Jimma University

School of Graduate Studies

Collage of Natural Science

Department of Biology

Trend analysis of malaria prevalence in relation to climate variables in Mettu town, Oromia Region, South west Ethiopia.

By:

Fikadu Alehegn

October, 2015

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Advisor: Delenasaw Yewhalaw (PhD.)
Eba Alemayehu (PhD. Candidate)

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September, 2015

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Declaration

I, the undersigned, hereby declare that this thesis is my original work, has not been presented for a degree in any other University and all sources of materials used for the study have been duly acknowledged.

Name**:** Fikadu Alehegn

Signature___________

Date__________

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List of acronyms

ACT: Artemisin-based combination therapy

BCC: Behavioural Change Communication

DDT: Dichlorodiphenyltetrachloro ethane

FAO: Food and Agriculture Organization

FMOH: Federal Ministry of Health

GGHD: Gilgel-Gibe Hydroelectric Dam

RBM: Global Roll Back Malaria

HEWs: Health Extension Workers

HSEP: Health Services Extension Program

IRS: Indoor Residual Spraying

ITNs: Insecticide Treated Nets

LLINs: Long-lasting, insecticide-treated bed nets

MIS: Malaria Indicator Survey

MOH: Ministry of Health

RDT: Rapid diagnostic test

SSA: Sub-Saharan Africa

SP: Sulfadoxine-pyrimethamine

SPSS: Statistical Package for the Social Sciences

USAID: United States Agency for International Development

WHO: World Health Organization

Abstract

Malaria is a major global health concern. It is also one of the leading causes of illness and death in Ethiopia. A retrospective study was conducted to determine malaria prevalence in relation to climate variables in the years 2000 – 2014 in Mettu town, Illubabora Zone, South West Ethiopia. Malaria prevalence was determined using data obtained from Mettu health facilities and the meteorological data for minimum temperature, maximum temperature, rainfall and relative humidity of the past fifteen years (2000- 2014) were obtained from Mettu Meteorology agency/office. The obtained data were analyzed using SPSS software package, version 16.0. Within the last fifteen years (2000-2014) a total of 51,865 cases were visited the health facilities for malaria diagnosis and a total of 9,816 microscopically confirmed malaria cases were recorded from the town with the annual total case of malaria ranged from 110 in 2007 to 1644 in 2010 with 654 mean annual malaria cases. The overall malaria prevalence in the study area was 19%. Males were more affected than females but this varied year to year. The infection rate among males was 55.8% (5,474/9,816) and females was 44.2% (4,342/9,816). Malaria was reported in all age groups from the area but the age group 15–44 was the most affected with a prevalence rate of 44.3% (4349/9,816), while the age group <1 years was the least affected (3.6%). A high predominance of P. falciparum over P. vivax was recorded with 61.3% and 34.3% respectively. Highly significant positive correlation was observed between monthly maximum temperature and malaria (r = 0.88; p=0.000), between minimum temperature and malaria (r = 0.874; p=0.000), between mean temperature and malaria (r = 0.85; p=0.000), between rainfall and malaria (r = 0.79; p=0.000) and between mean relative humidity and malaria (r = 0.876; p=0.000). Finally the result of this study helps the malaria control program to understand the trend of malaria and the impact of climate variables on malaria in the past fifteen years in the study setting.

1. Introduction

Malaria has been a major public health problem throughout human history, particularly in the tropical and subtropical parts of the world (Raghavendra, 2011). Globally, an estimated 3.3 billion people were at risk of being infected with malaria and developing disease, and 1.2billion are at risk, with populations living in sub-Saharan Africa having the highest risk of acquiring malaria, approximately 80% of cases and 90% of deaths are estimated occur in the world health organization (WHO) African Region, with children under five years of age and pregnant women most severely affected. The burden is heaviest in the WHO African Region, where an estimated 90% of all malaria deaths occur, followed by the WHO South-East Asia Region (7%) and the WHO Eastern Mediterranean Region (2%), and in children aged under 5 years, who account for 78% of all deaths(WHO, 2014; 2012).

There are some evidences that shows malaria and poverty are intimately connected and currently given as a cause of poverty in poor malarias countries. World health organization (WHO) report has shown that the disease is estimated to be responsible for an estimated average annual reduction of 1.3% in economic growth for those countries with the highest burden (WHO, 2005; 2002).The malaria eradication program had little success in many parts of Africa south of the Sahara. The number of people at risk of malaria in this Region grew to over 74% (about 600 million) at the end of the 20th century (Hay *et al.*, 2004; Carter and Mendis, 2002). These upward demographic changes have important implications for malaria control since the proportion of the population residing in malarias areas is increasing through time.

Malaria admission rates are projected to decrease by 50ï 75% by 2015 in Ethiopia (based on a study in 41 hospitals (Aregawi *et al.,* 2014*)*. Decreases in malaria admissions were also seen in Mozambique, but no comparable data from earlier than 2007 are available. Recent increases in admissions and deaths in Madagascar reflect the fragility of the gains achieved if control efforts are not maintained. The high transmission season coincides with the cultivation months; hence malaria has a deleterious effect on agricultural production (WHO, 2013). Studies have shown that the *Plasmodium species* compositions and the number of malaria cases vary over time Zhou *et al.,* (2011) due to different factors, such as previous weather conditions or intervention measures. In Ethiopia, malaria is one of the most important public health problems, with more than three-quarters of the landmass (altitude <2000 m) of the country is either malarias or potentially malarias, and an estimated 68% (>50 million people) of the total population resides in areas at risk of malaria infections (UN Population Division New York, 2013; Adhanom *et al.,* 2006). Annually, half a million microscopically confirmed cases of malaria are reported to the Federal Ministry of Health (FMOH) from basic health services. A primary health care unit consists of a health centre and, a number of health posts together serving population under the health centers. The health centers usually include health professionals, including laboratory technicians and technologists, thus cases with fever are often tested for malaria. The health posts are staffed by health extension workers in 2005, and they can conduct also rapid diagnostic tests for malaria suspected cases and treat uncomplicated malaria cases at health posts level which are part of the primary health care unit (Karunamoorthi and Bekele, 2012).

Health Services Extension Program (HSEP)was introduced in Ethiopia in 2003 as part of the primary health care service (MOH, 2004).Health Extension Workers (HEW) who had been trained and deployed since 2005 (Teklehaimanot *et al*., 2007). The program aims for the universal coverage of primary health care through focusing on the prevention and control of priority communicable diseases with active community participation. As of 2007/2008, 24, 571 Health Extension Workers (HEWs) have been trained and deployed in different parts of the country (MOH, 2007/2008). By 2009 over 30,000 HEWs had been deployed (Teklehaimanot, 2013). The coverage of health services and community-based malaria control interventions through the HSEP has been significantly improved particularly since 2005. The major activities of HEWs with regard to malaria prevention and control, as outlined in the malaria extension package (MOH, 2004), include educating community on mode of malaria transmission and its prevention, promotion of the use of Insecticide Treated Nets (ITNs) and Indoor Residual Spraying (IRS), community mobilization on environmental management for elimination of mosquito breeding sites, epidemic monitoring and detection, and dispensing anti-malarial drugs for people with signs and symptoms of the disease. But the impact of the resistance to Dichlorodiphenyltetrachloro ethane (DDT) and perimethrin/deltamethrin on vector control interventions in Ethiopia should be further investigated. As a result it is needed to guide the further use of insecticides in malaria control programs and vector resistance management interventions such as the need for alternatives to the currently used DDT and perimethrin/deltamethrin for IRS and treatment of mosquito nets, respectively. In Ethiopia, populations of *An. arabiensis*, the major malaria vector in the country, developed resistance to three (organochlorines, organophosphates and pyrethroids) out of the four insecticide families commonly used for public health use (Yewhalaw *et al.,* 2010). Therefore, alternative malaria vector control tools, targeting mosquito immatures either alone or as part of integrated vector management, should be envisaged to reduce human-vector contact and hence malaria transmission intensity.

P. falciparum and *P.vivax* are the most dominant malaria parasites in Ethiopia. They are prevalent in all malarious areas in the country with *P.falciparum* representing about two-thirds to three-quarters of the cases, although their relative composition can be variable. *P. malariae* and *P. ovale* are rare and account for <1% of all confirmed malaria cases. The major malaria vector incriminated in Ethiopia is *An. arabiensis*; in some areas *An. pharoensis*, *An. funestus* and *An. nili* also transmit malaria (MOH, 1997).

Malaria has been a major cause of both morbidity and mortality in Oromia Regional State. Despite the accurate and reliable information on the burden of the disease were necessary for current interventions deployed to revitalize the fight against malaria. Quantitative data have been provided from healthy information systems, the use and interpretation have been maximized for planning and timely decision-making and assessing the burden and health impact of malaria. Routine reports on malaria morbidity and mortality are compiled monthly and annually from healthy facilities. Thus, health facility records are important sources of malaria data, because they are readily available and can provide useful indicators on the situation of malaria. They are useful not only for planning malaria control and evaluating the impact of health services but also for epidemiological surveillance. If properly utilized, this information will urge the decision makers to act timely to intensify malaria control interventions effectively and efficiently (Deressa *et al.*, 2004).

1.1. Statement of the problem

According to the world health organization(WHO, 2011), of the 216 million cases of malaria in 2010, most of the deaths occur among children in Africa where a child dies of malaria every minute and the disease accounts for approximately 22% of all childhood deaths.

In Ethiopia, malaria transmission is known to be highly heterogeneous between Regional States, zones, districts and municipalities. Similarly, the Malaria Indicator Survey (MIS) data could also show that malaria is unstable. Oromia Region with an estimated population of 27.2 million in 2007(National Census Preliminary Report for Ethiopia,2008). About 37% of the countryǿs population lives in Oromia Region and only about 13% of the population resides in urban areas. Malaria in Oromia is also considered to be the most important communicable disease. Three quarters of the region, are considered malarious, accounting for over 17 million persons at risk of infection. There are an estimated 1.5 to 2 million clinical cases per year, with malaria accounting for 20-35% of outpatient consultations, 16% of hospital admissions, and 18-30% of hospital deaths in the region (MOH, 2010).

Thus, Illubabora Zone including Mettu malaria has become the most common cause of out-patient visits in the area. Currently, it is unknown whether the observed increase or decrease in malaria is due to a real change in malaria transmission. Malaria transmission is predominantly unstable with frequent and often large-scale epidemics. The impact of malaria, in addition to its health consequences, is a significant impediment to social and economic development in the country. In the area, malaria strikes during planting, harvesting seasons, cutting down productive capacity at a time when there is the greatest need for agricultural work. The disease is also associated with loss of work force and time both of the sick and the family members, who provide care, low school attendance, and high treatment cost as well as school absenteeism. Health facilities are also overwhelmed with patients and a lot of resources are required to deal with the emergency situation.

Instead, the economic impact of malaria is very significant in the area, as the countryǿs economy is based on agriculture and peak malaria transmission coincides with the planting and harvesting season and malaria has forced people to inhabit the less agriculturally productive. Based on the above dispute this study attempted to assess the impact of climate variables on the prevalence of malaria.

This study was conducted to answer the following questions.

1. What does malaria prevalence trends look like over the course of fifteen years?
2. What does malaria prevalence looks like by sex and age over the past fifteen years?
3. What does the distribution of malaria cases by *plasmodium parasite species* among different age groups and season look like over the past fifteen years?
4. Is there correlation between malaria and meteorological variables?

1.2. Objective

1.2.1. General objective

- The General objective of the study is to investigate trend analysis of malaria prevalence in relation to climate variables in Mettu town, Southwest Ethiopia from 2000 – 2014
- 1.2.2 Specific objectives
- To determine annual trends of malaria dynamics in Mettu town, Southwest Ethiopia from 2000 – 2014.
- To determine sex and age specific malaria cases in Mettu town, Southwest Ethiopia from 2000 – 2014.
- To determine the distribution of malaria cases by *Plasmodium parasite species* among different age groups and seasons in Mettu town, Southwest Ethiopia from 2000 – 2014.
- To assess the correlation between climate variables and malaria in Mettu town, Southwest Ethiopia from 2000 – 2014.

1.3 Significance of the study

In the new strategic plan of United States Agency for International Development (USAID) for center for disease control and prevention in 2010, community empowerment and social mobilization are given top priority among malaria control strategies following the MIS 2007, which showed substantial differences between the coverage and utilization of key malaria interventions by the population at risk of malaria. Similarly, malaria case management, disease surveillance and epidemic control are geared to serve Ethiopiaôs goal of shrinking malaria endemic areas by 2015 and country-wide elimination by 2020.

Accordingly, surveillance is planned to focus mainly on individual human cases to identify the sources of infection and limit further spread of malaria transmission. Thus in this study area with a poor health information system, the little information that is available is frequently unreliable. Hence, this study has attempted to assess the impact of climatic factors on the prevalence of malaria and the trends of malaria dynamics indicating that scale-up of malaria risk factor interventions to prevent and control. The result of this study would be used as base line information for researches that have envisioned compressively understanding the trends of malaria prevalence and the impact of climatic factors on the prevalence of malaria and thereby designing holistic interventions approach.

2. Literature Review

2.1 Global Malaria Burden

Globally, it is estimated that 670 million fewer cases and 4.3 million fewer malaria deaths occurred between 2001 and 2013 than would have occurred had incidence and mortality rates remained unchanged since 2000. Of the estimated 4.3 million deaths averted between 2001 and 2013, 3.9 million (92%) were in children aged under 5 years in sub-Saharan Africa (WHO, 2014). Thus, reductions in malaria deaths have contributed substantially to progress towards achieving the target for Millennium Development Goals, which is to reduce, by two thirds, the under-5 mortality rate between 1990 and 2015 (Radeva-Petrova, 2014).

Between 2000 and 2013, estimated malaria mortality rates decreased by 47% worldwide and by 54% in the WHO African Region. They are estimated to have decreased by 53% in children aged less than 5 years globally, and by 58% in the WHO African Region. If the annual rate of decrease that has occurred over the past 13 years is maintained, then by 2015 malaria mortality rates are projected to decrease by 55% globally, and by 62% in the WHO African Region. In children aged less than 5 years, by 2015 they are projected to decrease by 61% globally and by 67% in the WHO African Region (WHO, 2014). It primarily affects low- and lower-middle income countries. Within endemic countries, the poorest and most marginalized communities are the most severely affected, having the highest risks associated with malaria, and the least access to effective services for prevention, diagnosis and treatment. Thus, malaria control and ultimately its elimination are inextricably linked with health system strengthening, infrastructure development and poverty reduction.

Malaria is caused by protozoan parasites of the genus *Plasmodium*. It is one of the leading causes of illness and death in Africa. Nine out of ten of these deaths occur in Africa and the rest occur in Asia and Latin America, being the world's most prevalent vector-borne disease. It is the fourth leading cause of death of children under the age of five years and pregnant women in developing countries (Rowe *et al.*, 2006; Martens and Hall, 2000). Also, the disease remains one of the most important causes of human morbidity and mortality with enormous medical, economic and emotional impact in the world. More than half of the world's population is at risk of acquiring malaria, and the proportion increases each year because of deteriorating health systems, growing drug and insecticide resistance, climate change and natural disasters (WHO, 2000). Africa remains the region that has the greatest burden of malaria cases and deaths in the world. *P. falciparum* accounts for 93% of parasitological species of malaria cases, which is predominantly transmitted by *An. gambiae* and *An. funestus* vectors. Two-third (66%) of African population is at risk of malaria. The estimated contribution of Africa to the global burden of clinical *falciparum* malaria cases and malarial mortality burden were 74% and 89% respectively. Each year approximately 25 million African women become pregnant in malaria endemic areas and at risk of *P. falciparum* infection during pregnancy (WHO, 2005).

2.2 Malaria in Ethiopia

The problem of malaria is very severe in Ethiopia where it has been the major cause of illness and death for many years (Adhanom *et al.,* 2006). In epidemic years mortality levels of up to 100,000 children are not uncommon. The transmission of malaria in Ethiopia depends on altitude and rainfall with a lag time varying from a few weeks before the beginning of the rainy season to more than a month after the end of the rainy season. Epidemics of malaria are relatively frequent involving highland or highland fringe areas of Ethiopia, mainly areas 1,000-2,000 m above sea level (MOH, 2006).

Ethiopia is the highest score for out patient visit goes for malaria. It is also one of the main causes of hospitalization and death in all corners of the country. More than two-thirds of population lives in malarious areas (Tulu, 1993; MOH, 2004b). In 2000-2003, the disease was the primary cause of reported morbidity and mortality accounting for 16% of out patient visit, 20% of hospital admission, and 27% of hospital deaths. In 2004-2005, malaria was reported as the primary cause of health problems in Ethiopia, accounting for 17 percent of outpatient visits, 15 percent of hospital admissions, and29 percent of in-patient deaths (MOH, 2004/2005).

Oromia Regional State, in 2004, the Regional annual malaria report showed that 701,539 patients were clinically diagnosed as malaria. Among 335,799 patients whose blood films were examined microscopically, 31.5 % were positive for malaria. Among blood film positives 17.3% were children under 5 years of age (Oromia Regional Health Bureau, 2005).

However, in the past few years, the rapid scaling up of interventions to control malaria (i.e., the distribution of more than 20 million bed nets to 10 million households in 2005 and doubling of DDT spraying between 2007 and 2008) appears to have resulted in an appreciable decline in the overall malaria burden of the country (MOH, 2008). Nevertheless, malaria remains a major cause of mortality and is a severe economic loss to the country. Peak malaria transmission occurs at the end of the rainy season, generally lasting from mid-September to mid-November (Adhanom *et al*., 2006).

The malaria prevention and control program in Ethiopia is to reduce malaria morbidity and malaria-related mortality by 75% by the end of the year 2013 with100% household coverage with two ITNs per household in all malarious areas. More than 85% of the population living in epidemic prone areas covered with indoor residual spraying above 80% of the population have access to prompt and effective treatment with artemisin-based combination therapy (ACT)(MOH, 2012).

2.2.1 Epidemiology of Malaria

Malaria is one of the most widely distributed parasitic diseases in the tropics. However, on the globe it extends up to 60^o north and 40^o south of latitudes. Its distribution in the world is not uniform. Different species of *Plasmodium* are found in different countries. *P. falciparum* is predominantly found in the warm and moist parts of Africa, the Middle East, Asia, Haiti, the Caribbean Islands, and Central and South America. *P. vivax* is dominant in the tropical and subtropical parts of Asia and in Eastern Africa and in some temperate regions such as in the Middle East and Iran. It is not found in the natives of West African. Though *P. malariae* is much less common than *P. falciparum* and *P. vivax,* it is widely distributed throughout the tropics. *P. ovale*, which is uncommon species of malaria, occurs in Africa and South America (Whittle and Van Hensbroek, 1994).

The variation of malaria epidemiology is not limited by continents or between countries. Unstable malaria occurs when there is sudden development of circumstances which are conductive for the transmission of infection at levels far above the usual period of occurrence. In this case it occurs as an acute febrile illness and it affects all age groups and result in high mortality and morbidity. At the other extreme malaria could be stable, in such a way that there is very little difference in the incidence of its occurrence from year to year. In this condition, transmission is usually perennial and it attacks the community intensely. The most attacked groups are children, however, adults usually develop immunity and they are less affected. The epidemiology of malaria in a given country is determined by different factors (McGregor, 1989). These are conductive environments for the transmission, the presence of suitable *An. mosquitoes*, the presence of *Plasmodium*, and the presence of a reservoir of the parasite. In some exceptional cases, there might be malaria without being fulfilled the above conditions. This occurs when the parasite is taken by travelers and immigrants while they are traveling from endemic areas. This type of malaria is called imported malaria.

The major malaria transmission season in Ethiopia is from September to December, following the main rainy season from June to September. There is a shorter transmission season from April to May following the shorter rainy season in some parts of the country. Currently, areas <2,000 meters of altitude are considered malarious.

Transmission of malaria depends greatly on local environmental factors; Temperature, relative humidity, rain fall pattern, availability of breeding sources and man-made environment. The others are parasite; host and vector factors. Altitude and climatic factors are the main determinants of malaria epidemiology in the country. Areas below 2000 meter altitude are classified as malarious (Tulu, 1993; Gebremariam, 1988). On the other hand, studies had done shown that malaria occurs in highland fringe areas including urban sites, the main factor being climate change (Woyessa, 2001).

Historically, the unstable nature of malaria transmission has been characterized by frequent focal and cyclical epidemics which reach national scale at irregular intervals of 5ï 8 years. In the Ethiopian highlands, several large-scale epidemics have been documented since 1958. In that year, an estimated 150,000 people died during a widespread epidemic of malaria in the highlands. Several major epidemics have been reported since then. Abnormal transmission of unusual proportions affected the highlands and highland-fringe areas in 1988 and 1991ï 92, which was associated with abnormally increased minimum temperature. In 1997-1998, widespread epidemics occurred in the highlands and, in the most recent national scale epidemic in 2003-2004, more than 2 million clinical malaria cases and 3,000 deaths were reported from 3,368 villages in 211 districts (Abeku *et al*., 2003).

2.2.2 Plasmodia: The Parasite

Malaria is caused by a protozoan belonging to the genus *Plasmodium*. Over 400 species of the malarial parasites (*Plasmodium spp.*) are said to exist. Many infect a wide variety of cold-and-warm-blooded animals - only four routinely infect humans. Malaria is transmitted from one person to another by the bite of an infected female *Anopheles spp.* mosquito. Malaria is caused by five species of parasite that affect humans, and all of these species belong to the genus *Plasmodium*: *P. falciparum*, *P. vivax*, *P. ovale*, *P. malariae* and *P. knowlesi*. Of these, *P. falciparum* and *P. vivax* are the most important. In Ethiopia the two epidemiologically important species are *P. falciparum* and *P.vivax*, 60% and 40%, respectively. Malaria due to *P. falciparum* is the most deadly form, and it predominates in Africa. *P. vivax* has a wider distribution than *P. falciparum* because it is able to develop in the *An. mosquito* vector at lower temperatures, and to survive at higher altitudes and in cooler climates. It also has a dormant liver stage (known as a hypnozoite) that enables it to survive during periods when *Anopheles mosquitoes* are not present to continue transmission, such as during winter months. Although *P. vivax* can occur throughout Africa, the risk of *P. vivax* infection is considerably reduced in the region by the high frequency of the Duff y negativity trait among many African populations; in individuals without the Duff y antigen, red blood cells are resistant to infection with *P. vivax*. In many areas outside Africa, infections due to *P. vivax* are more common than those due to *P. falciparum* (WHO, 2013).Four species: *P. falciparum*, *P. vivax*, *P. ovale*, and *P. malariae* infect humans but they each differ in many aspects of their biology and geographic distribution. ñ*P. falciparum* is found in most tropical regions throughout the world, and is the most dangerous of the four in terms of both its lethality and morbidity.

All undergo two forms of replication: sexual and asexual. The, parasites develop optimally in the vector but cease developing at temperatures decreases below a certain degree. Humidity affects the life of the vector and transmission is extended under these conditions. In the human intermediate host, the parasite must function in relation to temperature, since the infection induces a significant rise in core temperature during the height of the infection. (http://www.medicalecology.org/diseases/malaria/printmalaria.htm#sect5.2).

2.2.3 Anopheles Mosquito: The Vector

Mosquitoes belong to the order Diptera, sub-order Nematocerca of the class Insecta which contain three subfamilies Toxorhynchitinae, Culicinae and Anophelinae. Mosquitoes belong to the genus Anopheles, subfamily Anophelinae and are the exclusive vectors of human malaria because of their behavior, physiology and the close relationship with humans (Cui *et al*., 2006). Only 12% out of the almost 380 described species of *An. mosquitoes* have been implicated as malaria vectors. Malaria transmission involves complex interactions between *P. parasites* (i.e., the causative agent of malaria), female *An. mosquitoes* and people. In sub-Saharan Africa, there are 140 *Anopheles* species of which approximately 20 are known to transmit malaria to human beings under natural conditions (Fontenille and Lochouam, 1999).

In sub-Saharan Africa, where 90% of the worldôs malaria cases occur, *An. gambiae* Giles, *An. arabiensis* Patton and *An. funestuts* Giles are the most efficient malaria vectors (Coetzee *et al*., 2000). In Ethiopia *Anopheles gambiae s.l* was the most prevalent known vector and all other *anopheline species* including *An. funestus* and *An. pharoensis*, which have a secondary role in malaria transmission in Ethiopia (Yewhalaw *et al.,* 2013). *An. pharoensis* is also a major transmitter in arid and semiarid regions with permanent water bodies (Gillies and Coetzee, 1987). *An. arabiensis* is the principal vector adapted to different ecological locations in Ethiopia and the most determinant for malaria prevalence. Historically, members of the *An. gambiae complex* from Ethiopia have been identified chromosomally as either *An. arabiensis* or *An. quadriannulatus*. Populations of the *Anopheles gambiae Giles* complex from Ethiopia were first identified by cross-mating studies as *An. arabiensis* and *An. quadriannulatus* of the *An. gambiae complex* (Turner, 1972)

Changes in the environment of the mosquito habitat, such as those taking place in Ethiopia, whether natural or man-made, rearranges the ecological landscape in which these vectors breed. Every *An. species* occupies a specific ecological niche that is genetically determined. Changes in temperature, humidity, altitude, population density of humans, and deforestation are just a few ecological factors that play essential roles in the transmission of malaria (http://www.medicalecology.org/diseases/malaria/printmalaria.htm#sect5.2).

Temperature and humidity have a direct effect on the longevity of the mosquito. Each species can thrive at an optimal level as a result of ecological adaptation. The spread of malaria requires that conditions are favorable for the survival of both the mosquito and the parasite. In tropical regions temperature and humidity are often mediated by altitude. Altitude is significant in determining the distribution of malaria and its seasonal impact on many regions of the world. In Africa, for example, altitudes above 1,000-1,500 m are considered safe from malaria. However, it must be cautioned that with continuing global climate change, these figures may change, extending the range of mosquitoes well above those altitudes as ambient temperatures rise.

2.2.4 Role of Human Factor in the Spread of Malaria

Human factors in Ethiopia contributing to the spread of malaria include population growth and movements, urbanization, water development schemes, agricultural development, conflicts, and improper use of drugs and the attendant consequences of the emerging drug-resistant malaria parasites. In Ethiopia large irrigation schemes have been established along different rivers and their tributaries, especially in semi-arid areas of the country where temperature is high and humidity is low. If water is available these lowland areas have fertile soils, which are potentially productive. Major agricultural irrigation schemes are found in malaria areas of the country and the nature of the malaria transmission is perennial because of the presence of permanent standing water bodies throughout the year (Tulu, 1993). In addition to the above, there are other factors that aggravate the malaria problem. Such as low status of the health facilities, low economic status of the workers, poor house qualities, and large number of people living together in small areas. Lack of coordination among different government sectors during the preparation of the projects are also another factor. Micro dams have been built in different parts of the country where there has been drought and sever famine for a long period of time, due to unreliable rainfall.

However, the dams have changed the ecology of the area and created favorable breeding sites for the An. vectors and for the development of *Plasmodium*. As a result of this the epidemiology of these areas is changed and malaria has become a great health problem which threatens the life of the human population and affects the peasant economy.

Drought and famine have brought notoriety to Ethiopia; among the obvious strategies embarked on by the countryφs government is a shift away from rain-fed agriculture to small-scale irrigation agriculture through run-off harvesting in micro dams and ponds (Adhanom *et al.*, 2006). Large-scale irrigation agriculture has also been in existence for decades as is the practice of damming rivers for the production of hydroelectric power. None of these have been without health consequences, however, and the toll in malaria illnesses and death has been documented in one of the few studies focusing on the subject (Adhanom *et al*., 1999). As in most tropical countries river-fed agriculture has also led to the resurgence of malaria even in areas where its threats have been receding. What is good for crops like cotton and sugar cane high temperature and plenty of water is also a heaven for the malaria vector. The relation between irrigated crops and the presence of malaria has long been noted in the Awash Valley plantations of sugarcane, fruit, and cotton and the introduction of irrigated rice cultivation in parts of Gambella has been suggested as an important contributing factor in malaria transmissionò (Adhanom *et al.*, 2006).

However, recent information on the epidemiology of malaria indicates that the disease has encroached to areas that were free of malaria during the eradication period (Woyessa and Ali, 2003). Ethiopia is also characterized by a high population growth rate, which is currently estimated at 2.7%, with the projected population to reach 118 million in 2025, from the current estimate of 77 million (World Population Prospects, 2004). The population is growing at an average of 2 million annually between 2000 and 2005. High population growth and ecological degradation in the highland and midland areas of Ethiopia have induced population mobility into lowland areas. This has led to increased exposure of people to communicable diseases like malaria, trypanosomiasis and other vector-borne diseases that are rampant in the lowland areas (Roundy, 1976).

2.2.5 Role of climate on malaria

Climate is a major parameter in all ecosystems and has always been a fundamental factor in human settlement, economy and culture. Currently, world climate is in a warming phase that began in the early decades of the eighteenth century. Such changes are entirely natural, but there is evidence that in recent years a portion of the current warming may be attributable to human activities (Wigley and Schime, 2000; Houghton *et al.*, 1996). The potential impact of this global warming on human health is a major subject of debate (Gubler, 1998; Kerr, 1997).The three elements of climate i.e. temperature, rainfall and humidity are strongly associated with altitude and relief. Changes in climate factors "higher temperatures and heavier rainfall" and changes in climate variability would encourage insect carriers of some infectious diseases to multiply and move further (Nkomo, 2006). Changes in climate may alter the distribution of important vector species and may increase the spread of disease to new areas- populations-that fall outside areas of stable endemic malaria transmission may be vulnerable to increases in malaria due to climate changes. Many of the diseases that currently occur in the tropics are mosquito borne (Cook, 1996). It is a widely-held view that global warming and climate change affect infectious diseases such as malaria. It is commonly assumed that malaria distribution is determined by climate and that warmer global temperatures will increase their incidence and geographic range (Watson *et al*., 1998; McMichae *et al.*, 1996).

In Ethiopia also elements of climate are strongly associated with altitude and relief. Moreover, the location contributes to seasonal variation of rainfall and temperature in the country. In the hottest places of the low lands there is a problem of heatstroke where as in the cool highlands hypothermia is the health problem of the community. The pattern of rainfall in the country is seasonal and comes during summer. As a result of this the transmission of malaria, tryponosomiasis, leishmaniasis and other water-related diseases is seasonal (Kloos *et al*., 1988). Moreover, Ethiopia is among the most affected countries by malaria epidemic, mainly due to its topographical and climatic features. Distinct from the ñnormalò seasonal increase in many areas, major periodic epidemics have occurred in the country from time to time.

2.2.6 Ecological changes and malaria

Malaria transmission intensity, along with its temporal and spatial distribution in Ethiopia, is mainly determined by the diverse eco-climatic conditions. Climatic factors including rainfall, temperature and humidity show high variability. Temperature, and to a lesser extent rainfall and humidity, varies as a function of altitude. In general terms, 75% of the landmass of Ethiopia is considered at risk of malaria, which corresponds to areas below 2,000m altitude. However, this estimate has not recently been revised to account for possible changes such as urbanization or land use (irrigation or dams).

Ecological alterations favoring the spread of these insects also facilitate the spread of the infection wherever malaria occurs. To get some idea of the complexity of the ecological differences among the numerous malaria endemic zones, one must consider at least four different, yet related, aspects: the host, the insect vectors, the parasites, and the physical conditions under which transmission occurs. Integration of these seemingly disparate subject areas into a unified view with respect to geographic locale is essential to begin identifying environmental factors that might be taken advantage of for the purpose of controlling the spread of the parasite (Hay *et al.,* 2004).

The effects of land use comprising of water impoundment schemes, irrigation schemes, deforestation, agricultural development, road and hydro-electric power construction in malarias areas result in ecological disturbances that exert considerable influence on the proliferation of mosquito breeding sites, resulting in high malaria transmission. Changes in land use followed by variations in climatic conditions singly or in combination have been incriminated by increases in morbidity and mortality from a number of parasitic diseases like malaria and schistosomiasis (Adhanom *et al.,* 2002; Patz *et al*., 2000; Adhanom *et al*., 1999; Alemayehu*, et al*., 1998 and Packard, 1986). Changes in government policies since the 1960s have emphasized on the exploitation of fertile, but sparsely populated lowlands, particularly for agricultural development. As a result, sugarcane, cotton and coffee plantations were extensively practiced in malarious areas of the country. Irrigation schemes and agricultural developments launched in the Upper and Middle Awash valleys during the 1970s and 1980s resulted in major ecological changes (Meskal and Kloos, 1989). This brought a dramatic rise in the incidence of malaria and other vector-borne diseases in these areas particularly among the non-immune migrants. Similarly, state-sponsored resettlement programs conducted in western and southwestern parts of the country resulted in ecological disruption followed by high morbidity and mortality from malaria (Kloos, 1990; Woldemeskel, 1989).

2.2.7 Urbanization and malaria

Urban agriculture has become common place in sub-Saharan Africa (SSA) and provides optimal conditions for vector breeding, leading to a higher risk of malaria transmission in its vicinity. Agricultural trenches create ideal breeding sites due to the formation of shallow water between seed beds (Yadouleton *et al*., 2010). Ethiopia and other countries in the Sub-Saharan Africa (SSA) are characterized by rapid urban population increase particularly in areas where the highest rates of *P. falciparum* are common. There are two possible explanations about malaria transmission in urban areas. The first explanation argues that urban areas seem to have lower rates of malaria transmission probably due to the effects of pollution on mosquito breeding habits and reduction of man-vector contact through the use of vector control measures such as house screening, insecticides and mosquito nets (Robert *et al*., 2003). The second explanation stems from the idea that urban environment may influence malaria transmission often by providing ample mosquito breeding habitats like broken or blocked water drains, new construction activities, irrigation schemes and new water collection reservoirs (Keizer *et al*., 2004; Robert *et al*., 2003).

As a result, the importance of urban malaria has been recently recognized as one of the major health problems for the urban community. The urban population of Ethiopia has remained significantly low. In 1965 and 2005, about 7% and 16% of the Ethiopian population lived in urban areas, respectively (World Population Prospects, 2004). The total number of people living in urban areas has increased from 1.9 million in 1965 to 12.5 million in 2005. Urban population growth is partly fuelled by internal migration. Migration from rural to urban areas increased during the 1980s and 1990s (Central Statistical Authority, 1996; 1991). Most of the significant increase in the number of the population in urban areas in Ethiopia occurs in lowland areas where the risk of malaria infection is very high.

Ethiopian towns are also characterized by poor housing, lack of proper sanitation, poor drainage of surface water, weak health services and widespread economic disparity (Keizer *et al*., 2004). All these factors, independently or together, facilitate urban malaria transmission. *An. gambiae* and *An. arabiensis*, the main vectors for malaria transmission in Sub-Saharan Africa (SSA) and *An. arabiensis* in Ethiopia, are also the most important *An species* to maintain urban malaria transmission (Keizer *et al*., 2004; Robert *et al*., 2003). Malaria transmission in urban areas results in large variations in malaria prevalence in different parts of the towns. Therefore, understanding urban factors that facilitate or inhibit malaria transmission is important for planning malaria control interventions in urban areas.

2.2.8 The Socio-Economic Impacts of Malaria

Socioeconomic factors are clearly related to health risks, including the risk for malaria. It is now well established throughout the world that morbidity and mortality rates are directly associated with socioeconomic status. The lower the status the higher the rates (WHO,2003).

Malaria causes great economic loss in many African countries and is considered a major barrier to the socioeconomic development of the continent (Kouyate *et al*., 2007). The economic cost of malaria is estimated to be more than $12 billion a year in lost productivity. Throughout Africa, resistance to chloroquine, the cheapest and most widely used antimalarial drug, is common. Sulfadoxine-pyrimethamine (SP), often seen as the first and least expensive alternative to chloroquine is also among drugs to which resistance has developed, especially in East and Southern Africa. Quantification of the social economic burden of malaria in Ethiopia is problematic since the victims live mostly in rural areas out of sight and out of mind of social scientists and other researchers, but some estimates abound.

The social and economic consequences of the disease are sobering, with a large number of people kept from work by debilitating illness resulting in low productivity. While household malaria burden is likely to be underestimated by institution data, routine health reports clearly reveal the burden of Malaria on the health system. According to annual national health indicator reports, malaria has consistently ranked in the top 10 causes of outpatient visits, admissions, and death at health centers and hospitals for the past seven years (id21 health highlights, 2002).

Malaria is a significant impediment to social and economic development in Ethiopia. In endemic areas, malaria has affected the population during planting and harvesting seasons, cutting down productive capacity at a time when there is the greatest need for agricultural work. The disease has also been associated with loss of earnings, low school attendance, and high treatment cost. During epidemics, health facilities are overwhelmed with patients and many resources are diverted to deal with the emergency. There are several methods used for estimating the burden of malaria morbidity and mortality in Ethiopia, including cross-sectional surveys, routine surveillance data including incidence, case fatality ratios, health facility based surveys, and special longitudinal studies. As unbiased estimates of malaria morbidity and mortality are difficult to ascertain in the population, the most robust picture of the burden of disease emerges from assessment of all of these sources combined. One of the most valid and unbiased proxy measures of malaria morbidity is parasite infection prevalence in the population obtained from population-based surveys (Carter Center, 2007).

The Federal Ministry of Health (MOH) quoted in summarizes Malariaós socio-economic impacts in Ethiopia (Gebremariam *et al*., 1988). The high morbidity and mortality rate in the adult population significantly reduces activities, The prevalence of malaria in many productive parts of the country prevents the movement and settlement of people in resource-rich low-lying river valleys; on the flip side, the concentration of population in non-malaria risk highland areas has resulted in a massive environmental and ecological degradation and loss of productivity, exposing a large population of the country to repeated droughts, famine and overall abject poverty; The increased school absenteeism during malaria epidemics significantly reduces the learning capacity of students

Coping with malaria epidemics overwhelms the capacity of the health services in Ethiopia to focus on other diseases, and thus substantially increases public health expenditures. This makes malaria in Ethiopia not just a health issue but a food-security and environmental issue as well. The malaria season coincides with peak economic activity in rural Ethiopia when both rainfall levels and temperature are high and conducive for the growing of subsistence crops. Vector activity peaks in the months often set aside for cultivation, weeding, harvesting and winnowing.

Weddings and other culturally important activities also peak at this time. In other words, optimal climatic regimes for socio-economic activities in rural Ethiopia also favor the reproduction, propagation and thereby the preying up human blood of vector mosquitoes. Gebremariam *et al.*, (1988) showed the link between temperature/rainfall on the one hand and infection rates on the other. They also show that infection rates have been increasing sharply throughout the years. This could be attributed partly to better reporting of cases enabled by increases in accessibility to health centers and larger institutions catering to the needs of malaria patients.

2.2.9 Malaria prevention and control

Coordinated action against malaria (as malaria eradication) was launched between 1955 and 1969, Ethiopia being one of the 3 countries in Africa to implement the program. Although the program had remarkable result in industrialized countries and lager areas of sub-tropical Asia and Latin America, the problem of malaria has remained serious in Ethiopia and same for the continent. Hence, the program was reorganized in to malaria control program (WHO, 2005; Tulu, 1993). The country has adopted a new strategy of malaria control that integrates the program in to primary health care system along with the ongoing decentralization and health sector reform. An enabling environment that recognizes malaria as a serious development problem has been created. Malaria control is no longer seen as a largely top-down vertical intervention. Instead, effective malaria actions are being included in local health development efforts. Furthermore, Ethiopia has adopted the world health organization (WHOȇs) Global Roll Back Malaria (RBM) strategy which mainly relies on early diagnosis and treatment by community health workers, vector control with insecticides and use of insecticide treated nets(MOH, 2004a; WHO, 2000;MOH, 1993).

Currently, progress in malaria control activities is seen. Among the major recent achievements: Change in anti-malarial drug policy, development of new malarial treatment guidelines, development of a national strategic plan for scaling up the distribution and use of Insecticide Treated Nets (ITNs) (WHO, 2005; Louis Sullivan, 1991). However, in the past few years, the rapid scaling up of interventions to control malaria (i.e., the distribution of more than 20 million bed nets to 10 million households in 2005 and doubling of DDT spraying between 2007 and 2008) appears to have resulted in an appreciable decline in the overall malaria burden of the country (MOH, 2008). Nevertheless, malaria remains a major cause of mortality and is a severe economic loss to the country.

Since 2007, there has been a major shift from clinical diagnosis to confirmatory diagnosis following the wide-scale use of rapid diagnosing test (RDTs) in peripheral health facilities. To improve the quality of malaria diagnosis and treatment at peripheral health facilities (health posts) pan specific RDTs are now being introduced. Health extension worker (HEWs) would be trained on the use of multi-species RDTs in the integrated refresher training (IRT). Treatment seeking behavior of the population is persistently low. The 2007 National Malaria Indicator Survey (2007) revealed that overall, 22.3% of children under age five years reported a fever in the two weeks preceding the survey, of whom 15.4% sought medical attention within 24 hours of onset of fever. The objectives of this component was 100% of suspected malaria cases are diagnosed using RDTs and or microscopy within 24 hours of fever onset, 100% of positive malaria diagnosis is treated according to national guidelines and 100% of severe malaria cases are managed according to national guidelines.

The two main major vector control activities implemented in the country are Indoor Residual Spraying (IRS) and long-lasting insecticidal nets (LLINs). The 2007 MIS showed significant improvements in LLIN ownership in malaria risk areas from 3.5% in 2005 to 65.6% in 2007 (MIS, 2007). It appears more than 20 million LLINs that have been distributed to 10 million families have contributed to the reduction of malaria, and the strategies and activities required to implement this have now been tried and tested. The objective of this component was to ensure that 100% of households in malarious areas own one LLIN per sleeping space, and that at least 80% of people at risk of malaria use LLINs. This was achieved by both covering the existing gap (catch-up) and replacing worn out nets (keep-up), geographically targeting households in need (MOH, 2008). IRS is currently targeted to cover epidemic-prone areas and malaria-affected communities with low access to the health care system. Despite a dramatic scale-up of IRS activities, the FMOH estimates that 55% of IRS-targeted areas have been sprayed. This Strategic Plan aims at increasing and maintaining IRS coverage to 90% of households in IRS-targeted areas. Geo-coding activities help to determine the quantity, quality, and location accessibility of human habitations, as well as measure spray able surfaces within a specific area.

The main approaches affordable malaria treatment included improving diagnosis of malaria cases using microscopy and RDTs, and providing prompt and effective treatment of cases. The Artemether-lumefantrine (ACT) is used to treat *P. falciparum*, chloroquine *P. vivax*, and quinine is used for the treatment of severe malaria, pregnant women in the first trimester, children <5kg, and/or first line treatment failures. Laboratory diagnosis using microscopy is done at hospitals and health centers. Even though there has been rapid expansion of health centers and hospitals in efforts to improve access, it is estimated that only 30% of the population has access to microscopy-based malaria diagnosis. With the establishment of the health extension program (HEP), most diagnosis and treatment of uncomplicated malaria is now carried out at community level through the health extension worker (HEWs), using rapid diagnosing test (RDTs). Between2005-2009, almost 25 million RDTs and treatment courses of Artemisin-based combination therapy (ACTs) were procured and distributed to all health facilities in malaria risk areas.

3. Materials and Methods

3.1 Study area

Ethiopia is a tropical country which is located in the horn of Africa, between 3^{o} 25ô and 14^{o} 54ô North latitudes and between 33^{o} and 48^{o} East longitude (Shibeshi, 2001). The country has total area of 1.1 million square kilometers. Ethiopiaôs topographic features range from peaks as high as 4,550m above sea level to 110m below sea level in the Afar Depression. The Great East African Rift Valley divides the highland into two- the western and northern highlands and the southeastern. Moreover, Ethiopia has now become one of the land-locked countries, since the independence of Eritrea. Due to higher altitudes in most parts of the country the physical and biotic environments as well as the type of food production are similar with that of temperate regions

Ethiopia, with an estimated 74 million people in 2007 Central statistical agency, is the second most populous country after Nigeria, in Africa. Currently, the country is governed by a parliamentary Federal Government composed of nine National Regional States and two city administrative councils (Addis Ababa and Dire Dawa). The regional states and city administrations are further subdivided into woredas (districts). A woreda is an area delineated as the basic unit of planning and political administration at the lower level, and further sub-divided into the lowest government administrative units known as *kebeles*. About 84% of the countryôs total populations live in rural areas.

Illubabor Zone is one of the 18 Zones Oromia Regional State which is found in the South-Western part of Ethiopia. It has a total area of approximately 16, 555 km^{2} and lies between longitudes 33^{o} 47ج W and 36^{o} 52ج E and latitudes 7^{o}05ج S and 8^{o}45ج N. It is bordered to the South by Southern Nations Nationalities and People Regional States, to the North by West Wollega, to the East by Jimma Zone and to the West by Gambella Regional State. Illubabor Zone has 24 Woreda. Agriculture especially coffee production is the backbone for the communities of the Zone. Mettu is the Zonal capital city and is located 600 km South West of Addis Ababa to the Gambella main road.

This study was conducted at Mettu town which is one of the oldest town found in IlluAbabora Zone (Figure 1). The total area of Mettu Woreda is 146,322 hectares. The townôs geographical coordinates are approximately located between 8^{o} 6ôS ï 8^{o} 30 N latitudes and 30^{o} 15 ï 35^{o} 45 E longitudes. The town is located on elevation of 1460-1740m above sea level.
(Mettu woreda Municipalities)

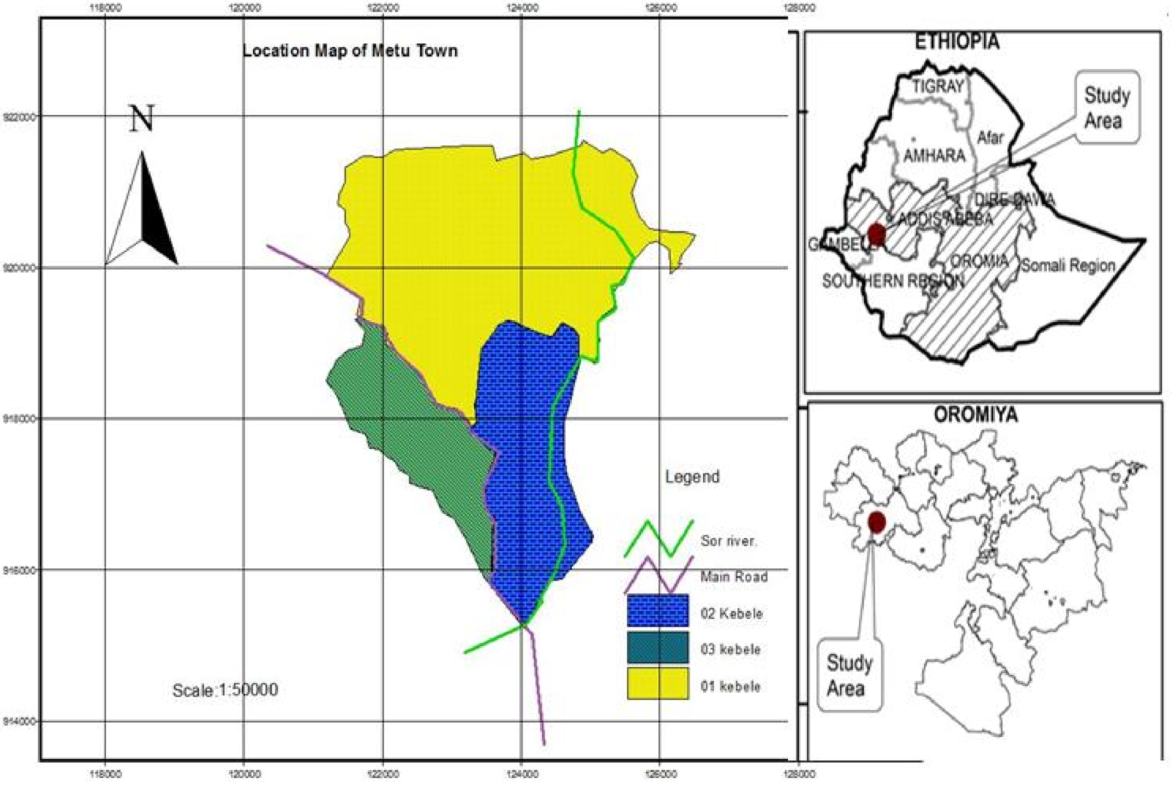

Figure-1 Map of the study area.

3.1.1 Demographics

Based on the 2007 Census conducted by the Central statistical agency (CSA), Illubabor Zone has a total population of 1,271,609, of which 636,986 were men and 634,623 were women; with an area of 16,555 square kilometers, Illubabor has a population density of 84.02. While 124,428 or 12.16% are urban inhabitants, a further 68% are pastoralists. A total of 272,555 households were counted in this Zone, which results in an average of 4.67 persons to a household, and 263,731 housing units.

3.1.1.1 Population

The total population of Mettu Woreda according to Central Statistical Authority (2007) census was estimated at 61,954 out of which 21,231 were living in rural and 40,723 in urban centers. Mettu is one of the populated Woreda in Illubabor Zone. The majority of the population (88%) is directly or indirectly dependent on agriculture for their livelihoods.

3.1.2 Climate

There are three broad ecological zones that follow the topography. The ñKollaò or hot lowlands are found below an altitude of 1,000 meters (m), the ñWeyna Degaò between 1000 and 1500m, and ñDegaò or cool temperate highlands between 1500 and 3000m above sea level. Mean annual temperatures range from 10 to 16^0C in the ñDegaò, 16 to 29^0C in the ñWeyna Degaò and 23 to 33^0C in the ñKollaò. In general, the highlands receive more rain than the lowlands, with annual rainfalls of 500mm to over 2000mm for the former and 300mm to 700mm for the latter (Tulu, 1993).

The Southwestern high lands of Ethiopia receive the highest amount of rainfall in the country. In the same way Mettu Woreda is one of the areas that receive high rainfall in the Southwestern highlands. The data analyzed from National Meteorological Service Agency records on rainfall and temperature shows about 48% of the total annual rainfall is mainly concentrated between June and August. In fact the six months from March to August account for 60% of the total annual rainfall and these months are also the months during which the main agricultural activities are carried out. Whiles the mean annual temperature of the woreda is 21^0C. The corresponding amounts of maximum and minimum temperature are 27^0C and 15^0C respectively.

3.1.3 Geology

The rocks of the Mettu Woreda are basalt of the trap series lava (National Atlas of Ethiopia, 1988).This geological event occurred in the Tertiary Period of the Cenozoic era when faulting was accompanied by widespread volcanic activity which led to the formation of vast quantities of basalt lava.

3.1.4 Soils

According to the National Atlas of Ethiopia (1988) and the FAO (1990) classification of soil the dominant soil types of the study Mettu Woreda is Haplic Acrisols and Haplic Nitisols. The former occur mainly on sloping terrain whereas the latter on almost flat to sloping terrain in high rainfall areas. Haplic Acrisols have limited agricultural potential and are chemically poor. Haplic Nitisols, on the other hand, have good potentialities for agriculture. These soils have very good physical properties such as uniform profile, a porous, stable structure and deep rooting volume but high moisture storage capacity as well (National Atlas of Ethiopia, 1988; FAO, 1990). A study by Murphy (1968) identified the area as typical of coffee-forest ecology with soils ranging generally from reddish brown to dark reddish brown clay-loam. They are high in organic matter and very high in nitrogen.

3.2 Study design

A retrospective study was conducted to determine fifteen year trend prevalence of malaria in relation to climate variables by reviewing fifteen year microscopically-confirmed malaria data obtained from Mettu health facilities.

3.2.1 Source of Malaria and Meteorological Data

3.2.1.1 Source of Malaria data

Fifteen years (2000-2014) microscopically-confirmed malaria data were obtained from Mettu health facilities from October-January 2014/2015.

3.2.1.2 Source of Meteorological data

The meteorological data variables of monthly minimum, maximum and mean temperature, total rainfall and mean relative humidity of the last fifteen years (2000- 2014) were obtained from Mettu meteorological agency branch office.

3.3 Data analysis

Pearsonô correlation and regression analysis between malaria cases and various climate variables was conducted. Fifteen years microscopically-confirmed malaria data and the meteorological data of monthly minimum, maximum and mean temperature, total rainfall and relative humidity of the previous fifteen years (2000- 2014) were entered and analyzed using Statistical Package for the Social Sciences(SPSS) 16.0 statistical software. To determine the correlation between malaria cases and climate variables data were fed in to linear regression analysis could be interpreted and the results of the data analysis was described and presented using figures and tables. To determine frequency distribution of sex and age specific malaria cases by *Plasmodium parasite species* were analyzed using descriptive statistics.

3.4 Ethical consideration

Ethical clearance for this study was obtained from Department of Biology, College of Natural science, Jimma University. Official letter written from Jimma University, department of Biology was explained to the woreda health offices. Then, the purpose of the study was explained to the woreda health office principals to get permission to carry out the work. Consequently to start the study, the objective and advantage of the study to the respondents (laboratory technician) to obtain their voluntarily participation and also inform that the information would be kept confidential.

4. Results

4.1 Annual trends of malaria prevalence in Mettu town, Southwest Ethiopia from 2000-2014

From January 2000-December 2014, a total of 9,816 confirmed malaria cases were recorded in Mettu town (Figure 2). There was slight increase of malaria from 2000-2005 and thereafter a remarkable declining trend was observed during the next successive two years, 2006 and 2007. Again from 2008 onwards, there was a remarkable increase with peak in 2010 and then a decline in number of confirmed cases was observed from 2011- 2014. Moreover the lowest number of microscopically confirmed malaria cases (110) was observed in 2007 and the highest microscopically confirmed cases of malaria was recorded in 2009 and 2010 with 1387 and 1644 respectively (Figure 2). There was statistically significant inter annual variation of malaria cases in the study area (p = 0.000).

Figure 2.Annual trends of malaria cases in Mettu town, Southwest Ethiopia from 2000- 2014.

A high fluctuation of malaria cases was observed in the Town, it declined and it increased with a maximum year to year thus exhibiting a periodic fluctuation.

There was a high pre-dominance of *P. falciparum* over *P. vivax* within the last fifteen years. About 61.3% (6,015/9,816) of the total malaria cases were due to *P. falciparum* infections while the remaining 34.3% (3365/9,816) cases were due to *P. vivax* infection. Mixed infections of both *P.falciparum* and *P.vivax* malaria were 4.4% of the cases. Inter- annual variation of both *P. vivax* and *P. falciparum* malaria cases was statistically significant (p =0.000). Thus, remarkable increment in total malaria cases was mainly due to *P. falciparum* rather than *P.vivax* except 2009 where *P. falciparium* cases declined while *P. vivax* was increased, which shows that there was a trend of shift from *P. falciparium* to *P. vivax* in the study area(Figure3).

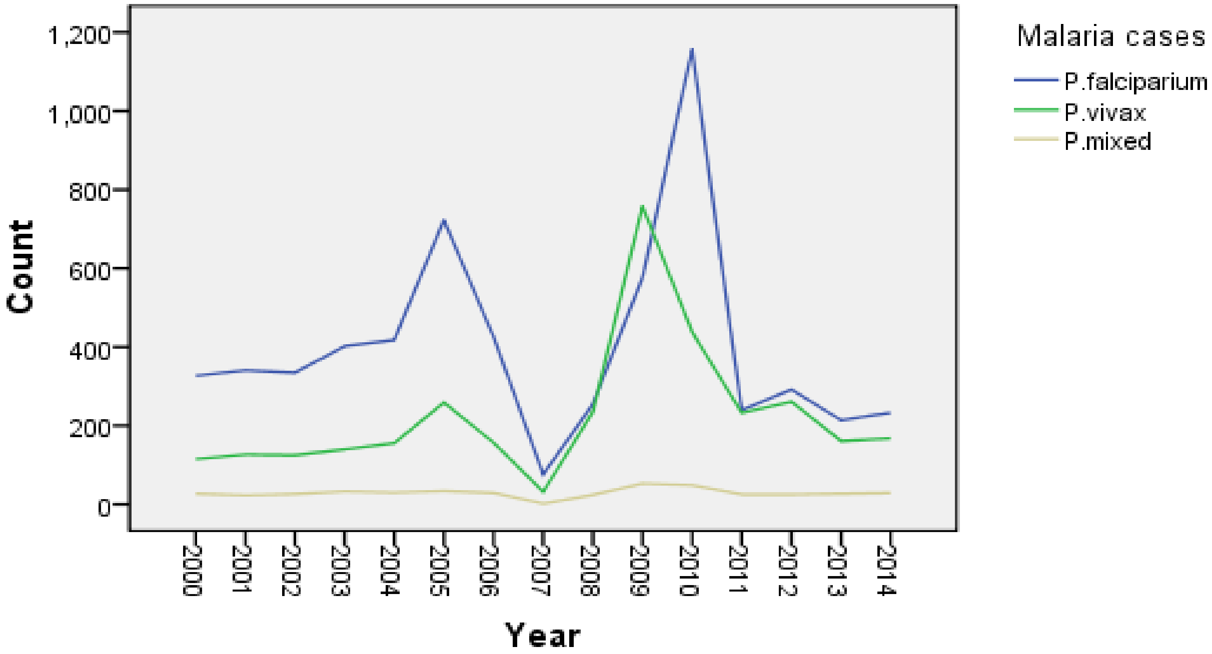

Figure 3.Trends of malaria parasite dynamics in Mettu town, Southwest Ethiopia from 2000-2014.

4.2 Prevalence of malaria cases by sex and age in Mettu town, Southwest Ethiopia from 2000- 2014.

The infection rates among males and females were 55.8% (5,474/9,816) and 44.2% (4,342/9,816) respectively. Males had a higher risk of contracting malaria than females in all age groups, accounting for 55.8% of confirmed cases compared to 44.2% in females. However, the difference was not significant (p = 0.208). As shown in figure below all age groups were affected by malaria. Of all the cases, 3.6% (356/9,816) were under the age of 1 year, 13.9% (1,366/9,816) were 1-4 years, 23.5% (2,306/9,816) were 5-14years, 44.3% (4,349/9,816) were 15-44 years, 9.5% (933/9,816) were 45-64 years and 5.2% (502/9,816) those above 65 years. But the age group 15ï 44 years were more affected, with a prevalence rate of 44.3% (4,349), followed by 5ï 14 year olds with a prevalence rate of 23.5% (2,306) ((Figure4). In all age groups, males were more affected than females in the study area.

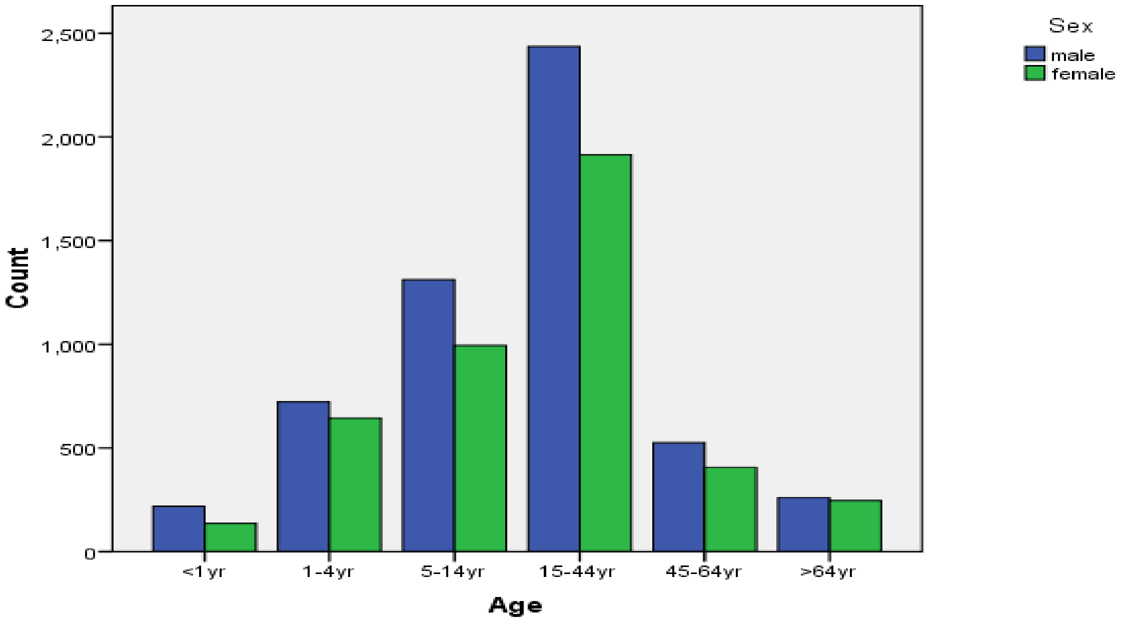

Figure 4.Sex and age specific malaria cases in Mettu town, Southwest Ethiopia from 2000- 2014.

With regard to *Plasmodium species* and age groups in the study area *P. falciparum* was the predominant parasite in all age groups and it was higher among 15ï 44 and 5ï 14 year age groups with a prevalence rate of 43.52% (2,618/6,015) and 22.74% (1,368/6,015) respectively and followed by 1-4 age group and 45-64 year age group with a prevalence rate of 13.26% (798/6,015) and 10.40% (626/6,016) respectively. The 15ï 44 age group was more affected by *P. vivax* with a prevalence rate of 44.88% (1510/3,365) followed by 5ï 14 years old 23.57% (793/3,365) and less than 1 year 2.46% (83/3,365) where as mixed infection was the least prevalent as compared with all other age groups (Figure 5).

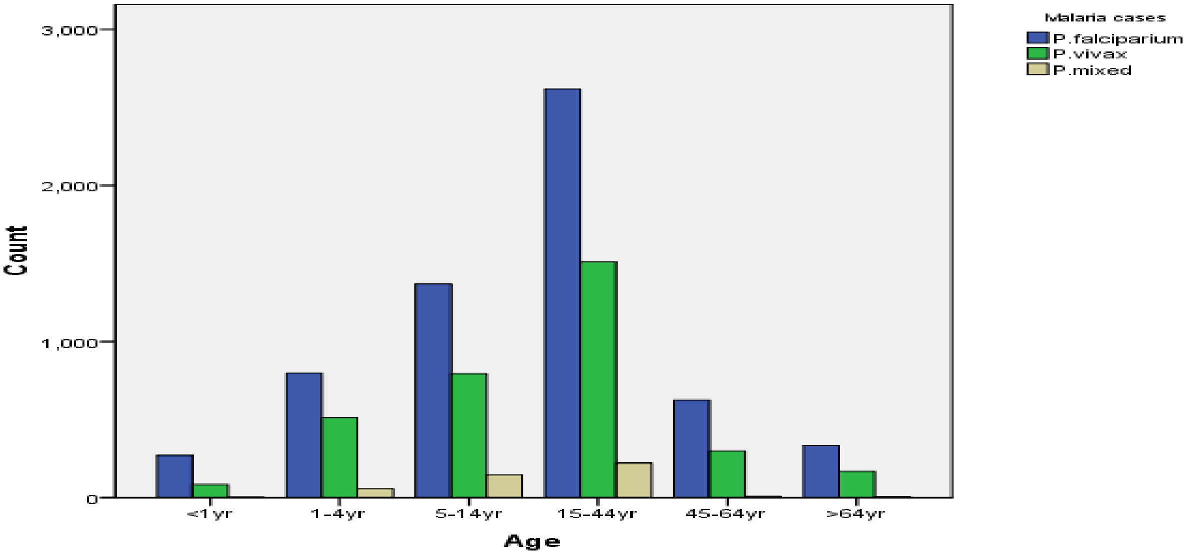

Figure 5.Age specific malaria cases by *Plasmodium parasite species* in Mettu town, Southwest Ethiopia from 2000-2014.

4.3 Seasonal variation of malaria cases by *Plasmodium parasite species* in Mettu town, Southwest Ethiopia from 2000-2014.

Although malaria was prevalent throughout year, transmission was seasonal, at its peak during September and followed by October and November respectively and decreasing thereafter. Least transmission occurred during February and January each year. The highest peak of malaria cases in almost all years was during spring (September, October and November) and transmission was lowest during winter (December, January and February). At species level, the maximum number of cases due to *P. falciparum* and *P. vivax* were observed in September, October and November followed by June, July and August. The minimum number of malaria cases was observed during December, January and February of winter (Figure 6). In all seasons *P. falciparum* cases were higher than *P. vivax cases* peak transmission occurred during September, October and November.

The pattern of malaria transmission was more pronounced in 2010. In general, there was a temporal fluctuation trends with inter-annual variation throughout the fifteen-year.

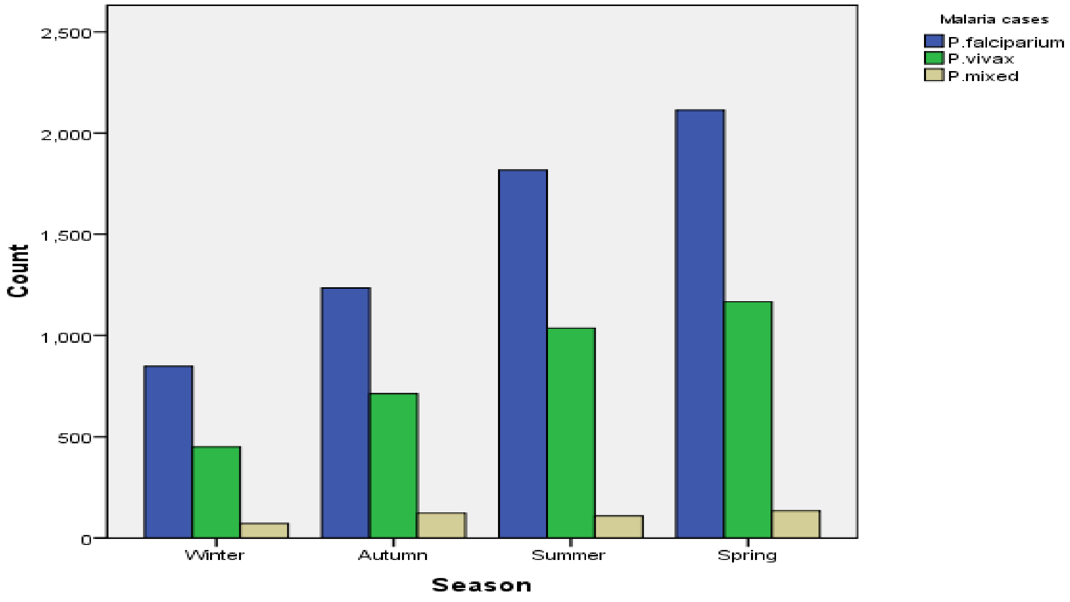

Figure 6. Malaria cases by *Plasmodium parasite species* and season in Mettu town, Southwest Ethiopia from 2000- 2014.

4.4 Correlation between malaria cases and climate variables in Mettu town Southwest Ethiopia from 2000-2014.

Time trend analysis was conducted to determine the association between malaria cases and climatic variables, such as temperature, rainfall and relative humidity. Linear regression analysis was conducted relating malaria cases vs. climatic variables (temperature, rainfall and relative humidity).

Table1: Coefficient determination of multiple regression model

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Sig. change
1	.920	.847	.846	.605	0.000

R= .92 indicated that all the selected climatic variables (maximum temperature, minimum temperature, mean temperature, total rain fall and average relative humidity) have strong positive significant relationship with malaria cases and R^2=.847 indicated that all the selected climatic variables(maximum temperature, minimum temperature, mean temperature, total rain fall and mean relative humidity) determine variation in malaria prevalence by 84.7%. However, 15.3% of the malaria prevalence were determined by other unknown extraneous variables. (Table1)

On the basis of correlation analysis, strong significant positive correlation was observed between maximum temperature and malaria cases (r =0.88; p=0.000); minimum temperature and malaria cases (r =0.874; p=0.000); mean relative humidity and malaria cases (r =0.876; p=0.000); total rainfall and malaria cases (r =0.79; p=0.000) and mean temperature and malaria cases (r 0.85; p=0.000). All the meteorological variables showed strong significant positive correlation with malaria cases (Table 2).

In contrast with regard to degree of correlation, relatively strong positive correlation was found between maximum temperature and malaria cases.

Generally, result of this stepwise regression indicated that all the climatic variables were found to be determinants of prevalence of malaria in the study area.

Table 2: Coefficients of multiple regressions between climate variables and malaria cases in Mettu town, Southwest Ethiopia from 2000- 2014.

	Variables	R(correlation coefficient)	R^2(coefficient of determination)	Std. Error of the Estimate	P- value
1	Maximum temperature	.88	.77	.75	0.000
2	Minimum temperature	.874	.76	.73	0.000
3	Mean temperature	.85	.73	.80	0.000
4	Total rain fall	.79	.62	.94	0.000
5	Mean relative humidity	.876	.76	.74	0.000

*significant at $p < 0.05$

From table 2, we can write the fitted multiple linear equation.

Then the linear regression equation for climatic factors and malaria is = 1.62 + 0.88 max temp.+ 0.87 min temp + 0.85 mean temp + 0.79 rainfall + .87 mean relative humidity

Generally, there was a strong significant positive correlation was observed in 2010 between maximum temperature with *P. falciparium* and *P.vivax* (*r* =1.00, p =0.000) and (*r* =0.526, p =0.037) respectively. Strong significant positive correlation was also observed in 2009 between maximum temperature with *P.vivax* and *P. falciparium* (*r* =0.972, p =0.000) and (*r*=0.365, p = 0.135) respectively. Similarly strong significant positive correlation was observed in 2005 between maximum temperature and *P. falciparium* (*r* =1.00, p =0.000) and insignificant positive correlation was observed with *P.vivax* (*r* =0.376, p =0.169). From 2000-2014 except 2013 there were positive correlation but a strong significant positive correlation was observed in 2010 and 2009 between minimum temperature with *P. falciparium* and *P.vivax* (*r* =1.00, p =0.000; *r* =0.889, p =0.000) respectively. From 2000-2006 except 2005 there were negative correlation and from 2007-2014 there were positive correlation with minimum temperature. The total rainfall from 2000-2014 were positively correlated but a strong positive correlation for *P. falciparium* were observed in 2005 and 2010 (*r* =0.972, p =0.000; *r* =0.889, p =0.000) respectively. In the same way for *P.vivax* except in 2009 there were a strong positive correlation with rainfall (*r* =0.889, p =0.000). For the relative humidity from 2000-2014 except 2013 there were a positive correlation with *P. falciparium* but a strong positive correlation for *P. falciparium* were observed in 2005 and 2010 with (*r* =0.968, p =0.000; *r* =1.00, p =0.000) respectively. And *P.vivax* were a strong positive correlation with relative humidity in 2009 (*r* =0.877, p =0.000).

Linear regression analyses were also conducted for monthly malaria cases with meteorological variables (maximum temperature, minimum temperature, mean temperature, rainfall and mean relative humidity).

For monthly malaria cases there was insignificant positive correlation between *P. falciparium* and maximum temperature (*r* =0.027, p=0.68) and significant positive correlation between *P. vivax* and maximum temperature (*r* =-0.130, p=0.05). There was significant positive correlation between minimum temperature and *P. falciparium* (*r* =0.129, p=0.000) and insignificant negative correlation between *P. vivax* and minimum temperature(*r* =-0.048, p=0.19). Insignificant positive correlation between rainfall and *P. falciparium* (*r* =0.003, p =0.945) and significant positive correlation between rainfall and *P. vivax* (*r* =0.112, p=0.012). There was also insignificant positive correlation between mean relative humidity with *P. vivax* and *P. falciparium* (*r* =0, 01, 0.818) and (*r* =0.055, p=0.197) respectively (Table3).

Table 3 Correlation between monthly climate variables with *P. falciparium/vivax* in Mettu town, Southwest Ethiopia from 2000-2014.

	P.falciparium/vivax			
	Pf		Pv	
Meteorological variables	(β)	p-value	(β)	p-value
Maximum temperature	0.027	0.684	0.13	0.05*
Minimum temperature	0.129	0.000*	-0.048	0.19
Total rainfall	0.003	0.945	0.112	0.012*
Mean relative humidity	0.055	0.197	0.01	0.818

*significant at $p < 0.05$

For each months climatic variables also further analyzed in relation to malaria cases by *P.falciparium* and *P.vivax*. The maximum temperature during (June- December) were insignificant and positively correlated with *P. falciparium*, (February-May) were negatively correlated with *P. falciparium* but during August and November were significant and positively correlated with *P. falciparium*(r =0.557,p =0.039 and r =0.578,p = 0.024) respectively and maximum temperature during (January-December) were insignificant and positively correlated with *P. vivax* but during November were significant(p =0.012). Minimum temperature during (June-December including January) were insignificant and positively correlated while (February-May) were negatively correlated with *P. falciparium* but during November were significant with (p =0.048). The minimum temperature during (January-June) were insignificant and positively correlated with *P. vivax* but during March were negatively correlated and (July- November) were significant with minimum temperature (0.014, 0.003, 0.043 and 0.005) but during October were insignificant (0.114).

Rainfall during (February-May) were insignificant and negatively correlated with *P. falciparium* and rainfall during (January-October) were insignificant and positively correlated with *P. falciparium* and rainfall during (February-May) were negatively correlated but November were significant (p =0.026) with *P. vivax*. Mean relative humidity during (February-June) were insignificant negative correlation with *P. falciparium* and relative humidity during (July-December including January) were insignificant positive correlation with *P. falciparium* but relative humidity during November were significant (p=0.032) with *P. falciparium*.

Annual total rainfall was significant positive correlation with *P. vivax* (*r* =0.235, p = 0.000) and insignificant negative correlation with *P. falciparium* (*r* =-0.012, p=0.745).There were a positive correlation between maximum temperature from 21-28.5^{o}c and negative correlation from 28.5-33^{o}c with *P. falciparium* and from 21-30^{o}c were positively correlated and from 30-33^{o}c were negatively correlated with *P.vivax*.

Autocorrelation among the independent variables exhibited high positive correlation between mean temperature and maximum temperature (0.78), followed by rainfall and mean relative humidity (0.61), mean temperature and minimum temperature (0.39). Also, negative association was observed between monthly maximum temperature and rainfall (-0.58), followed by maximum temperature and mean relative humidity (-0.56). (Table4).

Table4. Autocorrelation among climate variables in Mettu town, Southwest Ethiopia from 2000- 2014

	MeanTemp	MaxTemp	MinTemp	Rainfall	Relative humidity
MeanTemp	1.00				
MaxTemp	0.78	1.00			
MinTemp	0.39	-0.15	1.00		
Rainfall	-0.43	-0.58	0.14	1.00	
Relative humidity	-0.40	-0.56	0.15	0.61	1.00

5. Discussion, Conclusion and recommendation

5.1 Discussion

Malaria is a huge public health problem in terms of morbidity and burden on health care facilities, accounting for the increasing percentage of outpatient consultations in most health facilities in different regions in Ethiopia (Deressa *et al.*, 2003)**.** This study also revealed that the burden of malaria was high in the study area where the most deadly species, *P. falciparum*, accounted for 61.3%.

During the last fifteen years, a fluctuating trend of malaria cases was recorded in the area. A decrease in the number of malaria cases was recorded from 2005ï 2007 with a minimum number of malaria cases reported in 2007. However, there was an increase in the number of malaria cases from 2008ï 2010 with the peak number of malaria cases being reported in 2010. From the study except 2009 every year remarkable increment of total malaria cases was mainly due to an increase of *P. falciparum* with little increase of *P. vivax*, which indicates that *P. falciparum* was the deadly *plasmodium species* in the study area. This study supported by earlier study of Teklehaimanot *et al.,* (2007) observed that the reduction of malaria cases from 2005 due to health extension workers who had been trained and deployed at village level since 2005 can conduct also rapid diagnostic tests for malaria and treat uncomplicated cases at health posts level which are part of the primary health care unit. Such expansion of health services at grass root level has increased accessibility to health services and hence, there has been a report of positive health outcomes (Amare, 2013). Other possible reasons for malaria reduction during this period (2005ï 2007) might be due to the increased attention to malaria control (intervention) and preventive activities by different responsible bodies, increased awareness of the community on use of Insecticide Treated Nets (ITNs), increment of budget for malaria control and prevention activities and climate change at national and international level. It is likely that the excessive flooding due to heavy rains in 2007 might have also impaired mosquito breeding and flushed out the mosquito larvae. *P. falciparium* was the predominant species in the study area and accounted for 61.3 % of malaria morbidity. This finding found to be similar with the malaria parasite distribution in Ethiopia which indicates that *P. falciparum* and *P. vivax* are the two predominant malaria parasites, distributed all over the country and accounting for 60% and 40% of malaria cases, respectively (MOH, 2004). This study also shows that in 2009 *P. falciparium* decreased but *P. vivax* is slightly increased, which indicates a trend shift. This trend shift was similar to other study reported in Ethiopia carried out by Deressa *et al.,* (2003) in that the possible reason for this trend shift from *P. falciparium* to *P. vivax* might be due to the public health importance of *P. vivax* that is frequently overlooked and left in the shadow of the enormous problem caused by *P. falciparum* (Hay *et al.,* 2004; Alemu *et al.,* 2011). In addition, the prevention and control activities of malaria as guided by the National Strategic Plan (2006ï 2010) mainly focus on *P. falciparium* because it is assumed to be more prevalent and fatal malaria in the country Ethiopia. Other possible reasons might be climate variability and *P. vivax* might have developed resistance for the currently used drug chloroquine (Alemu *et al.,* 2011).

Regarding the age groups, 15ï 44 years (44.3%) were highly affected age groups showed that have high association in parasite infection and the prevalence of malaria parasites among males (55.8%) was higher than females (44.2%) which are similar to other findings(Alemu *et al*, 2012). The reason why malaria affected productive age groups (15ï 44) and more males might be due to the fact that in this area agriculture is the main occupation and irrigation is common for along period of time to produce sugar cane, onion, potato, etc and others passed more their time around there and exposed to the bite of Anopheles mosquitoes. More infection of malaria was recorded from 01 kebele where areas of this irrigation take place. Due to these and other different reasons this age groups and males were more exposed to anopheles mosquito bites, which can transmit malaria parasites. Other possible reasons may be their source of economy in agriculture, lack of skill how to use Insecticide Treated Nets (ITN), inadequate distribution of ITN, IRS, unavailability of the preferred ITN brand, lack of environmental management and swampy areas. This study is in agreement with the study made at Gilgel-Gibe Hydroelectric Dam (GGHD) Yewhalaw *et al.,* (2009) and implies dams and small irrigation projects also contribute to an increase in the mosquito population by increasing the number of suitable larval habitats, prolonging the breeding season and allowing the expansion of their distribution range and this coincide with the study of the past five year trend prevalence of malaria in Abeshge South central-Ethiopia (Kibret *et al*., 2010). This study also in agreement with study made by Yimer *et al*.,(2015) in that sex-related occupational and behavioral differences as well as travel history. Although the prevalence of malaria among the age group between 14-44 years were mostly affected. This might be because of differences in occupational and behavioral risk factors, such as staying outdoors before bedtime for various reasons. The most productive segment of the community, individuals older than 14 years of age, and more males might be more affected due to the fact that these two groups often stay outdoors at night for work and go to bed late in the night. People who work in the field during the night have little practice of personal protective measures, such as repellents and protective clothing. As people get older their sleeping patterns may be less regular and they may therefore be more at risk of infective mosquito bites. Moreover, some older individuals might have been more vulnerable as a result of lower immunity (Yimer *et al*., 2015).

Many other factors might be responsible for seasonal changes, e.g., climatic variables, ecologic and environmental factors, host and vector characteristics, and social and economic determinants such as change in health care infrastructure. Social, biological and economic factors such as mosquito control measures, population immunity, local ecological environment, governmental policy, availability of health facilitates and drug resistance also has an impact on malaria prevalence (WHO, 2005a). Although there were different malaria control activities in each year, such as insecticide spraying, elimination of mosquito breeding sites, health education about malaria, distribution of ITNs and some malaria drugs and other activities to decrease mortality and morbidity of malaria, the prevalence is still sustained. In general, there was a fluctuation in malaria cases during the last fifteen years. From the trend increase of malaria period 2008-2010, the highest malaria cases occurrence was observed during 2010 which was the main contributor for annual malaria cases increase. This findings supported by other non-climatic factors, earlier studies of MOH, (2012) and Yewhalaw *et al.,* (2011) around at GGHD area during that time malaria trend increase from 2006-2008 this might be due to old Long-lasting insecticide-treated bed nets (LLINs) not replaced at that time since 2005 and the resistance of dichlorodiphenyltetrachloro ethane (DDT) (75% WP) and partly malathion (50% WP) that was in use for indoor residual spraying (IRS) in the country since 1960s until *Anopheles mosquitoes* resistance to DDT was detected in 2007. Due to resistance of malaria vectors to DDT, the use of this insecticide for indoor residual spray (IRS) has been discontinued in 2009 (MOH, 2011). Deltametrin was used as an interim substitute insecticide for DDT for IRS operations. However, the selection of insecticides for IRS use in Ethiopia was determined annually based on the insecticide resistance pattern of the vectors and other factors. Additionally, extensive resistance to deltametrin and malathion was reported. This might be the reason why laboratory confirmed malaria cases increased in number starting from November 2010 besides other factors and coartem supply to the health extension workers and managing at community level MOH(2011), others may be poor environmental management, road constructions, expansion of the town to wards where areas of malarious, population movement from areas of hyper-epidemic malaria from Gambella and Harrer people settled at border of Darimu woreda to Mettu where Mettu is a transitory Town for daily passengers to Jimma and Addis Ababa.

After 2010 in the study area strict decline of the number of malaria cases was recorded, possibly due to the replacement of old long-lasting insecticidal nets (LLINs), shifting of insecticide used for Indoor Residual Spraying (IRS) to deltamethrin or bendiocarb insecticides MOH(2012) , such coincidence of interventions followed by a drastic drop of malaria was also revealed by other findings Bekele *et al*., (2013) in Ethiopia the need for alternatives to the currently used dichlorodiphenyltetrachloro ethane (DDT) and perimethrin/deltamethrin for IRS and treatment of mosquito nets, respectively and Karema *et al*., (2012) and Masaninga *et al*., (2013) in other African countries. This suggests the need for the effective combined intervention methods using IRS with potent insecticides and LLINs as evidenced by different studies Bekele *et al.,* (2013), as well as the need to monitor insecticide resistance of mosquitoes. The study made by Yimer *et al*., (2015) from 2011 onwards, the reduction of malaria cases coincides with the increased availability of the new, effective anti-malarial drug, artemisinin combination therapy (ACT), the increased political commitment and community awareness concerning malaria control intervention.

The transmission of malaria is determined by climatic, non climatic and biological factors (Srinivasulu *et al*., 2013). The climatic factors include all the independent variables like temperature, rain fall, and humidity. while the non climatic factors are human activities, socio-economic conditions like developmental changes, housing and living conditions, adopted control measures, local ecological environment (vegetation, introduction of irrigation schemes) and drug resistance in malaria parasites. The biological factors comprise abundance of *An.* species, the propensity and frequency of the mosquitoes to bite human beings, its susceptibility to the parasite, the longevity of mosquitoes, the rate at which the parasite develops in mosquitoes, aquatic stages of immature, etc. that are dependent on independent climatic variables. Climatic variables exhibit impact on the incubation rate of *Plasmodium parasites* and the breeding of *Anopheles* (Reiter, 2001; Christophers, 1993) and thus considered as the important environmental contributors to malaria transmission (Reiter, 2001).

This study also supported by those other study in that the three main climate factors that affect malaria are temperature, rainfall and relative humidity (Pampana, 1996). Among these, the temperature in particular has been found to affect life cycle of malarial parasite and the vector mosquito that carries the infection. Bouma and Van der Kaay (1996) who pointed out that the climate predicts to a large degree the natural distribution of malaria. The mosquitoes are cold blooded creatures; hence their developmental stages of life cycle and development of parasite in their body could be affected by temperature, rainfall, relative humidity. In fact, the role of climatic factors has been studied extensively in malaria transmission since a long (Bruce-Chwatt, 1980). At the present scenario (situation) is witnessing a major change in climate because of developmental activities in land-use pattern, it is expected that the role of some non climatic factors if integrated, the actual spread of malaria could be enlightened.

Even though this study revealed that higher positive correlation was observed between monthly malaria cases and maximum temperature, rainfall, minimum temperature, relative humidity. The correlation coefficient between monthly maximum temperature and malaria cases was found greater than that for the correlation between other climate variables and malaria cases. This indicates that maximum temperature seems to play a more important role in the transmission of malaria than other does. Several works from different places (Gupta, 1996; Greenwood and Pickering, 1993; Ramasamy, 1992) found the same results.

From the trend increase of malaria period 2008-2010, the highest monthly malaria cases was observed during September 2010 which was the main contributor for 2010 annual malaria cases increase. In this month a small increase of maximum temperature during September (26.6°C), after summer rainfall of August (25.5°C), this implies the correlation analysis at one month lagged effect was the first meteorological variable that affects malaria transmission in the study area. A combination of the monthly maximum temperature in the range 24 -28.5°C provides suitable conditions for malaria transmission. But more prevalence was observed between 25.5°C -27°C. Specifically *P.falciparium* negatively correlated between 28.5°C -31°C while *P. vivax* negatively correlated between 30°C -31°C. Relatively this study revealed that *P.vivax* needs more high temperature than *P.falciparium*. This study contradicts with the study made in Zimbabwe on malaria prevalence in relation to climate variation in that the negative association attained by maximum temperature in the range of 24-27°C malaria incidence , could indicate a need of warmer temperature for malaria transmission (Mabaso *et al.,* 2005).

Malaria cases in the study area high during spring (September to November), which was influenced by monthly rainfall after the rainy season of summer (June, July and August).This result agree with the study by Yimer *et al.,* (2015) they pointed out that the number of malaria suspected and infected cases varied with season and highest number of cases was registered in mid-September through November shortly after the heavy rainy season. There was a strong positive correlation between malaria cases and season of spring and summer and negative correlation between season of winter and autumn. This result is consistent with the study of Grover-Kopec *et al.,* (2006) who revealed that the rainfall is largely responsible for creating the conditions that allow sufficient surface water for mosquito breeding sites and this recognized as one of the major factors influencing malaria transmission.

Rainfall plays an important role in malaria epidemiology because water not only provides the medium for the aquatic stages of the mosquito s life but also increases the relative humidity and thereby the longevity of the adult mosquitoes (Yeshiwondim *et al.,* 2009).

Rainfall may prove beneficial to mosquito breeding if it is moderate (September to November), but may destroy breeding sites and flush out the mosquito larvae when it is excessive (June to August). After a heavy rain, there is a possibility for water to recede so as to provide new breeding sites. Further, time is needed for larvae to hatch, mature pupae and form adults, for the adult female to find an infected host and become infected itself and for completion of sporogonic development of malaria parasite within the vector. Additional time may be required for the infected mosquito to bite an uninfected host. This study revealed highest correlation between rain-fall and malaria cases was with a lag of one or two-month. This is why further malaria transmission was observed after one or two month lag of rainfall. This finding in response of one month lag effect are supported by earlier studies of Prakash *et al.,* (1997) who observed a two-week time lag between rainfall and vector abundance in a forest-fringed villages of Mahaboobnagar. *An. mosquitoes* just require a right amount of precipitation for breeding purpose but too much continuous rainfall (June, July and August) or rainfall accompanied by storm conditions in 2007 in the study area may flush away breeding larvae. This result was also supported by the study made by Himeidan *et al*., (2007) in Eastern Sudan on climatic variables and transmission of *falciparum* malaria. This is why malaria prevalence may reduced in 2007 in the area. Also, different *An. mosquitoes* prefer a particular type of water bodies to breed (Nagpal, 1995). But with out sufficient rainfall or water collections in winter mosquitoes cannot proliferate and infect humans. This clearly indicates that the malaria transmission is clearly associated with the rainy season (Yeshiwondim, 2009).

From this trend analysis 2009 and 2010 were the main malaria cases accounted, due to a strong correlation was observed between malaria cases and small rise of temperature after during the rainy season. This result agree with the study of Lindsay and Martens (1998) who explained out that the temperature has a strong role in malaria transmission through its influence on the development rate of mosquito larvae and the survival rate of adult mosquitoes. Moreover, at warmer temperatures, adult female mosquitoes feed more frequently and digest blood more rapidly and the *Plasmodium parasite* matures more rapidly within the female mosquitoes.

A rise in temperature, especially maximum temperature would enhance the survival chances of *Plasmodium* and *Anopheles* and thus accelerates the transmission dynamics of malaria and spread it into populations that are currently malaria-free and immunologically negative.

The relative humidity and malaria cases in the study area show that during the malaria season (September to November) monthly relative humidity facilitates the prevalence of malaria after rainfall season. There is a significant positive correlation between relative humidity and malaria cases. This implies relative humidity directly affect both the *Plasmodium* and the activity and survival of mosquitoes (Srinivasulu *et al*., 2013). Generally, more malaria transmission does not start immediately with the onset of rain; usually there is a time lag during which the vectorǿs population increases. This study was supported by the study made recently in Mahaboobnagar

District of Andhra Pradesh, India by (Srinivasulu *et al*., 2013). In high transmission zones, the average monthly temperature, rainfall and relative humidity have to be suitable to be counted as part of the transmission malaria season and at least one-month lag of highly suitable conditions for malaria to occur. The increased average relative humidity after heavy rainfall proliferate the prevalence of malaria in the area.

5.2 Conclusion

A high fluctuation of malaria cases was recorded through the years 2000- 2014 in the Town, it was in descending and again it rises with a maximum from year to year thus exhibiting a periodic fluctuation. Malaria transmission was higher in 2005, 2009 and 2010 than in other years. All age groups were affected by malaria but age group15-44 was the most affected. Males were more affected with malaria than females. There was higher predominance of *P. falciparum* over *P. vivax* within the last fifteen years in the study area. The results of this study revealed that seasonality and climate influence malaria in the area. Peak malaria transmission occurred from September to November. There was significant association between climatic factors (maximum temperature, minimum temperature, mean temperature, rainfall and relative humidity) and malaria cases. All of these analyses identified a positive correlation between climate variables and malaria. Thus, climate variability would cause both increases and decreases in the area thus played an important role thereby influence malaria prevalence. Finally, further in-depth study using additional variables is needed to understand malaria epidemiology in the study area.

5.3 Recommendations

On the bases of the finding known about the likely impacts of climate variables on malaria cases the following recommendations were forwarded to guide strategic formulations to enhance adaptation mechanism and to reduce the adverse impacts of malaria prevalence.

By supplementing this information; it is possible to inform judgments of the risk of malaria season and possible outbreaks and strengthening public health system capacity to monitor malaria cases by promoting awareness and mobilization of the public as well as health and other professionals; developing multidisciplinary approaches sustained by a new mechanism of inter sectoral collaboration;.

A prediction based on seasonal climate forecasts that are available in advance of the main transmission season is important to prevent the impact of malaria. These forecasts can predict based on overall likelihood of whether a particular climate variables would be above or below average possible to decide suitable or not suitable for prevalence of malaria.

A strong early warning system can allow preparedness measures and early response to outbreaks, saving lives and reducing pressure on the health care system in the area. Climate data monitoring should be put the light, which should respond by increased disease surveillance (weekly reporting for instance) in order to pick up a possible outbreak at the earliest stages. Public health management at different scales of the health system could raise warning flags signaling the need for increased level of alertness, preparedness and proactive interventions. This study recommends the development of climate prediction help to forecast outbreaks of malaria in the area.

Finally, risk of malaria is not an end by itself; it always needs continuous and holistic interventions. Hence, efforts should be exerted by the Town health bureau to establish collaborative networking among the various organizations like; healthcare providers, community leaders, municipality and the community at large in the whole activities pertaining to the management, prevention and control of malaria.

References

Abeku,T. A.,Van Oortmarssen, G.J., Borsboom, G., De Vlas, S.J. and Habbema, J.D.F. (2003). Spatial and temporal variations of malaria epidemic risk in Ethiopia: factors involved and implications. *Acta Tropica* **87**: 331-340.

Adhanom, T., Deressa, W., Witten, K.H., Getachew, A. and Soboxa, T.(2006).Malaria. In: Berhane, Y., Haile Mariam, D., Kloos, H. (eds)).*The ecology and epidemiology of health and disease in Ethiopia.* Third edition, Shama Books, Addis Ababa,pp.556-576.

Adhanom,T., Witten, K.H. and Getachew, A.(2002).Schistosome transmission, water-resource development and altitude in northern Ethiopia. *Annals of Tropical Medicine and Parasitology* **96**:489-495.

Adhanom,T., Haile, M. and Witten, K.H.(1999). Incidence of malaria among children living near dams in northern Ethiopia: Community based incidence survey. *British Medical Journal* **319**:663-666.

Alemayehu, T., Ye-ebiyo, Y. and Ghebreyesus, TA.(1998). Malaria, schistosomiasis, and intestinal helminths in relation to microdams in Tigray,Northern Ethiopia. *Parassitology***40**:259-267.

Alemu, A., Tesfaye, W., Golassa, L. and Abebe, G. (2011). Climatic variables and malaria transmission dynamics in Jimma town, South West Ethiopia. *ParasitVectors* **4**:30ï 41.

Alemu, A., Muluye, D., Mihret, M., Adugna, M., Gebeyaw, M.(2012).Ten year trend analysis of malaria prevalence in Kola Diba, North Gondar, Northwest Ethiopia. *Parasit Vectors***5**:173.

Amare, S.A. (2013).The Impact of Ethiopian Health Services Extension Program on Maternal and Child Health Outcomes: The Case of Tigray Region. Atlanta, Georgia: Georgia State University

Aregawi, M., Lynch, M., Bekele, W., Kebede, H., Jima, D. and Taffese, H.S. *et al.,* (2014). Time Series Analysis of Trends in Malaria Cases and Deaths at Hospitals and the Effect of Antimalarial Interventions, 2001-2011,Ethiopia.*Public Library of Science One*, **9** (11) e106359.

Bekele, D., Petros, B., Deressa, W. and Belyhun, Y.(2013). Decline of malaria using combined long lasting insecticide treated nets and DDT house spraying strategies in Adami Tulu

Jido Kombolcha District, Central Ethiopia: a longitudinal study from parasitological and entomological indices data. *ScientificReports* **2:**647.

Bouma, M.J. & van der Kaay,H.J. (1996). El Nino Southern Oscillation and the historic malaria epidemics on the Indian subcontinent and Sri Lanka: an early warning system for future epidemics. *Tropical Medicine and International Health* **1**: 86ï 96.

Bruce-Chwatt, L.J. (1980). *In Essential Malariology*, William Heinemann Medical Books Ltd, London, pp. 129-168.

Carter Center (2007). Prevalence and risk factors for malaria and trachoma in Ethiopia: A household survey in Amhara, SNNPR, and Oromia Regional States. Addis Ababa.

Carter, R. and Mendis, K.N.(2002).Evolutionary and historical aspects of the burden of malaria. *Clinical Microbiology Reviews***15**:564-594.

Central Statistical Authority (1991).The 1984 Population and Housing Census Results.Addis Ababa, Ethiopia.

Central Statistical Authority(1996).The 1994 Population and Housing Census Results.Addis Ababa, Ethiopia.

Central Statistical Authority(2008).The 2007 National Census Preliminary Report for Ethiopia.

Christopher s, S.R.(1993).The Fauna of British India including Ceylon and Burma. Diptera, v IV (Family;Culicidae, Tribe Anopheline). London: Taylor and Francis. pp. 371

Coetzee, M., Craig, M. and Le Sueur, D.(2000). Distribution of African malaria mosquitoes belonging to the *Anopheles gambiae* complex. *Parasitology* **16**(2): 74-77

Cook, G. (1996).Manson's Tropical Diseases. WB Saunders Company Ltd, London.

Cui, L. and Rosenberg, R. (2006): Anophelinae vector of malaria in sub-saharan Africa. The South African Institute for Medical Research,Johannesburg.

Deressa, W., Olana, D. and Chibsa, S.(2003).Treatment seeking of malaria patients in east Shewa of Oromia. *Ethiopian Journal of Healthy Development***17**:9ï 15.

Deressa, W., Chibsa, S. and Olana, D.(2004).The distribution and magnitude of malaria in Oromia, Ethiopia.*Ethiopia Journal of Health Development* **18**(3).

FAO(1990). *Guidelines for soil profile descriptions* 3rd eds. Ethiopia, Addis Ababa

Fontenille, D. and Lochouam, L.(1999).The complexity of the malaria vectorial system in Africa. *Parasitology* **41**: 267-271.

Gebre-Mariam, N. (1988). Malaria In: Zein Z.A, Kloos H. (Eds). *The ecology of health and disease in Ethiopia*.First edition. Addis Ababa, Ministry of Health,136-150.

Gillies, M.T. and Coetzee, M.(1987). A supplement to the Anopheline of Africa south of the Sahara, Johannesburg: The South African Institute for Medical Research.

Greenwood, B.M. and Pickering, H.A.(1993). A malaria control trial using insecticide-treated be nets and targeted chemoprophylaxis in a rural area of the Gambia, West Africa. *Transactions of the Royal Society of Tropical Medical and Hygiene* **87**(2): 3

Grover-Kopec, E.K., Blumenthal, P., Ceccato, T., Dinku, J.A.,Omumbo and Connor, S.J. (2006).Webbased climate information resources for malaria control in Africa. *Malaria J*ournal **5**(1):38

Gubler, D.J. (1998). Climate change: implications for human health. *Healthy Environmental Digest* **12**:54ï 55

Gupta, R.(1996).Correlation of rainfall with upsurge of malaria in Rajasthan. *Journal of the Association of Physician of India* **44**: 385-9.

Hay, S.I., Guerra,C.A. and Tatem, A.J. (2004).The global distribution and population at risk of malaria: past, present, and future. *Lancet Infection Disease* **4**:327ï 336.

Himeidan, Y.E., Hamid, E.E., Thalib, l., Elbashir, M.I. and Adam, I.(2007). Climatic variables and transmission of falciparum malaria in New Halfa, eastern Sudan. *Eastern Mediterranean Health Journal* **13**:17ï 24.

Houghton, J.T., MeiraFilho, L.G., Callander, B.A., Harris, N., Kattenberg, A. and Maskell, K.(1996).*The Science of Climate Change.Contribution of Working Group I to the Second Assessment of the Intergovernmental Panel on Climate Change* (IPCC). Cambridge:Cambridge University Press.

http://www.medicalecology.org/diseases/malaria/printmalaria.htm#sect5.2

id21 health highlights(2002). Battle plan: strategies for malaria prevention www. Id21.org

Karema, C., Aregawi, M.W., Rukundo, A., Kabayiza, A., Mulindahabi, M., Fall ,I.S *et al.,* (2012). Trends in malaria cases,hospital admissions and deaths following scale-up of anti-malarial interventions, 2000ï 2010, Rwanda. *Malaria Journal* **11**:236.

Karunamoorthi, K. and Bekele, M.(2012). Changes in Malaria Indices in an Ethiopian Health Centre: A Five Year Retrospective Analysis. *Health Scope*,**1:**118-126.

Keizer, J., Utizinger, J. and Castro, M.C.(2004).Urbanization in sub-Saharan Africa and implication for malaria control. *American Journal of Tropical Medicine and Hygiene* **71**:118-127.

Kerr, R.A.(1997).Greenhouse forecasting still cloudy. *Science* **276**: 1040ï 1042.

Kibret, S., Alemu, Y., Boelee, E., Tekie, H., Alemu, D. and Petros, B.(2010). The impact of a small-scale irrigation scheme on malaria transmission in Ziway area Central Ethiopia.*Tropical Medicine and International Health* **15:**41-50.

Kloos, H., Adugna, A. and Sahlu, E.(1988). The Physical, Biotic and Human Environment in Ethiopia; The perspective of Medical Geography: The Ecology of Health and Disease in Ethiopia, Ministry of Health, Addis Ababa

Kloos, H.(1990).Health aspects of resettlement in Ethiopia. *Social Science Medicine* **30**:643-646.

Kouyate, B., Sie, A., Ye, M., Allegri, M. and Muller, O.(2007). The great failure of malaria control in Africa: A district perspective from Burkina Faso. *Public Library of Science One* **4**: (e127).

Lindsay,S.W. and Martens, W.J. (1998). Malaria in the African highlands: Past, present and future. *World Health* **1**: 33

Louis, S.(1991).US Secretary for Health. American Association for the Advancement of Science. Malaria and development in Africa

Mabaso, M.L.H., Craig, M., Vounatsou, P. and Smith, T.(2005). Towards empirical description of malaria seasonality in southern Africa: the example of Zimbabwe**.** *Tropical Medicine and International Health***10:**909-918.

Martens, P. and Hall, L. (2000).Malaria on the move: Human population movement and malaria transmission. *Emergence Infection Disease* **6**:28ï 45

Masaninga, F., Chanda, E., Chanda-Kapata, P., Hamainza, B., Masendu, H.T., Kamuliwo, M., Kapelwa, W., Chimumbwa, J., Govere, J., Otten, M., Fall, I.S. and Babaniyi, O.(2013). Review of the malaria epidemiology and trends in Zambia. *Asian Pacific Journal of Tropical Biomedicine* **3:**89-94.

McGregor, I.A.(1989).*Epidemiology and Control of malaria*. In: Robinson, D., Epidemiology and the community control of disease in warm climate Countries, 2nd ed. New York, pp. 413-430

McMichael, A.J., Haines, A., Slooff, R. and Kovats, S. (1996). Climate Change and Human Health.Geneva:World Health Organization.

Meskal, F.H. and Kloos, H. (1989).*Vector-borne disease occurrence and spread as affected by labor migrations to irrigations schemes in Ethiopia* In: Service M.W. (eds), Demography and Vector-Borne Diseases. CRC Press, Florida,USA.pp.225-236.

MOH(1993).Health policy of the Transitional Government of Ethiopia, Addis Ababa.

MOH(1997).Ministry of health guideline for vector control in Ethiopia.

MOH(2004).Malaria Prevention and Control Extension Package. Federal Democratic Republic of Ethiopia, Addis Ababa.

MOH(2004a). Malaria: diagnosis and treatment guidelines for health workers in Ethiopia. Addis Ababa. pp. 1ï 57

MOH(2004b).National health communication strategy. Federal Democratic Republic of Ethiopia, Addis Ababa.

MOH(2004/2005). Ministry of Health and health related indicators.Planning and Programming Department, FMOH, Addis Ababa,Ethiopia.

MOH(2006): National five-year strategic plan for malaria prevention and control in Ethiopia. Addis Ababa.

MOH(2007/2008). Health and Health Related Indicators. Planning and Programming Department,Federal Democratic Republic of Ministry of Health, Addis Ababa.

MOH(2008).Ethiopia National Malaria Indicator Survey 2007. Addis Ababa: FDRE Ministry of Health.

MOH(2010). Health and Health related Indicators. Planning and Programming Department, Addis Ababa, Ethiopia

MOH(2011). Malaria diagnosis and treatment guidelines for health workers in Ethiopia, Addis Ababa.

MOH(2012). National Strategic Plan for Malaria Prevention and Control in Ethiopia, Addis Ababa.

MOH(2012a).*National Malaria Guidelines*. 3rdedition. Addis Ababa: Federal Ministry of Health of Ethiopia;.

Murphy, H.L.(1968).A report on the fertility status and other data on some soils of Ethiopia. College of Agriculture, Haile SellassieI University,Addis Ababa.

Nagpal, B.N., Sharma, V.P.(1995).*Indian Anophelines*. New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd. 416 pp.

National Atlas of Ethiopia.(1988). Ethiopian Mapping Authority, Addis Ababa

Nkomo, J.C., Nyong, A.O.and Kulindwa, K. (2006). The impacts of climate change in Africa, The Stern Review on the Economics of Climate Change.

Oromia Regional Health Bureau(2005). Annual malaria report, ORHB, AddisAbaba.

Packard, R.M.(1986).Agricultural development, migrant labor and the resurgence of malaria in Swaziland. *Social Science of Medicine* **22**:861-867.

Pampana, E. (1996)**.** *A Textbook of Malaria Eradication,*2nd Edn. London, New York, Toronto Oxford University Press,593 pp.

Prakash, A., Bhattacharyya, D.R., Mohapatra, P.K. and Mahanta, J.(1997). Seasonal prevalence of *Anophelesdirus* and malaria transmission in a forest fringed village of Assam, India. *Indian Journal Malaria* **34**: 117-125.

Patz, J.A, Graczyk, T.K. and Geller, N.(2000). Effects of environmental change on emerging parasitic diseases. *International Journal for Parasitology* **30**:1395-1405.

Radeva-Petrova, D., Kayentao, K., TerKuile, F.O., Sinclair, D. and Garner, P.(2014). Drugs for preventing malaria in pregnant women in endemic areas: any drug regimen versus placebo or no treatment. *Cochrane Database Syst Rev***10**: 169

Raghavendra, K., Barik, T.K., Reddy, B.P., Sharma, P. and Dash, A.P.(2011). Malaria vector control: from past to future. *Parasitology Research* **108**:757-779

Ramasamy, R. (1992). High seasonal malaria transmission rates in the intermediate rainfall zone of SriLanka *Annals of Tropical Medicine and Parasitology* **86**: 591 600.

Reiter, P.(2001). Climate change and mosquito borne diseases: *Environmental Health Perspectives***109**:223-234.

Robert,V., Macintyre, K. and Keating, J. (2003). Malaria transmission in urban sub-Saharan Africa. *American Journal of Tropical Medicine and Hygiene* **68**:169-176.

Roundy, R.W.(1976).Altitudinal mobility and disease hazards for Ethiopian population. *Economic Geography* **52**:103-115.

Rowe, A.K., Rowe, S.Y. and Snow, R.W.(2006).The burden of malaria mortality among African children. *Intererernational Journal of Epidemiology***35:** 691ï 704.

Shibeshi, W.(2001).Junoir Atlas for Ethiopia.

Srinivasulu,N., GujjuGandhi, B., Reddya, N. and Sambashiva, D. (2013).Influence of Climate Change on Malaria Incidence in Mahaboobnagar District of Andhra Pradesh, India. *International Standard Serial Number* **2**: 256-266.

Teklehaimanot, A., Kitaw, Y., G/Yohannes, A., Girma, S., Seyoum, A., Desta, H. and Ye-Ebiyo, Y.(2007).Study of the Working Conditions of Health Extension Workers in Ethiopia. *Ethiopian Journal of Health Development* **21:**246-259.

Teklehaimanot,H.D. and Teklehaimanot, A. (2013). Human resource development for a community based health extension program: a case study from Ethiopia. *Human Resources for Health* **1**: 11-39

Tulu, A.N. (1993). Malaria.In: Zein, Z.A., Kloos, H. (Eds).*The ecology of health and disease in Ethiopia.* Second edition Westview Press, Boulder,USA, pp.341- 352.

Turner, R.L.(1972).Malaria epidemiological observations from unsprayed study districts in Ethiopia. *Mosquito News* **32**: 608-613

United Nations,UN Population Division New York (2013).World population prospects.

Watson, R.T., Zinyowera, M.C. and Moss, R.H. (1998).*The Regional Impacts of Climate Change*: An Assessment of Vulnerability.Special Report of the Intergovernmental Panel on Climate Change (IPCC) Working Group II. Cambridge: Cambridge University Press

Whittle, H. and Bole van Hemsbroek, M. (1994). Malaria, In: Lankinen, KS., Bergstorm, S. Makela, PH. and Peltomaa, M. eds. *Health and Disease in Developing countries,* The Macmillan Press limited, London, pp. 147-162

WHO(2000). The Abuja declaration and plan of action: an extract from the African summit on the Roll Back Malaria. WHO/CDS/RBM/2000.17. Geneva, Switzerland.

WHO(2002). Bulletin of WHO. *The International Journal of public health* **80**: 845-992

WHO(2003). World Health Organization on behalf of the Special Programme for Research and Training in Tropical Diseases.

WHO(2005).United Nation Childrenös Fund and Roll Back Malaria.World malaria report, WHO, Geneva.

WHO(2005a). World Malaria Report: Global malaria situation.

WHO(2007). Insecticide-treated mosquito nets: A WHO position statement. Global malaria programme. Geneva.

WHO(2011).World malaria report. Geneva, Switzerland

WHO(2012).World malaria report. Geneva, Switzerland

WHO(2013).World Malaria Report. Geneva, Switzerland.

WHO (2014).World Malaria report. Geneva, Switzerland.

Wigley, T.M.L. and Schimel, D.(2000).*The Carbon Cycle*. Cambridge: Cambridge University Press

Woldemeskel,G. (1989).The consequences of resettlement in Ethiopia. *AfricanAffairs***88**:359 374.

Woyessa, A.(2001). The elucidation of malaria transmission and its prevalence in highland urban area of Akaki town, Addis Ababa,pp.120.

World Population Prospects (2004).The2004 revision Population Database.

Woyessa, A. and Ali, A.(2003). Highland fringe malaria and challenges in its control in Akaki Town. *Ethiopian Medicine of J* ournal**41**:293-300.

Yadouleton, R.N., Guessan, H. and Allagbe *et al.,* (2010).The impact of the expansion of urban vegetable farming on malaria transmission in major cities of Benin.*Parasites and Vectors* **3**:118.

Yeshiwondim, A.K., Gopal, S., Hailemariam, A.T., Dengela, D.O. and Patel, H.P.(2009).Spatial analysis of malaria incidence at the village level in areas with unstable transmission in Ethiopia. *International Journal of Health Geography* **8**:5

Yewhalaw, D., Legesse, W., Bortel, W.V., Gebre-Selassie, S., Kloos, H., Duchateau, L.and Speybroeck, N.(2009). Malaria and water resource development: The case of Gilgel-Gibe hydroelectric dam in Ethiopia. *Malaria Journal* **8:**21.

Yewhalaw, D., Van Bortel, W ., Denis, L., Coosemans, M., Duchateau, L., and Speybroeck, N.(2010). First evidence of high knockdown resistance frequency in *Anopheles Arabiensis* (Diptera: Culicidae) from Ethiopia. *American Journal of Tropical Medicine and Hygiene* **83**(1):122-125

Yewhalaw, D.,Wassie, F., Steurbaut, W., Spanoghe, P., Van Bortel, W., Denis, L., Tessema, D.A., Getachew, Y., Coosemans, M., Duchateau, L. and Speybroeck, N. (2011). Multiple insecticide resistance: an impediment to insecticide-based malaria vector control program. *Public Library of Science One* **6(**1**):**e16066.

Yewhalaw, D., Getachew, Y., Tushune, K., W/Michael, K., Kassahun, W., Duchateau, L. and Speybroeck, N. (2013**).**The effect of dams and seasons on malaria incidence and anopheles abundance in Ethiopia. *Biomedical Central Infectious Diseases* **13**:161 doi:10.1186/1471-2334-13-161

Yimer, F., Animut, A., Erko, B. and Mamo, H.(2015). Past five-year trend, current prevalence and household knowledge, attitude and practice of malaria in Abeshge, south-central Ethiopia. *Malaria Journal* **14**:230.

Zhou, G., Afrane, Y.A., Vardo-Zalik, A.M., Atieli, H., Zhong, D., Wamae, P., Himeidan, YE., Minakawa, N., Githeko, A.K. and Yan, G. (2011).Changing patterns of malaria epidemiology between 2002 and 2010 in Western Kenya: the fall and rise of malaria. *Public Library of Science One* 6:e20318.