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ADDIS ABABA UNIVERSITY



Faculty of Natural Science

SCHOOL OF EARTH SCIENCES

**Exploring geospatial and socio economic factors contributing
for malaria prevalence
in Aysaita woreda, Afar Regional state, Ethiopia**

BY: IDRIS MAHMUD

June 2013

Addis Ababa

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A thesis submitted to the school of graduate studies of Addis Ababa
University in partial fulfillment of the requirements for the degree of
Master of Science (M.sc) in Remote sensing and GIS.

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DECLARATION

I hereby declare that the dissertation entitled “Exploring geospatial and socio economic factors contributing for malaria prevalence in Aysaita woreda, Afar regional state, Ethiopia” has been carried out by me under the supervision of Dr. K.V Suryabhagavan, School of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2012 - 2013 as a part of Master of Science program in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa

Date: June, 2013

Idris Mahmud

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Malaria found throughout the world except the frozen part of our world. It has been affecting human beings since the dawn of history. Currently, it is one of the major tropical diseases specially affecting the health of the peoples and the economic development of many developing countries, particularly in sub-Saharan Africa. The study area (Aysaita woreda) is considered as one of the most malaria susceptible area which is located in North East of Ethiopia. Its geographic locations which is suitable for malaria to develop and reproduce, like overflow of awash river due to the rainy season on high lands, environmental conditions including temperature, elevation, seasonality, and vegetation cover. Biological and social factors also share in influencing vector development and malaria transmission. Therefore, this study has attempt in identifying and mapping of malaria prone area with the use of Remote Sensing and GIS technology. Possible geospatial and socio economic factors were identified, assessed and finally overlaid with the help of malaria risk computation model. Based on this model the mapping of malaria risk includes hazard, element at risk, and vulnerability. These layers were prioritized according to their degree of influence. Pair wise comparison of the factors was carried out to develop the following weights for each factor in IDRISI software. The weights given for the factors was computed, Combined and analyzed in ArcGIS environment using spatial analyst tool and the final output map produced. And it shows that 46.45 percent, 53.24 percent and 0.31 percent of the total area are subject to High, Moderate and Low respectively. Hence, it is possible to conclude that 99.69 percent of the study area is under epidemic area (high and moderate). Only 0.31 percent is in low epidemic area. Furthermore, the produced map of malaria risk area which can be used as an input for policy makers and other responsible bodies. Besides these groups, the experts in the field will benefit more by acquiring readymade information which serves as a spring board for national malaria eradication and prevention program.

Key words: Remote Sensing and GIS, Malaria risk, Malaria Hazard

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Abbreviation

AHP	Analytical hierarchy process
CDC	Centers for Disease Control
CSA	Central Statistical Agency
DEM	Digital Elevation Model
EMA	Ethiopian Mapping Agency
ETM	Enhanced Thematic Mapper
FMOH	Federal Ministry of Health
GIS	Geographic Information System
GPS	Global Positioning System
IDW	Inverse Distance Weight
Km	kilometer
M -	meter
MAX	maximum
MIN	minimum
NDVI	Normalized Difference Vegetation Index
P	Plasmodium
RS	Remote sensing
Sq –	square
UNICEF	United Nations Children’s Fund
WHO	World Health Organization
WLC	Weighted Linear Combination

1. Introduction

1.1 General background

Malaria has been affecting human beings since the dawn of history. Currently, it is one of the major tropical diseases specially affecting the health of the peoples and the economic development of many developing countries, particularly in sub-Saharan Africa. It is transmitted from human to human by the female Anopheles mosquito. It is caused by five species of parasites of the genus Plasmodium that affect humans (*P. falciparum*, *P. vivax*, *P. ovale*, *P. malariae* and *P. knowlesi*). Malaria due to *P. Falciparum* is the most deadly form and it predominates in Africa; *P. vivax* is less dangerous but more widespread, and the other three species are found much less frequently. Malaria parasites are transmitted to humans by the bite of infected female mosquitoes of more than 30 *anopheline* species. Globally, an estimated 3.3 billion people were at risk of malaria in 2011, 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 WHO African Region, The infective parasite enters the bloodstream, and after developing and multiplying in the liver, quickly begins to move and destroy the red blood cells of its human host. Individuals most susceptible to the disease include pregnant women and their unborn babies, children, people infected with HIV/AIDS and non-immune adults (people from areas of with no malaria, or travelers to the continent). But, Mostly affects the children under five years of age and pregnant women. (WHO 2012).

According to the latest WHO estimates, there were about 219 million cases of malaria in 2010 and an estimated 660 000 deaths. Africa is the most affected continent: about 90% of all malaria deaths occur there. Between 2000 and 2010, malaria mortality rates fell by 26% around the world. In the WHO African Region the decrease was 33%. During this period, an estimated 1.1 million malaria deaths were averted globally, primarily as a result of a scale-up of interventions (WHO 2012).

Malaria in Ethiopia has different names in different languages. This obviously indicates the extent of the spread of the dreadful (very bad) disease that had long lived with people. In the past, the cause of the disease was associated with more lack of awareness and/or ignorance.

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Historically, the Italians had associated the disease with water in ponds and swampy/marshy areas and offensive smell. As a result, they gave the disease the name malaria which meant “bad air.” (Ethiopian Federal Ministry of Health, 2003)

The problem of malaria is very severe (series) in Ethiopia, where it has been the major cause of illness and death for many years. According to records from the Ethiopian Federal Ministry of Health, 75% of the country is malarious with about 68% of the total population living in areas at risk of malaria. This means Approximately 52 million people. Every year it is the leading cause of outpatient consultations, admissions and death. It is seasonal in the highland fringe areas and of relatively longer transmission duration in lowland areas, river basins and valleys. The cold zone, which covers areas higher than 2,500 meters (m) above sea level, has a mean annual temperature of 10–15°C. This highland area is considered free of local malaria transmission. The midland area, ranging in altitude from 1,500–2,500m with a mean annual temperature between 15–20°C, has diverse malaria transmission patterns. In the hot lowland zone, located in areas below 1,500m above sea level, where the mean annual temperature varies from 20–25°C, malaria transmission is endemic, and its intensity and duration are mainly dictated by the amount and duration of rainfall. (Ghebreyesus, *et al*, 2006).

Communicable diseases and malnutrition are major health problems in the Afar region. Malaria, tuberculosis, *Pneumonia*, upper respiratory diseases *diarrhea* and *gardiasis* are among the most prevalent diseases in the region. The climate and the topography of the area create favorable situations for the growth of disease vectors like mosquitoes, flies and snails. About 70 – 80% of diseases in the region are communicable diseases. The risks of morbidity and mortality caused by *Plasmodium falciparum* and *plasmodium vivax* vary spatially and temporally. Those are the types of malaria disease and are commonly found in afar region. *Plasmodium Falciparum* accounts for 60% of cases, while *Plasmodium Vivax* is 40%. (WHO Horn of Africa Initiative, 2003)

Aysaita woreda is one of malaria endemic area in Ethiopia. Its elevation is 300 meter above sea level. It has average temperature of 30°C which is suitable for malaria distribution. Malaria is a Vector borne disease. The vector *Anopheles* mosquitoes are particularly influenced by environmental conditions. Indeed, insect vectors in particular are very sensitive

to their environments, which in turn determine their presence, and development. As a consequence, climatic as well as landscape and land cover factors greatly influence the spatial distribution of vectors and the diseases they transmit.

Today's technology provides valuable information on such environmental conditions. Remote Sensing and Geographic Information System (GIS) techniques are one of the best techniques, which can help epidemiologists to identify vector focuses. These technologies, allow them to relate disease occurrence indexes and environmental characteristics, enabling the exact observation of geographic area and the determination of how some physical factors (rivers, mountains, vegetation) can influence the spreading or controlling of the disease. Generally GIS enabled researchers to locate high malaria prevalence areas and populations at risk, identify areas in need of resources, and make decisions on resource allocation. And also Remote Sensing and GIS have created new opportunities for public health administrators to enhance planning, analysis and monitoring of vector born disease elimination.(Praveen Kumar, *et al*, 2011) Somehow in this study the technique of remote sensing and GIS is to explore geospatial and socio economic factors contributing malaria prevalence for Aysaita woreda, afar Region, Ethiopia.

1.2 Problem statement

Malaria is ranked as the leading communicable disease in Ethiopia, especially in Afar which is located in the North-East of Ethiopia, geographically located at altitude of 300 meter above sea level and has temperature of 30°C, which is suitable for malaria distribution and Availability of Awash River also have effect. They are prone areas to malaria disease and many people are dying of this. The risks of morbidity and mortality caused by *Plasmodium falciparum* and *plasmodium vivax* which are very common types found in Afar region, vary spatially and temporally.

The study area (Aysaita woreda), is resulting in different factors that makes it to be epidemic area like its geographic locations which is suitable for malaria to develop and reproduce, overflow of awash river due to the rainy season on high lands and waters that are collected during rainy season and also like environmental conditions including temperature, elevation and vegetation cover. Biological and social factors also share in influencing vector

development and malaria transmission. These are some conditions that contribute a lot for the prevalence of malaria. These serious problems affect the living system of the local people in different means as the area is susceptible for the disease. However, their life depends on crop production and livestock rearing.

According to Alen (2002), before the development of GIS technology, the only way to assess human risk was manually monitor larval and adult mosquito populations. This time consuming and tiresome fieldwork has been costly and not frequently put in practice especially in countries with fewer resources. Now a day by using remote sensing and GIS technique, it is possible to produce thematic and attribute map for each malaria support factors and to measure the level of risk for the study area. Therefore to identifying and mapping the malaria risk areas by considering geospatial and socio economic factors that can contribute malaria prevalence in the study areas are needed.

1.3 Significant of the study

This study is aimed at using GIS and RS tools for identification of malaria prone areas and The ability of identifying risk areas will greatly enable decision makers use and ensure that the scarce resource implemented to the most high risk areas and can make the radiations and prevention task successful and will substantially reduce costs of prevention with efficient targeting of high risk areas. Applying GIS and RS for visualizing and analyzing epidemiological data will provide valuable information for evaluation and monitoring.

1.4 Objective

1.4.1 General objective

The general objective of this study is to assess malaria prone areas using Remote Sensing and GIS and to develop malaria risk and hazard zone map.

1.4.2 Specific objective

- ✚ To identify environmental and Socio economic factors that contributes for malaria incidence in the study area.
- ✚ To show the relationship between malaria incidence and climatic variables such as temperature and rainfall of the study area.
- ✚ To allocate on map malaria risk areas using remote sensing and GIS technique.
- ✚ To identify, classify and map areas at risk of malaria that will help the decision-makers to better allocate limited resources in the fight against the disease.

1.6 Organization of the research

The study is organized in five chapters from introductory part up to recommendation. Chapter one provides research background, problem definition, objectives and scope of the research. Chapter two provides a literature review on malaria transmission, history of malaria and use of RS and GIS technology in the study. Chapter three provides description and background of the study area, Methodology and analysis part. Chapter four provides the output of the study which is Results and discussion, and finally Chapter Five is about conclusion and recommendations.

2. Literature review

2.1 Malaria distribution in the world

Malaria has been one of the most prominent and ancient disease. Which is one of the greatest burden to mankind, with a mortality rate that is unmatched by any other modern disease other than tuberculosis. This dreadful disease caused by five different parasites with the same genus (*plasmodium falciparum*, *plasmodium vivax*, *plasmodium oval*, *plasmodium malariae* and *plasmodium knowlesi*), WHO (2010).

According to the World Health Organization (WHO) 2010 World Malaria Report, the estimated number of global malaria deaths has fallen from about 985,000 in 2000 to about 781,000 in 2009. Similar improvements were also documented in the 2010 United Nations Children's Fund (UNICEF) Progress for Children report and in a 2009 Lancet article, Levels and trends in under-5 mortality, 1990–2008.

In spite of this progress, malaria remains one of the major public health problems on the African continent, with about 80% of malaria deaths occurring in African children under five years of age (figure 2.1). Malaria also places a heavy burden on individual families and national health systems. In many African countries, 30% or more of outpatient visits and hospital admissions in children under five are reported to be caused by malaria. Economists estimate that malaria accounts for approximately 40% of public health expenditures in some countries in Africa and causes an annual loss of \$12 billion, or 1.3% of the continent's gross domestic product. Because most malaria transmission occurs in rural areas, the greatest burden of the disease usually falls on families who have lower incomes and whose access to health care is most limited (WHO 2012).

During the past decade, global malaria prevention and control efforts have been scaled up, with notable progress in sub-Saharan Africa, where the vast majority of malaria cases occur. The number of long-lasting insecticidal nets delivered to malaria-endemic countries in sub-Saharan Africa increased from 5.6 million in 2004 to 145 million in 2010. Programs to spray the interiors of buildings with insecticides were also expanded, with the number of people protected in sub-Saharan Africa rising from 10 million in 2005 to 81 million in 2010.

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However, malaria transmission still occurs in 99 countries around the world, and the malaria burden continues to cripple health systems in many African countries. In 2010, this entirely preventable and treatable disease caused an estimated 655 000 deaths worldwide. About 560 000 of the victims were children under five years of age, which means malaria killed one child every minute (World malaria report 2012).

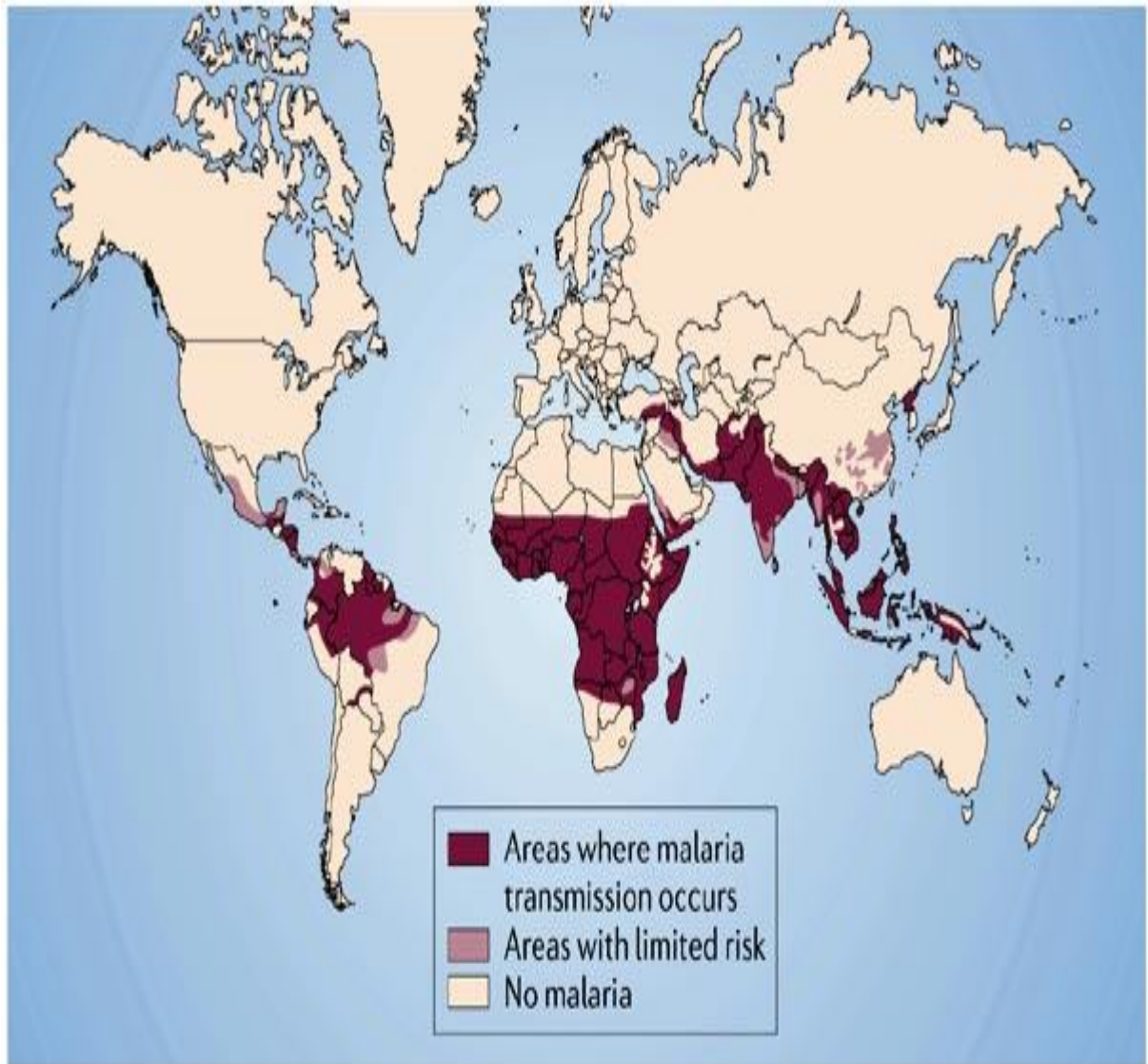


Figure 2.1. World malaria distributions

Source: http://www.nature.com/nrmicro/journal/v4/n9_supp/fig_tab/nrmicro1525_F2.html

2.2 Over view of Malaria distribution and status in Ethiopia

Malaria is a leading health problem in Ethiopia (Figure 2.2). About two-thirds of the population lives in areas where malaria is transmitted. It is the leading communicable disease in Ethiopia. It contributes up to 20% of under-five years of age deaths. In Ethiopia generally low land and moderate areas below 2000 meters altitude are considered Malarious. (Federal Ministry of Health, 2011).

According to UNICEF, Out of an estimated 9 million malaria cases annually in Ethiopia, only 4-5 million will be treated in a health facility. The remainder will often have no medical support. It is estimated that only 20% of children under five years of age that contract malaria are treated in a facility. *P. Falciparum* and *P. Vivax* is two common malarial parasites in the region. The former is considered the more severe of the two and almost all deaths occur by infection from this parasite. *P. Falciparum* can rapidly become resistant to malarial treatment and poses a significant challenge to malarial medicine. (<http://www.unicef.org/ethiopia/malaria.html>)

Overall, according to the Federal Ministry of Health (FMOH), malaria accounts for up to 12% of outpatient consultations and 10% of health facility admissions. About 75% of the country has malaria transmission (areas which are found at altitude of <2,000 m), with about 68% (i.e. 50 million) of the country's total population living in areas at risk of malaria as shown in figure 2.2. The FMOH estimates that there are 5 – 10 million clinical malaria cases each year. However, of these, at present, only 1,349,659 are reported at national level, with 245,499 (18%) being confirmed by a diagnostic test (note, this does not include data from all health posts). According to FMOH reports, approximately 70,000 people die of malaria each year in Ethiopia. (Federal Ministry of Health (2011), cited in Malaria Operational plan (MOP), Ethiopia, 2011).

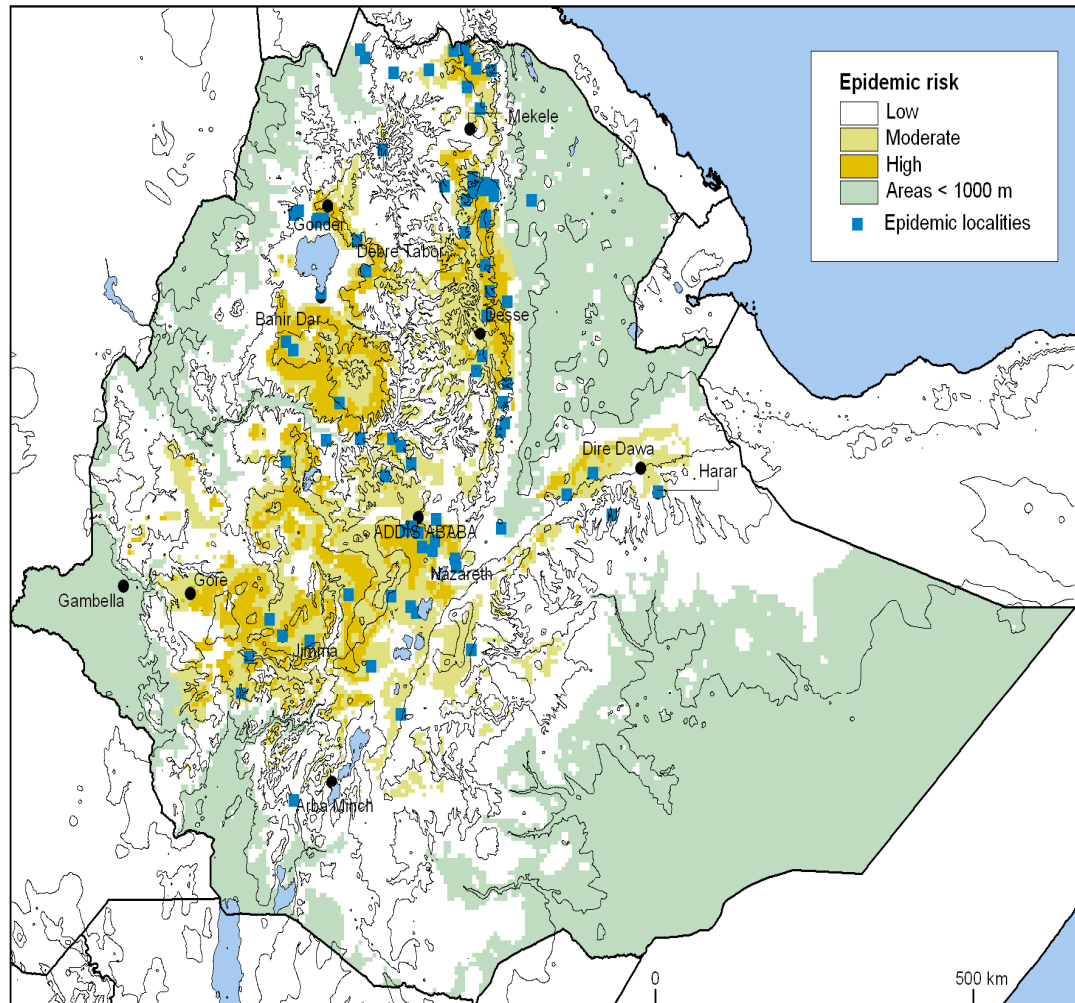


Figure 2.2. Malaria epidemic risk map
Source from Abdlesemed Jamal, 2012.

2.3 Importance of mapping malaria risk areas

The need for maps of malaria distribution has been recognized by malaria epidemiologists for as long as the disease has been studied (Gill 1920; Boyd 1930; Lysenko & Beljaev 1969). It becomes important in mapping malaria distribution and risk. Such maps would make it possible to target control measures at high risk areas and greatly increase the cost efficiency of malaria control programs. Most risk maps that have been developed so far have used as key inputs climatic models and information on weather data such as rainfall, temperature, and relative humidity, which to a large extent determine the survival and reproduction of the mosquito and the development of the parasite in the vector. Other studies have used different indicators of vector presence, reproduction, and survival, such as vegetation

patterns, land use, and soil moisture. The environmental and climatic variables are then linked with entomological (the study of insects) and epidemiological information to identify geographical areas at high risk for malaria. These have covered either vast areas, such as the efforts to map the malaria risk in Africa or a relatively limited number of villages (Wim, *et al*, 2003). GIS and Remote Sensing offers powerful tools to present spatial information on malaria risk areas. Such information has important implications for the disease eradication strategy to be employed. GIS allows policy makers to easily understand and visualize the problems in relation to the available resources and target resources to those communities in need.

2.4 Malaria and the mosquito vector group

Malaria found throughout the world except the frozen part of our world. It is transmitted by anopholes mosquito, generally bite at night and usually rest on a surface (such as the wall of a house) before or after feeding. Unfortunately Africa is home for some of the most effective malaria vectors. Which are caused by five species of parasites of the genus *Plasmodium* that affect humans (*P. falciparum*, *P. vivax*, *P. ovale*, *P. malariae* and *P. knowlesi*). Malaria due to *P. Falciparum* is the most deadly form and it is predominates in Africa. It is generally confined to tropical and subtropical regions because the development of the parasite in the mosquito is greatly retarded when the temperature falls below 20°C. At this temperature, Three weeks are required for maturation of sporozoites. *P.falciparum* is the chief infection in areas of endemic malaria in Africa, and is also responsible for the great regional epidemics, which were a feature of malaria in North West India and Sri Lanka. *P. vivax* is less dangerous but more widespread, it occurs in most of the temperate zones and also in large areas of the tropics (Gilles and Warrell, 1993). It is found mostly in Asia, Latin America, and in some parts of Africa (CDC, 2004). Thus, *P. vivax* contributes substantially to the disease burden (morbidity) of malaria, with a resulting social and economic impact.

The two other species are less frequently encountered. *P. ovale* is found mostly in Africa (especially West Africa) and the islands of the western Pacific. It is biologically and morphologically very similar to *P. vivax*. However, differs from *P. vivax* as it can infect individuals who are negative for the Duffy blood group, which is the case for many residents of sub Saharan Africa. This explains the greater prevalence of *P. ovale* (rather than *P. vivax*)

in most of Africa. The fourth one is, *P. malariae* is found worldwide and causes a long lasting, chronic infection that in some cases can last a lifetime. In some patients, *P. malariae* can cause serious complications (CDC, 2004).

The four *Plasmodium* species known to cause malaria are listed above, and a fifth species, *Plasmodium knowlesi*, is typically found in nature as macaques (monkeys) and has recently been identified as a clinically significant pathogen in humans. This is an emerging infection that was reported for the first time in humans in 1965 (chin, *et al*, 2008). It accounts for up to 70% of malaria cases in South East Asia particularly the forested areas where it is mostly found. This parasite is transmitted by the bite of an *Anopheles leucosphyrus* mosquito (McCutchan, *et al*, 2008).

Although the infecting parasite was initially identified as *P. falciparum*, one day later it was then identified as *P. malariae* and it was only confirmed to be *P. knowlesi* after the infected blood was used to inoculate Rhesus monkeys (Coggeshall, 1940).

2.5 factors influence malaria incidence

The distribution of malaria is governed by a large number of factors relating to the parasite, the vector and the host. Among these are climatic and environmental factors, particularly those that affect habitat and breeding sites of the *Anopheles* mosquito vectors such as temperature, precipitation, humidity, presence of water, vegetation, migration and man to vector contact etc.

2.5.1 Temperature

Temperature plays an important role in the variability of malaria transmission by regulating the development rate of mosquito larvae and influencing the survival rate of adult mosquitoes. In cold temperatures the larvae develop very slowly and in many cases they may be eaten by predators and may never live to transmit the disease (Grover-Kopec, *et al*, 2006). At 26°C the extrinsic incubation period of this malaria species is about 9-10 days whereas at 20- 22°C it may take as long as 15-20 days. In highland areas, where cold temperatures preclude vector and/or parasite development during part/or all of the year, increased prevalence rates may be closely associated with higher than average minimum temperatures (Bouma, *et al*, 1994).

Therefore generally we can say that in the cooler the ambient temperature, the slower the malaria parasite develops. The warmer the ambient temperature, the faster the malaria parasite develops. If the incubation period takes longer than the life of the mosquito, the parasite will never infect a human. In some places, especially at higher elevations, malaria does not exist or is seasonal because, with cooler temperatures the mosquitoes die before the parasites are mature.

2.5.2 Rainfall

Malaria vectors depend on rainfall, since it provides breeding sites for the mosquitoes to lay their eggs. The amount and the seasonality of rainfall are important parameters in determining the location of mosquito breeding habitats as well as the total density of adult mosquitoes. Breeding increases dramatically in the rainy season when water collects in stagnant bodies and these provide ample breeding ground through wells, ponds, water tanks and paddy fields. (Yazoume, *et al*, 2008)

During periods of heavy rainfall, breeding may be hampered due to the excess water resulted from heavy rain make the streams and the pools move fast and torrential (rushing the streams), so it flushing away the eggs and larvae. Excessive rains may also have the opposite effect increase vector populations in many circumstances by increasing available *Anopheles* breeding sites. According to Yazoume, *et a.*, (2008)

In general, high transmission is often related to either excessive rainfall, creating additional vector- breeding places, or exceptionally low rainfall causing the pooling of rivers and streams to form major breeding sites. In such instances, malaria can become epidemic, and several devastating epidemics have occurred after the failure of the southwest monsoon (Konradsen, *et al*, 2000).

2.5.3 Humidity

Rainfall apart from creating mosquito breeding sites, affects malaria transmission through increasing humidity, which in turn will help to increase the longevity of the adult vectors. The optimum temperature for development of malaria parasite is between 25 °C to 30 °C and average relative humidity at least 60 %. These temperature and relative humidity conditions

increase the longevity and density of mosquitoes and thus initiate malaria transmission, if parasite load exists in the community (Yazoume, *et al*, 2008) cited in aster tirunesh, 2010.

2.5.4 Altitude

Altitude is one the factors that contribute for malaria transmission. The transmission level varies from altitude to altitude. The cold zone, which covers areas higher than 2,500 meters (m) above sea level, has a mean annual temperature of 10–15°C. This highland area is considered free of local malaria transmission. The midland area, ranging in altitude from 1,500–2,500m with a mean annual temperature between 15–20°C, has diverse malaria transmission patterns. In the hot lowland zone, located in areas below 1,500m above sea level, where the mean annual temperature varies from 20–25°C, malaria transmission is endemic, and its intensity and duration are mainly dictated by the amount and duration of rainfall. (Ghebreyesus, *et al*, 2006).The Malaria prevalence is observed up to 3500 meter above sea level, even though it decreases with increase in altitude (Graves, *et al*, 2008).

Altitude and temperature are explicitly linked, with every 100 m increase in height corresponding to an approximately 0.5°C decline in temperature. The use of altitude can be confusing, however, with the limit for malaria transmission variously reported above 2000 m in Ethiopia (Covell, 1957)

2.5.5 Slope

Slope is an important habitat characteristic for many species (Jenness, 2007). Steeper slope does not favor plant and animal dwelling relative to gentle slopes. It is a measurement of how steep the ground surface is, the steeper the surface, the greater the slope. Generally flat topography characterized by restricted natural drainage. It is more pronounced with the type of soils. Therefore, without the existence of efficient water drainage systems can led to the creation of stagnant water pools and used as a crucial factor of water stagnates, which in turn, encourage the breeding and survival of mosquito (Malhotra and Aruna, 1995) cited in aster, (2010).

2.5.6 Land use/Land cover

Land cover affects the temperature of larval habitats directly and food conditions and other factors indirectly, but the synergistic effects of these factors may be more significant to larval

survivorship. Different kinds of land cover indicate different types of residential areas suitable for various vectors. Productivity of malaria vectors is significantly higher in aquatic habitats located in farmlands compared with those in swamps and forests. Pupation rate was significantly greater and development time was shorter in habitats in farmlands compared with other land cover types (Munga, *et al*, 2006).

The type and distribution of vegetation can influence mosquito populations. The presence of vegetation creates microclimatic conditions which are moderate temperature and humidity, it is suitable for mosquitoes. Land cover can be measured directly by field observation or indirectly by satellite imagery. Satellite imagery can quantify the amount of vegetation by Normalized Difference Vegetation Index (NDVI) (Yazoume, *et al*, 2008).

2.6 GIS and RS Technique in malaria risk map

GIS is defined as an information system that is used to input, store, retrieve, manipulate, analyze and output geographically referenced data or spatial data. GIS is an umbrella term which integrates wide range of datasets available from different sources including Remote sensing (RS) and Global Positioning System (GPS). All methods of collecting information about earth without touching it are forms of remote sensing. Satellites, radars and aerial photographs are the different ways of acquiring remotely sensed data. GPS is a system of twenty-four satellites that allows the co-ordinates of any point on or near earth's surface to be measured with extremely high precision.

GIS and Remote Sensing offers powerful tools to present spatial information on malaria risk areas. Such information has important implications for the disease eradication strategy to be employed. GIS allows policy makers to easily understand and visualize the problems in relation to the available resources and target resources to those communities in need. Therefore, GIS is often termed as core of spatial technology having built-in power to analyze integrated dataset and to present the results as useful information to assist decision making. (Boulos, *et al*, 2001).

GIS mapping has assisted in monitoring and evaluation of malaria control activities in various countries. In comparison with tables and charts, maps developed using GIS are more effective means for communicating messages clearly even to those who are not familiar with

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the technology. Therefore, GIS is a potentially powerful tool for epidemiology, in mapping diseases and their determinants, quantifying risk, linking diseases and their potential risk actors, and creating databases for further statistical and epidemiological analyses. For malaria research and control, GIS has great potential since it has the capacity to integrate information on all aspects of malaria including the environmental factors, infrastructure and demography. GIS has been intensively used in malaria research to examine the link between environmental factors and malaria transmission risk (Yazoume, *et al*, 1988).

3. Material and Methods

3.1 Study Area

Aysaita is one of the woreda found in the Afar Region of Ethiopia and before 2007 was the capital of the Afar Region of Ethiopia. Part of the Administrative Zone 1, Aysaita is bordered on the south by Afambo, on the west by Dubti, then on the north by Elidar woreda, and on the east by Djibouti. The major town in Aysaita woreda is Aysaita. It have 13 kebeles where two are located inside Aysaita town, namely kebele 01 and kebele 02. The denser population is also in Aysaita town. The Part of the shoreline of Lake Gargori (abihi bad) lies within the boundaries of this woreda. The study area bounded by latitude $11^{\circ} 39' - 11^{\circ} 36'N$ and longitude of $41^{\circ} 24' - 41^{\circ} 36'E$ covering a total area of 1731 km^2 and an elevation of 300 meters (figure 3.1). It is 50 kilometers south by unpaved road from Awash–Asseb highway. The total population of this woreda is 77,383. The life of the people in this woreda is depends on crop production and livestock rearing.

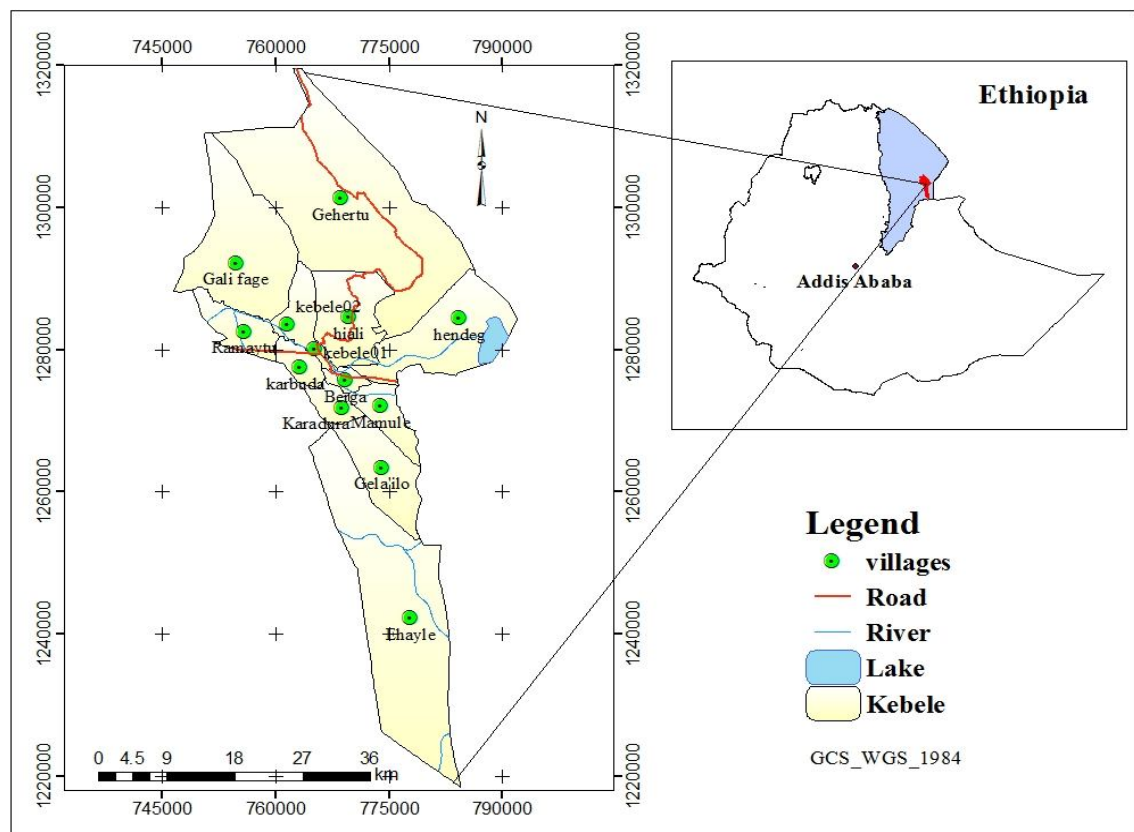


Figure 3.1. Location map of study area

3.1.1 Topography of the study area

Elevation is known to define the ecology of malaria transmission through temperature. At certain altitudes malaria transmission does not occur because of extreme temperatures that inhibit the mosquito and parasite life cycle. The altitude of the study area ranges from 270 up to 1378 meter above sea level. Most part of the study area is characterized by flat lying topography which covers more than half of the area having altitude of from 0 up to 270m, the medium ranged areas are from 270m up to 600m above sea level and the higher altitude of this study area is from 600m up to 1378m above sea level as shown in figure 3.2.

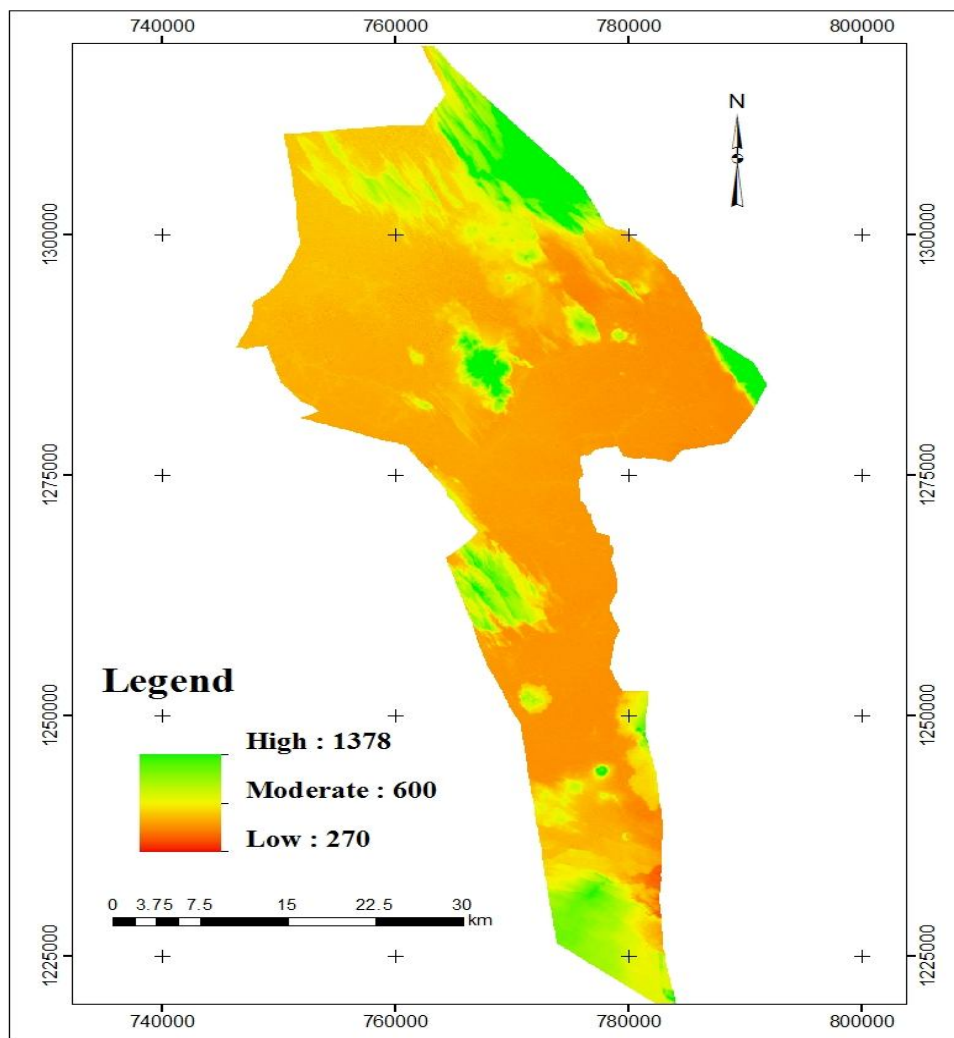


Figure 3.2. Altitude map

3.1.2 Population

Based on statistical data of health bureau in Aysaita woreda, the total population of this woreda is 77,383. The major town in Aysaita woreda is Aysaita; it is highly populated with more than 22,350 people. It has a population density of 34.7. While 16,052 or 31.60% are urban inhabitants, a further 9,358 or 18.42% are pastoralists. A total of 11,096 households were counted in this woreda, which results in an average of 4.6 persons to a household, and 11,404 housing units. This woreda is consists of 13 kebele. Kebele 01 and kebele 02 are found in Aysaita town. The Population of this woreda by kebeles is clearly shown in figure 3.3.

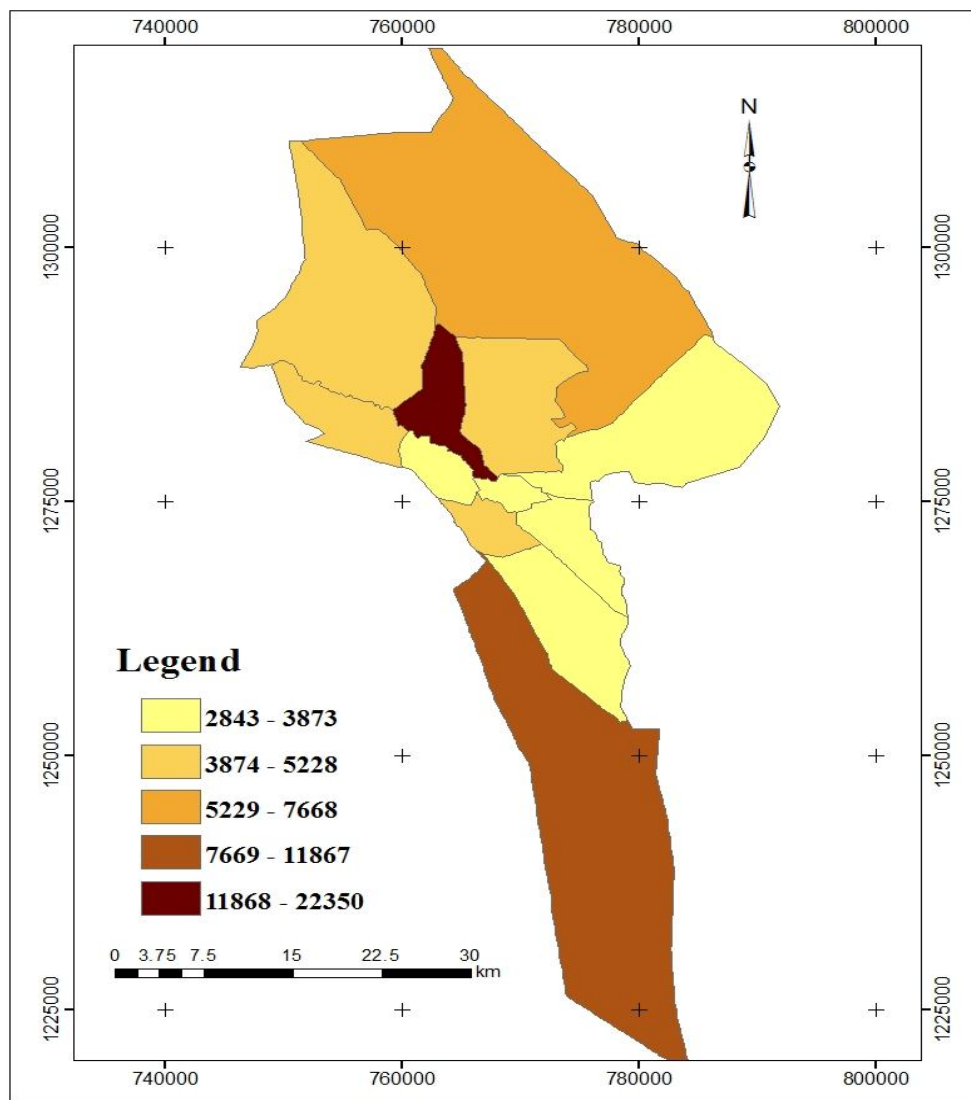


Figure 3.3. Population map

3.1.3 Population density

The Population density indicates the number of people per area. From the map shown in figure 3.4, Aysaita woreda is characterized by an average population density ranging 94-445 people per km². These areas cover the West part of the study area, while the Aysaita town and Berga kebele are densely populated with more than 255 up to 445 people per km². the rest of the kebeles have population density of below 94 people per km². In relation to malaria transmission with the population density is directly proportional, which means that higher population density, will cause higher malaria transmission.

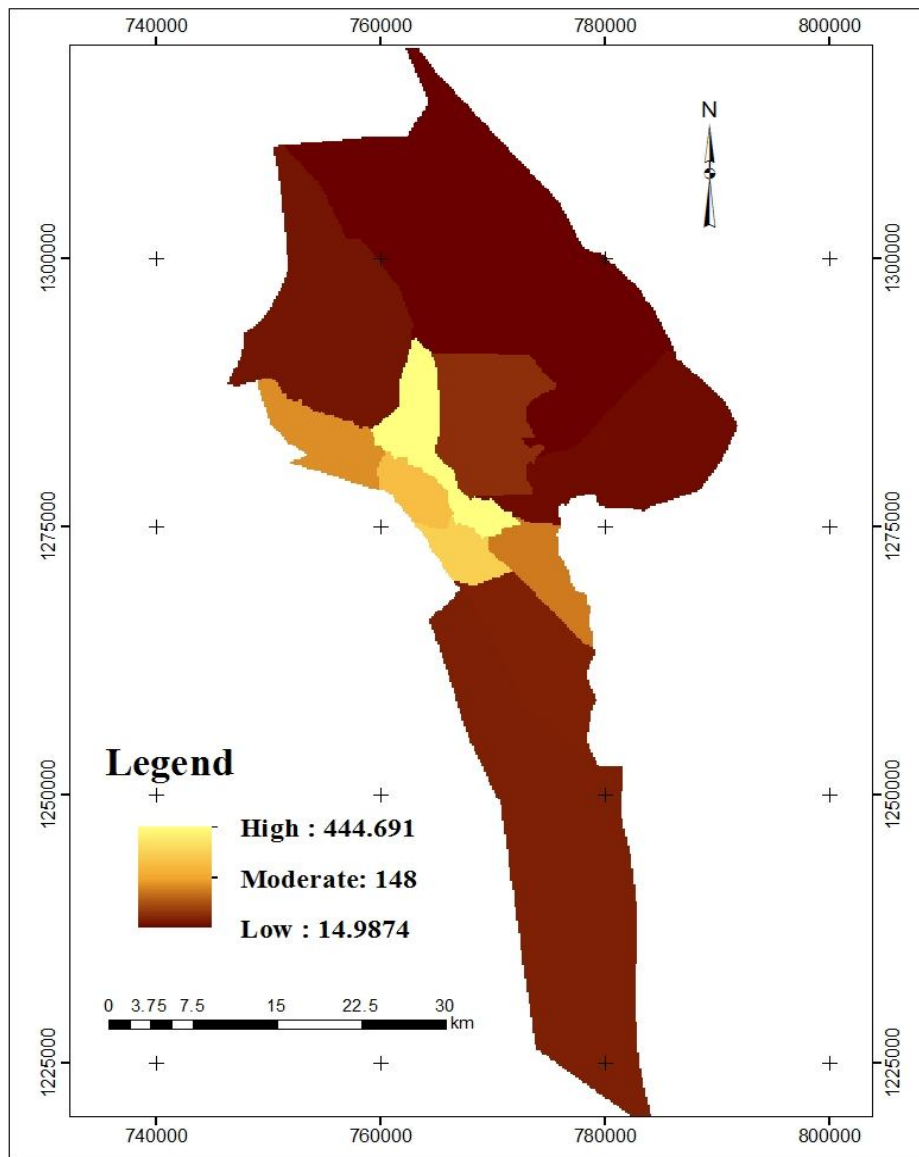


Figure 3.4. Population density map

3.1.4 Health facility

Aysaita woreda have total number of nine health facilities as shown in figure 3.5. From this, one is hospital which is found in Aysaita town kebele 02 and the rest eight are health post and there is one newly constructing health posts. Malaria diagnostic laboratories were found only at the hospital in kebele 02. There were trained Community Health Workers in the district serving the community. Most of the Health centers are found in the center part of the study area where there is access to road for transportation. Four kebeles does not get any health facility center. Especially for Ehayle kebele doesn't have any way to get access from the woreda. Instead if there is any need for that kebele they travel from Dubti woreda.

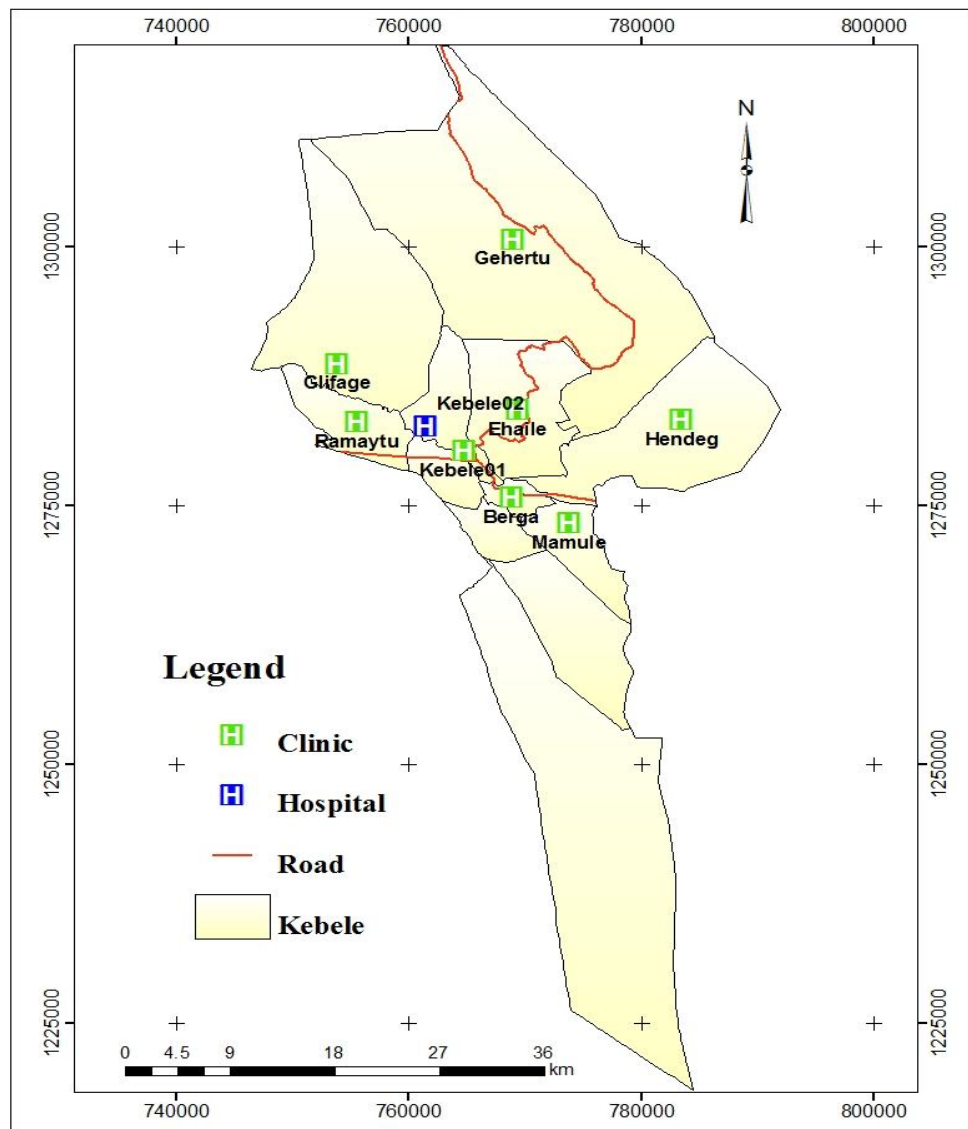


Figure 3.5. Health facility map

3.1.5 Major climate variables

The Afar regions climate experienced four rainy seasons throughout the year; the ‘Karma’ rain considered the main rainy season and lasts for a period of approximately 2 months and comes from the highlands (in the months of July and August). The second season is ‘Daddah’ and comes from the direction of the red sea (in the months of November and December or winter rains) and is now the most unreliable often giving only a single shower. ‘Suggum’ is the third or short rainy season (in the months of March and April). The regional decrease in rain has seen the ‘Karma’ rainfall for only 15 days, then the ‘Suggum’ rain for 1-2 days only. Now the region generally sees rain in only one of these periods. The emerging pattern has been that if the ‘karma’ rains come, then the ‘suggum’ rains fail or vice versa, and these are at a much reduced quantity than usual. The rainfall that has fallen has occurred in patches and is not distributed evenly throughout the area. Rainfall has also been reduced in the highlands which in turn affects the amount of water flowing through numerous rivers and siphoning off of water for irrigation has further reduced water flow. (Vanessa Moss and logia councilor, 2009)

Climate feature have direct influence on the spreading of mosquito and their survival. The average temperature of the study area is suitable for spread and survival of mosquito. Which is the average maximum temperature of the study area are 33.15, the average minimum temperature is 29.1 and average rainfall is 12.54millimeter as shown in figure 3.6. The temperature of the study area is higher in between March and June. And after June rainy season will follow for about three month. The monthly climatic data collected from meteorology agency of Ethiopia from 1999 up to 2010 G.C. from seven stations. In table 3.1 is shown that the mean maximum and minimum temperature of the study area.

Table 3.1. Average monthly temperature and rainfall value

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Seb	Oct	Nov	Dec
Temperature Min(°C)	24.4	25.3	27.7	29.8	31.9	32.3	30.5	30.4	32.4	30.1	28.8	25.3
Temperature Max(°C)	28.7	30.1	31.8	34.9	37.1	37.9	36.7	34.4	33.9	31.9	31.31	29.4
Rainfall(mm)	1.75	6.03	13.9	14.3	1.53	3.51	23.6	56.7	14	5.74	3.49	5.96

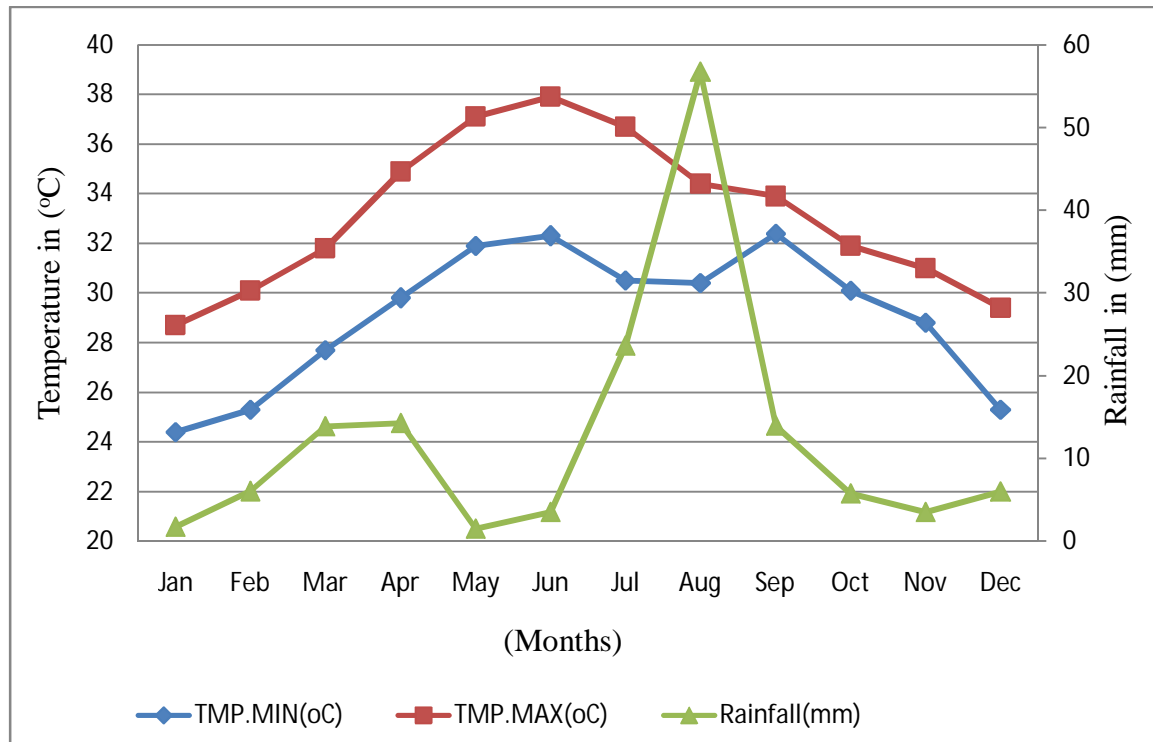


Figure 3.6. Average monthly temperature and rainfall in 1999-2010.

3.2 Data used

As shown in table 3.2, Different data of primary and secondary sources were collected from field survey and respective institutions. Climatic data which constitute temperature and rain fall of the study area was taken from National meteorology agency of Ethiopia. Shape files of the study area which is comprised of different thematic and attribute data of road, rivers, existing town, rural kebeles, and woreda boundary were taken from EMA. Satellite image landsat ETM+ obtained in 2011 having 30m Resolution is used for LULC classification and for accuracy assessment ground truth data collected by using GPS. And also it has been used to collect locations of different types of health institutions within the study area and also the location of the kebeles. Elevation and other topographic data were taken from SRTM data of USGS.

Table 3.2. Data source

Data	Data source	availability
Toposheet	EMA	YES
Satellite image Landsat ETM+ 2011	EMA	Yes
STRM	AAU server	Yes
Climatic data	Meteorology of Ethiopia	Yes
Mobility and morbidity data	Afar health bureau	Yes
Population data	CSA	Yes
GPS data	Field	yes
Literature	Books and Internet	yes

3.3 Methodology and Analysis

The summarized activities and flow charts of the methodology of this study are shown in figure 3.7. The objective or aims of this research is at assessment of malaria prone areas by identify environmental factors like altitude, temperature, rainfall, distance from rivers, lake and swampy area, that will contribute malaria prevalence. And map malaria risk areas by using different software like ArcGIS 10.1 and ERDAS Imagine 9.2.

Environmental factors including temperature, Rainfall, altitude, slope and Distance from River were combined by weighted multi criteria evaluation for mapping malaria hazard area at the district level. Similarly, risk map was developed by overlaying weighted hazard, land use/land cover, population density and distance from health facilities.

The collected data like population, Health facilities GPS data, temperature, rainfall, satellite image and STRM 30m resolution data are needed for assessment of malaria risk map and done by using different techniques of Remote Sensing and GIS technology. Create shape files of the factors. Different techniques are applied to achieve the objective of this study is like Buffering and overlay are two of the most common operations in disease modeling. A buffer zone is an area that is within a given distance from a map feature. Points, lines, or polygons can be buffered. Buffers are used to identify areas surrounding geographic features. The 2000m is the average flight distance of the mosquito (Wim, *et al.*, 2003). For example by considering this we can buffer distance from water bodies and generally we can say from

mosquito breeding site. An overlay is the primary way to combine information from two or more separate themes. Overlays are most common for polygonal data, and perform a geometric intersection, which results in a new layer with the combined attributes of both initial layers. And also some calculation is also done to calculate the average monthly climate data using Microsoft excel.

A monthly alert threshold was proposed for all the health facility centres. This threshold is calculated as the monthly average of presumed malaria cases during the six years. The risk maps were validated with the results of the investigation in health facility centres, which had posted an alert. Only nine such centres were included in the study area, and were defined or renamed as the villages in which they operate. These villages were superimposed on the risk map.

On the second phase after prepared all the factors in the form of shape file, the weighting preceded will be applied in order to analyze the factors done on the first phase. The factors present different units. They were standardized to a continuous common numeric range on a 0 to 255-byte scale. Fuzzy method was used for their standardization. Fuzzy set membership is the result of data classification according to the possibility of belonging to a class in which the boundaries between classes are not distinct. Consequently, the transition between membership and non-membership of the area is gradual.

The technique developed by Saaty (1977), cited by Rakotomanana, *et al*, (2007) was used for factor weighting. This is a decision-making procedure known as the Analytical Hierarchy Process (AHP). It includes a pair-wise comparison in which only two variables were considered at a time. The continuous rating scale of Saaty (1977) was used to rate factors with the following values, 9 (extremely important), 7 (very highly important), 5 (highly important), 3 (moderately important) and 1 (equally important).

Inversely, less important variables were rated $1/3$ (moderately less important), $1/5$ (much less important), $1/7$ (very much less important) and $1/9$ (extremely less important). The pair-wise comparison table was completed with the values corresponding to the degree of importance of the factors based on the correlation study. For example, if the temperature was extremely more important than indoor insecticide spraying, one could enter 9 on the scale; and

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consequently indoor insecticide spraying would be extremely less important than temperature, so 1/9 would be entered.

Factors weights were calculated from the table of pair-wise comparisons and scaled with IDRISI Version 3.2 release 2 (Clark University, 950 Main street Worcester USA). The weights have to sum to one as required by the WLC procedure. The ratio consistency was calculated as the ratio of the index of coherence in the initial matrix to the random index of the matrix with the same dimension. It indicated the probability that the matrix ratings were randomly generated. If the ratio consistency is higher than 0.10, pair-wise comparison had to be re-evaluated.

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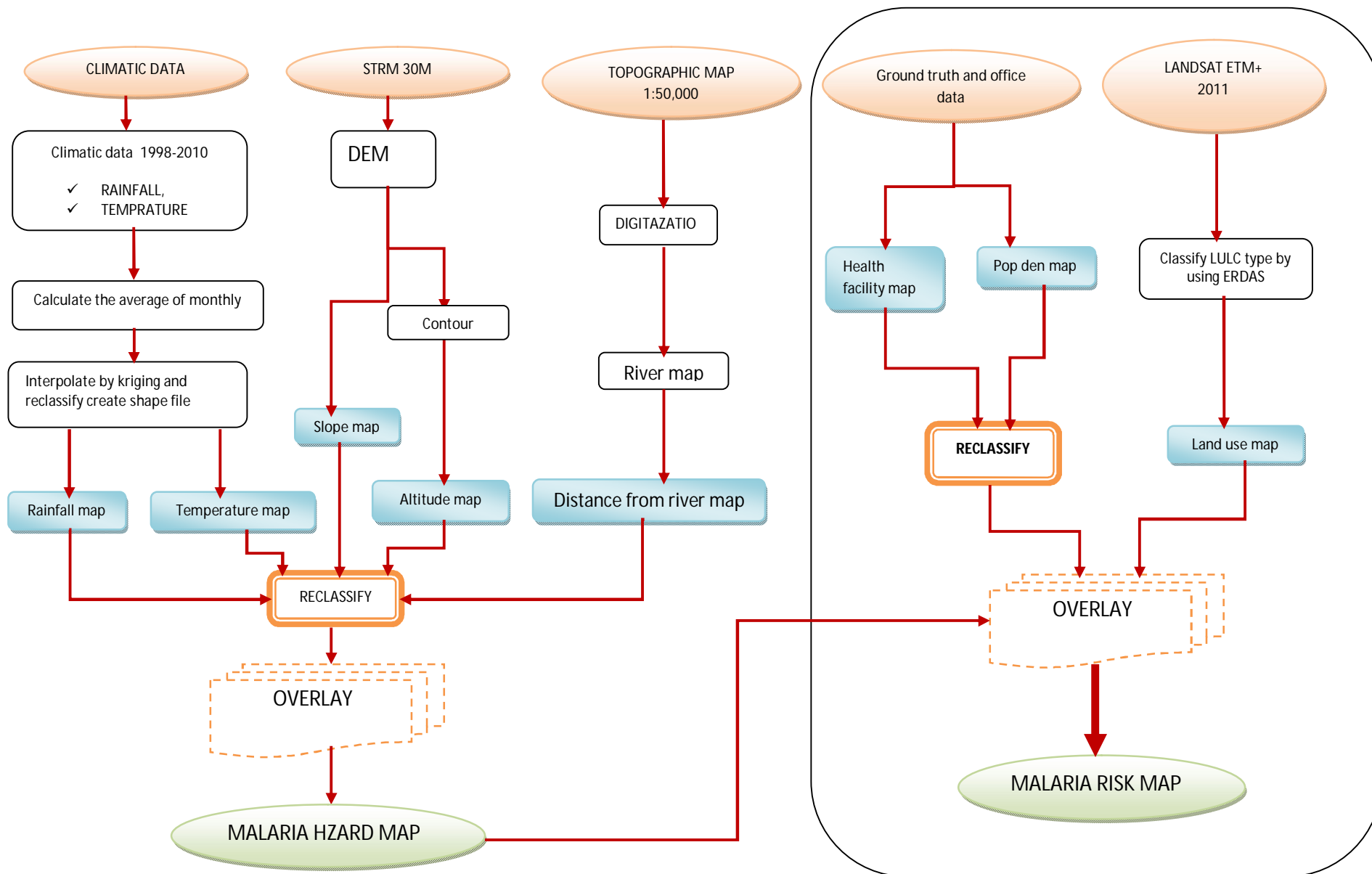


Figure 3.7 Methodology flow chart

3.3.1 Assessment of malaria hazard areas

Hazard is defined as the inherent capacity of a chemical substance to cause adverse affect in human and animals and to the environment, while risk is defined as the probability that a particular adverse effect will be observed under certain specified condition, exposure or use, WHO (2012). Hazard map, therefore, a map that highlights areas which are vulnerable for breeding and maintenance of malaria vectors and parasites, was prepared by weighting and overlaying environmental factors (Jeefoo, *et al*, 2008) (figure 3.8).

The collected data, like altitude, slopes, temperature, rainfall and Distance from River. are used for assessment of malaria hazard map. These are done by using different remote sensing and GIS techniques. Temperature and rainfall data are collected from meteorological agency of Ethiopia year of 1999 - 2010. The temperature calculated as the average of maximum and minimum temperature of 12 years. The rainfall also Calculated the monthly average using Microsoft excel. Interpolation and reclassification process are done using ArcGIS10.1. For the altitude and the slope are generated from STRM data. This STRM data imported using global mapper convert to DEM file and patched using 3DEM software. At the result Slope and altitude Layer created using ArcGIS 10.1 spatial Analysis tool. From landsat ETM+ satellite image year of 2011 downloaded. Layer stacking process done using ERDAS Imagine software to combine all the bands. And also using this software supervised classification is done. After all this environmental factors reclassified using different RS and GIS technique the malaria hazard map is generated (figure 3.8), and weighting and overlay analysis process also applied (table 3.3).

Table 3.3. Pair-wise comparison of factor layers for Hazard map.

Layer	Rainfal 1	Temperature	Elevation	Slope	Distance from river	Weight (%)
Rainfall	1					45%
Temperature	1/3	1				26%
Elevation	1/3	1/3	1			14%
Slope	1/5	1/5	1/3	1		7%
Distance from river	1/7	1/3	1/3	1/3	1	8%

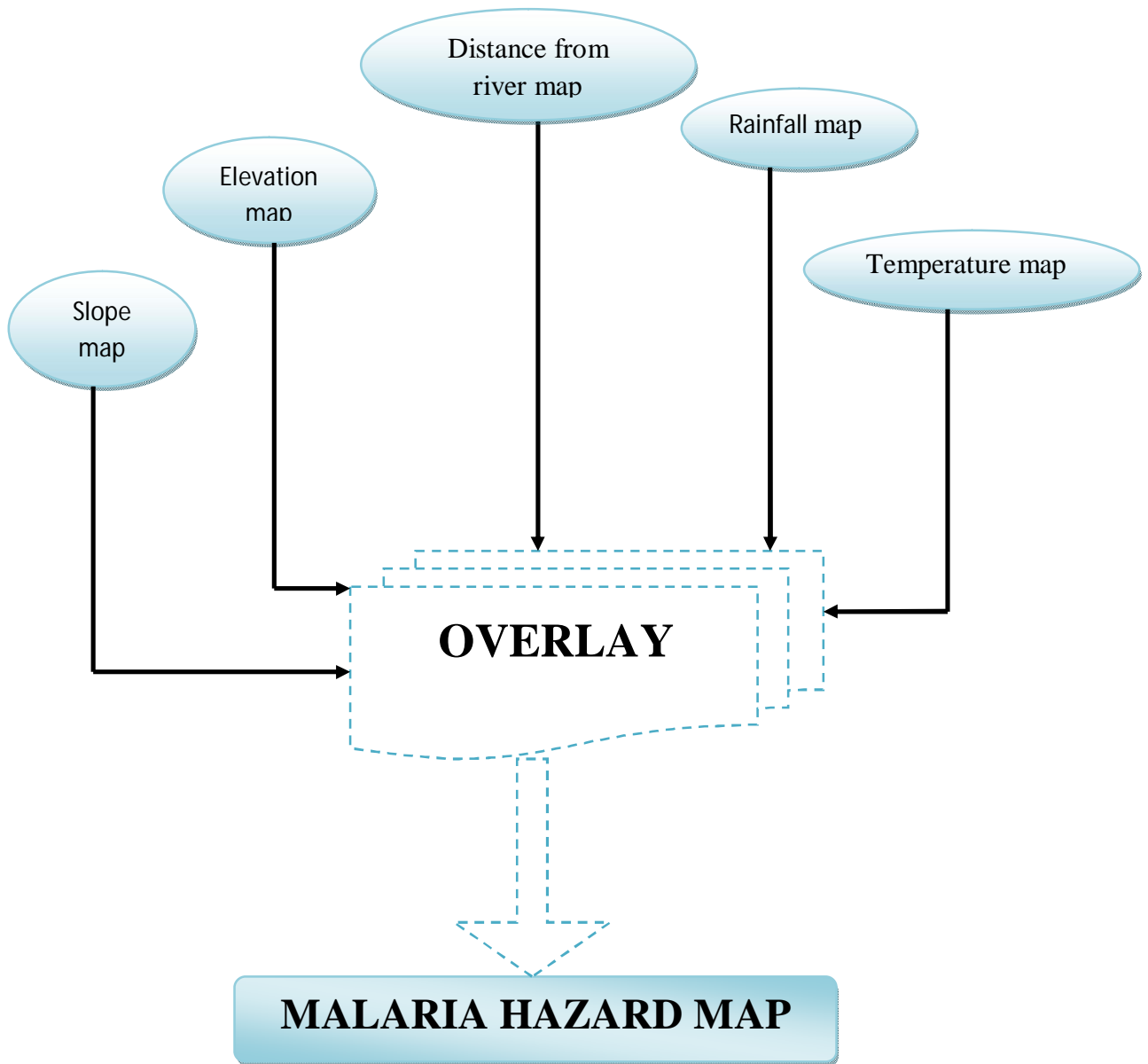


Figure 3.8. Flow chart of Assessment of malaria Hazard map

3.3.2 Assessment of malaria risk

All the input environmental factor were given weights and overlaid and the new malaria hazard map were produced, further the malaria risk map were generated. The basis for this map is the risk computation model which is developed by Shook (1999).

$$\text{Risk} = (\text{Hazard}) * (\text{Element at Risk}) * (\text{Vulnerability})$$

$$R = H * E * V$$

“Hazard (H)” is the probability of occurrence of a potential damaging natural phenomenon within a specified period of time and within a given area

“Element at risk (E)” includes the population, buildings, and civil engineering works, economic activities, public services, utilities and infrastructures, etc., at risk in a given area.

“Vulnerability (V)” is the exposure of a given element or set of elements at risk resulting from the occurrence of a damaging phenomenon of a given magnitude.

“Risk (R)” is the expected degree of loss due to a particular natural phenomenon. It may be expressed as the product of hazard (H), vulnerability (V), and element at risk (E)

In mapping malaria risk map by using Shook (1999) model is the product of malaria hazard areas, computing and reclassifying the population density map which is the element at risk layer and vulnerability map that is produced by reclassifying land use/land cover layer and distance from River Figure 3.9. Since Water body is one of the factors for malaria's breeding site, therefore distance from river were calculated by using buffering tool in ArcGIS 10.1. And also GPS data taken in field for each health facilities. Then the maximum and minimum distance from the boundary is taken. Which is the minimum distance of health facilities are 2 km and the maximum distance from health center to the administrative boundary is 62 km. then classification process is done using in between the range of this two minimum and maximum distance from boundary is taken and classified using ArcGIS 10.1. Weighted overlay analysis using multicriteria decision technique were implemented to produce the Malaria risk map of the area. The overflow of the methodology is shown in figure 3.9 and also the weight given by IDRISI is also shown in table 3.4.

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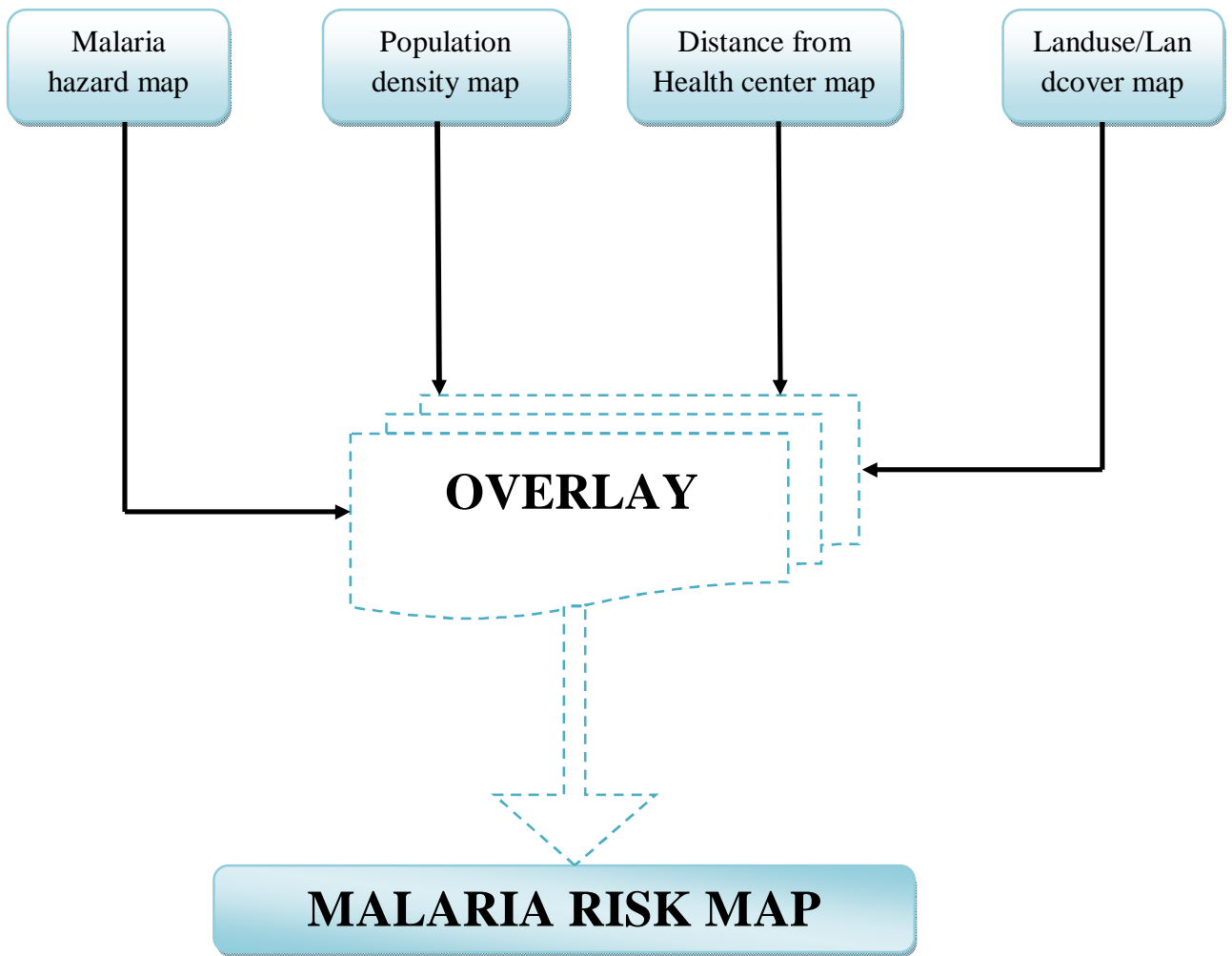


Figure 3.9. Flow chart of Assessment of malaria risk map

Table 3.4. Pair-wise comparison of factor layers for malaria risk map

Layer	Hazard	Pop den	Health	LULC	Weight (%)
Hazard	1				56%
Pop den	1/3	1			26%
Health	1/5	1/3	1		11%
LULC	1/7	1/5	1/3	1	7%

3.4 Data Analysis

3.4.1 Parameter for identifying Malaria Hazard area

Malaria is an environmental and climatic related disease affected by a variety of factors such as topography, temperature, rainfall, land use. A malaria risk map was generated based upon these environmental risk factors that allowed us to extrapolate malaria risk throughout the study area. The aim of this study is for identification of areas at highest risk of malaria epidemics based on environmental and climatic factors and the incidence of previous malaria epidemics. Based on literature search, previous works, and interviews with malaria experts; the following environmental factors that greatly influence on malaria prevalence were identified.

3.4.1.1 Altitude

Altitude is one of an important determinant of malaria endemicity. It affects various transmission factors which are epidemiologically significant. Probably the most important of these factors is temperature, which affects longevity of vectors and the process of parasite development. The relation of temperature and altitude is, when the altitude increases the temperature decreases.

The altitude of the study area ranges from 270 up to 1378 meter above sea level. Most part of the study area is characterized by flat lying topography which covers 81.3% of the area when compare with temperature it is categorized as hottest area, the medium ranged areas are covers 15.8% and the higher altitude of this study area covers only 2.9% of the area which is above 600 meter above sea level.

The layer was shown in figure 3.10 below. Which shows the reclassified Altitude map in to five classes and new values were assigned to each class and based on this classification, 1, 2, 3, 4 and 5 values were given to elevation ranges of 270 – 380m, 380 – 451m, 451 – 600m, 600 – 925m and 925 – 1378m above sea level respectively and the elevation of this study area are all suitable for malaria to survive according to FMOH. The classification is done by default equally classified. Because of the change in altitude will make variation in malaria prevalence even though with the same category. Accordingly, the classes were labeled in the figure 3.10 as Very high, High, Moderate, Low and Very Low according to their prevalence to malaria.

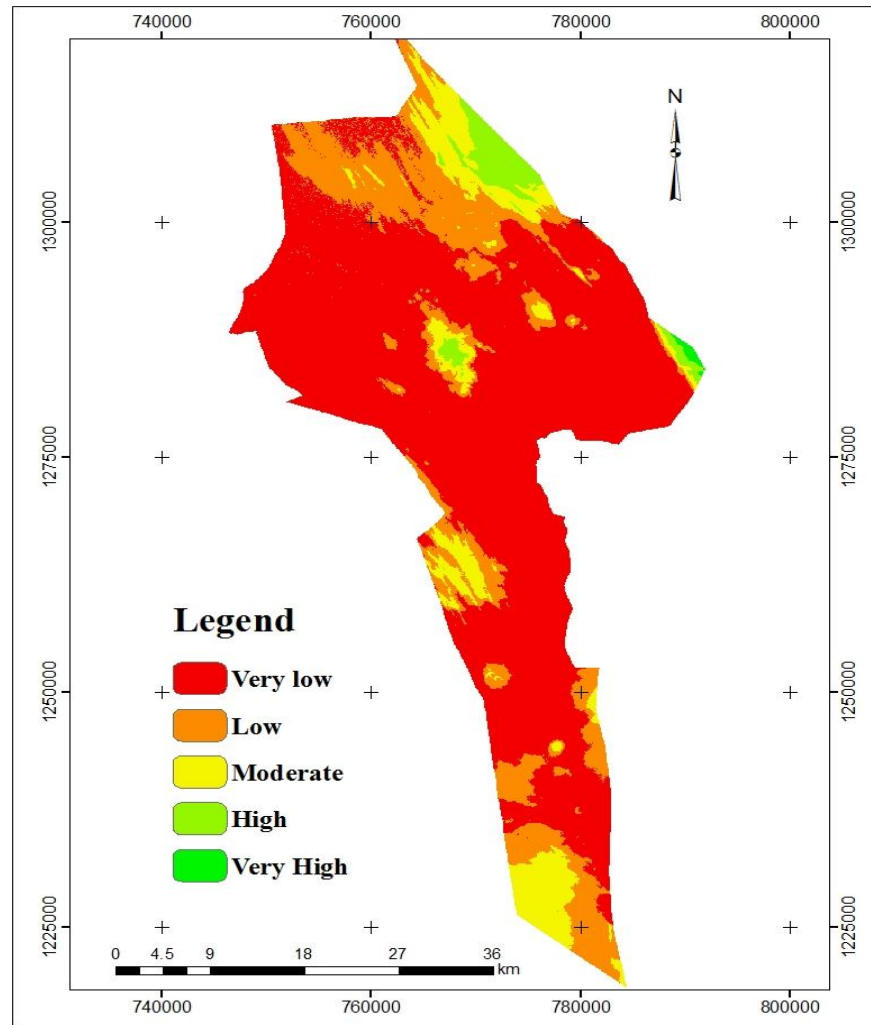


Figure 3.10. Reclassified Altitude map

3.4.1.2 Slope

Since, Slope is one of the topographic parameters that can determine the existence of mosquito larval habitat. Steeper slopes are slopes that allow the fast movement of water. Hence, they restrain the development of stagnant aquatic bodies which can be conducive for breeding of mosquito. Relative to steeper slopes, gentler slopes are slopes where surface water movement is stagnant and this creates fertile situation for mosquito breeding. Therefore, identifying gentler slopes can help to detect the relative importance of areas for mosquito breeding.

The slope of the study Area was derived from SRTM data 30m and reclassified in to five classes like the other parameters using natural break standard reclassification technique.

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The new classes (0-5°, 5-12°, 12-22°, 22-36°, 36-69°) in the reclassified slop layer shown in figure 3.11 were ranked to 5, 4, 3, 2, and 1 and described as very high, high, moderate, low, and very low respectively based on the relative degree of suitability of the slope class for malaria incidence. This means that relatively, gentler slopes are better suitable for malaria incidence and steeper slopes are less suitable.

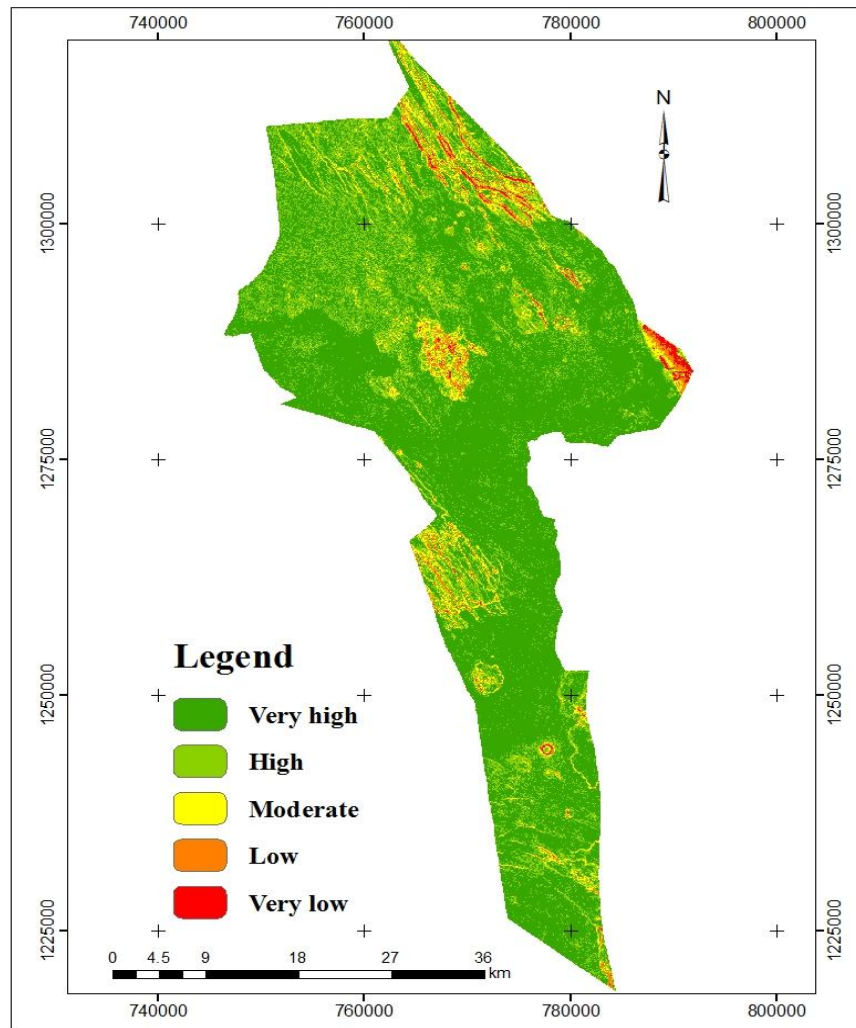


Figure 3.11. Reclassified Slope map

3.4.1.3 Temperature

Temperature affects malaria transmission for two reasons: either the minimum temperature is so low that it prevents parasite and vector development or else the temperature is too high resulting in increased mortality of the vector. A minimum temperature of 16°C restricts parasite development and also prevents the development of

the vector in its aquatic stages. At 17°C parasites develop but not rapidly enough to cause an epidemic (Lindsay *et al.*, 2004).

Temperature is also one of the main meteorological parameters associated with malaria transmission, and is a determining factor that aids in determining the persistence of breeding sites, the duration of the larval development, the adult mosquito survival rate, the duration of the gonotrophic and sporogonic cycles. Most of the Studies have indicated that *P. falciparum* cannot be transmitted when the average daily temperature is below 18°C; likewise *P. vivax* transmission is usually impossible if the average daily temperature is below 16°C. An average daily temperature of above 30°C is lethal to the *sporogonic* stages of the parasite within the mosquito vector. An average daily temperature of above 30°C is also unfavorable to the vectors, as adult longevity may be reduced especially in arid environment (FMoH, 2004). And also in some studies is says up to 32°C.

This study area has average temperature of from 24 up to 31°C which fulfills the standard temperature in between 16°C to 32°C suitable for malaria prevalence (FMoH, 2004). Temperature data is collected from meteorology agency of Ethiopia for about 12 years and from seven stations. Inside study area there were only three stations therefore I face a problem on interpolation process in ArcGIS10.1

The layer was reclassified in to five classes and new values were assigned to each class and based on this classification, 5, 4, 3, 2 and 1 values were given to the area with temperature below 24 – 26°C, 26 – 27°C, 27 – 28°C, 28 – 29°C and 29 – 31°C, respectively. Hence, the classes were labeled in the figure 3.12 as very high, high, moderate, low and very low based on the level of vulnerability of those areas to malaria incidence.

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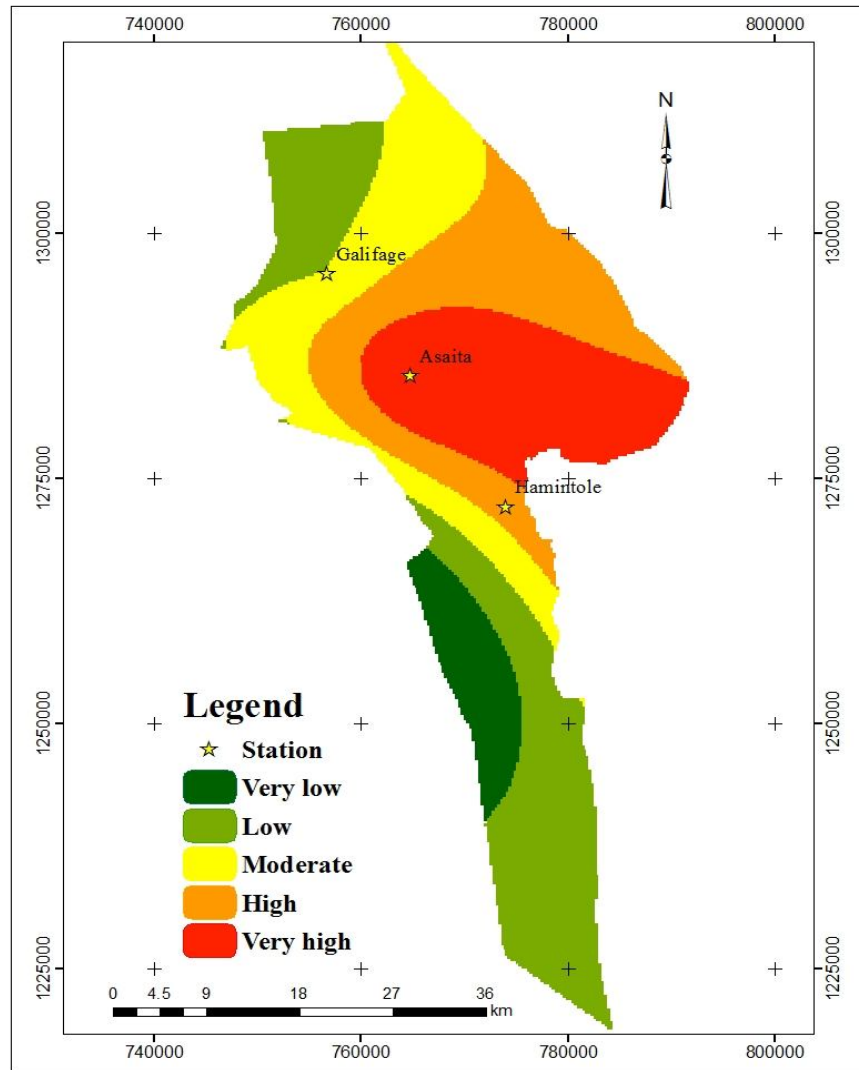


Figure 3.12. Temperature map

3.4.1.4 Rainfall

One of the variables used in this study is rainfall data. Its grids were interpolated based on rainfall point data from rainfall stations and covering the whole Division using kriging technique in ArcGIS 10.1. The rainfall data of the study area was collected from Meteorological agency of Ethiopia. It includes seven stations three of them are found inside Aysaita Woreda and the other four stations are found in the surrounding the study area and the layer were created by Inverse Distance Weight (IDW). The layer was reclassified based on the amount of rainfall within that woreda. The amount of rainfall of the study area doesn't fulfill the standard rainfall amount mentioned in most of the studies. It was reclassified in to five classes and new values were assigned to each class

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and based on this classification, 5, 4, 3, 2 and 1 values were given to the mean annual rainfall 12mm and 79mm, respectively. The amount of rainfall on this study area is very low. This may not contribute for malaria prevalence when compare to other factors. Hence, the classes were labeled in the figure 3.13 as Very high, High, moderate, low and Very low based on the level of amount of rainfall on those areas to malaria incidence.

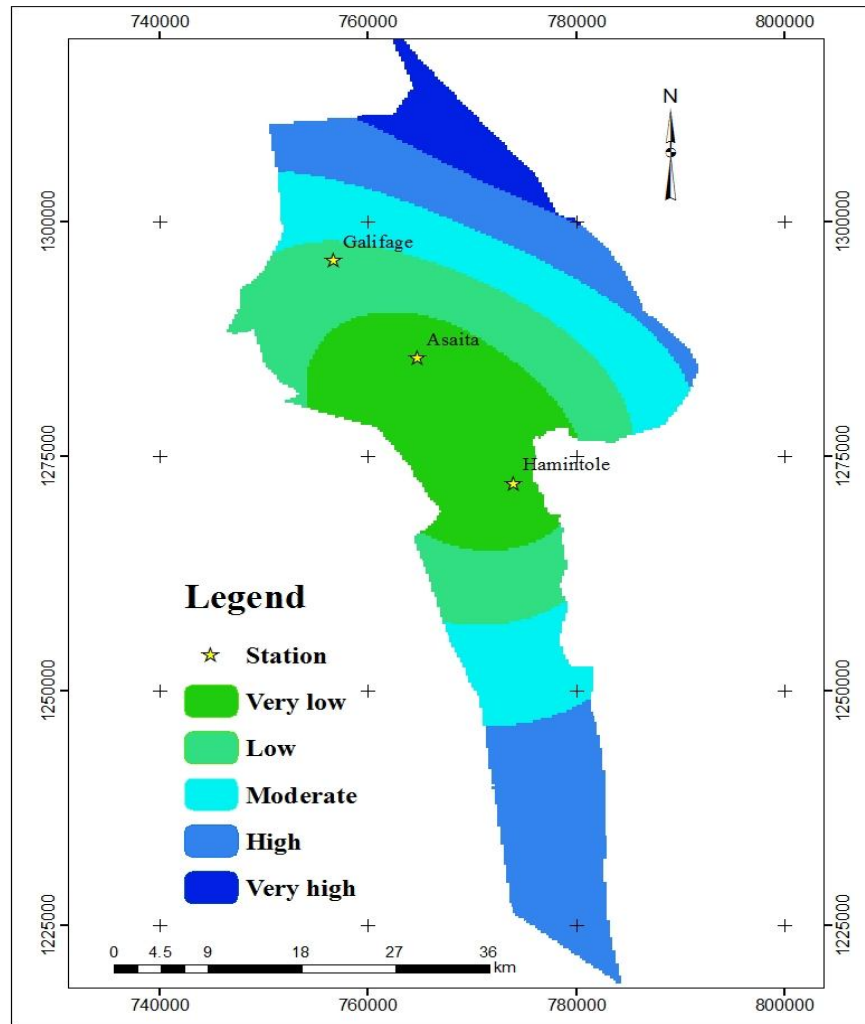


Figure 3.13. Reclassified Rainfall map

3.4.1.5 Distance from River

In this study area there are two different rivers pass through it namely awash and Logia River. Awash River which crosses nine kebeles and logia river crosses only one kebele. Distance was computed from every river. The computed distance was reclassified based on the maximum distance that mosquitoes can fly. Different literatures indicate that

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mosquitoes have typical flight ranges up to 2 km depending upon species (Kaya, *et al.*, 2001). Therefore, for this study, similar to the distance calculated around wetlands, new classes of 0-2km, 2 – 5km, 5 – 10km, 10 – 15km and above 15km were computed and assigned values of 5, 4, 3, 2, and 1 respectively. Then, each class shown in figure 3.14, beginning from the class with the highest value, was labeled as very high, high, moderate, low, and very low based on the degree of vulnerability of the area to malaria.

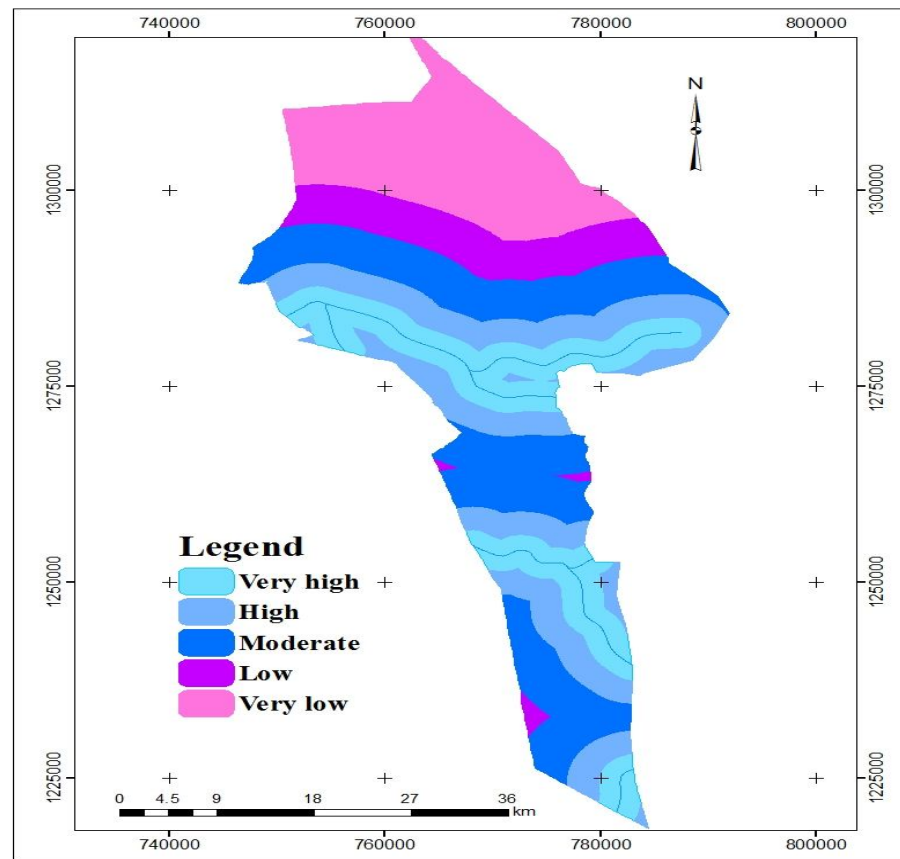


Figure 3.14. Distance from river map

3.4.2 Socio-Economic Factors for Identifying Malaria Risk Areas

Mapping which is based on natural conditions is not sufficient but socio-economic factors, such as population distribution, health facility distribution and land use should also be included. Because it is then that one can better site the area where there is high risk of Malaria and can at the same time locate people at risk.

3.4.2.1 Distance from Health Facilities

Assessing the location of health facilities is important, because it is necessary not only to map risky areas but also to uncover the potential needs and the location of existing Health facilities so that allocation of the new facilities can be done effectively.

The map shown in figure 3.15 was done by calculating distance from each health facility and by reclassifying the distances in to 5 classes based on the lowest easily accessible distance set by WHO. According to WHO (2003), areas found within 2- 3 km radius from a health facility is assumed to be less risky than areas found beyond this distance. Hence, classes of distances; 0-2km, 2 – 5km, 5-10km, 10 – 15km and 15- 62km were computed in figure 3.15. The classes were given values of 1, 2, 3, 4 and 5 and scaled as Very low, Low, moderate, high and very high respectively based on the degree of vulnerability to the risk of malaria.

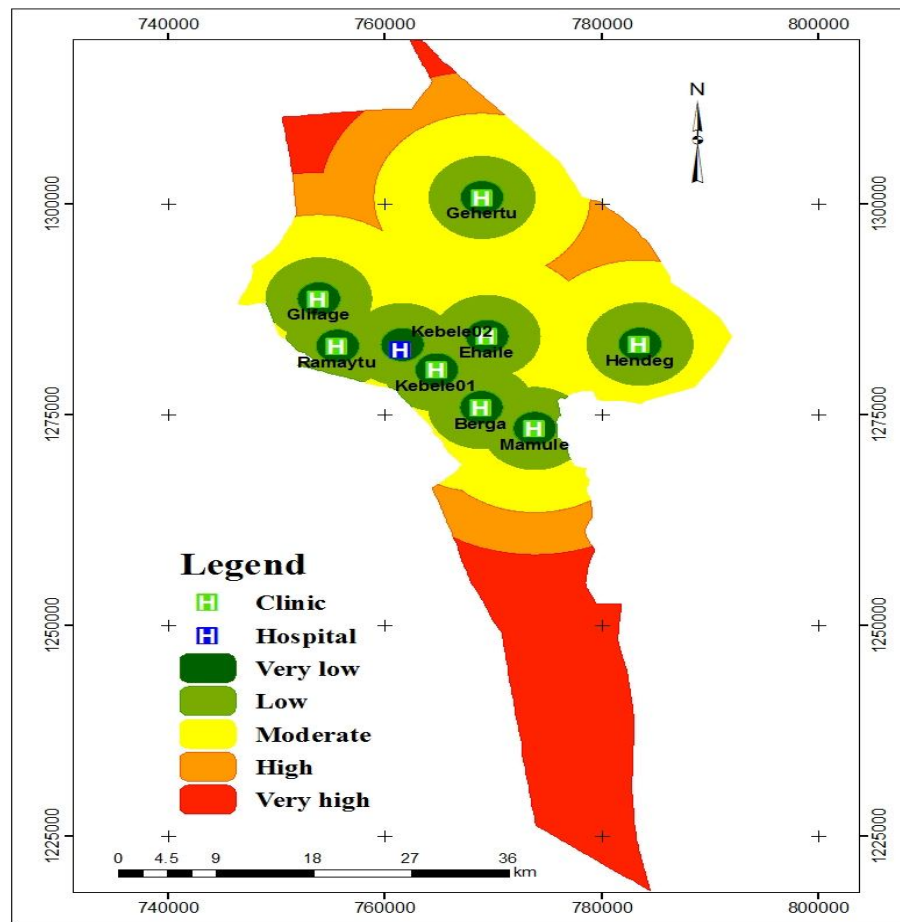


Figure 3.15. Distance from Health facilities map

3.4.2.2 Landuse/Landcover

Land use land cover of an area play an important role in the abundance of malaria insect differs in space and time. The type of land use land cover especially type of vegetation which surrounds the breeding sites basically supply sugar feeding for adult mosquitoes, and provided ideal sites for resting.

In the study area, in order to identify aquatic habitats and land cover types that affect the survivorship of *anopheline* mosquito, Landsat ETM+ satellite image of the year 2011 was classified using a supervised classification method in ArcGIS 10.1 software. A total of four land-cover classes were identified: Bare land, Agriculture, Bush and Shrubs and Water body. Ground truth was conducted by direct field inspection of 40 points randomly, which assesses the accuracy of landuse and land cover classification. Moreover, the landuse/ land cover map in figure 3.16 was reclassified in to four sub-groups in order of susceptibility and suitability for malaria risk. Thus, the reclassified version in figure 3.16 implies 1 to 4 values, where 1 stands for highly prone landuse/land cover and 4 for less prone landuse / land cover for malaria. The different types of the LULC of the study area are bare land, Bush and Shrubs, Farm land and the water body respectively (table 3.5).

Water body laying over an extended land surface for long period of time. This water body includes the Awash River, the awra (logia) river and the lake gorgori. The Awash River separates the study area halfway. And the awra (logia) river intersects in the south part of the study area. The lake gorgori located in the east part of the study area which is bordered with Afambo woreda and Djibouti. The overall coverage of the water body is almost 5% of the study area.

Bare land includes a molten rock laying over an extended land surface as a result of volcanoes and the soil. It is unfertile and does not support crop production. It is not compact enough to support construction of houses for residential purpose. Currently this area is not serving for any use type and it covers 67% of the area. Located mostly in the North West and some are in the south part of the study area.

Bush and Shrubs are one of the LULC types which are widely distributed in the area. Located in the west, east and some are to the south part of the study area. These are

largely used by the local peoples for the production of charcoal which supplement their livelihood especially during the dry season of the year. This bush and shrubs are destroying the agricultural lands and also the settlement areas.

Farm land: land used for cultivation of crops from Awash River. It is scarcely distributed and mainly used for the production of maize and cotton. Population of the area were largely adapting themselves with crop production as their main livelihood in the near past but recently they are adapting themselves for charcoal production, the livestock is decreasing from time to time. This because of the high speed distribution of the bush and shrubs and proportion of each land-use land-cover type of the study area is summerized in table 3.5.

Table 3.5. Land use/Land cover class for the year 2011.

No.	Landuse/Land cover	Area (km ²)	Area (%)
1.	Bare land	1159.77	67
2.	Bush and shrubs	294.27	17
3.	Agriculture	190.41	11
4.	Water body	86.55	5

One of the most common means of expressing classification accuracy is the preparation of a classification error matrix. Accordingly, classification error matrix was prepared using the image used for this study, ground truth during field survey (the data collected by GPS) and the final classified LULC map. The result indicated that an overall classification accuracy of 80% and overall kappa statistics of 0.72. Producer and user accuracy ranges from 66.67 - 100 percent and 60.00 – 100 percent respectively as described in table 3.6.

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Table 3.6. Accuracy Assessment for Land use/Land cover

Class	Reference (Field data)	Classified	Number correct	Producers Accuracy	Users Accuracy
Bush and shrubs	4	5	3	75.00%	60.00%
Agriculture	6	5	4	66.67%	80.00%
Water body	2	2	2	100.00%	100.00%
Bare land	28	28	25	89.67%	87.25%
Total	40	40	34		

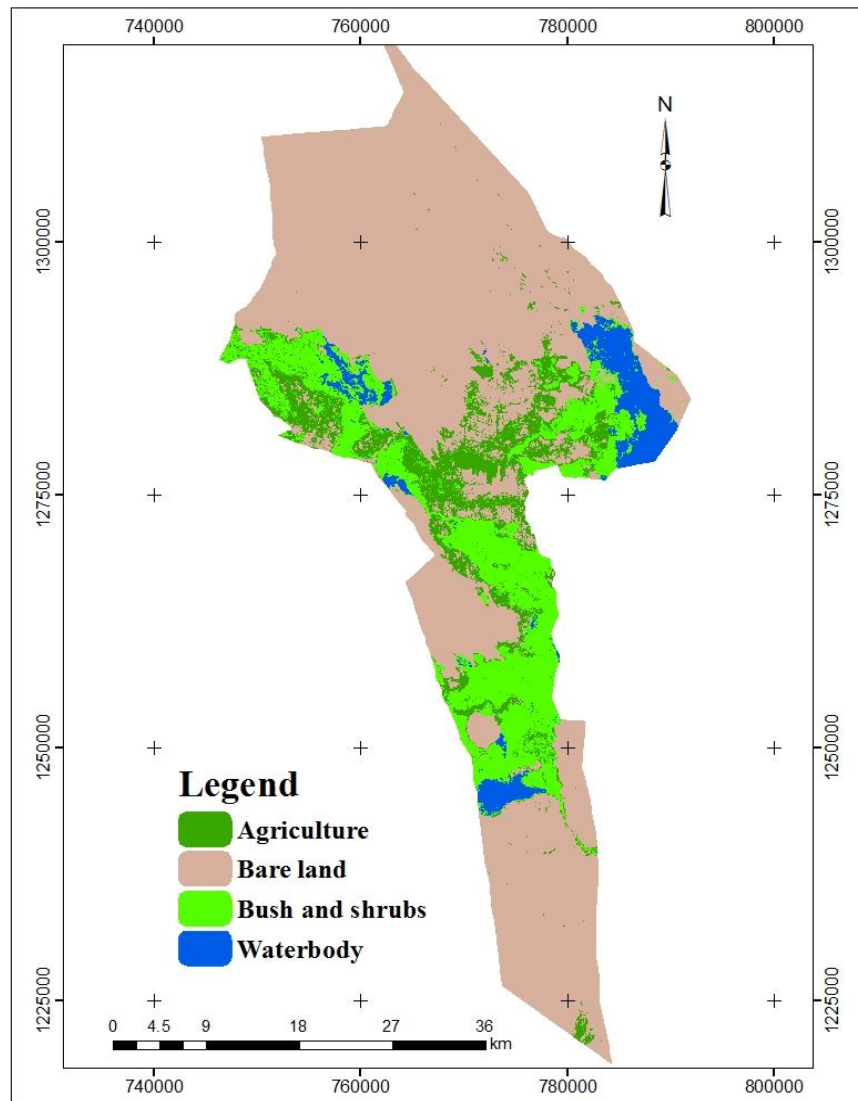


Figure 3.16. Land use/Land cover map of the year 2011.

3.4.2.3 Population Density

The population data used for this study area is the 2010's population data which is obtained from Health office of the woreda. As it is indicated in figure 3.17, areas colored dark brown are areas of high population density with the range of 254 – 444 person per km². These areas are dense because they are areas of urban settlement and also agricultural land. The areas are Aysaita town with two kebele and berga kebele. The second dense areas is only one kebele which is keredura kebele bordered with the Dubti woreda, having population density of 149 person per km². The third denser areas are four kebeles namely ramaytu, karbuda, hinale and handeg. Having with the range of 38 – 148 people per km². Finally, low denser areas in which classified as low and very low class found in the border part of the woreda in four sides. The areas are mostly covered by rocky lands and soil which is shown in the figure 3.16 above, having the range of 14 – 38 people per km².

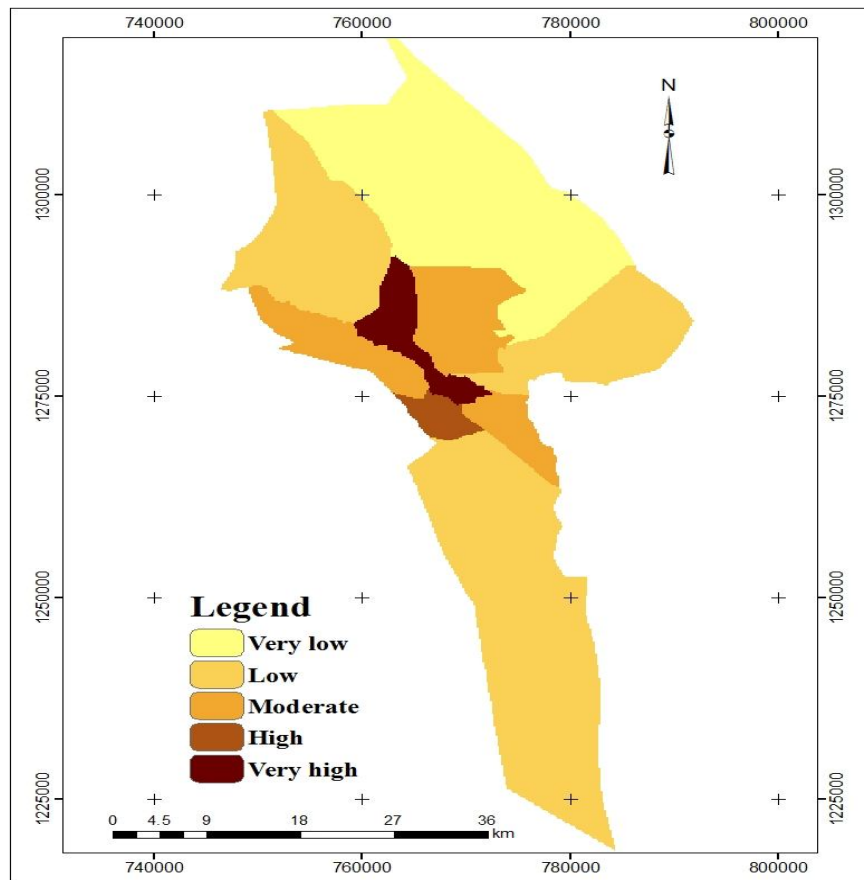


Figure 3.17. Reclassified Population Density map

4. Results and Discussion

4.1 Malaria cases versus Temperature

Temperature is an important factor that determines the distribution of the mosquito. There is almost parallel or a positive relationship between malaria case (patients came to the health facilities in the woreda and confirmed that they are positive to malaria with laboratory tests) (figure 4.1) and temperature from January to February, April to May and from October to December. The negative different flow of chat was seen in months from April to June, August and November and December. The temperature of the study area increases continuously from January up to June and from July it continuously decreases up to December. But even if the temperature decreases, the malaria case remains increasing. This means that the seasonality of temperature should be combined with other climatic variables especially with rainfall as most of the time malaria epidemics are related to the seasonal pattern of rainfall in Ethiopia.

Temperature also increases transmission of malaria by increasing the frequency with which the vector takes blood meals, which increases the growth rate of vector populations through shortening of the generation time. However, as I have mentioned before, the temperature should be combined with the availability of rainfall for this to be effective. The following graphs illustrate the relationship between malaria incidence and temperature of the study area. Table 4.1 shows the min and max temperature of the study area from seven stations (1999-2010). And figure 4.1 shows the malaria case versus the temperature.

Table 4.1. Malaria cases and Min and Max Temperature (1999-2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Seb	Oct	Nov	Dec
Min Temperature(°C)	24.4	25.3	27.7	29.8	31.9	32.3	30.5	30.4	32.4	30.1	28.8	25.3
Max Temperature(°C)	28.7	30.1	31.8	34.9	37.1	37.9	36.7	34.4	33.9	31.9	31	29.4
Malaria cases	9304	11777	9282	8232	9568	9016	9579	9724	10900	11831	10384	9342

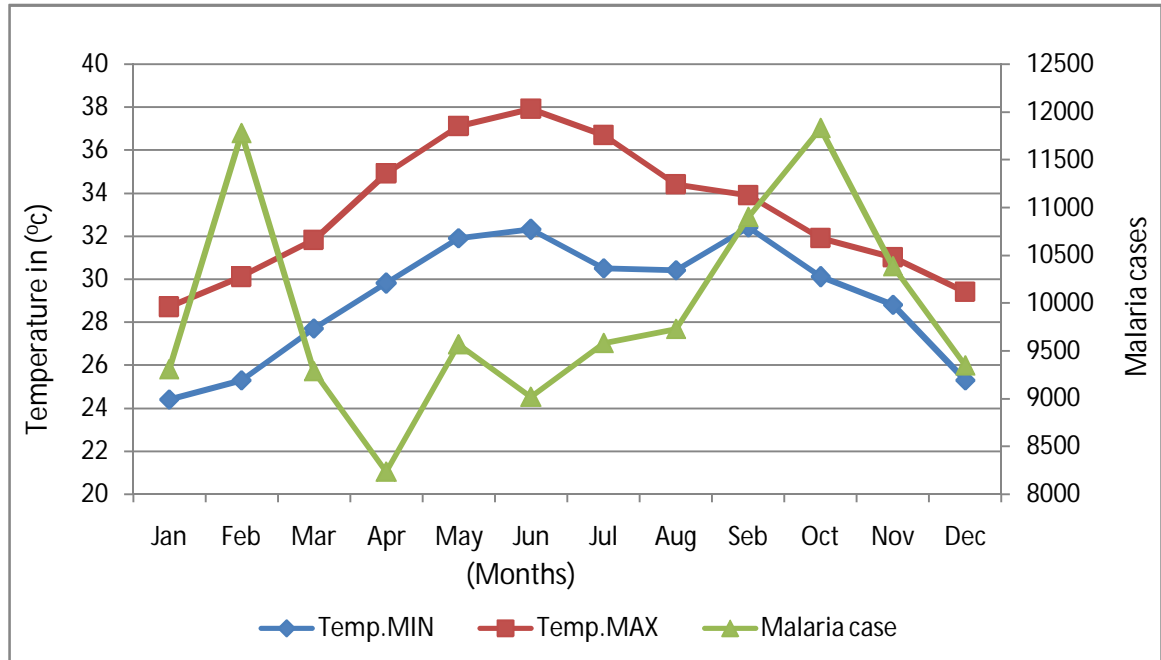


Figure 4.1. Malaria cases versus Temperature of 1999-2010

4.2 Malaria cases versus Rainfall

There is small positive relationship between rainfall and malaria case from January up to February, June to July and October to November as shown in Figure 4.2. Almost for 6 months the increment and decrement patterns of malaria cases and the rainfall are the same. However, the relationship becomes negative on March, April, May, August, September and December. The highest malaria case is seen in February and October. The lower seasonal variability of malaria epidemics might be due to the availability of irrigation practices around Awash River. Irrigation structures in the area might have provided suitable breeding sites for mosquitoes during the dry season. Since mosquito-breeding sites are equally available both in the dry and rainy season, such a very high increase in malaria prevalence was not observed during and after the rainy season. The humid environment, which is created through irrigation during the dry season, might have enhanced vector longevity and resulted in lower seasonal variation of malaria epidemics. The malaria transmission cannot be explained only by the rainfall but by the lag time in mosquito breeding and parasite life cycle inside the mosquito, which are dependent on air temperature and humidity together with rainfall.

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Concerning to the relationship between rainfall and malaria epidemics of the study area, the following graphs in table 4.2 and figure 4.2 shows the monthly average rainfall and malaria cases of Aysaita woreda from one Hospital and eight Health centers for the year between 1997 – 2002 E.C.

Table 4.2. Mean annual Rainfall versus Malaria cases

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Seb	Oct	Nov	Dec
Rainfall(mm)	1.75	6.025	13.8	14.2	1.53	3.51	23.6	56.7	13.99	5.74	3.49	5.96
Malaria cases	9304	11777	9282	8232	9568	9016	9579	9724	10900	11831	10384	9342

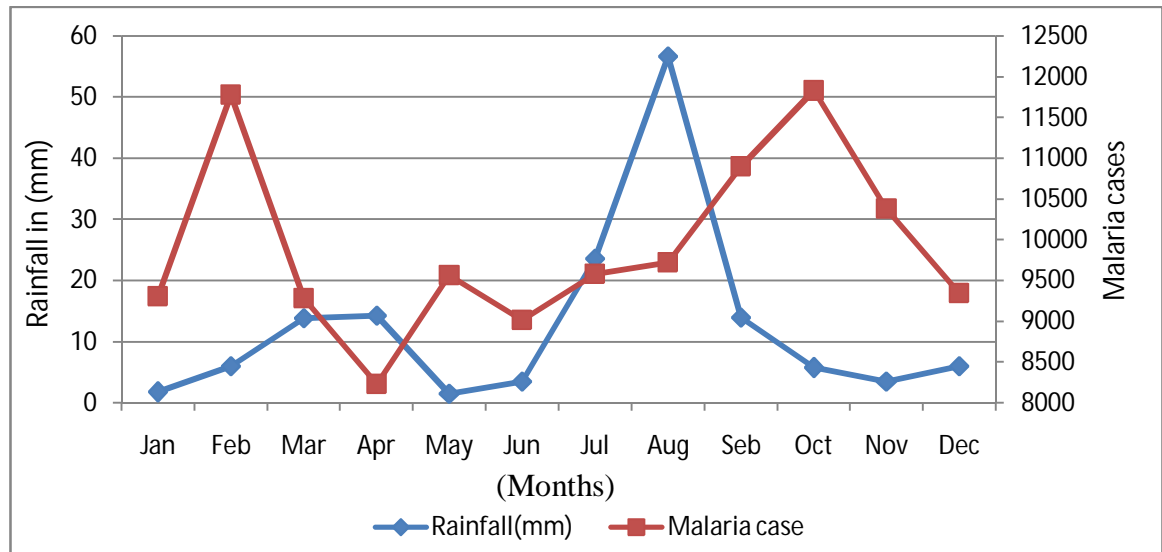


Figure 4.2. Malaria cases and mean annual Rainfall of 199-2010

4.3 Identifying malaria Hazard areas

Malaria hazard area is mapped by depending on environmental factors that create favorable condition for the survival of the vector *Anopheles* mosquitoes. These variables are including rainfall, temperature, altitude, distance from River and Slope, by overlaying these factors that areas vulnerable to malaria were identified. The overlay analysis was done using ArcGIS software, after each factor was given the appropriate weight. The factors were ranked in Table 4.3, according to the degree of importance that they have for the incidence of malaria in this research. This was done based on the previous studies, by consulting the malaria expert of Aysaita woreda, and by using weighted linear combination method in IDRISI software. Pair wise Comparison of the five parameters

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was carried out to develop the pair wise comparison matrix. Accordingly, the above weights of factors in table 4.3, was computed, Combined and analyzed in ArcGIS environment using spatial analyst tool after each factor was given the appropriate weight in IDRISI software.

Table 4.3. Derived factor maps and weight of malaria hazard

Assessment of malaria Hazard area					
No.	Factors	Weight (%)	Class	Rank	Degree of vulnerability
1	Rainfall	45%	12 - 19mm	1	Very low
			19 - 27mm	2	Low
			27 - 35mm	3	Moderate
			35 - 43mm	4	High
			43 - 55mm	5	Very high
2	Temperature	26%	25 - 26°C	1	Very low
			26 - 27°C	2	Low
			27 - 28°C	3	Moderate
			28 - 29°C	4	High
			29 - 30°C	5	Very high
3	Elevation	14%	270 - 380 ASL	1	Very high
			380 - 451 ASL	2	High
			451 - 600 ASL	3	Moderate
			600 - 925 ASL	4	Low
			925 - 1378 ASL	5	Very low
4	Slope	7%	0 - 6°	1	Very high
			6 - 16°	2	High
			16 - 33°	3	Moderate
			33 - 58°	4	Low
			58 - 356°	5	Very low
5	Distance from river	8%	0 - 2km	1	Very high
			2 - 5km	2	High
			5 - 10km	3	Moderate
			10 - 15km	4	Low
			15 - 62 km	5	Very low

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After the overlay analysis of the five factors namely; Rainfall, Temperature, Elevation, Distance from River and Slope done, the following malaria hazard map in figure 4.3 was produced.

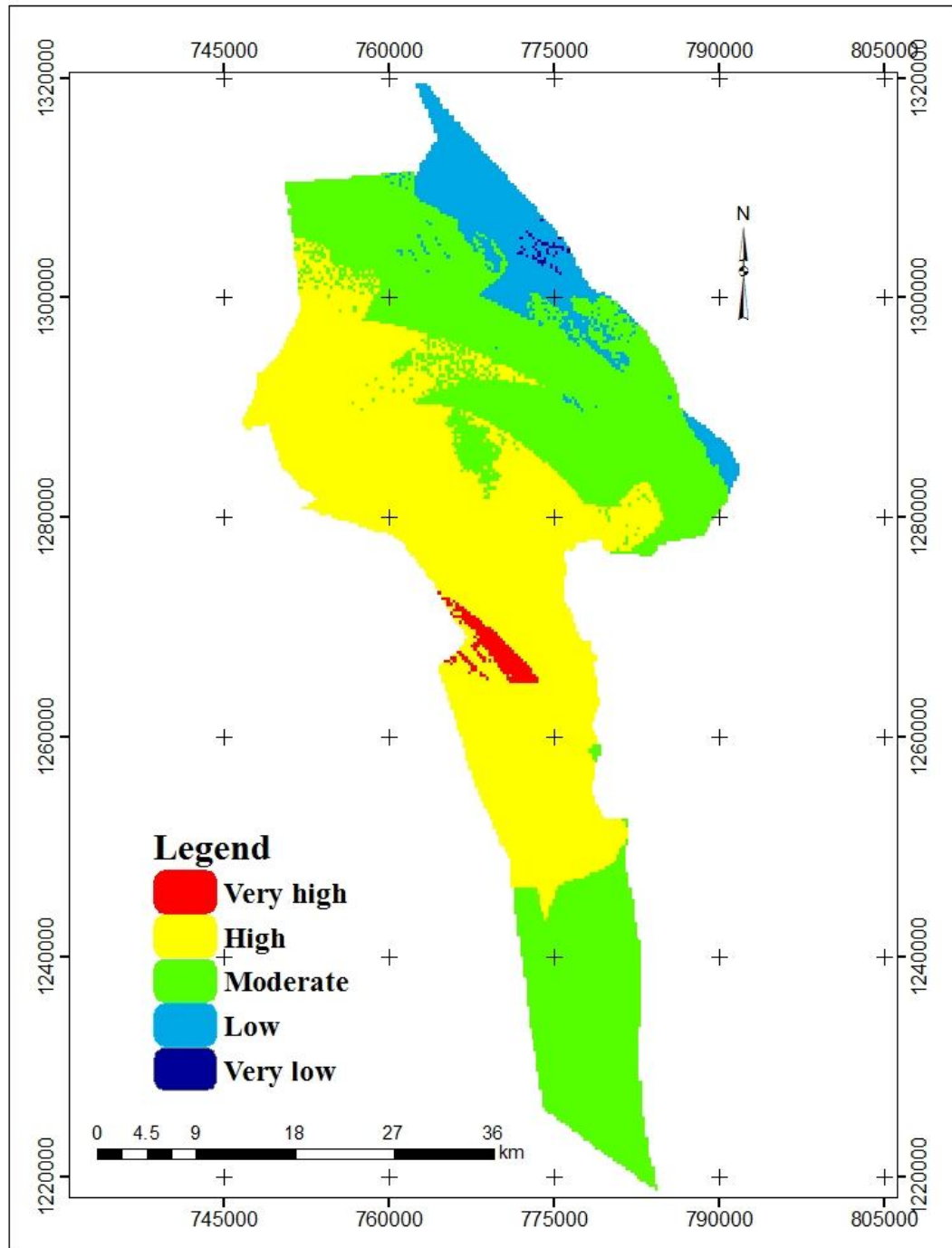


Figure 4.3. Malaria Hazard Map

The malaria hazard map, in figure 4.3, illustrates that 18.83 km² very high, 787.68 km² high, 763.92 km² moderate, 157.21 km² Low and 3.33 km² Very low level of malaria vulnerability, that are representing from the total area 1.1%, 45.5%, 44.1%, 9.1% and 0.2% of the study area respectively subject to very high, high, moderate, low and very low level of malaria susceptibility. Hence, from these figures it is possible to conclude that over 46.6% of the total areas are in high and very high malaria hazard, 44.1% of the total areas are in Moderate malaria hazard and the remaining area was 9.3% as low malaria Hazard area.

4.4 Identifying area of malaria at risk

In fighting against Malaria, hazard mapping which is based on natural conditions is not sufficient, but socio-economic factors, such as population density, distribution of health facilities, and land use land cover should also be included. Because, it is only then that one can cite the area where there's high risk of malaria. The malaria hazard map, Population distribution map, health facilities map, and land use land cover map were multiplied and malaria risk indicator map which is shown in figure 4.4 was created. As I have mentioned in the methodology part, the basis for the calculation of the map was the risk computation model developed by Shook (1999).

$$\text{Risk} = \text{Hazard} * \text{Element at Risk} * \text{Vulnerability}$$

As it is indicated above, the mapping of malaria risk includes hazard, element at risk, and vulnerability. The malaria hazard layer was computed by overlaying the five selected causative factors which includes Rainfall, Temperature, elevation, Distance from river and slope the element at risk layer was developed by reclassifying population density layer. Moreover, vulnerability layer was developed by reclassifying land use/ land cover layer on the basis of the degree of susceptibility of each landuse/ land cover to malaria and by computing and reclassifying distance from the existing health facilities layers. The layers were prioritized according to their degree of influence. Pair wise comparison of the four parameters was carried out to develop the following weights in Table 4.4. The weights given for the factors in table 4.4, was computed, Combined and analyzed in

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ArcGIS environment using spatial analyst tool. The map in Figure 4.4 showing areas of malaria risk was produced.

Table 4.4. Derived factor maps and weight of Malaria Risk

Assessment of malaria Risk area					
No.	Factors	Weight (%)	Class	Rank	Degree of vulnerability
1	Hazard	56%		1	Very high
				2	High
				3	Moderate
				4	Low
				5	Very low
2	Population density	26%	14 - 18	1	Very low
			18 - 38	2	Low
			38 - 148	3	Moderate
			148 - 254	4	High
			254 - 444	5	Very high
3	Health Facility	11%	0 - 2km	1	Very high
			2 - 5km	2	High
			5 - 10km	3	Moderate
			10 - 15km	4	Low
			15 - 62km	5	Very low
4	Landuse/Landcover	7%	Water body	1	Very high
			Agriculture	2	High
			Bush and shrubs	3	Moderate
			Bare land	4	Low

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After the overlay analysis of the four factors, the following malaria hazard map in figure 4.4 was produced.

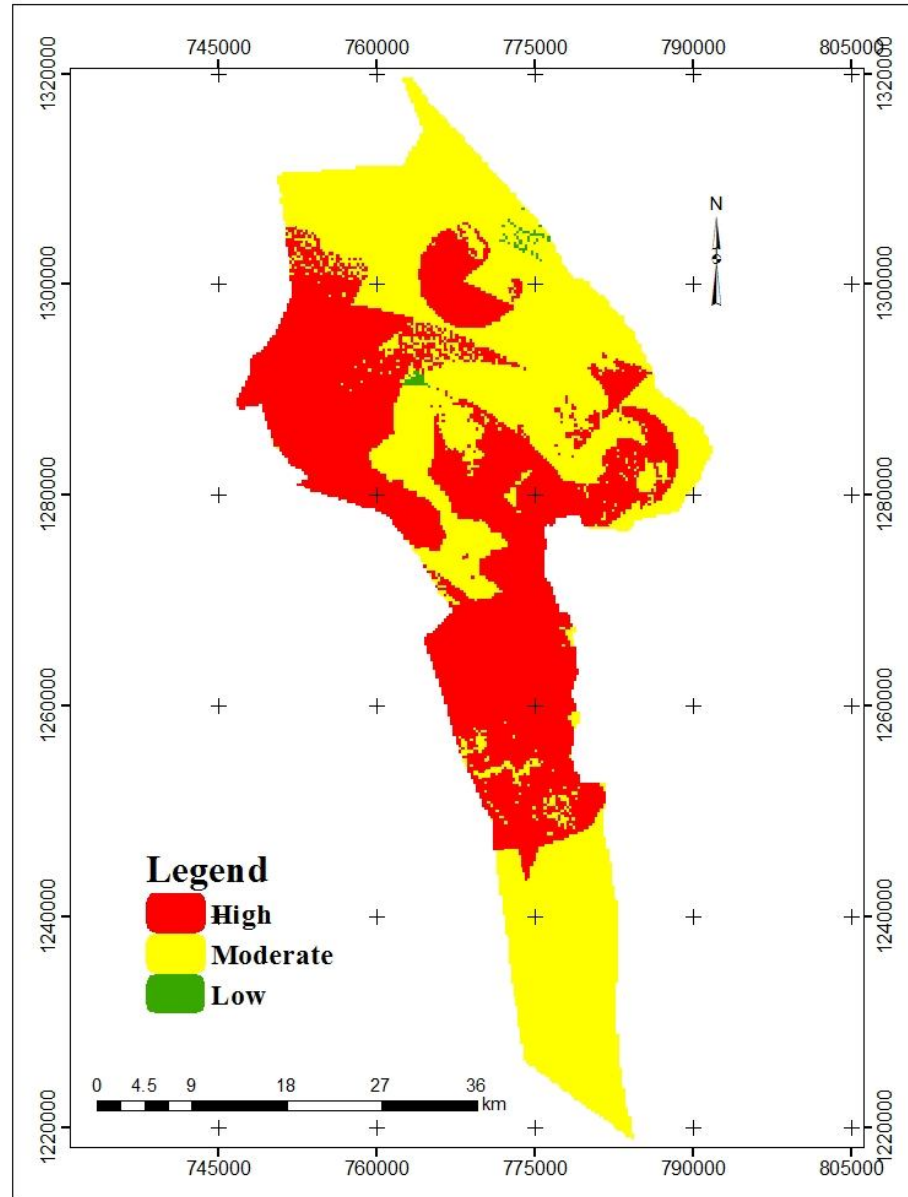


Figure 4.4. Malaria Risk Map

In this study, to map malaria risk areas four factors were used as input factors namely; Malaria Hazard, population density, distribution of health facilities and landuse/land cover. As a result, the risk map shows 804 km², 921.6 km² and 5.4 km² of the total area is

subject to High, Moderate and Low respectively (figure 4.4). That are representing in percent from the total area 46.45%, 53.24% and 0.31% of the study area respectively. Hence, it is possible to conclude that 99.69% of the study area is under epidemic area (high and moderate). This seems due to the availability of favorable climatic condition to the vector mosquito, the presence of water body around Awash River and the overflow of Awash River during rainy season in high lands which will create the breed site. The slope of the area is nearly level to gentle slope and the availability of large number of people with lower health facility. Moreover, the existence of the green area might have provided more shelter and sites for resting for adult mosquitoes, which extends their longevity and density. Only 0.31% is in low epidemic area. This due to the areas located at higher altitude and rocky land in the north part of the study area.

4.5 Comparing malaria Risk map with kebeles which are labeled as Malarious by woreda health bureau

In general, the whole woreda is in risk of malaria as labeled as malarious by the woreda bureau (figure 4.5). Almost all of the kebeles in the study area are subject to high and moderate risk of malaria. Among them Galifage, Ramaytu, Karbuda, Gelealo and Mamule are almost fully in high malaria risk. Some part of Gehertu, Handeg, Ehayle and hinale are subject to high risk of malaria moreover the remaining part of these Kebeles is under moderate risk of malaria. This seems due to the availability of favorable climatic condition to the vector mosquito, the presence of water body around Awash River and the overflow of Awash River during rainy season in high lands which will create the breed site, Additionally the degree of slope for these areas nearly level to gentle slope, and the presence of large number of people in the area. Moreover, the existence of green area might have provided food and more shelter for resting for adult mosquitoes, which extends their longevity and density. It should be noted that the population of these at high risk malarious kebeles are 20,453 people which is about 26% of the total population in the Woreda. The low risk areas are found in some part of Gehertu Kebele and Aysaita town. This seems due to the presence of high slope area, rocky land and no water body in the area. These conditions together make uncomfortable situation for the vector malaria.

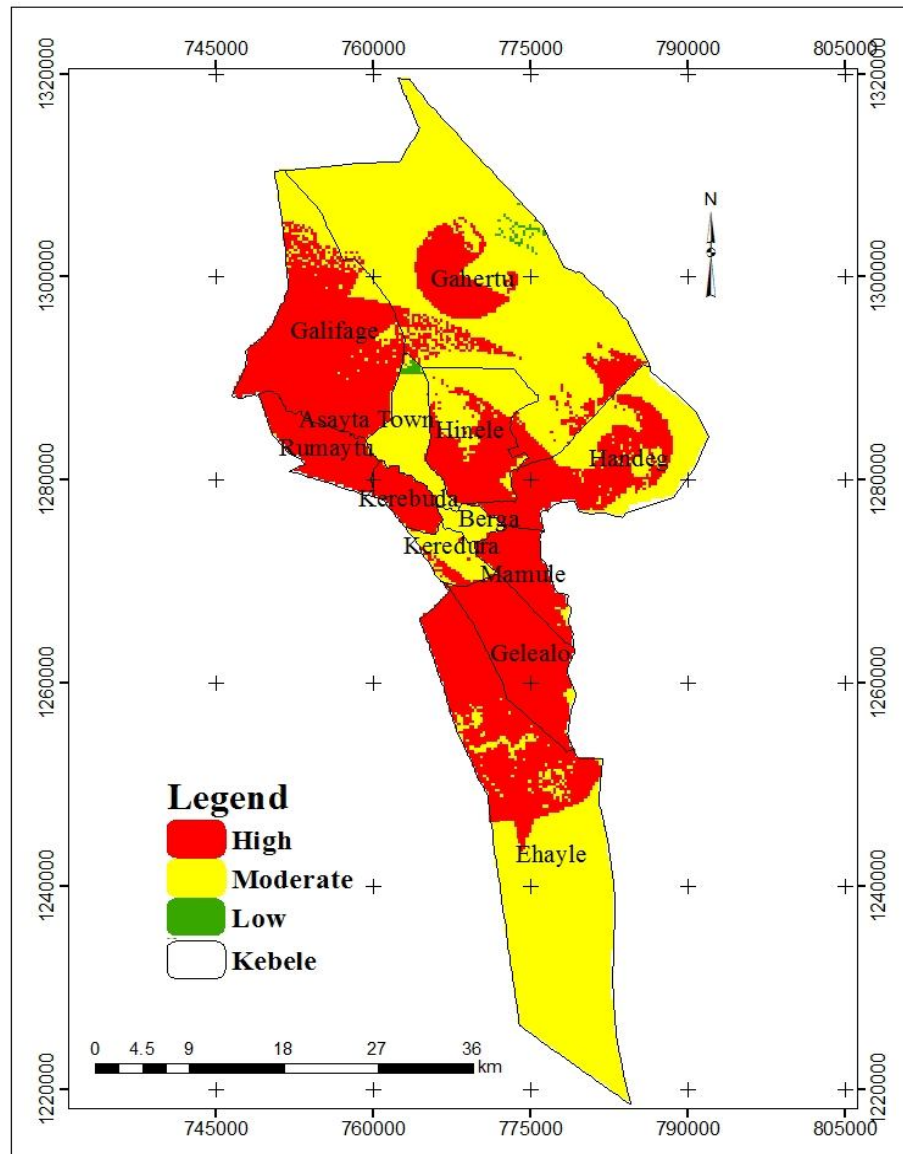


Figure 4.5. Kebele wise malaria risk map

Malaria Risk Model Verification

The validity of the model was checked against health facility based malaria case report which reflects the malaria risk zone of the area. Based on data collected from health bureau is monthly health facility based report from 1997 up to 2002 Ethiopian calendar, where out of nine health facility, five are on high risk zone also these five health facility are reports high malaria case than others as shown in figure 4.6. And the rest of four

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health facilities are on moderate as shown in table 4.5. The Figure 4.7 shows that the Comparism of the health facility reports with malarias risk area and figure 4.6 shows that the line indicates the malaria case recorded in each Health facility and the color shows the level of the risk.

Table 4.5. Comparison of Malaria cases data with risk model result.

Health center	Easting	Northing	Malaria cases	Malaria risk model result
Galifage	753860	1288833	15752	High
Ramaytu	755606	1283225	15445	High
Kebele02	761435	1282764	10119	Moderate
Kebele01	764761	1280389	11556	Moderate
Berga	768889	1275923	12672	Moderate
Mamule	773810	1273436	13736	High
Hamdeg	783528	1283448	13668	High
Ehaile	769418	1284357	13314	High
Gehertu	768942	1300866	12477	Moderate

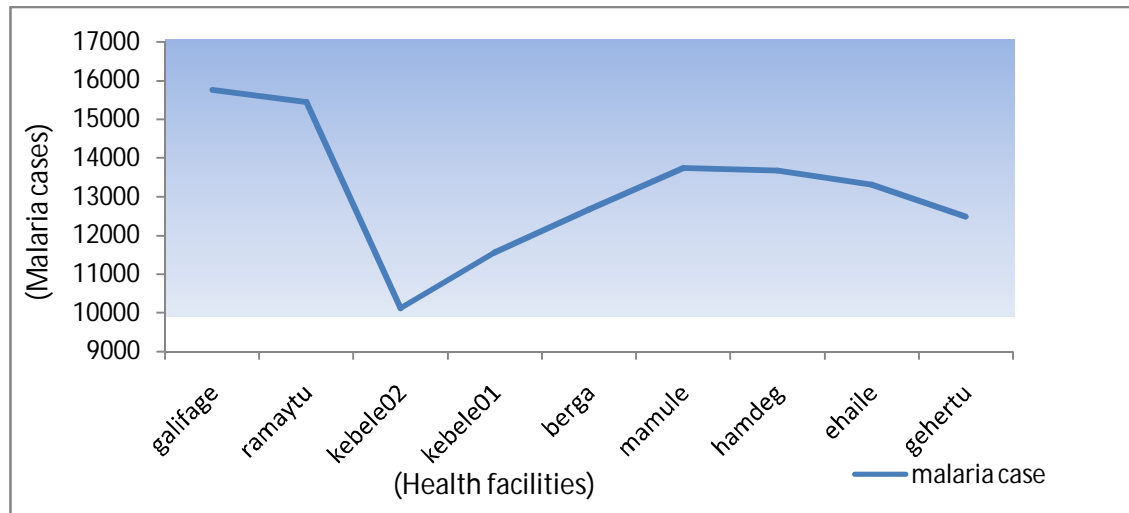


Figure 4.6. Comparison of Health center cases versus malaria risk

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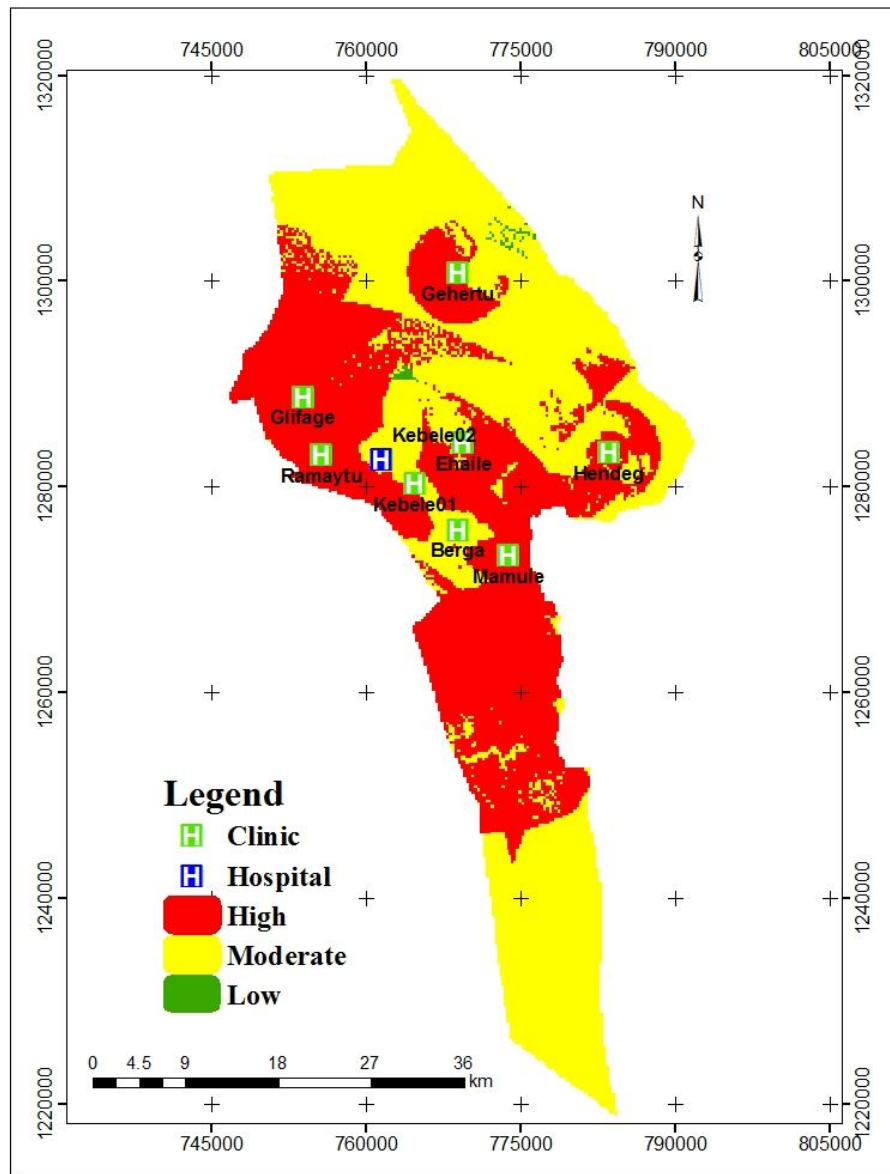


Figure 4.7. Comparison of Health center cases versus malaria risk.

5. Conclusion and Recommendation

5.1 Conclusion

The main purpose of the study was achieved by identifying possible environmental and socio-economic conditions that contribute for malaria spread in Aysaita Woreda. Furthermore, the study produced mapping of malaria risk area which can be used as an input for policy makers and other responsible bodies. Besides these groups, the experts in the field will benefit more by acquiring readymade information which serves as a spring board for national malaria eradication and prevention program.

The hazard map was produced depending upon the physical parameters which are capable of providing fertile environmental situations for mosquito breeding. The study focused on Rainfall, Temperature, elevation, slope and distance from rivers as the factors of malaria incidence having 45%, 26%, 14%, 7% and 8% weights respectively in the overlay analysis. The malaria incidence and transmission requires the environment with lower elevation (higher temperature), occurrence of gentle slopes and availability of still waters around rivers. Hence, from the result of the overlay analysis of the physical parameters shows, from the total area 1.1%, 45.5%, 44.1%, 9.1% and 0.2% of the study area subject to very high, high, moderate, low and very low level of malaria susceptibility. It is possible to conclude that about 46.6% of the total areas are in high and very high malaria hazard. In addition, Galifage, Ramaytu, Karbuda, Berga, Aysaita, Keredura, Mamule and Gelealo kebeles were highly found to be under malaria hazard. This is mainly due to the availability of aquatic bodies and irrigation practices in the study area.

The risk computation model was used to achieve the final output (Malaria Risk map). Similarly, after producing the hazard map, the malaria risk map was produced depending upon the overlay analysis of malaria hazard map, element at risk (Population density) and Vulnerability parameters like distance from health facility and Landuse/Land cover. The factors had 56%, 26%, 11% and 7% of weights in the overlay analysis respectively. The result indicated that 46.45%, 53.24% and 0.31% of the total area are subjected to High, Moderate and Low respectively. Almost half of the area about 46.45% is under high risk

of malaria. Including Galifage, Ramaytu, Karbuda, Mamule and Gelealo kebele. And half of the total areas of some kebeles are at high malaria risk namely: Hinale, Handeg, Ehayle and Gehertu kebele. This is not only due to the physical parameters but also the existence of suitable landuse/land covers for mosquito breeding and also some fields partially flooding, possibly due to some broken irrigation canals will occur due to the high rainy season in the high lands, the kebeles found in moderate risk areas are 53.24% of the total area, namely: 01, 02 and berga kebele. Hence, it is possible to conclude that 99.69% of the study area is under epidemic area (high and moderate). This shows that, the final malaria risk map of the study area only 0.31% is in low epidemic area.

5.2 Recommendation

The final malaria risk map of the study area shows, there is no area within Aysaita Woreda with malaria free risk level. Since maps are considered as one of the very vital input it is therefore, important to use them in every aspect of planning, implementation, monitoring and evaluation of any development processes as well as malaria eradication and prevention program in the Woreda. Therefore, Based on the finding of this study, the following Recommendation were given as follows:-

- ✓ My first recommendation will be the woreda must develop to use RS and GIS technique to identify ecology of mosquito and other vector born disease. This technique will help them to know the rate of the yearly status of malaria in the woreda and will help the decision-makers to better allocate limited resources in the fight against the disease.
- ✓ To increase the health facilities in the woreda, health professionals and better management, this is necessary for reduction and elimination of malaria from the woreda and to give more training on malaria prevention and way of transmission. Almost all people use traditional treatment for any disease.
- ✓ Distribution of malaria nets, insecticide spraying and environmental measures must be follow priority set by malaria risk map developed in this study.

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- ✓ The identified environmental factors that are known very conducive for the multiplication of the vectors such as clearing of Bushes and shrubs around the house and laying rainfall water, keeping environmental sanitation by avoid old vessels, tires, cans, pots. from the residential areas. These have to be done through promoting voluntary participation of the community at large.

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Annex

Annex 1. Health center based malaria report.

Annex 2. Health facility GPS data.

Annex 3. Meteorology data.

Annex 4. Satellite image 2011.

Annex 5. Ground truth data.

Annex 6. Picture of Aysaita.

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Annex 1. Health center based malaria report.

Health center based report 1997 E.C										
Month	Galifage	Ramaytu	Kebele2	Kebele1	Berga	Mamule	Handeg	Ehaile	Gehertu	Total
Jul	271	234	134	156	154	213	225	204	172	1763
Aug	289	235	102	142	176	215	204	185	180	1728
Sep	176	194	89	97	76	132	126	172	142	1204
Oct	145	123	108	100	122	148	117	181	169	1213
Nov	247	264	158	195	218	161	185	227	249	1904
Dec	321	285	193	216	226	213	249	256	194	2153
Jan	302	243	148	169	183	272	251	261	205	2034
Feb	278	314	165	201	191	236	200	187	193	1965
Mar	371	342	182	220	263	215	289	256	165	2303
Apr	294	302	145	166	182	194	243	158	132	1816
May	241	192	156	180	195	212	226	146	128	1676
Jun	223	245	151	174	163	195	176	189	175	1691

Health center based report 1998 E.C										
Month	Galifage	Ramaytu	Kebele2	Kebele1	Berga	Mamule	Handeg	Ehaile	Gehertu	Total
Jul	199	176	123	132	150	144	153	120	123	1320
Aug	201	233	130	153	186	200	174	159	146	1582
Sep	221	203	156	169	188	214	191	134	125	1601
Oct	145	135	98	103	122	132	120	117	111	1083
Nov	254	229	155	182	195	221	189	206	253	1884
Dec	215	228	127	169	213	216	194	181	176	1719
Jan	327	304	184	202	210	250	238	276	213	2204
Feb	187	179	143	161	137	186	125	122	117	1357
Mar	206	216	131	156	152	194	188	196	173	1612
Apr	365	347	184	235	237	258	276	293	241	2436
May	278	297	168	191	192	237	223	197	210	1993
Jun	272	281	179	207	212	205	213	221	202	1992

Health center based report 1999 E.C										
Month	Galifage	Ramaytu	Kebele2	Kebele1	Berga	Mamule	Handeg	Ehaile	Gehertu	Total
Jul	185	208	154	172	187	193	184	179	185	1647
Aug	210	194	154	181	193	205	197	199	175	1708
Sep	182	170	147	162	191	173	190	128	115	1458
Oct	171	163	102	128	154	127	141	186	169	1341
Nov	165	173	121	130	133	143	158	144	161	1328
Dec	124	136	98	103	121	129	120	120	114	1065
Jan	113	140	87	91	100	127	125	131	126	1040
Feb	185	173	105	115	134	156	172	168	143	1351
Mar	140	138	101	112	119	132	134	116	109	1101
Apr	197	207	123	158	164	178	192	182	162	1563
May	276	259	160	178	201	243	262	200	219	1998
Jun	123	132	85	94	102	125	116	122	105	1004

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Health center based report 2000 E.C										
Month	Galifage	Ramaytu	Kebele2	Kebele1	Berga	Mamule	Handeg	Ehaile	Gehertu	Total
Jul	172	183	124	156	158	185	191	148	179	1496
Aug	204	217	137	187	192	201	192	200	193	1723
Sep	192	209	143	185	191	169	219	143	185	1636
Oct	205	198	152	170	179	158	157	172	207	1598
Nov	230	211	156	187	195	192	200	212	201	1784
Dec	148	157	120	156	178	129	147	153	104	1292
Jan	205	211	167	146	155	163	124	136	148	1455
Feb	221	228	124	155	172	198	186	201	195	1680
Mar	149	186	149	134	160	161	130	162	124	1355
Apr	216	234	156	182	225	213	203	216	205	1850
May	178	183	132	125	124	153	174	156	143	1368
Jun	169	175	135	149	164	158	179	177	169	1475

Health center based report 2001 E.C										
Month	Galifage	Ramaytu	Kebele2	Kebele1	Berga	Mamule	Handeg	Ehaile	Gehertu	Total
Jul	206	213	143	162	181	195	179	191	183	1653
Aug	392	345	188	224	286	301	331	314	287	2668
Sep	186	207	155	160	182	190	187	177	154	1598
Oct	192	167	134	155	180	194	196	201	176	1595
Nov	201	172	123	127	152	133	159	162	144	1373
Dec	142	124	122	139	183	152	139	142	98	1241
Jan	127	131	120	143	125	172	166	116	114	1214
Feb	185	190	145	158	173	179	182	168	171	1551
Mar	278	253	152	191	225	251	216	241	221	2028
Apr	281	268	153	184	204	241	253	230	207	2021
May	202	194	155	167	183	192	188	175	169	1625
Jun	186	192	121	146	165	197	173	169	159	1508

Health center based report 2002 E.C										
Month	Galifage	Ramaytu	Kebele2	Kebele1	Berga	Mamule	Handeg	Ehaile	Gehertu	Total
Jul	191	203	126	156	147	162	136	151	153	1425
Aug	368	391	177	213	203	256	261	270	229	2368
Sep	215	223	169	172	189	212	206	209	190	1785
Oct	172	176	127	153	164	158	165	152	135	1402
Nov	148	127	118	129	142	165	138	174	154	1295
Dec	192	205	137	151	178	162	186	177	158	1546
Jan	215	189	124	158	167	205	214	163	197	1632
Feb	235	219	162	158	192	221	204	217	212	1820
Mar	322	295	163	172	201	257	275	266	250	2201
Apr	284	273	176	192	233	245	236	241	265	2145
May	234	207	153	163	185	233	207	215	227	1824
Jun	210	195	135	151	197	189	203	198	194	1672

Annex 2. Health facility GPS data

Health center	Easting	Northing
Galifage	753860	1288833
Ramaytu	755606	1283225
Kebele02	761435	1282764
Kebele01	764761	1280389
Berga	768889	1275923
Mamule	773810	1273436
Handeg	783528	1283448
Ehaile	769418	1284357
Gehertu	768942	1300866

Annex 3. Meteorology data

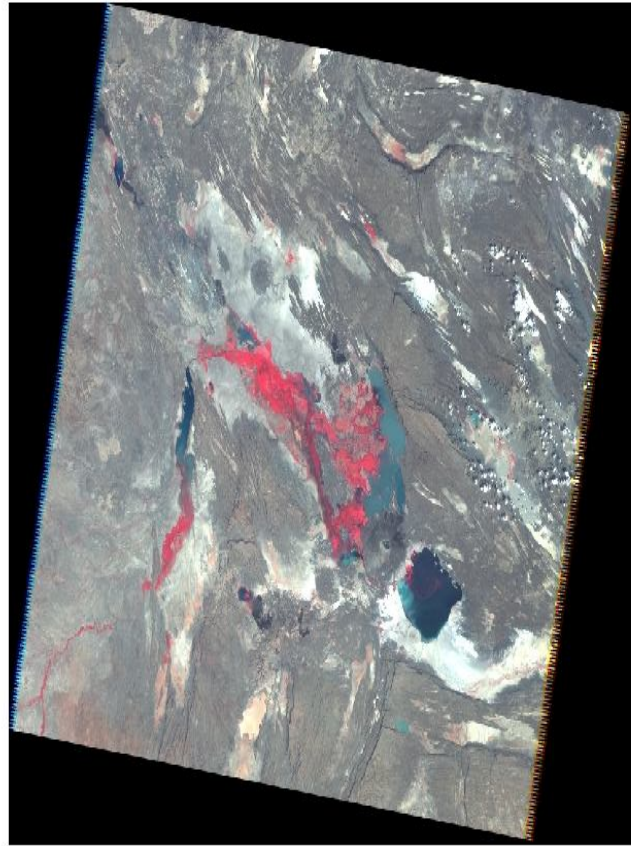
Month	Temp	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Jan	MIN	19.9	19.3	19.4	21.0	21.0	22.0	20.5	20.7	32.0	32.6	31.4	32.6
	MAX	33.2	32.1	31.6	32.9	33.4	33.1	32.9	33.0	21.0	20.3	20.0	20.6
Feb	MIN	20.4	19.7	20.5	21.1	22.1	20.9	21.1	22.1	34.9	32.9	34.0	33.5
	MAX	34.7	34.1	34.0	34.1	35.7	33.8	35.4	34.5	22.2	19.5	21.4	22.0
Mar	MIN	23.0	22.6	22.8	23.7	23.9	22.2	24.4	23.3	37.1	36.7	36.5	36.2
	MAX	35.5	36.3	35.8	36.9	36.7	36.4	37.2	37.0	23.4	20.0	23.0	23.4
Apr	MIN	26.5	24.9	24.4	24.8	25.3	25.6	25.1	25.0	38.5	39.3	38.6	39.5
	MAX	39.9	38.7	39.4	38.4	38.6	37.8	39.0	37.8	25.0	24.3	25.0	35.1
May	MIN	28.5	27.5	24.5	27.2	27.4	26.5	27.6	27.2	41.5	41.4	41.4	41.5
	MAX	42.3	41.7	42.1	42.3	41.9	41.9	40.7	41.4	28.1	26.9	26.8	28.7
Jun	MIN	27.2	29.3	24.1	29.0	29.5	28.1	28.7	29.1	42.3	42.5	43.4	34.9
	MAX	42.7	43.4	43.8	43.0	42.5	42.1	42.5	42.8	28.8	28.7	29.6	25.2
Jul	MIN	22.3	27.0	27.4	29.9	28.3	28.5	28.8	27.9	39.3	41.4	41.2	24.4
	MAX	40.4	41.5	41.3	42.8	41.2	41.2	32.4	40.8	26.0	28.0	28.2	37.2
Aug	MIN	39.9	24.5	26.4	27.7	25.5	26.5	23.4	25.6	38.7	40.5	41.0	25.1
	MAX	27.5	38.6	38.6	41.1	37.9	40.0	40.2	38.8	26.2	26.9	28.2	28.5
Seb	MIN	38.4	26.9	26.1	27.3	27.9	26.6	24.8	27.1	39.4	40.4	41.1	42.3
	MAX	24.7	39.0	38.7	40.0	39.2	39.3	38.4	38.8	27.1	27.5	27.5	27.2
Oct	MIN	35.6	24.2	25.3	25.1	24.0	24.3	27.2	24.2	37.3	38.0	33.7	42.7
	MAX	21.7	36.7	37.7	38.8	37.6	37.3	42.3	37.5	24.2	24.5	22.5	22.3
Nov	MIN	33.9	22.8	21.4	22.9	22.8	22.3	29.0	22.5	34.7	34.3	38.6	40.4
	MAX	20.5	34.1	34.7	36.9	35.1	35.2	38.5	34.8	22.3	22.5	27.4	30.4
Dec	MIN	31.7	20.8	17.1	22.5	20.5	20.9	25.0	22.1	32.7	32.1	28.6	29.6
	MAX	27.3	32.7	33.4	32.9	32.6	33.0	30.5	32.9	20.2	19.7	29.5	28.4

Aysaita rainfall data(1999-2010)	Month	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVERAGE
	Jan	0	0	0	3.8	0	3	0	0	1.2	0	13	0	1.75
	Feb	0	0	0	0	45.6	0	0	1.2	0.3	0	0	25.2	6.03
	Mar	36.6	0	15	5.1	0	38	31.2	15	7.5	0	0	18.1	13.88
	Apr	0	37.1	1.2	20.7	40.5	13.2	21	17.6	6.8	13.2	0	0	14.3
	May	0	0.4	2.7	4.8	0	0	0	0	0.2	6.5	0	3.8	1.53
	Jun	0	0	0	0	7.3	3.2	25.3	0	0	0	0	6.3	3.51
	Jul	8	37	39.8	0	18.1	12.4		23.6	54.6	23.7	13.4		23.06
	Aug	18.4	105.6	43.1	32.4	117.4	22.8		132	36.4	31.3	27.9		56.73
	Sep	31.9	8.1	24.8	3.2	2.8	27.5		2	24.3	9.9	5.4		13.99
	Oct	30.7	15.7	0	0	0	0.4		0	3.4	1.5			5.74
	Nov	0	30.8	0	0	0	0		0	0	0.6			3.49
Dec	0	2.8	0	15.2	23.4	1.6		16.6	0	0	0		5.96	

Annex 4. Ground truth data

S.No.	Easting	Northing	Class
1	753405	1307579	Bare Land
2	773475	1276919	Bare Land
3	748005	1289969	Bush and Shrubs
4	764475	1273889	Bare Land
5	784095	1284419	Bush and Shrubs
6	756765	1285619	Agriculture
7	760155	1295520	Bare Land
8	772005	1277400	Agriculture
9	757755	1284420	Agriculture
10	774165	1290570	Bare Land
11	782295	1234230	Bare Land
12	756255	1281660	Agriculture
13	770775	1296960	Bare Land
14	783075	1281810	Agriculture
15	769305	1290360	Bare Land
16	767685	1298940	Bare Land
17	759615	1305780	Bare Land
18	771285	1297950	Bare Land
19	767745	1306890	Bare Land
20	771075	1258260	Bare Land
21	788595	1280070	Water body
22	775185	1273440	Bush and Shrubs
23	754545	1305240	Bare Land
24	783675	1222020	Bare Land
25	751155	1309140	Bare Land
26	757815	1310760	Bare Land
27	763635	1289940	Bare Land
28	761175	1307340	Bare Land
29	753165	1291350	Bare Land
30	776685	1288620	Bare Land
31	764925	1309740	Bare Land
32	778305	1258650	Agriculture
33	784545	1288530	Water body
34	765315	1289160	Bare Land
35	764925	1275000	Bush and Shrubs
36	773475	1298940	Bare Land
37	761805	1300680	Bare Land
38	778575	1291440	Bare Land
39	761655	1304010	Bare Land
40	749565	1291980	Bare Land

Annex 5. Satellite image of 2011



Annex 6. Photos of Aysaita.



Plate 1. Sugar cane production in Aysaita woreda



Plate 2. Maize crop production around Awash River

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Plate 3. Natural dam formed during Rainy season



Plate 4. Houses surrounded by Bush and Shrubs around Awash River



Plate 5. The photo shows the reproduction site of mosquito around Awash River

