 2014, Algeria's gross national income (GNI) per capita was USD 5,480, rendering it ineligible for support from major global health donors such as the Global Fund, PMI, and the World Bank's International Development Association (140) Instead, the country relied on sustained domestic financing, demonstrating that strong political will and national investment can compensate for limited external funding. (135,141)

Key political decisions also shaped elimination outcomes. In 2009, Algeria implemented stricter border control policies to limit the inflow of malaria cases from neighbouring countries, particularly Mauritania, Mali, Niger, Libya, and Tunisia. This was especially important given the Trans-Saharan Highway, which served as a route for migrants from malaria-endemic regions.(140)

Algeria's malaria elimination efforts were underpinned by a robust surveillance system, both epidemiologic and entomologic. Each confirmed malaria case triggered a case investigation and epidemiologic survey to trace and prevent further transmission. Additionally, GIS-based mapping tools were deployed to track imported cases with precision. This granular surveillance capacity enabled rapid response to outbreaks and improved targeting of vector control interventions. (136) (135)

The country also maintained a Malaria Control Service Institute, a dedicated institution tasked with overseeing environmental management and vector control efforts. A hallmark of Algeria's approach was the use of larvivorous fish for biological larval source management, alongside chemical interventions such as targeted IRS. (135)

Health service delivery was marked by strong system reach, even into remote areas, and universal access to malaria prevention and treatment services. These services were provided free of charge, regardless of nationality or residency status. (136) Moreover, Algeria ensured adequate staffing, consistent training of health personnel, and continuous notification systems, contributing to the timeliness and effectiveness of interventions. (135)

Chapter 4: Discussion

This study explored malaria vector control interventions through the lens of health system components. It also examined experiences from selected African countries that have achieved or are nearing malaria elimination, aiming to draw policy-relevant lessons for Ethiopia.

Ethiopia has shown a significant political commitment to the elimination of malaria and has vector control interventions in place. There have been efforts to launch health extension workers widely for more than 2 decades. There have also been attempts to digitize health information systems. The country has had campaigns for LLINs and IRS and limited LSM activities that have proven to be efficient in their own scale. There are policies in place to protect vulnerable groups despite hurdles for execution.

Despite these efforts, the findings show persistent gaps in malaria vector control implementation in Ethiopia, including suboptimal LLIN and IRS coverage, inadequate training and support for frontline workers, and weak health information and entomological surveillance systems. Centralized policy development, limited district-level capacity, and heavy donor dependence further constrain effective delivery, leaving vulnerable groups such as migrant workers, pastoralist community, internally displaced people, pregnant women, and children disproportionately affected. In contrast, countries like Rwanda, Algeria, and Cabo Verde illustrate the value of strong domestic ownership, evidence-informed strategies, and coordinated multisectoral efforts in advancing toward or achieving malaria elimination, offering important lessons for Ethiopia.

4.1. Identified gaps and strengths

Ethiopia's ambition to eliminate malaria by 2030 is undermined by several gaps across the health system building blocks. While policy frameworks are in place, the execution often falls short due to under-resourced systems, weak surveillance, and a misalignment between intervention design and community realities.

Though national campaigns have achieved moderate levels of LLIN ownership, access remains critically low. There is a mismatch as net ownership is defined as the availability of one LLIN in a household while the latter is defined as the availability of 1 net for 2 people in a household. Ethiopia's net distribution guideline policies cap nets at four per household, irrespective of household size. This is in part due to financial constraints. However, it highlights a top-down planning approach that fails to account for the demographic realities of rural and agrarian households. Hence the discordance between ownership and access of nets. A policy and community disjuncture are evident in addition as campaigns are at times planned without considering the context of the community such as sleeping habits and harvesting time. This further contributes to the failure to replace nets in time, undermining their protective effect.

Despite political commitment at the national level, malaria control in Ethiopia suffers from overcentralized planning and under-decentralized execution. District-level actors lack technical capacity, and access to real-time data, resulting in rigid interventions poorly suited to local needs. Procurement and supply chains are also fragmented; all these factors have resulted in a mismatch between need and availability.

Ethiopia's efforts to integrate LLIN distribution into ANC and EPI platforms have shown promise in other countries like Rwanda but remain under-implemented domestically. Hence, pregnant women and young children continue to be inadequately protected. This is similar for migrants and internally displaced people. Despite policy recognition of these risks, operationalization remains minimal, reflecting a gap between equity rhetoric and practice. An intersectional lens reveals how overlapping vulnerabilities such as gender, age, displacement status, and geographic marginalization compound the risk of malaria and limit access to preventive services. Addressing these layered inequities requires more than universal coverage goals; it demands tailored approaches that acknowledge and respond to these intersecting social determinants.

Perhaps the most critical shortfall is in malaria surveillance. Ethiopia's DHIS2 system offers a potential backbone for real-time monitoring but is undercut by fragmented data streams, low data quality, and limited analysis capacity at district and facility levels. Entomological data, when collected, is often not centralized or linked to decision-making processes. For example, although resistance patterns have informed shifts in insecticide selection, these changes are reactive rather than predictive. Rwanda, by contrast, has used integrated epidemiological-climate platforms to anticipate outbreaks and guide pre-emptive IRS campaigns. Based on patterns of resistance, Rwanda has deployed dual active ingredients actively. Even though similar patterns of resistance are recorded in Ethiopia, the deployment of these new LLINs is not initiated yet despite policies in place.

This challenge is also evident in the misalignment of vector control strategies to local epidemiology. For instance, LSM remains underutilized. This is in part due to Ethiopia's varied topography and financial burdens but also because of lack of entomological insight. However, where implemented with contextual sensitivity, such as in Rwanda's irrigated zones, LSM has proven effective. Rwanda's LSM efforts in irrigated rice zones using drone-deployed larvicides and fish stocking demonstrate that with appropriate targeting and inter-ministerial collaboration, LSM can be both scalable and impactful. Ethiopia's own irrigation expansion should prompt re-evaluation of LSM feasibility, especially in settings with persistent outdoor biting or insecticide resistance. Similarly, Cabo Verde's use of real-time case geolocation to trigger IRS and vector control demonstrates how technology-enabled surveillance can halt outbreaks.

Surveillance data in Ethiopia is rarely disaggregated for vulnerable groups or geospatial analysis, impeding targeted responses. The conflict in some part of the country remains to hinder the coverage to malaria services. Similarly migrant workers carry a high burden of the disease. However, the report is delayed and so are the targeted interventions.

The lack of coordination between the experts and policy makers, inefficient targeted capacity building and supervision at district and sub-district level and financial constraints contribute to the fragmentation of the surveillance system. To aid the surveillance system innovations such as Rwanda's "citizen science" initiatives which crowdsource mosquito disturbance reports offer low-cost, participatory models that Ethiopia could adapt.

The strain on frontline health workers, particularly HEWs, who are expected to bridge the gap between national policy and community is also a contributing factor to ineffective implementation of malaria vector interventions. Despite being central to health education, LLIN distribution, and follow-up, HEWs are often undertrained, underpaid, and overextended, serving up to 5,000 people each with minimal logistical support. This misalignment between task delegation and workforce support reflects a health system struggling to translate its strategies into community-level behaviour change. It's reported that community acceptance of intervention such as IRS is also low. This can in part be attributed to the lack of health education and follow up. Though Ethiopia has piloted community-based IRS approaches, the shift further burdens HEWs and lacks sustainable staffing models.

Availability of funding is also a major influencing factor. Financially, Ethiopia's malaria program has been heavily donor-dependent, Global Fund and PMI contributions once comprised 40% of the budget. With recent donor withdrawal trends, the country faces serious risks to program continuity. Unlike Algeria, which financed its malaria elimination without external aid, Ethiopia lacks a clear sustainability roadmap. While willingness-to-pay studies for LLINs have been piloted, broader health financing reforms are urgently needed. Similar to Rwanda, initiatives such as social marketing to fund part of the strategy are worth the exploration.

In addition, the importance of intersectoral collaboration is consistently under-addressed in Ethiopia's malaria efforts. Urbanization and infrastructure projects such as dams, roads, and housing contribute significantly to vector ecology, yet ministries of urbanization and agriculture are rarely engaged in malaria control planning. Rwanda has addressed this through joint programs with its agriculture ministry and proactive involvement of local leaders. Similarly, Cabo Verde's strategic focus on airport and seaport surveillance and even IRS on aircraft emphasizes the value of intersectoral collaboration for efficient vector control.

Despite the persistent implementation gaps outlined above, Ethiopia has made important foundational investments that can be leveraged to strengthen vector control efforts. The national HEP, now over two decades old, has established a community-level health workforce capable of delivering prevention and treatment interventions. While under-resourced, this platform represents a scalable delivery system that few low-income countries have institutionalized. Similarly, the digitization of health information through DHIS2 and other platforms, though currently underutilized, signals growing infrastructure for data-driven decision-making. Ethiopia has also demonstrated political commitment through the adoption of WHO-recommended vector control strategies LLINs, IRS, and LSM alongside policies aimed at protecting vulnerable groups. These efforts, while inconsistently executed, provide a technical and policy basis from which to expand and tailor malaria elimination strategies. Notably, pilot programs in integrated service delivery and community-based IRS suggest the presence of local innovations worth scaling. Recognizing and investing in these capacities is critical to ensuring that future reforms are grounded in existing institutional strengths.

4.2. Learning from Regional Successes: Rwanda, Cabo Verde, and Algeria

The comparative cases reveal transferable lessons for Ethiopia: adaptive surveillance systems, integration of vector control into routine health services, and domestic ownership and financing

Rwanda's success stems not only from intervention scale-up but from systemic coherence: blanket IRS, targeted LSM, integrated ANC/EPI distribution, and timely data use all reflect a learning system responsive to changing epidemiology. Citizen engagement is embedded through community-based surveillance, and intervention choice reflects context not just global recommendations. Though Rwanda's malaria programme is still donor dependent, the country is attempting to domestically fund part of the operation with initiatives such as social marketing.

Cabo Verde's malaria-free certification in 2024 was achieved by redefining vector control around imported case management. Rather than routine LLIN distribution, it prioritized LSM and IRS, guided by real-time surveillance. This contrasts sharply with Ethiopia's adherence to uniform national strategies regardless of transmission ecology. The meticulous surveillance led to better understanding of the context and that resulted in influencing the policy for malaria vector control intervention.

Algeria's case reinforces the role of sustained domestic investment. The country eliminated malaria without major donor support, leveraging GIS mapping, intersectoral governance, and universal health access to everyone within the border of the country to respond rapidly to imported cases. Ethiopia also offers free malaria services for citizens. But the free health delivery is complicated with accessibility and availability of the services. Ethiopia's health system remains far from Algeria's model, yet Algeria's example illustrates what is possible with political alignment and local financing.

4.3. Limitations of the study

Reflections on use of conceptual framework

Using the health system framework to examine vector control intervention has not been widely practiced. There are publications on Ethiopia's malaria vector control assessing components of the framework, but the six components have not been widely applied together. Using the framework in such manner gave the platform to view the success and limitations of the implantation of the intervention from the provider point of view.

While providing a broad systematic lens using this framework also came with limitations. The framework has been critiqued for not being considerate of the service recipient perspective, which may limit its ability to reflect individual or social factors that can influence the interventions. To mitigate this risk, literatures focusing on individual/societal factors had not been excluded, rather they were explored to trace back to a systemic factor that is contributing to them. For instance, lack of awareness was reported as one reason for inappropriate use of nets and post IRS wall modification. But that was traced to not getting the proper information from HEWs as the HEWs are overburdened to execute their responsibilities to the fullest. It was also seen that pregnant women had low utilization of nets. Further look reveals the absence of integration between ANC services with malaria services as one factor.

The framework also presents each block separately but that is rarely the case in real-time where one block is highly dependent on the other. However, the interconnection between the different aspects within the six blocks is depicted above.

Methodological limitations

Other limitations of the study include, although the review followed a systematic approach to searching, selecting, and synthesizing evidence, it was conducted as a narrative review rather than a formal systematic review. This approach may introduce some risk of selection bias.

Finally, the analysis relied largely on peer-reviewed publications and publicly available policy documents. Evaluations or system-level reports, especially regarding the ongoing 2020–2025 malaria elimination plan, were limited, as comprehensive assessments have not yet been finalized or published. Articles that were not in English were excluded. Part of the publications on Algeria and Cabo Verde were not in English, and this may contribute to missing key information. These limitations should be considered when interpreting the findings and recommendations presented.

Chapter 5: Conclusion and Recommendations

5.1. Conclusion

This study examined malaria vector control efforts in Ethiopia through the lens of the health system building blocks, identifying systemic gaps that hinder the effectiveness and sustainability of current interventions. Despite political commitment and the formal adoption of WHO-recommended strategies such as LLINs, IRS, and LSM, persistent weaknesses in planning, execution, and health system capacity continue to impede progress toward malaria elimination.

Key bottlenecks include the misalignment of intervention design with local contexts, overburdened and under-supported frontline health workers, and poor integration of malaria services into routine care platforms like ANC and EPI. Health information systems remain underutilized, with weak surveillance and poor data quality preventing timely, targeted responses. Financial sustainability is also in question as donor support declines, and domestic funding remains inadequate. Procurement inefficiencies, supply imbalances, and limited intersectoral collaboration further weaken the vector control ecosystem.

Comparative experiences from Rwanda, Cabo Verde, and Algeria highlight the role of adaptable, well-financed, and integrated health systems in achieving malaria elimination. Rwanda's strategic integration of health services; Cabo Verde's evidence-based vector control strategy shifts; and Algeria's domestically funded, GIS-driven response emphasizes the importance of alignment between policy, epidemiology, and system capacity.

For Ethiopia, strengthening malaria vector control will require more than scaling up existing interventions. It demands systemic reforms: embedding community-informed planning, decentralizing operational capacity, improving surveillance and data use, securing sustainable financing, and fostering intersectoral engagement. By drawing from both domestic lessons and regional experiences, Ethiopia can build a more resilient, adaptive, and equitable malaria response as it moves toward the 2030 elimination target.

5.2. Recommendations

Based on the finding of this review, the following recommendations are proposed to key stakeholders. Even though the recommendations are presented separately, their feasibility highly depends on intersectoral collaboration.

5.2.1. Ministry of Health

- Integrate the distribution of LLIN into ANC/ EPI platforms

Coverage of LLINs among pregnant women and children under five remains inadequate. As demonstrated in Rwanda, integrating LLIN provision into ANC and EPI services, in addition to mass campaigns, can enhance access and improve coverage among vulnerable populations.

- Develop tailored policy and delivery strategies for vulnerable populations

Populations such as migrant workers, migrants and internally displaced people face heightened malaria risk but remain underserved by standard delivery mechanisms. The Ministry should establish and operationalize tailored prevention strategies such as mobile LLIN and IRS services with structured follow-up and monitoring frameworks

- Develop and pilot localized LLIN distribution policy

The discrepancy between coverage and access needs more probing. Piloting a localized LLIN distribution policy in the rural part of Ethiopia and reviewing the result could help in addressing one of the possible reasons (inadequate distribution) for low access.

- Expand and support the Health Extension Program

HEWs are essential to vector control implementation but remain overburdened and under-resourced. The Ministry should prioritize recruitment to reduce workload per HEW and invest in improving remuneration, career progression, and ongoing training to ensure long-term workforce sustainability.

- Strengthening real-time surveillance by combining the scattered efforts and timely use of data to inform policy

Ethiopia's surveillance platforms remain fragmented and underutilized. The Ministry should work with research institutions to consolidate existing health, entomological, demographic, and meteorological data into a unified, real-time surveillance system. This would support more timely, evidence-based adjustments to vector control strategies

- Assess LSM feasibility using surveillance data.

Using improved surveillance data, targeted operational research should be conducted to evaluate the feasibility, adaptability, and cost-effectiveness of LSM, particularly in irrigated and high-burden regions.

- Strengthen district and sub-district technical capacity to execute true decentralization

Effective decentralization requires robust technical capacity at the sub-national level. Continuous training, supervision, and support for district and sub-district health officers are essential to ensure data quality, promote evidence-informed planning, and enable locally adapted intervention delivery.

5.2.2. Ministry of Finance

- Develop a short-, medium-, and long-term domestic financing roadmap

Ethiopia's malaria program remains highly dependent on external funding. In partnership with the Ministry of Health, the Ministry of Finance should develop a phased strategy for increasing domestic contributions. This roadmap should define milestones for gradually transitioning to sustainable, country-led financing of malaria prevention and control.

5.2.3. Ministry of Agriculture and Ministry of urbanization

- Integrate vector control considerations in agriculture and construction practices

Irrigation and construction projects significantly influence malaria transmission, especially with the emergence of *Anopheles stephensi* in urban areas. Both ministries should integrate vector control measures into project planning such as improved drainage, habitat modification, and environmental management to mitigate breeding site proliferation.

Annexe

I. AI use declaration

KIT Institute Masters Participants
Declaration for Use of Generative AI (GenAI)

Check the box that applies to your completion of this assignment:

☐ I confirm that **I have not used** any generative AI tools to complete this assignment.

☒ I confirm that **I have used** generative AI tool(s) in accordance with the ***"Guidelines for the use of Generative AI for KIT Institute Master's and Short course participants".*** Below, I have listed the GenAI tools used and for what specific purpose:

Generative AI tool used	Purpose of use
1. ChatGPT	brainstorming
2. copilot	brainstorming
…	

References

1. World Health Organization. WHO malaria terminology: 2021 update [Internet]. Geneva: World Health Organization; 2021 [cited 2025 Jun 16]. Available from: https://www.who.int/publications/i/item/9789240043334

2. World Health Organization. World malaria report 2024 [Internet]. Geneva: World Health Organization; 2024 [cited 2025 Jun 16]. Available from: https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2024

3. Amanuel M, Tadesse S, Tamene A. House-wall modification after indoor residual spraying in Shashogo district, southern Ethiopia. *Malar J* [Internet]. 2023 Oct 31 [cited 2025 Jun 19];22:328. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10619287/

4. World Health Organization. Fact sheet about malaria [Internet]. Geneva: WHO;2025 [cited 2025 Jun 16]. Available from: https://www.who.int/news-room/fact-sheets/detail/malaria

5. Thellier M, Gemegah AAJ, Tantaoui I. Global fight against malaria: goals and achievements 1900–2022. *J Clin Med* [Internet]. 2024 Sep 24 [cited 2025 Jun 16];13(19):5680. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11477079/

6. World Health Organization. Malaria [Internet]. Geneva: WHO; 2025 [cited 2025 Jun 16]. Available from: https://www.who.int/teams/immunization-vaccines-and-biologicals/diseases/malaria

7. World Health Organization Regional Office for Africa. Malaria | WHO | Regional Office for Africa [Internet]. Brazzaville: WHO Regional Office for Africa; 2025 [cited 2025 Jun 16]. Available from: https://www.afro.who.int/health-topics/malaria

8. World Health Organization. Malaria - Ethiopia [Internet]. Geneva: WHO; 2024 [cited 2025 Jun 16]. Available from: https://www.who.int/emergencies/disease-outbreak-news/item/2024-DON542

9. World Bank. World Bank open data [Internet]. Washington, DC: World Bank; 2025 [cited 2025 Jul 8]. Available from: https://data.worldbank.org

10. Markos D, Ababa A. Building end-to-end visibility into national LLIN distribution in Ethiopia: piloting of interactive voice response as a scalable communication channel [Internet]. Presented at: Global Health Supply Chain Summit; 2018 Nov 28–30; Lusaka, Zambia. Available from: https://ghscs.com/wp-content/uploads/2018/12/15.3Building-end-to-end-visibility-into-national-LLIN-distribution-in-Ethiopia-piloting-of-interactive-voice-response-as-a-scalable-c%E2%80%A61.pdf

11. Federal Ministry of Health [Ethiopia]. Ethiopia malaria elimination strategic plan: 2021–2025. Addis Ababa: Federal Ministry of Health; 2020.

12. Federal Ministry of Health. Ethiopia health sector transformation plan I (2015–2020): endline review [Internet]. Ethiopia: Federal Ministry of Health; 2022 [cited 2025 Jul 8]. Available

from: https://www.countdown2030.org/wp-content/uploads/2023/07/2.-Ethiopia-Health-Sector-Transformation-Plan-I-2015-2020-Endline-Review.pdf

13. Federal Ministry of Health. Health extension program in Ethiopia [Internet]. Ethiopia: Federal Ministry of Health; 2007 [cited 2025 Jul 8]. Available from: https://www.hcwpolicylab.org/wp-content/uploads/2024/07/Ethiopia_Health-Extension-Program_2007.pdf

14. Mariam DH, Estifanos A, Wondimagegn D, Simmons B, Conteh L. Strategies to address workforce challenges. In: Soucat A, Scheffler RM, editors. Human resources for health: policies for universal health coverage. Geneva: World Health Organization; 2016. p. 133–52.

15. Federal Ministry of Health. Ethiopia health sector transformation plan II (HSTP-II): 2020/21–2024/25 [Internet]. Ethiopia: Federal Ministry of Health; 2021. [cited 2025 Jul 8]. Available from: https://www.globalfinancingfacility.org/sites/default/files/Ethiopia-HSTP-II.pdf

16. World Health Organization. Domestic general government health expenditure (GGHE-D) as percentage of gross domestic product (GDP) (%) [Internet]. Geneva: World Health Organization; 2025 [cited 2025 Jul 8]. Available from: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/domestic-general-government-health-expenditure-(gghe-d)-as-percentage-of-gross-domestic-product-(gdp)-(-)

17. Taffese HS, Hemming-Schroeder E, Koepfli C, Tesfaye G, Lee M-C, Kazura J, et al. Malaria epidemiology and interventions in Ethiopia from 2001 to 2016. *Infect Dis Poverty* [Internet]. 2018 Dec [cited 2025 Jun 16];7(1):103. Available from: https://idpjournal.biomedcentral.com/articles/10.1186/s40249-018-0487-3

18. Ontheworldmap.com. Ethiopia physical map [Internet]. Ontheworldmap.com; 2025 [cited 2025 Jul 22]. Available from: https://ontheworldmap.com/ethiopia/ethiopia-physical-map.html

19. World Health Organization. Global technical strategy for malaria 2016–2030 [Internet]. Geneva: World Health Organization; 2015 [cited 2025 Jul 14]. 29 p. Available from: https://iris.who.int/handle/10665/176712

20. Woldesenbet D, Tegegne Y, Mussema A, Tamene E, Mohamed K, Abebe W, et al. Can Ethiopia eliminate malaria? Malaria burden: insights from the pre-elimination era, current challenges and perspectives. *Front Malar* [Internet]. 2025 Jan 30 [cited 2025 Jun 16];3:1492444. Available from: https://www.frontiersin.org/journals/malaria/articles/10.3389/fmala.2025.1492444/full

21. Ethiopia's Tigray war: the short, medium and long story [Internet]. London: BBC News; 2020 Nov 17 [cited 2025 Jul 22]. Available from: https://www.bbc.com/news/world-africa-54964378

22. International Committee of the Red Cross. Ethiopia: thousands of people unable to access healthcare services after upsurge in violence [Internet]. Geneva: ICRC; 2024 [cited 2025 Jul 22]. Available from: https://www.icrc.org/en/document/ethiopia-thousands-people-unable-access-healthcare-services-after-upsurge-violence

23. Federal Ministry of Health [Ethiopia]. Malaria elimination roadmap: Ethiopia, 2017 [Internet]. Addis Ababa: Federal Ministry of Health; 2017 [cited 2025 Jul 22]. Available from: https://www.researchgate.net/publication/342889504_Malaria_Elimination_Roadmap_in_Ethiopia

24. Gari T, Lindtjørn B. Reshaping the vector control strategy for malaria elimination in Ethiopia in the context of current evidence and new tools: opportunities and challenges. *Malar J* [Internet]. 2018 Dec 5 [cited 2025 Jul 22];17(1):454. Available from: https://doi.org/10.1186/s12936-018-2607-8

25. Federal Ministry of Health [Ethiopia]. National malaria guidelines – 5th edition, 2022 [Internet]. Addis Ababa: FMoH; 2022 [cited 2025 Jul 22]. Available from: https://www.scribd.com/document/589612562/National-Malaria-Guideline-2022

26. Malaria Consortium. Progress in the fight against malaria in Ethiopia [Internet]. London (UK): Malaria Consortium; 2025 [cited 2025 Jun 16]. Available from: https://dp.malariaconsortium.org/malaria-upsurge-in-ethiopia/

27. Yalew AW. Achievements, gaps, and emerging challenges in controlling malaria in Ethiopia. *Front Trop Dis* [Internet]. 2022 Jan 25 [cited 2025 Jun 16]; 2:771030. Available from: https://www.frontiersin.org/journals/tropical-diseases/articles/10.3389/fitd.2021.771030/full

28. Adugna F, Wale M, Nibret E. Review of Anopheles mosquito species, abundance, and distribution in Ethiopia. *J Trop Med* [Internet]. 2021 Sep 23 [cited 2025 Jun 5]; 2021:6726622. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8486561/

29. Abebe W, Sisay A, Mihret Y, Setegn A, Asmare Z, Woldesenbet D, et al. Prevalence of *Anopheles stephensi* in Horn of Africa: a systematic review and meta-analysis. *BMC Infect Dis* [Internet]. 2025 Apr 27 [cited 2025 Jun 2]; 25:614. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC12036230/

30. Teshome A, Erko B, Golassa L, Yohannes G, Irish SR, Zohdy S, et al. Resistance of *Anopheles stephensi* to selected insecticides used for indoor residual spraying and long-lasting insecticidal nets in Ethiopia. *Malar J* [Internet]. 2023 Jul 27 [cited 2025 Jun 2]; 22:218. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10375616/

31. Messenger LA, Impoinvil LM, Derilus D, Yewhalaw D, Irish S, Lenhart A. A whole transcriptomic approach provides novel insights into the molecular basis of organophosphate and pyrethroid resistance in *Anopheles arabiensis* from Ethiopia. *Insect Biochem Mol Biol* [Internet]. 2021 Dec [cited 2025 Jun 6]; 139:103655. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11705372/

32. Bhatt S, Weiss DJ, Cameron E, Bisanzio D, Mappin B, Dalrymple U, et al. The effect of malaria control on *Plasmodium falciparum* in Africa between 2000 and 2015. *Nature* [Internet]. 2015 Oct [cited 2025 Jun 16];526(7572):207–11. Available from: https://www.nature.com/articles/nature15535

33. Esayas E, Gowelo S, Assefa M, Vajda EA, Thomsen E, Getachew A, et al. Impact of nighttime human behavior on exposure to malaria vectors and effectiveness of using long-lasting insecticidal nets in the Ethiopian lowlands and highlands. *Parasit Vectors* [Internet]. 2024 Dec 18 [cited 2025 Jun 2];17:520. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11658354/

34. World Health Organization. Everybody's business: strengthening health systems to improve health outcomes: WHO's framework for action [Internet]. Geneva: World Health Organization; 2007 [cited 2025 Jul 14];44 p. Available from: https://iris.who.int/handle/10665/43918

35. Mounier-Jack S, Griffiths UK, Closser S, Burchett H, Marchal B. Measuring the health systems impact of disease control programmes: a critical reflection on the WHO building blocks framework. *BMC Public Health* [Internet]. 2014 Mar 25 [cited 2025 Jun 16]; 14:278. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3974593/

36. Niguse W, Alemayehu B, Gebremedhin T, Alemu M, Mamo G, Negeri E, et al. Low ITN utilization among households in SWEPR Ethiopia: challenge for malaria elimination, a mixed design approach. *BMC Public Health* [Internet]. 2025 Feb 5 [cited 2025 Jun 2]; 25:472. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11800501/

37. Tadesse EM, Baruda YS, Tadesse TM. Assessment of household insecticide-treated bed net ownership, utilization, and associated factors in Kersa Woreda, Jimma Zone, Southwest Ethiopia. *J Health Popul Nutr* [Internet]. 2024 Dec 18 [cited 2025 Jun 6]; 43:214. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11658537/

38. Endriyas M, Kassa M, Chisha Y, Mekonnen E, Misganaw T, Loha E, et al. Low long-lasting insecticidal net use in malaria elimination areas in Southern Ethiopia: results from community based cross-sectional study. *Malar J* [Internet]. 2024 Apr 4 [cited 2025 Jun 2]; 23:94. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10996104/

39. Endriyas M, Solomon T, Gari T, Samuel T, Lindtjørn B. A decline in the coverage and utilization of long-lasting insecticidal nets in Southern Ethiopia: A repeated cross-sectional study. *PLoS One* [Internet]. 2025 Apr 24 [cited 2025 Jun 2];20(4): e0322342. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC12021140/

40. Bayou FD, Kebede N, Tsega Y, Nigussie S, Legassu TD, Muche A, et al. Underutilization of long-lasting insecticidal nets (LLINs) is challenging malaria elimination program in Ethiopia: a systematic review and meta-analysis. *BMC Public Health* [Internet]. 2024 Mar 15 [cited 2025 Jun 2]; 24:815. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10941431/

41. Mekuria M, Binegde DN, Derega J, Bala ET, Tesfa B, Deriba BS. Insecticide-treated bed net utilization and associated factors among households in Ilu Galan District, Oromia Region, Ethiopia. *Environ Health Insights* [Internet]. 2022 Feb 24 [cited 2025 Jun 5]; 16:11786302221078122. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8883365/

42. Merga T, Adane MM, Shibabaw T, Salah FA, Ejigu LJ, Mulatu S. Utilization of insecticide-treated bed nets and associated factors among households in Pawie District, Benshangul Gumuz, Northwest Ethiopia. *Sci Rep* [Internet]. 2024 Dec 30 [cited 2025 Jun 2]; 14:31712. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11685494/

43. Elemo N, Worko KT, Mama D, Guye AH. Long-lasting insecticidal nets utilization and associated factors among households of West Arsi Zone, Oromia Region, Ethiopia. *Sci Rep* [Internet]. 2024 Jul 30 [cited 2025 Jun 2]; 14:17498. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11289461/

44. World Health Organization. World health statistics [Internet]. Geneva: WHO; 2025 [cited 2025 Jul 15]. Available from: https://www.who.int/data/gho/publications/world-health-statistics

45. Hiruy HN, Zewde A, Irish SR, Abdelmenan S, Woyessa A, Wuletaw Y, et al. The effect of long-lasting insecticidal nets (LLINs) physical integrity on utilization. *Malar J* [Internet]. 2021 Dec 18 [cited 2025 Jun 5]; 20:468. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8684122/

46. Aliyo A, Golicha W, Fikrie A. Pastoral community malaria prevention practice and associated factors among households in three districts of the Borena Zone, Southern Ethiopia. *Health Serv Res Manag Epidemiol* [Internet]. 2023 Jan 12 [cited 2025 Jun 6]; 10:23333928221144555. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9841874/

47. Yirsaw AN, Gebremariam RB, Getnet WA, Nigusie A, Lakew G, Getachew E, et al. Barriers of persistent long-lasting insecticidal nets utilization in Northwest Ethiopia: a qualitative study. *BMC Public Health* [Internet]. 2024 Oct 15 [cited 2025 Jun 5]; 24:2828. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11476254/

48. Asale A, Abro Z, Enchalew B, Teshager A, Belay A, Kassie M, et al. Community knowledge, perceptions, and practices regarding malaria and its control in Jabi Tehnan district, Amhara Region, Northwest Ethiopia. *Malar J* [Internet]. 2021 Dec 9 [cited 2025 Jun 6]; 20:459. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8656029/

49. Getnet Y, Teym A, Wubie M, Shiferaw S, Tilahun Assaye B, Aneley Z, et al. Long-lasting insecticide-treated nets utilization and associated factors among pregnant women in Shebel Berenta District, Northwest Ethiopia. *Environ Health Insights* [Internet]. 2024 Oct 21 [cited 2025 Jun 2]; 18:11786302241291957. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11528622/

50. Kuse KA, Chikako TU, Bacha RH, Hagan JE, Seidu AA, Ahinkorah BO. Multilevel modelling of individual, community and regional level factors associated with insecticide-treated net usage among pregnant women in Ethiopia. *Healthcare (Basel)* [Internet]. 2022 Jul 29 [cited 2025 Jun 6];10(8):1418. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9408330/

51. Donacho DO, Korsa Tura S, Tefera Kefeni B. Determinants of long-lasting insecticide-treated bed net utilization among pregnant women in Gechi District, Buno Bedele Zone, Southwest

Ethiopia: a community-based cross-sectional study. *Environ Health Insights* [Internet]. 2025 May 11 [cited 2025 Jun 6]; 19:11786302251335135. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC12066862/

52. Kassie GA, Adella GA, Gebrekidan AY, Gebeyehu NA, Gesese MM, Abebe EC, et al. Insecticide-treated bed net utilization and associated factors among pregnant women in Ethiopia: a systematic review and meta-analysis. *Malar J* [Internet]. 2023 Aug 2 [cited 2025 Jun 5]; 22:223. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10398969/

53. Demoze L, Adane KC, Gizachew N, Tesfaye AH, Yitageasu G. Utilization of insecticide-treated nets among pregnant women in East Africa: evidence from a systematic review and meta-analysis. *BMC Public Health* [Internet]. 2024 Nov 7 [cited 2025 Jun 2]; 24:3083. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11545497/

54. Tesfaye T, Alemu BM, Egata G, Bekele H, Merga BT, Eshetu B, et al. Insecticide-treated nets utilization and associated factors among pregnant women in Miesso Woreda, Eastern Ethiopia: observational study. *Int J Women's Health* [Internet]. 2022 Mar 31 [cited 2025 Jun 5]; 14:445. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8979939/

55. Eshetu B, Bekele H, Debella A, Eyeberu A, Balis B, Habte S, et al. Insecticide-treated net utilization and associated factors among pregnant women in Ethiopia: a systematic review and meta-analysis. *Front Glob Women's Health* [Internet]. 2023 Nov 6 [cited 2025 Jun 5];4:1147583. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10657856/

56. Negasa K, Huluka TK, Yebassa MA, Waqkene T. Utilization of long-lasting insecticide-treated net and its associated factors among pregnant women in Dawo District, Southwest Shoa Zone, Oromia, Ethiopia, 2023. *Front Public Health* [Internet]. 2024 Jan 29 [cited 2025 Jun 2];11:1261254. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10859520/

57. Kebede W, Tolcha A, Soboksa NE, Negassa B, Kanno GG, Aregu MB. Utilization of insecticide-treated nets in households for under-5 children and associated factors in East Mesekan District, Gurage Zone, Southern Ethiopia. *Environ Health Insights* [Internet]. 2023 Mar 26 [cited 2025 Jun 2]; 17:11786302231164287. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10052613/

58. Zerdo Z, Bastiaens H, Anthierens S, Massebo F, Masne M, Biresaw G, et al. Long-lasting insecticide-treated bed net ownership, utilization and associated factors among school-age children in Dara Mallo and Uba Debretsehay districts, Southern Ethiopia. *Malar J* [Internet]. 2020 Oct 15 [cited 2025 Jun 6]; 19:369. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7559455/

59. Salcedo-Mason S. Net gains in malaria prevention: in Ethiopia, new approaches to LLIN distribution achieve near universal coverage in high-risk areas [Internet]. Arlington (VA): USAID Global Health Supply Chain Program – Procurement and Supply Management; 2018 Dec 10 [cited 2025 Jun 6]. Available from: https://www.ghsupplychain.org/sites/default/files/2018-12/2018_12_10%20GHSC-PSM_Ethiopia_LLIN_Distribution_FINAL.pdf

60. Ajemu KF, Hadgu T, Gebreegziabher G, Ayele B, Gebretnsae H, Desta AA, et al. Conflict and fragmented public health emergency management system in Tigray region of Northern Ethiopia: a double burden to accommodate resilient and advanced public health emergency management. *Health Res Policy Syst* [Internet]. 2024 Sep 3 [cited 2025 Jun 2]; 22:121. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11370228/

61. Yitbarek GY, Haile Mariam D, Hailemariam M, Asfaw M, Yeshiwondim AK, Taffese HS, et al. Access to malaria prevention and control interventions among seasonal migrant workers: a multi-region formative assessment in Ethiopia [Internet]. *Malar J*. 2021 Feb 8 [cited 2025 Jun 29];20(1):75. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7901780/

62. The PMI VectorLink Project. *The PMI VectorLink Project final report: 2017–2023* [Internet]. Rockville (MD): Abt Associates; 2023 [cited 2025 Jun 6]. Available from: https://stacks.cdc.gov/view/cdc/146401

63. Mekasha W, Daba C, Malede A, Debela SA, Gebrehiwot M. The need for strengthening health information dissemination toward indoor residual spraying for malaria prevention in malarious area of Ethiopia. *Front Public Health* [Internet]. 2022 Jun 13 [cited 2025 Jun 6]; 10:913905. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9234660/

64. Ibrahim M, Beyene H, Tolcha A, Eskendir H, Assefa AA. Altering of the sprayed wall after indoor residual spraying and associated factors among households in Boricha district, Sidama regional state, Ethiopia, 2019: community-based cross-sectional study. *Malar J* [Internet]. 2023 May 2 [cited 2025 Jun 2]; 22:144. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10152723/

65. Necho W**.** Building end-to-end visibility into national LLIN distribution in Ethiopia: piloting interactive voice response as a scalable communication tool. Presented at: Global Health Supply Chain Summit; 2018 Dec 10–12; Lusaka, Zambia [Internet]. Lusaka (Zambia): GHSC Summit; 2018 [cited 2025 Jul 19].Available from: https://ghscs.com/wp-content/uploads/2018/12/15.3Building-end-to-end-visibility-into-national-LLIN-distribution-in-Ethiopia-piloting-of-interactive-voice-response-as-a-scalable-c%E2%80%A61.pdf

66. Nesara P. Unveiling malaria grant audits: insights from Global Fund projects in Ghana, Uganda, and Ethiopia [Internet]. African Constituency Bureau: 2024 March 7 [cited 2025 Jul 19]. Available from: https://www.africanconstituency.org/unveiling-malaria-grant-audits-insights-from-global-fund-projects-in-ghana-uganda-and-ethiopia/

67. The DHS Program. Ethiopia 2021–2022 Service Provision Assessment – Final Report [SPA36] [Internet]. Rockville, Maryland, USA: ICF International; 2023 [cited 2025 Jul 15]. Available from: https://dhsprogram.com/pubs/pdf/SPA36/SPA36.pdf

68. The Global Fund. Insecticide-Treated Nets Strategy. Presented at: ITN Supplier and Partner Consultative Meeting; 2023 Apr 18–20; Geneva, Switzerland [Internet]. Geneva (Switzerland): The Global Fund; 2023 [cited 2025 Jul 19]. Available from: https://www.theglobalfund.org/media/13043/psm_2023-04-itn-supplier-and-partner-consultative-meeting_presentation_en.pdf

69. Abate W, Nigatu W, Eukubay A, *et al.* Assessing longevity of long-lasting insecticidal nets in some selected sentinel sites of Ethiopia [Internet]. *ResearchGate*; 2019 Sep [cited 2025 Jul 19]. Available from: https://www.researchgate.net/publication/336020865_Assessing_longivity_of_long_lasting_insecticidal_nets_in_some_selected_sentinal_sites_of_Ethiopia

70. Wubishet MK, Berhe G, Adissu A, Tafa MS. Effectiveness of long-lasting insecticidal nets in prevention of malaria among individuals visiting health centres in Ziway-Dugda District, Ethiopia: matched case–control study. *Malar J* [Internet]. 2021 Jul 3 [cited 2025 Jun 6]; 20:301. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8254940/

71. Hiruy HN, Irish SR, Abdelmenan S, Wuletaw Y, Zewde A, Woyessa A, et al. Durability of long-lasting insecticidal nets (LLINs) in Ethiopia. *Malar J* [Internet]. 2023 Mar 26 [cited 2025 Jun 5]; 22:109. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10041722/

72. Chanyalew T, Natea G, Amenu D, Yewhalaw D, Simma EA. Composition of mosquito fauna and insecticide resistance status of *Anopheles gambiae* sensu lato in Itang special district, Gambella, Southwestern Ethiopia. *Malar J* [Internet]. 2022 Apr 18 [cited 2025 Jun 5]; 21:125. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9014582/

73. Demissew A, Animut A, Kibret S, Tsegaye A, Hawaria D, Degefa T, et al. Evidence of pyrethroid resistance in *Anopheles amharicus* and *Anopheles arabiensis* from Arjo-Didessa irrigation scheme, Ethiopia. *PLoS One* [Internet]. 2022 Jan 14 [cited 2025 Jun 5];17(1):e0261713. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8759678/

74. Kendie FA, Wale M, Nibret E, Ameha Z. Insecticide susceptibility status of *Anopheles gambiae* (s.l.) in and surrounding areas of Lake Tana, northwest Ethiopia. *Trop Med Health* [Internet]. 2023 Jan 13 [cited 2025 Jun 2]; 51:3. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9838068/

75. Simma EA, Zegeye H, Akessa GM, Kifle YG, Zemene E, Degefa T, et al. Determination of the residual efficacy of broflanilide (VECTRONTM T500) insecticide for indoor residual spraying in a semi-field setting in Ethiopia. *Malar J* [Internet]. 2025 Feb 13 [cited 2025 Jun 6]; 24:44. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11823107/

76. Yewhalaw D, Simma EA, Zemene E, Zeleke K, Degefa T. Residual efficacy of SumiShieldTM 50WG for indoor residual spraying in Ethiopia. *Malar J* [Internet]. 2022 Dec 2 [cited 2025 Jun 5]; 21:364. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9716761/

77. Animut A, Horstmann S. Residual efficacy of Fludora Fusion against *Anopheles arabiensis* in simple huts in Ethiopia. *PLoS One* [Internet]. 2022 Feb 11 [cited 2025 Jun 5];17(2): e0263840. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8836335/

78. Yewhalaw D, Balkew M, Zemene E, Chibsa S, Mumba P, Flatley C, et al. An experimental hut study evaluating the impact of pyrethroid-only and PBO nets alone and in combination

with pirimiphos-methyl-based IRS in Ethiopia. *Malar J* [Internet]. 2022 Aug 20 [cited 2025 Jun 5]; 21:238. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9392245/

79. Davis KM, Worku A, Balkew M, Mumba P, Chibsa S, Tongren JE, et al. An observational study evaluating the epidemiological and entomological impacts of piperonyl butoxide insecticide-treated nets (ITNs) compared to a combination of indoor residual spraying (IRS) plus standard pyrethroid-only ITNs in Amhara Region, Ethiopia, 2019–2023. *BMJ Glob Health* [Internet]. 2025 Jan 29 [cited 2025 Jun 2];10(1): e016617. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11781093/

80. Gari T, Lindtjørn B. Insecticide-treated bed nets and residual indoor spraying reduce malaria in areas with low transmission: a reanalysis of the Maltrials study. *Malar J* [Internet]. 2024 Mar 4 [cited 2025 Jun 2];23:67. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10913548/

81. Balkew M, Mumba P, Yohannes G, Abiy E, Getachew D, Yared S, et al. An update on the distribution, bionomics, and insecticide susceptibility of *Anopheles stephensi* in Ethiopia, 2018–2020. *Malar J* [Internet]. 2021 Jun 9 [cited 2025 Jun 5]; 20:263. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8189708/

82. Samake JN, Yared S, Getachew D, Mumba P, Dengela D, Yohannes G, et al. Detection and population genetic analysis of *kdr* L1014F variant in eastern Ethiopian *Anopheles stephensi*. *Infect Genet Evol* [Internet]. 2022 Feb 2 [cited 2025 Jun 5]; 99:105235. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC11959535/

83. Zhong D, Degefa T, Zhou G, Lee MC, Wang C, Chen J, et al. Esterase-mediated pyrethroid resistance in populations of an invasive malaria vector *Anopheles stephensi* from Ethiopia. *Genes (Basel)* [Internet]. 2024 Dec 15 [cited 2025 Jun 6];15(12):1603. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11675767/

84. Eba K, Duchateau L, Olkeba BK, Boets P, Bedada D, Goethals PLM, et al. Bio-control of *Anopheles* mosquito larvae using invertebrate predators to support human health programs in Ethiopia. *Int J Environ Res Public Health* [Internet]. 2021 Feb 12 [cited 2025 Jun 5];18(4):1810. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC7917980/

85. Gonzalez-Olvera G, Yared S, Aklilu E, Gebresilassie A, Bibiano-Marin W, Che-Mendoza A, et al. Laboratory evaluation of efficacy of the larvicide spinosad against *Anopheles stephensi* in Jigjiga, Ethiopia. *J Am Mosq Control Assoc* [Internet]. 2023 Dec 1 [cited 2025 Jun 2];39(4):284–7. Available from: https://jamca.kglmeridian.com/view/journals/moco/39/4/article-p284.xml

86. Mutero CM, Okoyo C, Girma M, Mwangangi J, Kibe L, Ng'ang'a P, et al. Evaluating the impact of larviciding with Bti and community education and mobilization as supplementary integrated vector management interventions for malaria control in Kenya and Ethiopia. *Malar J* [Internet]. 2020 Nov 3 [cited 2025 Jun 6]; 19:390. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7607826/

87. Debebe Y, Tekie H, Dugassa S, Hopkins RJ, Hill SR, Ignell R. Mosquito odour-baited mass trapping reduced malaria transmission intensity: a result from a controlled before-and-after

intervention study. *BMC Med* [Internet]. 2024 Jan 29 [cited 2025 Jun 6]; 22:41. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10823605/

88. Teklemariam Z, Awoke A, Dessie Y, Weldegebreal F. Ownership and utilization of insecticide-treated nets (ITNs) for malaria control in Harari National Regional State, Eastern Ethiopia. *Pan Afr Med J* [Internet]. 2015 May 25 [cited 2025 Jul 17]; 21:52. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4564406/

89. Federal Ministry of Health of Ethiopia. Case study for distributing ITNs during the COVID-19 pandemic in Afar, Benishangul-Gumuz and Gambella, Ethiopia, October 2020. Addis Ababa, Ethiopia: Federal Ministry of Health of Ethiopia; 2020 [Internet]. [cited 2025 Jul 17]. Available from: https://allianceformalariaprevention.com/wp-content/uploads/2021/03/CS_Campaign_Ethiopia_COVID_122020_EN.pdf

90. Johns B, Yihdego YY, Kolyada L, Dengela D, Chibsa S, Dissanayake G, et al. Indoor residual spraying delivery models to prevent malaria: comparison of community- and district-based approaches in Ethiopia. *Glob Health Sci Pract* [Internet]. 2016 Dec 23 [cited 2025 Jul 17];4(4):529–41. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5199172/

91. Asale A, Kussa D, Girma M, Mbogo C, Mutero CM. Community-based integrated vector management for malaria control: lessons from three years' experience (2016–2018) in Botor-Tolay district, southwestern Ethiopia. *BMC Public Health* [Internet]. 2019 Oct 21 [cited 2025 Jul 18];19(1):1318. Available from: https://doi.org/10.1186/s12889-019-7606-3

92. Eligo N, Wegayehu T, Pareyn M, Tamiru G, Lindtjørn B, Massebo F. *Anopheles arabiensis* continues to be the primary vector of *Plasmodium falciparum* after decades of malaria control in southwestern Ethiopia. *Malar J* [Internet]. 2024 Jan 9 [cited 2025 Jun 2]; 23:14. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10777518/

93. Tarekegn M, Dugassa S, Negash Y, Tekie H, Woldehawariat Y. A survey of malaria vectors feeding preference, biting site and resting behaviour in the malaria elimination settings of Dembiya District, north-western Ethiopia. *Malar J* [Internet]. 2024 Nov 20 [cited 2025 Jun 2]; 23:352. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11580510/

94. Adugna T, Getu E, Yewhalaw D. Species diversity and distribution of *Anopheles* mosquitoes in Bure district, Northwestern Ethiopia. *Heliyon* [Internet]. 2020 Oct 16 [cited 2025 Jun 5];6(10): e05063. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7569303/

95. Bedasso AH, Gutto AA, Waldetensai A, Eukubay A, Bokore GE, Kinde S, et al. Malaria vector feeding, peak biting time and resting place preference behaviors in line with indoor based intervention tools and its implication: scenario from selected sentinel sites of Ethiopia. *Heliyon* [Internet]. 2022 Dec 8 [cited 2025 Jun 6];8(12): e12178. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9791363/

96. Demissew A, Hawaria D, Kibret S, Animut A, Tsegaye A, Lee MC, et al. Impact of sugarcane irrigation on malaria vector *Anopheles* mosquito fauna, abundance and seasonality in Arjo-Didessa, Ethiopia. *Malar J* [Internet]. 2020 Sep 22 [cited 2025 Jun 6]; 19:344. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7510110/

97. Hawaria D, Kibret S. Increased malaria incidence following irrigation practices in the Endorheic Rift Valley Basin of Sidama Region, Ethiopia. *PLoS One* [Internet]. 2023 Apr 25 [cited 2025 Jun 2];18(4): e0284247. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10128979/

98. Jiang A, Lee M, Selvaraj P, Degefa T, Getachew H, Merga H, et al. Investigating the impact of irrigation on malaria vector larval habitats and transmission using a hydrology-based model. *Geohealth* [Internet]. 2023 Dec 10 [cited 2025 Jun 2];7(12): e2023GH000868. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10711417/

99. Degefa T, Githeko AK, Lee MC, Yan G, Yewhalaw D. Patterns of human exposure to early-evening and outdoor biting mosquitoes and residual malaria transmission in Ethiopia. *Acta Trop* [Internet]. 2021 Apr [cited 2025 Jun 6]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8682696/

100. Mekebo M, Gobena T, Hawulte B, Tamiru D, Debella A, Yadeta E, et al. Level of implementation of district health information system 2 at public health facilities in Eastern Ethiopia. *DIGITAL HEALTH* [Internet]. 2022 Jan 1 [cited 2025 Jul 16]; 8:20552076221131151. Available from: https://doi.org/10.1177/20552076221131151

101. Getachew N, Erkalo B, Garedew MG. Data quality and associated factors in the health management information system at health centers in Shashogo district, Hadiya zone, southern Ethiopia, 2021. *BMC Med Inform Decis Mak*. 2022 Jun 15;22(1):154. Available from: https://bmcinformdecismak.biomedcentral.com/articles/10.1186/s12911-022-01904-x

102. Operational Research and Coaching for Analysts (ORCA) - participants & team, Adane A, Adege TM, Ahmed MM, Anteneh HA, Ayalew ES, et al. Exploring data quality and use of the routine health information system in Ethiopia: a mixed-methods study. *BMJ Open*. 2021 Dec 23;11(12): e050356. Available from: https://bmjopen.bmj.com/content/11/12/e050356

103. Tilahun B, Gashu KD, Mekonnen ZA, Endehabtu BF, Asressie M, Minyihun A, et al. Strengthening the national health information system through a capacity-building and mentorship partnership (CBMP) programme: a health system and university partnership initiative in Ethiopia. *Health Research Policy and Systems* [Internet]. 2021 Dec 9 [cited 2025 July 16];19(1):141. Available from: https://doi.org/10.1186/s12961-021-00787-x

104. Dereje S, Birhanu A, Alemu K. Assessment of malaria data quality practice and its potential factors in Nedjo Woreda, West Wellega Zone, Oromia Regional State, West Ethiopia [Internet]. *Research & Reviews: Journal of Medical and Health Sciences*. 2019 [cited 2025 Aug 4] .Available from: https://www.rroij.com/open-access/assessment-of-malaria-data-quality-practice-and-its-potential-factors-in-nedjo-woreda-west-wellega-zone-oromia-regional-.pdf

105. Animut A, Lindtjørn B. Use of epidemiological and entomological tools in the control and elimination of malaria in Ethiopia. *Malar J* [Internet]. 2018 Jan 12 [cited 2025 July 16];17(1):26. Available from: https://doi.org/10.1186/s12936-018-2172-1

106. Federal Ministry of Health of Ethiopia. *Training of Health Extension Workers (HEW) on family folder and HMIS procedures* [Internet]. [cited 2025 July 28]. Available from: https://www.measureevaluation.org/resources/publications/ms-13-68.html

107. Melaku MS, Yohannes L. Data management practice of health extension workers and associated factors in Central Gondar Zone, northwest Ethiopia. *Front Digit Health* [Internet]. 2024 Nov 6 [cited 2025 July 28]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11576454/

108. Omer AM, Kinfe A, Denboba W, Kebede E, Birhan D, Alemu E, et al. Barriers and facilitators of the Electronic Community Health Information System (eCHIS) in Ethiopia: Practical Guidance for improved its implementation guided by the Consolidated Framework for Implementation Research (CFIR). [Internet]. *Ethiop J Health Dev*. 2024 [cited 2025 Jul 16]. Available from: https://ejhd.org/index.php/ejhd/article/view/1449

109. MalariaGEN: The Malaria Genomic Epidemiology Network [Internet]. Cambridge (UK): MalariaGEN; 2025 [cited 2025 July 18]. Available from: https://www.malariagen.net/

110. Entomological Surveillance Planning Tool (ESPT) Information and Communications Technology (ICT) Project [Internet]. MESA. [cited 2025 July 18]. Available from: https://mesamalaria.org/mesa-track/entomological-surveillance-planning-tool-espt-information-and-communications-technology/

111. USAID is linchpin in Ethiopia's fight against communicable diseases, malaria prevention and HIV/AIDS treatment. [Internet]. Ethiopian Tribune. 2025 [cited 2025 July 17]. Available from: https://ethiopiantribune.com/2025/03/usaid-is-linchpin-in-ethiopias-fight-against-communicable-diseases-malaria-prevention-and-hiv-aids-treatment/

112. Health gains and financial risk protection afforded by public financing of selected malaria interventions in Ethiopia: an extended cost-effectiveness analysis - *PMC* [Internet]. [cited 2025 July 17]. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC6979328/

113. Edossa DG, Wedajo AG, Koya PR. Optimal Combinations of Control Strategies and Cost-Effectiveness Analysis of Dynamics of Endemic Malaria Transmission Model. Computational and Mathematical Methods in Medicine [Internet]. 2023 May 29 [cited 2025 June 5]; 2023:7677951. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC10241587/

114. Addis B, Akele W, Minyihun A. Factors Influencing Willingness to Pay for Insecticidal Treated Bed Nets Among Rural Households of Bugina District North Wollo Zone, North-East Ethiopia. *Clinicoecon Outcomes Res* [Internet]. 2022 Apr 5 [cited 2025 June 6]; 14:179–87. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8994694/

115. Federal Ministry of Health Ethiopia. National Malaria Elimination Program (NMEP) [Internet]. Addis Ababa, Ethiopia: Federal Ministry of Health; 2023 [cited 2025 July 16]. Available from: https://www.moh.gov.et/en/National_Malaria_Elimination_Program?language_content_entity=en

116. Gosling R, Chimumbwa J, Uusiku P, Rossi S, Ntuku H, Harvard K, et al. District-level approach for tailoring and targeting interventions: a new path for malaria control and elimination. *Malar J* [Internet]. 2020 Mar 30 [cited 2025 July 18];19(1):125. Available from: https://doi.org/10.1186/s12936-020-03185-w

117. Aliye M, Hong T. Role of health extension workers in the relationship between vector control interventions and malaria in Ethiopia. *BMC Infect Dis* [Internet]. 2021 Nov 8 [cited 2025 June 6]; 21:1140. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8573560/

118. Ahn J, Sinka M, Irish S, Zohdy S. Modeling marine cargo traffic to identify countries in Africa with greatest risk of invasion by Anopheles stephensi. *Sci Rep* [Internet]. 2023 Jan 17 [cited 2025 June 2]; 13:876. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9843102/

119. Yared S, Gebresilassie A, Aklilu E, Abdulahi E, Kirstein OD, Gonzalez-Olvera G, et al. Building the vector in: construction practices and the invasion and persistence of Anopheles stephensi in Jigjiga, Ethiopia. *Lancet Planet Health* [Internet]. 2023 Dec [cited 2025 June 2];7(12):e999–1005. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11707895/

120. Tilaye T, Tessema B, Alemu K, Yallew WW. Perceived causes and solutions for malaria prevalence among seasonal migrant workers in Northwest Ethiopia: a qualitative study. *Malar J* [Internet]. 2025 Feb 17 [cited 2025 June 2]; 24:47. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11834219/

121. Rwanda Vital Statistics Report 2024_N.pdf [Internet]. [cited 2025 Jul 2]. Available from: https://statistics.gov.rw/sites/default/files/documents/2025-04/Rwanda%20Vital%20Statistics%20Report%202024_N.pdf

122. Umugwaneza A, Mutsaers M, Ngabonziza JCS, Kattenberg JH, Uwimana A, Ahmed A, et al. Half-decade of scaling up malaria control: malaria trends and impact of interventions from 2018 to 2023 in Rwanda. *Malar J* [Internet]. 2025 Feb 12 [cited 2025 Jun 30]; 24:40. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11817622/

123. Rwanda Biomedical Centre. *Rwanda Malaria Strategic Plan 2020–2024* [Internet]. [cited 2025 Jul 11]. Available from: https://rbc.gov.rw/fileadmin/user_upload/report23/Rwanda%20Malaria%20Strategic%20Plan%202020-2024.pdf

124. Karema C, Wen S, Sidibe A, Smith JL, Gosling R, Hakizimana E, et al. History of malaria control in Rwanda: implications for future elimination in Rwanda and other malaria-endemic countries. *Malar J* [Internet]. 2020 Oct 7 [cited 2025 Jul 2];19(1):356. Available from: https://doi.org/10.1186/s12936-020-03407-1

125. Hakizimana E, Ingabire CM, Rulisa A, Kateera F, van den Borne B, Muvunyi CM, et al. Community-Based Control of Malaria Vectors Using *Bacillus thuringiensis* var. *israelensis* (Bti) in Rwanda. *Int J Environ Res Public Health* [Internet]. 2022 Jan [cited 2025 Jul 2];19(11):6699. Available from: https://www.mdpi.com/1660-4601/19/11/6699

126. Munyakanage D, Niyituma E, Mutabazi A, Misago X, Musanabaganwa C, Remera E, et al. The impact of *Bacillus thuringiensis* var. *israelensis* (Bti) larvicide sprayed using drones for bio-control of malaria vectors in rice fields of Kigali Sub-Urban, Rwanda [Internet]. Research Square; 2024 [cited 2025 Jul 2]. Available from: https://www.researchsquare.com/article/rs-4257583/v1

127. Okumu F, Moore SJ, Selvaraj P, Yafin AH, Juma EO, Shirima GG, et al. Elevating larval source management as a key strategy for controlling malaria and other vector-borne diseases in Africa. *Parasit Vectors* [Internet]. 2025 Feb 7 [cited 2025 Jun 18]; 18:45. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11803969/

128. Murindahabi MM, Takken W, Misago X, Niyituma E, Umupfasoni J, Hakizimana E, et al. Monitoring mosquito nuisance for the development of a citizen science approach for malaria vector surveillance in Rwanda. *Malar J* [Internet]. 2021 Jan 10 [cited 2025 Jul 2];20(1):36. Available from: https://doi.org/10.1186/s12936-020-03579-w

129. Murindahabi MM, Takken W, Hakizimana E, van Vliet AJH, Poortvliet PM, Mutesa L, et al. A handmade trap for malaria mosquito surveillance by citizens in Rwanda. *PLoS One* [Internet]. 2022 May 11 [cited 2025 Jul 3];17(5): e0266714. Available from: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0266714

130. Asingizwe D, Poortvliet PM, van Vliet AJH, Koenraadt CJM, Ingabire CM, Mutesa L, et al. What do people benefit from a citizen science programme? Evidence from a Rwandan citizen science programme on malaria control. *Malar J* [Internet]. 2020 Aug 6 [cited 2025 Jun 30];19:283. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7409712/

131. Gansané A, Candrinho B, Mbituyumuremyi A, Uhomoibhi P, Nfalé S, Mohammed AB, et al. Design and methods for a quasi-experimental pilot study to evaluate the impact of dual active ingredient insecticide-treated nets on malaria burden in five regions in sub-Saharan Africa. *Malar J* [Internet]. 2022 Jan 10 [cited 2025 Jul 12]; 21:19. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8744060/

132. Kabera M, Mangala JLN, Soebiyanto R, Mukarugwiro B, Munguti K, Mbituyumuremyi A, et al. Impact of Pyrethroid Plus Piperonyl Butoxide Synergist-Treated Nets on Malaria Incidence 24 Months after a National Distribution Campaign in Rwanda. *Am J Trop Med Hyg* [Internet]. 2023 Dec [cited 2025 Jul 12];109(6):1356–62. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10793038/

133. DePina AJ, Gomes JAL, Moreira AL, Niang EHA. Situational analysis of malaria in Cabo Verde: From endemic control to elimination, history, cases data and challenges ahead. *PLOS Glob Public Health* [Internet]. 2025 Jan 10 [cited 2025 Jul 21];5(1): e0004153. Available from: https://journals.plos.org/globalpublichealth/article?id=10.1371/journal.pgph.0004153

134. DePina AJ, Niang EHA, Barbosa Andrade AJ, Dia AK, Moreira A, Faye O, et al. Achievement of malaria pre-elimination in Cape Verde according to the data collected from 2010 to 2016. *Malar J* [Internet]. 2018 Jun 19 [cited 2025 Jul 21];17(1):236. Available from: https://doi.org/10.1186/s12936-018-2376-4

135. World Health Organization. *E-2020 Country Briefs* [Internet]. [cited 2025 Jul 21]. Available from: https://cdn.who.int/media/docs/default-source/malaria/elimination/e-2020-country-briefs.pdf?sfvrsn=491d7810_5

136. World Health Organization. *Zeroing in on malaria elimination: final report of the E-2020 initiative* [Internet]. Geneva: World Health Organization; 2021 [cited 2025 Jul 21]. Available from: https://www.who.int/publications/i/item/9789240025702

137. Central Intelligence Agency. *Algeria.* In: *The World Factbook* [Internet]. Washington, DC: CIA; 2025 [cited 2025 Jul 22]. Available from: https://www.cia.gov/the-world-factbook/countries/algeria/

138. World Health Organization. *Algeria Country Overview* [Internet]. [cited 2025 Jul 22]. Available from: https://www.who.int/countries/dza

139. World Bank. *Climate Change Knowledge Portal* [Internet]. Washington, DC: The World Bank; 2025 [cited 2025 Jul 22]. Available from: https://climateknowledgeportal.worldbank.org/

140. Roll Back Malaria. *Algeria 2016 Country Brief* [Internet]. Geneva, Switzerland: Roll Back Malaria Partnership; 2016 [cited 2025 Jul 21]. Available from: https://shrinkingthemalariamap.org/sites/default/files/resources/Algeria2016_Final.pdf

141. Unwin V. *Algeria sets precedent for malaria elimination in other African countries* [Internet]. BugBitten (Biomed Central blog); 2019 Aug 9 [cited 2025 Jul 21]. Available from: https://blogs.biomedcentral.com/bugbitten/2019/08/09/a-malaria-elimination-catch-up-algeria-leads-the-way/