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DEPARTMENT OF GEOGRAPHYAND ENVIRONMENTAL

MALARIA RISK ASSESSMENT USING GIS AND REMOTE SENSING: A CASE OF KEWET WOREDA, NORTH SHEWA ZONE, AMHARA REGION

MAME ZEWGA GETANEH

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MALARIA RISK ASSESSMENT USING GIS AND REMOTE SENSING: A CASE OF KEWET WOREDA, NORTH SHEWA ZONE, AMHARA REGION

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 ART IN GIS, REMOTE SENSING AND DIGITAL CARTOGRAPHY

BY:

MAME ZEWGA GETANEH

ADVISOR:

Dr. ELLENI YESHANEH

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ADDIS ABABA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

This is to certify that the thesis prepared by Mame Zewga entitled: *Malaria Risk Assessment using GIS and remote sensing: A Case of Kewet Woreda, North Shewa Zone, Amhara Region,* is submitted in partial fulfillment of the requirements for the Degree of Master of Arts in Geography and Environmental Studies with specialization GIS, Remote Sensing and Digital Cartography compiles with the regulation of the university and meets the accepted standards with respect to originality and quality.

Signed by Examining committee:

Chairperson	Signature	Date
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Advisor	Signature	Date

DECLARATION

I, certify that this thesis is my original work and has not been presented for a degree in any other university and that all sources of material used for this thesis have been dully acknowledged.

Mame Zewga Getaneh
School of Graduate Studies
May, 2016.

This thesis has been submitted for examination with my approval as university advisor.

Dr. Elleni Yeshaneh ____

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ACRONYMS

ACT	Artemisinin Based Combination Therapy
ACIPH	Addis Continental Institute of Public Health
AED	Academy for Education
AHP	Analytical Hierarchy Process
AIDS	Acquire Immune Deficiency Syndrome
CDC	Centers for Disease Control and Prevention
CSA	Central Statistical Agency
DDT	Dicholoro-Dephenyl-Trichloroethane
DD	Decimal Degree
DEM	Digital Elevation Model
EMA	Ethiopia Mapping Agency
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agricultural Organization
FMoH	Federal Ministry of Health
GIS	Geographic Information System
GISSE	Geographic Information System Society of Ethiopia
GPS	Global Positioning System
HH	House Holds
INSA	Information Network Security Agency
ITBN	Insecticide Treated Bed Net
Km	Kilometer
m.a.s.l	Meter Above Sea Level
MCE	Multi Criteria Evaluation
MES	Malaria Eradication Service
MIS	Malaria Indicator Survey
MoA	Ministry of Agriculture
NIAID	National Institute of Allergy and Infectious Diseases
NMA	National Meteorological Agency
NOCMVD	National Organization for the Control of Malaria and other Vector Born Disease

NSDI	National Spatial Data Infrastructure
PMI	President Malaria Initiative
PPS	Proportional to Population Size
RBC	Red Blood Cell
RDT	Rapid Diagnostic Tests
SNNPR	South Nation Nationality and People Region
SRTM	Shuttle Radar Thematic Mapper
SSA	Sub Sahara Africa
T^o	Temperature
TM	Thematic Mapper
UNICEF	United Nations Children’s Fund
USIAD	U.S. Agency for International Development
WHO	World Health Organization

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Abstract

Malaria is grave and long lasting disease instigated by a protozoan parasite of the plasmodium species. It is the root cause for one million deaths annually throughout the world. From this, 90% of death is experienced by young children in South of the Sahara, in Africa. In Ethiopia, malaria is found in about 75% of the total area of the country and more than 68% of the total population is at risk of infection. The main objective of this study was to assess and map the risk of malaria using GIS and remote sensing in Kewet Woreda, North Shewa Zone, Amhara Region. For the last few years, the outbreak of malaria in the study area started to decrease. But still malaria was the top ten diseases which is the deep root cause for high morbidity and mortality in the Woreda. To assess and map the risk of malaria, nine determining factors included elevation, rain fall, wet land and swamp area, river, temperature, health center, slope, land use/cover and population density were selected. These factor maps were combined by using Weighted Multi Criteria Evaluation on IDRISI 17.0 environment. Multi criteria evaluation in GIS is focused on the allocation of land to suit for specific objective based on different attributes or factors. To assess the socio-economic aspect house hold survey was carried out. To do so, 137 respondents were systematically selected from five kebeles. Malaria risk map of the study area showed that there is no malaria risk free kebele within Kewet Woreda. Almost 3/4 of the areas fall in the very high (25%), high (45.4%), and moderate (22.9%) malaria risk levels and the remaining 6.7% of the area labeled as malaria free. Regarding the impact of malaria in the study area almost all respondents systematically selected from five kebeles indicated that their families were highly affected by malaria, and they use ITBN and insecticide spraying as coping mechanisms. GIS and remote sensing plays a great role in enhancing malaria risk zone mapping. Therefore, to minimize the risk of malaria in the area, the Woreda health office should use GIS and Remote sensing technology, could aware the people about the importance of drainage and effective use of ITBN, construct health center at very high and high risk area.

Key words: Malaria, GIS, Rs and MCE.

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

World Health Organization (WHO) (2008) defines malaria as serious disease caused by plasmodium. Cunningham et al. (2005) noted that malaria as grave and long lasting disease instigated by a protozoan parasite of the plasmodium species (plasmodium malariae, plasmodium ovale, plasmodium vivax and plasmodium falciparum). In addition, the prevalence of epidemic disease was explained by 'Miasma Theory' at the time of Hippocrates at about 450 BC (Akpala, 1994). Accordingly, malaria means "Bad Air" (Hempelmann, & Krafts, 2013). It is essentially an environmental disease since the vectors require specific habitats with surface water for reproduction, humidity for adult mosquito survival and the development rates of both the vector and parasite populations are influenced by temperature. It is caught by being bitten with an infected mosquito that is carrying the malaria parasites in its saliva (Ashenafi, 2008).

Based on the scientists discovery in 1880, one cell parasite is the major cause of malaria which is called "plasmodium" After a while, they discovered that the parasite is transmitted from one person to another through the bite of a female Anopheles mosquito, which requires blood to nurture her eggs (Ashenafi, 2003).

According to WHO (2008) report malaria is a root cause for one million deaths annually throughout the world. From this, 90% of death is experienced by young children in South of the Sahara, Africa. As compared to AIDS (Acquired Immune Deficiency Syndrome), the number of people killed by malaria is twofold. As many as half a billion people worldwide are left with chronic anemia, due to malaria infection (WHO, 2012). Currently, Nearly 90% of all malaria deaths occur across the tropical and sub-tropical regions of the world, where plasmodium falciparum, the most lethal species of malaria parasite, predominates and responsible for as many as 198 million illness (ranges 124-238 million) and 589,000 death (ranges 367,000-755,000) worldwide in 2013 (WHO, 2014).

Most of the world countries could control malaria from 1950-1960's, but the incidence of malaria increase again in 1970's across the globe as a re-emerging disease. Especially in SSA the rate of malaria transmission increases at an alarming rate (President Malaria Initiatives, 2012). The eradication of malaria transmission became more complex due to the resistance of disease to the drugs used for treatment. Its scourge is all encompassing (CDC, 2007).

According to WHO (2008) report, there are numerous and intricate factors for the spread of malaria. That makes the eradication of malaria difficult and time taking. It is obvious that co-infection, population dynamics, and drug and insecticide resistance are the major cause for the increment and transmission of malaria cases.

Malaria is a major public health problem in Ethiopia. Also it is the leading cause of outpatient consultations, admissions and death (Aster, 2010). In most parts of Ethiopia, malaria is seasonal with periodic transmission that leads to the outbreak of an epidemic. The transmission patterns and intensity vary greatly due to the large diversity in altitude, rainfall and population migration. In Ethiopia, areas below 2,000 m.a.s.l. elevation are considered to be areas with malaria risk or potentially area with malaria risk. These areas are home to approximately 68% of the Ethiopian population (FMoH, 2008).

The spatial and temporal pattern of malaria transmission at the local level (fixed spatial scale) in Africa has not been well investigated, accurately defined and well documented (Agarwal, Sikarwar, & Sukumaran, 2012). Researches are needed in developing dynamic and area specific malaria risk maps to identify the locations and populations at highest risk for appropriate planning and implementation of targeted goals and epidemiologically sound preventive and control measure against malaria. In line with this, the combined use of GIS and remote sensing provides a solution for monitoring environmental conditions that are conducive to malaria and mapping the disease risk to human populations.

These tools also serve as one of early warning system in the public health program (Kaya et al., 2002). Remote sensing data have been used widely for identification, characterization, monitoring, and surveillance of breeding habitats and mapping of malaria risk. Thus, combined with data from surveillance activities, and remotely sensed imageries as well as GIS and GPS are ideal tools for generating base maps, mapping breeding habitats and analysis of areas of high disease prevalence (Saxena et al., 2009).

1.2. Statement of the Problem and Justifications

Malaria is one of the top ten diseases which are responsible for high morbidity and mortality in the *Woreda* (Andagie, Abrham, and Berhanu, 2013). Seasonal rainfall, presence of unplanned small scale irrigation and land feature of the area create conducive environment for emergence of mosquito breeding sites. Severity of malaria increases at the rainy seasons putting challenging on the activity of the local people whose livelihood is dependent on crop farming. It reduces labor, time for on farm follow up, and children's school attendance that in turn result in the decline of agricultural production, economic dependency of vulnerable individuals on others, high school dropouts and social crisis.

In order to prevent malaria more of larvae assessment system and reports from different *kebeles* of the study area were used by health office. However, the mechanisms employed above are time consuming and impede quick response in time of the occurrence of epidemics which in turn deteriorate the living standard and to the extent death up on people residing in the study area. Thus, there is a need of malaria prevention and control system supported by more efficient methods which can contribute towards the alleviating the problem in the study area.

The development of malaria in an area is highly affected by climatic and topographic factors, like rainfall, temperature, altitude, and slope. GIS and remote sensing can be used to associate such variables and the distribution of mosquito responsible for malaria transmission. Other factors like population density, land-use/cover and proximity to different malaria causing or preventing factors can be also associated with the effect they do have on malaria prevalence using the same tools. Therefore, GIS and remote sensing are the appropriate tools to aid malaria control and prevention system through assessing potential malaria risk level of an area. Additionally, GIS and remote sensing enable us to produce different thematic and attribute maps for malaria causing factors and malaria risk level for the study area. This in turn helps in the malaria control and prevention system of emergency response, preparedness preventive measures, community awareness, identification of health facility accessibility and its location.

In the study area, particularly in Shewa Robit town some researches were conducted in relation to malaria. For instance a research conducted by Andargi et al. (2013) focused on community knowledge, attitude and practice about malaria in a low endemic setting of Shewa Robit town. However, the study didn't do malaria risk mapping and risk level identification. As a result, in the study area, the risk level of malaria based on environmental factors was not identified. Doing so could facilitate malaria prevention and control activities in the study area.

Therefore, in order to fill the above gaps, this study tried to identify environmental factors facilitating conditions for mosquito breeding and use GIS and remote sensing to generate malaria risk map, which will make malaria prevention and control exercise easier and cost effective and time effective.

1.3. Objective of the Study

1.3.1. General Objectives

The main objective of the study is to assess and map the risk of malaria using Geographic information system and Remote sensing techniques in Kewet *Woreda*, North Shewa Zone, Amhara Region.

1.3.2. Specific Objectives

In line with the above general objective, the specific objectives of this study were to:

- Investigate the environmental and socio-economic factors that aggravate mosquito breeding condition in the study area;
- Generate malaria risk map of the study area;
- To identify highly vulnerable areas for taking mitigation measures against the population at risk of malaria in Kewet *Woreda;*
- Examine the impact of malaria epidemic on the local community of the study area;
- Identify the coping mechanisms of malaria disease in the study area.

1.4. Research Questions

In order to address the stated problems, the study answers the following principal questions:

- What are the factors that facilitate the mosquito breeding conditions?
- How does the malaria risk map of the study area look like?
- Which parts the study areas are more vulnerable to malaria risk?
- What are the impacts of malaria in Kewet *Woreda* population?
- What kinds of coping mechanisms have been used to minimize the impact of the disease in the study area?

1.5. Significance of the Study

Identifying malaria risk areas depending on the various factors that contribute towards malaria risk will greatly improve prevention efforts and largely reduce costs of prevention in high risk areas. Using GIS and remote sensing technology in public health helps the policy makers and other stakeholders for early warning system. This study has a great importance in presenting possible intervention to avert the pressure of the disease in the light of the finding of the study. Moreover, the study is indispensable for the researchers to use it as a reference and motivate to conduct further study.

Finally, it can be used as an input for health institutions to identify malaria breeding site and for other research project it will contribute for the development of literature on the application of multi-criteria decision analysis using Geographic Information System (GIS) for the analysis of malaria risk area and for comprehensive study on risk assessment and mapping using GIS and remote sensing in the area and other related.

1.6. Scope of the Study

Assessing the risk of malaria is a broad subject matter. It is impossible to address all issue in this study like community knowledge, attitude, and practice about malaria and others. Therefore, this study is restricted in place and issue of concern. Geographically, it is delimited to Kewet *Woreda*, North Shewa Zone, Amhara National Regional State. As far as the issue of concern; it is concerned on assessing the risk of malaria by using GIS and remote sensing techniques to identify the overall impact of malaria in the study area.

1.7. Limitations of the Study

Throughout the process of conducting the study, the researcher faced many problems such as: lack of *kebele* wise well documented malaria cases and other organized temporal and spatial malaria related data over a long period of time, lack of adequate meteorological stations closer to the study area and appropriate data based on the plan of the researcher to get reliable climatic data (temperature and rainfall) for the study area, and reluctance of the sampled respondents to give information.

To fill the gaps the researcher used different techniques: for absence of well documented data throughout *kebele,* the researcher minimized the years of analysis from thirty (30) years to seven (7) years based upon the available data, takes the available data selectively to conduct the interpolation and finally by making strong rapport and systematic approaches, the researcher could get appropriate response from the respondents.

1.8. Organization of the Study

This study comprises five chapters. The first chapter deals with background of the study, statement of the problem, objectives of the study, research questions, significance, scope, limitation and organization of the paper. The second chapter deals with review of different related literature about the concept, risk of malaria in the world, in Africa as well as in Ethiopia and use of Geographic information system and remote sensing techniques to assess the risk of malaria. The third chapter discusses the methodology and data used for the study. Chapter four, comprises analysis of the data and discussions. This includes analysis of data gathered from field through ground survey, questionnaire, interview, observation as well as secondary sources. The final chapter constitutes summary of major findings and recommendations. Moreover, reference materials and additional information were presented in appendix.

CHAPTER TWO

2. REVIEW OF LITERATURES

2.1. Malaria Epidemics

The term “Malaria” originated and was first used in Rome, but until mid-18th century it was not known by its present name. Rather it was known by different names like swamp fever, intermittent fever, Roman fever, and death fever. From miasma theory of causation the name malaria or “bad” (mal) air was derived. Not only human beings but also all vertebrates like snakes are parasitized with the species of plasmodium (Aynalem, 2011).

By the introduction of Agriculture which results high population growth as well as breeding place for Anopheles mosquitoes, malaria widely spread in the course of Human Cultural Revolution. During the hunting and gathering period malaria transmission from animal to human or human to human was minimal due to people’s mobile life style and small size (Hempelmann and Krafts, 2013).

It is obvious that hunter-gatherer was nomadic who did not have permanent residence for a long period of time to be infected by mosquito. According to Hempelmann and Krafts (2013) 10,000 years ago or more recently hunter-gatherer of west Africa shifts their ways of life to a more permanent form of slash and burn agriculture as well as cattle raising which enable human malaria to be spread from human to human and/or human to animal.

Changes in social and ecological environment for agriculture facilitate high population density in a permanent and nearby neighborhood. This way of life leads to the emergence of pond water for different agricultural purpose create base for Anopheles gambiae vector. Then, female mosquitos produce their eggs on the food supply of human blood of the agriculturalists. Afterwards the migration of peoples played a pivotal role for the expansion of malaria disease (Ceccato et al., 2005).

According to NIAID (2007) there are 100 and more species of plasmodium that produce the disease in various types of animals and humans. Thus, Malaria is ancient disease that caused by parasites of the genus plasmodium and spread through various species of Anopheles mosquitoes.

Among plasmodium parasites four of them commonly infect humans. Namly: plasmodium falciparum, plasmodium vivax, plasmodium ovale and Plasmodium malariae.

Under microscope every plasmodium species has a typical form as well as slightly different pattern of sign (NIAID, 2007). Their description is given below:

Plasmodium falciparum: is the most dangerous specie of plasmodium and which is responsible for malaria death and morbidity in tropical and subtropical countries of the world including our country Ethiopia. The infection can develop suddenly and produce several life threatening problem, with quick and effective treatment, however, it is almost always treatable.

Plasmodium vivax: is another species of plasmodium which is widely spread geographically as well as produces less severe symptom as compared to the former one. In temperate climatic region the species is common, but now it found mostly in the tropics, especially Asia.

Plasmodium ovale: unlike other species, this type of plasmodium is rare, and can cause relapses. It is mostly common in the western part of Africa.

Plasmodium malariae: can prevail in the blood for a very long period of time maybe a decade, without showing any symptoms. Via blood donation or mosquito bites, a person infected by mosquito but with no symptom can also affect others. From temperate climate, its spread has been blocked but still found in Africa.

2.2. Nature of the Disease

Malaria is a serious disease with the maturity time of 7 days or more. Thus, a febrile illness prevails in less than one week subsequently of the first existence is not malaria. The greatest severe type is produced by plasmodium falciparum by having clinical features like fever, chills, headache, muscular aching and weakness, vomiting cough, diarrhea and abdominal pain. Other symptoms related to organ failure may supervene, such as acute renal failure, generalized convulsions, circulatory collapse followed by coma and death. The initial symptoms, which may be mild, may not be easy to recognize as being due to malaria (Nyika et al., 2009).

The probability of falciparum malaria can be well thought out in entire cases of unsolved fever began between 7 days after its possible exposure and 3 months after the last possible exposure.

Therefore, individuals who experience a fever in this interval should have to visit medical personnel because falciparum malaria is a disastrous one if not take treatment within 24 hours after the onset of clinical symptoms (NIAID, 2007). Vulnerable individuals like young children, pregnant women, and elders are more exposed to severe disease. Besides, plasmodium falciparum results maternal death, miscarriage, still birth and neonatal death on pregnant travelers. However, other plasmodium species of human malaria cause substantial morbidity but is rarely life threatening (FMoH, 2014).

Plasmodium vivax and ovale can remain dormant in the liver; relapses caused by these persistent liver forms ("hypnozoites") may appear months and rarely, several years after exposure. Relapses are not prevented by current chemo prophylactic regimens, with the exception of primaquine. Latent blood infection with Plasmodium malariae may be present for many years, but it is very rarely life threatening. Plasmodium knowlesi malaria is primarily a public health problem among populations living or working in forested areas in south-east Asia (Aynalem, 2011).

According to WHO (2013), the periodic cases of travelers malaria is due to plasmodium knowlesi. They are infected by this "monkey malaria" parasite while staying in rainforest and/or their fringe areas. Parts of Brunei Darussalam, Cambodia, China, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam are areas infected by this type of parasite.

2.3. Life Cycle of the Malaria Parasite

The life cycle of human malaria is very complex and it requires both human and insect hosts. The reproduction system of plasmodium in Anopheles mosquitos is sexually or by merging the parasite's sex cells while in people the reproduction is carried out through asexually (by cell division), first in liver cells and then, repeatedly, in red blood cells (RBCs) (NIAID, 2007).

An infected female Anopheles mosquito bites a people by injects saliva that contains the infectious form of the parasite, and then this sporozoite is distributed in to a person's blood stream. The thread-like sporozoite then invades a liver cell. After one or two weeks depending on the plasmodium species, the sporozoite develops into a schizont (a structure that contains thousands of tiny rounded merozoites). It is another stage of the parasite. When the schizont matures, it ruptures and releases the merozoites into the blood stream (CDC, 2006).

On the other hand, sometime some spices of plasmodium may turn into hypnozoites, a form that can remain inactive in the liver for months or more. But when it became active again, the hypnozoites develop into schizonts that then cause relapses in infected people. After the merozoites out from the liver it immediately invades RBCs, where they grow by consuming hemoglobin. Inside RBCs, the merozoites may create another round of asexual reproduction, and then they form schizonts that filled with addition merozoites. After the schizont develops, the cell falling out and erupt out. The newly released merozoites occupy other RBCs, and the infection carries on its cycle until it is brought under control, either by drug or the body's immune system defenses (Cox, 2010).

The life cycle of plasmodium parasite may end when some of the merozoites that penetrate RBCs do not develop asexually into schizonts but, can be changed into female and male sexual form gametocytes. These circulate in the person's bloodstream, awaiting the arrival of a blood seeking female Anopheles mosquito (American public health Association, 2010).

After a female mosquito bites an infected person, it sucks up gametocytes along with blood. Once the gametocytes is develop into sperm-like male gametes or egg-like female gametes in the mosquito's stomach the fertilization produce an oocyst filled with infectious sporozoites. When the oocyst matures, it ruptures and the thread-like sporozoites migrate by the thousands to the mosquito's salivary (saliva-producing) glands. The cycle starts over again when the mosquito bites its next victim (Friesen et al., 2010).

Thus, the parasite has a life-cycle of 24 hours and can give rise to daily fever spikes occurring 9-12 days after infection. Symptoms may be a typical of malaria. Severe plasmodium knowlesi malaria with organ failure may occur, and sporadic fatal out comes have been described. Plasmodium knowlesi has no persistent liver forms and relapses do not occur. Travelers to forested areas of southeast Asia where human Plasmodium knowlesi infections have been reported should protect themselves against mosquito bites between dusk and dawn to prevent infection and take chemoprophylaxis where indicated (NIAID, 2008).

2.4. Malaria Situation in the World and in Africa

Malaria is serious and fatal disease that affect the lives of 40% of the world population which accounts over 2,200 million people. Each year, there is an estimated amount of 300-500 million clinical cases. From over one million people annually, the greatly affected portions of society are young children. Thus, it is one of the leading causes of death among young children and more than 90% of malaria case found in Africa especially South of Sahara. Pneumonia, diarrhea, measles malnutrition, and malaria are causes for deaths of young children in developing countries including Ethiopia. In the course of pregnancy malaria became causes for various problems like maternal illness and anemia, as well as low birth weight among newborn infants also accelerate infant mortality (Robert et al., 2005).

The impact of malaria on human and social wellbeing is disastrous. Since, it repeatedly attacks, the number of labor force decreased, children lost school, and largely economic loss accounted nearly US$2 billion in Africa alone in 1997. Malaria has a direct impact on poverty situation by making life difficult and shocking economic development of developing countries (WHO, 2013).

According to WHO and WB rank (2012) malaria is an acute burden in Africa causing 35 million annual loss of life. As a result about 20-30% of hospital admission and 30-50% causality consultations was made by taking malaria as a critical case. Not only in Africa, but also it is a public health problem in different parts of the world like Eastern Europe, Latin America- Brazil with 50% of all malaria cases, Middle East, and the Pacific (WHO, 2012).

It is obvious that malaria is an infection of warm climate. Hot and humid climate associated with ponds serve as a breeding ground for Anopheles Mosquito. Besides, malaria flourishes in the conditions where people community awareness is low and health care systems are weak. Thus, its distribution is not the same across the world. For example, plasmodium falciparum is predominantly found in the warm and moist part of Africa, the Middle East, Asia, Haiti, the Caribbean Island, and central and South America. Plasmodium vivax is dominant in tropical and sub-tropical part of Asia and in Eastern Africa and some temperate region such as in Middle East and Iran (UNICF, 2000).

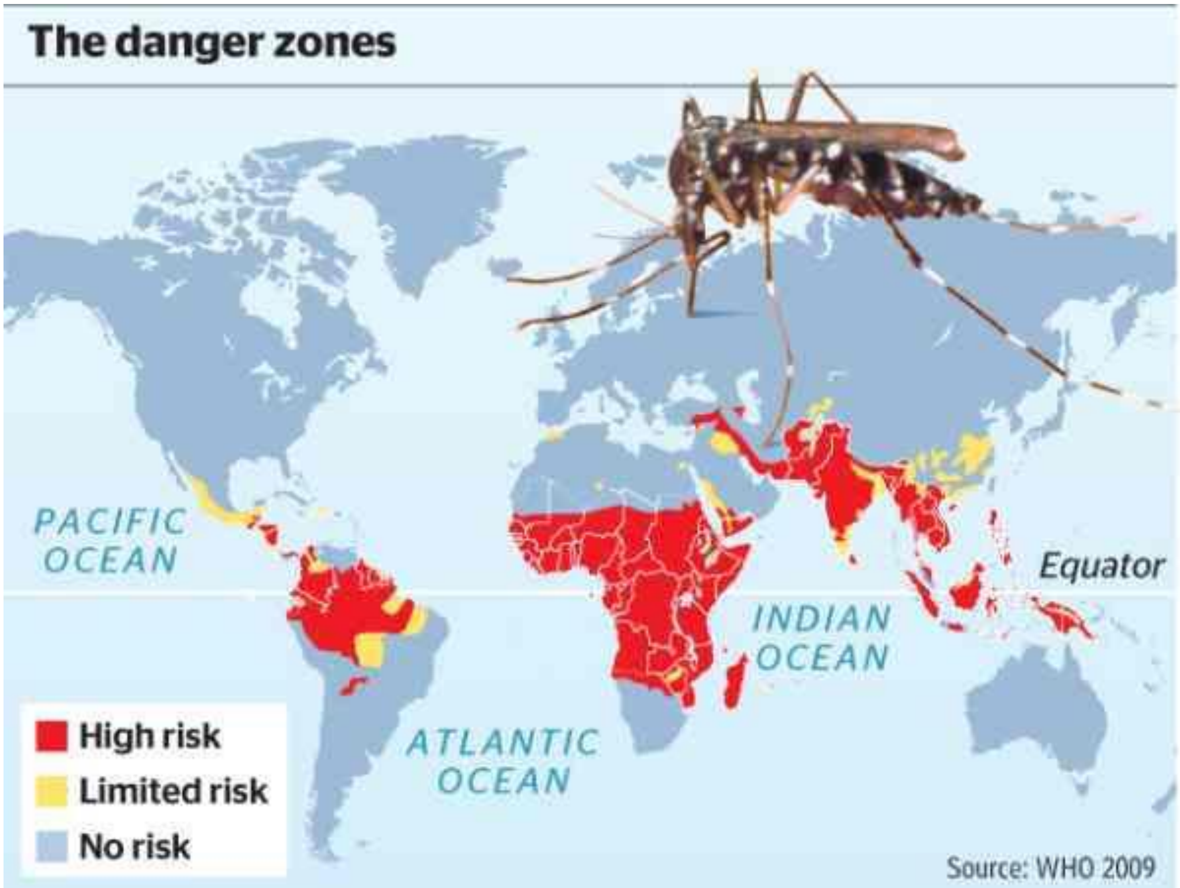

Figure 2.1: Global Distribution of Malaria Transmission Risk
Source: WHO, 2009.

2.5. Malaria Situation in Ethiopia

Altitude and climate (Rainfall and Temperature) which is highly affected by Indian Ocean and global weather situations like El Nino and La Nina has a direct relation for malaria transmission in Ethiopia. Transmission is seasonal and predominantly unstable. Seasons for malaria transmission and expansion are not uniform in all parts of the country where most of it takes place between September-December, after the main rainy season from June to August (summer). On the other hand, Western and Eastern parts of the country experience malaria transmission between April to May following the shortest rainy season (Belg) from February to March (Ashenafi, 2003).

Aynalem (2011) argued five main malaria eco-epidemiological strata in Ethiopia. These are:

- Stable, year round transmission in the western lowlands and river basin areas of Gambella and Benishangul-Gumuz Regional States;
- Seasonal transmission in lowland areas below 1,500 meters;
- Epidemic-prone areas in highland fringes between 1,500 – 2,500 meters;
- Arid areas where malaria is only found near semi-permanent water bodies; and
- Malaria-free highland areas above 2, 500 meters.

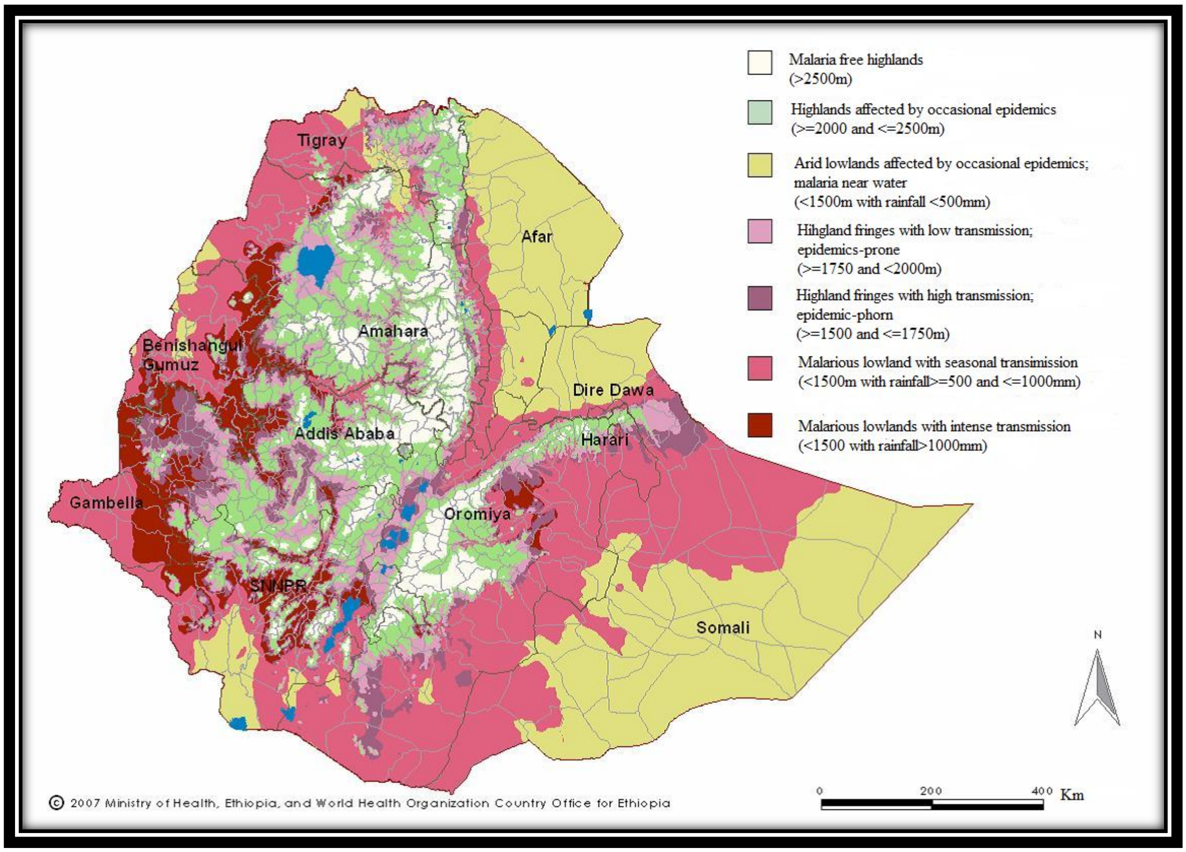

Figure 2.2: Distribution and Seasonality of Malaria in Ethiopia

Source: Malaria Indicator Survey, 2011.

The parasite prevalence of malaria which is measured by microscopy in Ethiopia was 0.7% and 0.3% respectively for both plasmodium falciparum and vivax below 2,000 meters altitude according to the 2007 Malaria Indicator Survey (MIS). And also the 2011 MIS shows that 1.3% of all age groups were positive for malaria using microscopy and 4.5% were positive for malaria using RDTs below 2,000 meters. Plasmodium falciparum constituted 77% of these infections.

The 2011 MIS survey demonstrated a remarkable demarcation of malaria risk at an altitude of 2,000 meters, with thirteen-fold higher malaria prevalence at lower altitudes compared to higher elevations. There was essentially no plasmodium falciparum detected by microscopy among persons surveyed within households having measured elevations above 2,000 meters in the 2011 MIS.

2.5.1. History of Malaria Control in Ethiopia

To control malaria, the first action was sprung as a pretest in the 1950's and the national eradication campaign took place by the 1960's. Later on, by the early 1970's the Malaria Eradication Service was re-organized into a control program. Following this, in 1976 the vertical organization known as the National Organization for the Control of Malaria and Other Vector borne Diseases (NOCMVD) evolved from the Malaria Eradication Service (MES). The organization however, was functional with one central office, 17 regional or zonal offices, consisting of 70 sector offices and more than 1,400 malaria detection and treatment posts until 1993 (FMoH, 2003).

According to FMoH (2003) starting from June 1993, for the protection and control of malaria, the responsibility and roles were shouldered by the Regional Health Bureaus in accordance to the federal arrangement system of democracy and decentralization principles.

2.5.2. Burden of Malaria in Ethiopia

Malaria is one of the major communicable diseases in Ethiopia despite its low parasite number of existence in comparison to other African countries (Aynalem, 2011). In history, the major factors that enforce people from productive areas to less agriculturally productive highlands were malaria. Since malaria transmission period is associated with the planting and harvesting season in Ethiopia, and the impact of malaria on economy is heavy due to dependency of country's economy up on agriculture. As stated previously, malaria is the leading cause of outpatient consultations and health facility admissions. About 75% of the geographic area of the country has significant malaria transmission risk (defined as areas <2,000 m), with about 68% (57.3 million) of the country's total population living in these areas (Negassi, 2008).

There are about 12 million suspected malaria cases each year. The FMoH (2012) reported a total of 3,384,589 malaria cases from July 2011-June 2012, with 1,793,832 (53.0%) of these laboratory confirmed, with 1,061,242 (59.2%) plasmodium falciparum and 732,590 (40.8%) plasmodium vivax. According to the 2012 World Malaria Report, Ethiopia reported 936 malaria deaths in 2011, Malaria morbidity reporting from these official FMoH surveillance sources and systems is improving, but is still substantially incomplete. PMI sponsored a micro planning survey in late 2012 to help estimate malaria morbidity and malaria commodity requirements based upon July 2011-June 2012 district level reports from all districts in Ethiopia, with essentially 100% completeness.

This micro planning survey documented 11,127,705 suspected malaria cases, of which 9,255,139 (83%) were tested with microscopy or RDT; 5,522,462 malaria cases were diagnosed as malaria, including 3,649,896 laboratory confirmed and 1,872,566 probable malaria cases (which were treated without diagnostic testing). There were 2,475,337 laboratory confirmed plasmodium falciparum cases, and 1,174,559 plasmodium vivax cases reported. Of those who underwent diagnostic testing (9,255,139), 39% were confirmed to have malaria (FMoH, 2006).

From these micro planning data, an estimated 2,976,165 plasmodium falciparum and 1,412,204 plasmodium vivax cases would have been diagnosed had all of the 11,127,705 suspected malaria patients been laboratory tested. There were 44,696 hospitalizations for severe malaria during this time according to the micro plan reports. The higher malaria test rate (83%) in the micro plan compared to FMoH surveillance estimates (53%) represents very complete micro plan data collection combined with inclusion of health post data, where compliance with RDT testing by health extension workers to guide treatment is apparently very high, in comparison with FMoH surveillance data from health centers and hospitals only, where microscopy services may be intermittent. It appears that the annual artemisinin-based combination therapy (ACT) requirements in Ethiopia may continue to decline well below the peak of approximately 9 million ACT treatments annually as RDTs and microscopy continue to be scaled-up especially at rural health posts, since more than half of malaria outpatients are diagnosed and treated by health extension worker (WHO, 2010).

As previously mentioned, there were widespread severe malaria epidemics in 2003-2004 in Ethiopia, with an estimated 41,000 malaria deaths, including 25,000 deaths among children under five years of age in 2003. There was an apparent low point of outpatient malaria morbidity in 2007, but an estimated 30% increase in annual malaria outpatient morbidity since 2007. Ethiopian malaria surveillance data was imprecise in years prior to 2011, when most malaria cases were clinically diagnosed and malaria reporting was grossly incomplete. While no large malaria epidemics were reported in 2006 and 2007, there were several focal outbreaks reported in Southern Nations, Nationalities and People's Regional State (SNNPR), Amhara, Tigray, and Oromia in the last five years (Aynalem, 2011).

Despite a recent apparent modest increase in outpatient malaria morbidity, annual malaria deaths in children under five years of age and malaria epidemics in Ethiopia have substantially decreased through early 2013, compared to the baseline year of 2003-2004. The FMoH's health and health related indicators report for 2010/11 shows deaths due to malaria in under five years constitute 12.6% compared to 21.1% in 2003/04. The World Health Statistics report by WHO estimated that there were 5,400 malaria deaths in Ethiopia in 2010 among Ethiopian children under five years of age, but a comprehensive analysis of all available data including recent surveillance reports suggests that the estimated number of annual malaria deaths in 2011 is 550, which is much lower for this age group (WHO, 2012).

2.5.3. Malaria Situation in North Shewa Zone

Most of the areas in north Shewa Zone Amhara regional state are found below 2000 m altitude. Due to this reason, the area is highly affected by malaria. It is remains to be the major public health challenge and major causes of morbidity and mortality, disproportionately affecting the most vulnerable and under-served group of the population in North Shewa Zone including the study area. Like other part of the country, malaria transmission occurs twice a year in the area. These are: between September and December, after the main rainy season from June to August (summer season) and second "minor" malaria transmission occurs from April to May, following a short rainy season from February to March (belg) (Aynalem, 2011).

2.6. Factors Aggravating Malaria

There are many factors that responsible for the spread of malaria epidemic in Ethiopia. Among these environmental factors (slope, elevation, soil, and proximity to water bodies) and climate (rainfall, temperature, and humidity) are the leading factors that affect the breeding site and habitat of Anopheles mosquito vectors. Especially, elevation, temperature and rainfall are act as major factors for the development of Anopheles mosquitoes, which are the transitional hosts in the transmission of malaria parasites. In addition, socio-economic factor like land use/cover, irrigation, increase in population size, migration, urbanization, and proximity to water body have all influenced the spatial distribution pattern of malaria (Aynalem, 2008).

2.6.1. Climatic Factors

There is a comfortable temperature and moisture conditions for the development of plasmodium parasite in the mosquito and breeding of Anopheles mosquitoes in most part of Ethiopia. This is the result of the countries location and topography. Ethiopia is located in the tropical region; most parts of the country have high temperature throughout the year; High amount of seasonal rainfall in most parts and all year round rainfall in some areas, are mainly related to the tropical location of the country. The seasonal rainfall with high temperature is responsible for the occurrence of unbalanced and seasonal malaria transmission after the onset of the rainfall in most part of the country (Ashenafi, 2008).

2.6.1.1. Temperature

Temperature plays a great role in the variability of malaria transmission by regulating the development rate of mosquito larvae and influencing the survival rate of adult mosquitoes. As the temperature decreases, the number of days necessary to complete the development increases for a given plasmodium species. The minimum temperature required for development of plasmodium vivax parasite in anopheles mosquitoes ranges from 14.5–16.5°C, while for plasmodium falciparum it ranges from 16.5–19°C. The maximum temperature for parasite development is 40°C. However, the best conditions for development of the malaria parasite are 20–30°C temperature and 60% relative humidity. The time needed for the parasite to complete its development in the mosquito, decreases to less than 10 days as temperature increases from 21°C to 27°C, with 27°C being the optimum. Below 18°C, the life cycle of plasmodium falciparum in the mosquito body is limited (Dhiman et al., 2010).

On the other hand it takes about 10 days for an egg to reach the adult stage of an anopheles mosquito at an optimum temperature of 28 °C. At lower temperature, the duration gets prolonged while at increased temperature the duration is reduced. However, at more than 40 °C, mortality occurs in adult mosquitoes (Dhiman et al., 2010).

2.6.1.2. Rainfall

In Ethiopia, water collections that support vector breeding appear mainly after the rainy seasons, thus, rainfall is another most important malaria initiating parameter causing soil saturation and a rise in stagnant water. Therefore, it creates favorable breeding ground, and in most part of tropical areas, malaria transmission is highest following rainy season (NIAID, 2007). Anopheles mosquitoes do not breed in polluted water rather it needs stagnant and fresh water with vegetation cover. Spatial and temporal variations in precipitation are critically important in determining the nature and scale of malaria transmission in highland areas.

As Cox (2010) pointed out that from a geographical perspective it is probably significant that, in addition to temperature, rainfall totals are usually strongly correlated with altitude. On tropical mountains rainfall maxima mostly occur at about 1500 m, above and below which totals can decline rapidly. Rains above 900mm, which maintain temperatures between 25^{o}C to 30^{o}C and relative humidity around 80% lead to increase vector density and longevity to initiate malaria transmission (Ifatimehin, 2009). On the other hand, Protopopoff et al. (2009) described heavy rain showers can washed away and kill larvae.

2.6.1.3. Humidity

The survival rate of adult insects is often thought to increase or decrease in relation to a factor called saturation deficit. Saturation deficit is derived by subtracting the actual water vapor pressure from the maximum possible vapor pressure at a given temperature. Evidence for other vectors (tsetse ticks) suggests that saturation deficit is an important environmental variable in larval and adult survivorship.

2.6.2. Topographical Factors

Elevation and slope are the most important topographic factors for the transmission of malaria. The mechanism of topographic factors influence on vector-borne disease lain in the fact that various terrain feature support different land cover, thus, provide certain habitats suitable for some vectors. For example, swamp is fitting for snails and mosquitoes while grass land, is suitable for mice, vector of plague (Liu, Zeng, and Cui, 2006). Topographic patterns affect the spatial distribution of mosquitoes and susceptibility level of human immune system (Zhou et al., 2004).

2.6.2.1. Altitude

The occurrence of malaria parasites in people varies with altitude. Protopopoff et al. (2009) stated that an altitude around 1800–2000 meters is usually considered the upper limit at which malaria transmission occurs, though epidemics have been recorded higher. Therefore, altitude is significant in determining the distribution of malaria and its seasonal impact on many parts of the world. Traditionally, 2000m is recognized as the upper limit of malaria transmission in Ethiopia except for highland fringe malaria epidemics that can extend up to 2500m. More than three-quarters of the landmass (altitude <2000 m) of the country is both area with malaria risk or potentially malarious, and an estimated 68% (>50 million people) of the total population resides in areas at risk of malaria infections (ACIPH, 2009).

Now a day due to temperature increase (Global warming) and other factors malaria is emerged in high altitude area of Ethiopia including those above 2000 m.a.s.l. during malaria non-epidemic year (Woyessa et al., 2012). On the other hand in Ethiopia lowland (Bereha) area have altitude < 500 m.a.s.l. and annual rainfall < 900 mm are not suitable for mosquito breeding as a result of low annual rainfall amount and very high temperature above 30^{o}c (FMoH,2008).

2.6.2.2. Slope

The topography of the land plays an important role that inhibits or enhances the malaria breeding site in a certain locality. For instance, steep slope cannot support for malaria breeding while flat land or gentle slope is favorable for malaria breeding together with other environmental factors.

Moreover, larvae developing in water pools in sloped area are more likely to be washed away during down pours. Thus, sloped areas create poor mosquito breeding ground, reducing the threat of malaria transmission (Munga, 2006 and Burlando, 2012). Slope is used as a pivotal factor of water stagnation. Water tends to be blocked in area with low slopes because of physical soil properties and slope gradient. The highest number of malaria cases showed in the area which slope gradient is below 5% (FAO, 1976).

2.6.3. Socio-Economic Factors

2.6.3.1. Irrigation Practice

The growth of population has led to an increased demand for food that is far exceeding normal agricultural production. So, to alleviate the problem, people in different part of the country use crop irrigation as a solution. These big and small water-related development projects, such as irrigation channels, dams and ponds, can increase the incidence of malaria in villages that are located near such projects. For instance, some people agreed that water reservoirs dam in rural areas might create favourable condition for malaria breading, this created malaria epidemic in rural Ethiopia. Irrigation creates an ideal habitat for mass-production of mosquitoes (Reiter, 2008).

2.6.3.2. Migration

In developing countries, especially in Africa, people are move from one place to another due to different reasons and it creates another risk factor to the development and spread of malaria. The migrant people might be categorized under either active transmitters or passive acquirers. Active transmitters port the parasite and transmit the disease when they move to areas of low transmission. Passive acquirers are exposed to the disease through movement from one environment to another; they may have low-level immunity or may be non-immune, which increases their risk for disease (Alemayehu, 2011). Migrants and refugees may bring new parasites (including drug resistant parasites) to an area and increase transmission in the settled population, or because they come from a low or no transmission area migrants and refugees may be highly vulnerable to severe disease when they enter a malaria endemic area (Ceccato et al., 2005).

2.6.3.3. Land Use/Land Cover

The terms land use/cover is often used interchangeably but, their actual meaning is quite distinct. land use refers to the purpose the land serves, for example, recreation, wildlife habitat, or agriculture while land cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, bare soil or other (Amdie, 2007). So, Land use/cover is a critical environmental factors associated with vector-borne disease. Different kinds of land cover indicate different types of residential areas suitable for various vectors.

In Ethiopia, forest and swamp regions were shifted to agricultural plot to feed an ever-increasing population. Water requirements for many crops have led to modifications of surface waters. All these can be used as a catalyst for the increment of malaria epidemic. As Haque (2007) demonstrated how landscape elements can be used to predict mosquito availability and subsequently malaria outbreaks. Land type is correlated with malaria incidence to identify the landscape elements that are most suitable for mosquito breeding.

2.6.3.4. Urbanization

The rapid growth of unplanned urbanization often leads to the increment of malaria transmission. The urban settlers are mainly migrant workers from rural villages thus conditions are crowded; the quality of housing is very poor; there is lack of proper drainage of surface water; they use unprotected water reservoirs and the provision of health care and sanitation is often in adequate, i.e. Settlers tend to dig several pits to extract stone and soil for house construction and this create numerous breeding grounds for mosquitoes (Martens and Hall, 2000). This can lead to increasing exposure of the population to vectors.

On the contrary, the incidence of malaria is generally lower in urban areas than in rural areas. This is because there is plenty of space for vector breeding in rural villages while mosquito breeding sites in urban areas are limited because more space is covered by houses. In addition to this, People in urban areas may have more access to health care than people in rural villages.

2.6.3.5. Soil

Soil is at the heart of terrestrial ecology and is vital to our very existence. Soils are classified as poorly drained and well-drained soil (Srivastava et al., 2009). Poorly drained soil has the capacity to accumulate water and create favorable condition for mosquito breeding while well drained soil doesn't allow water stagnation, so it creates uncomfortable condition for anopheles mosquito breeding.

2.6.4. Hydrological Factors

2.6.4.1. Proximity to Water Body

Malaria larva need relatively quiet water to grow. So, the closeness of residential area to water body or drainage systems plays a chief role for the spread of malaria in a given area (Kumar, Nathawat, & Onagh, 2012). The existence of permanent water bodies like river, swamps, lakes and streams create favorable ground for the breeding of mosquito and the transmission of malaria. In Ethiopia, during the rainy season both the rivers and lakes are full and sometimes they flow over their limits and these lead to flooding. But, during the dry season their volume is reduced and they create various pockets of water bodies that are favorable ground for the breeding of different vector born disease like mosquito. Therefore, water body, particularly not moving is a typical place for mosquito breeding (Ashenafi, 2008).

Abdulhakim (2014) and Hoek et al. (2003) states that two kilometer is the maximum flying distance for mosquito from their breeding sites. Therefore, people who are living within 2km distance from rivers, lakes and swamps, wet land or breading sites are vulnerable to malaria incidence than people living far from those areas.

2.7. Application of GIS and Remote Sensing in Malaria Risk Assessment

In this modern period, GIS is successfully utilized in order to fight against tropical disease like sleeping sickness, chagas desease, leishmaniasis, schistomaiasis, guinea worm and malaria. Therefore, GIS allows national health policy makers to identify risk areas, subsequent targeting and monitoring of intervention to these areas. Spatial and temporal patterns of vector borne diseases can be progressively studied using GIS and remote sensing technologies. In order to study associations between location, disease, intermediate host and environment, GIS is an appropriate technology due to its display capabilities especially for disease epidemiology at an illustrative level (Simoonga et al., 2009).

The relevance of GIS technologies to malaria control lies in the point that the global spectrum of malaria epidemiology is broad, and as varied as the natural diversity of the parasite, the mosquito vector and the biological constitution of the human host. The disease varies in its occurrence, strength, seasonality and clinical features depending on a multitude of local determinants such as the prevalence, position and nature of water bodies in which the mosquito vectors breed, and their relationship to human habitation and behavior. In turn it affected by environmental factors such as climate (rainfall, temperature and humidity), surface water distribution, elevation and prevailing fauna and flora in the area. So, meteorological and topographical attributes of a locality become important determinants of malaria (Mendis, 2009).

Therefore, to assess those determinants, GIS has also various applications that used for the study of mosquitoes and mosquito borne disease include studies of landscape architecture to assess how elevation, slope and land use/cover patterns influence the development of larval breeding sites (Giming, Hightower, & Hawley, 2005). For identification, characterization, monitoring, and surveillance of malaria breeding habitats and mapping risk area, remote sensing data's are widely used in GIS.

GIS based malaria incidence mapping has been used for risk assessment at international, national, regional, *woreda,* and village level. Such mapping is considered vital for analyzing past as well as disease trends. Risk maps developed on the basis of mapped malaria incidence are tools for targeted and cost effective control of disease (Saxena et al., 2009). GIS and Remote sensing methods are proved to be important in larval habitat identification and risk area mapping. So, GIS and remote sensing are increasingly used for the study of spatial and temporal pattern of vector born disease (Agarwal, Sikarwar, and Sukumaran, 2012).

CHAPTER THREE

2. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1. Location

Kewet *Woreda* is located in North Shewa Zone of Amhara National Regional State of Ethiopia as illustrated in figure 3.1. Geographically, the *woreda* lies at between latitudes 39° 9’ N-39^{o} 10’N and longitudes 39° 9’E 40^{o}9’E. It covers an area of about 146.32 km^{2}. The *woreda* have one urban and twenty four rural *kebeles*. The main town of Kewet *woreda* is located at a distance 94km from Debre Berhan and 225kms from Addis Ababa along Dessie road.

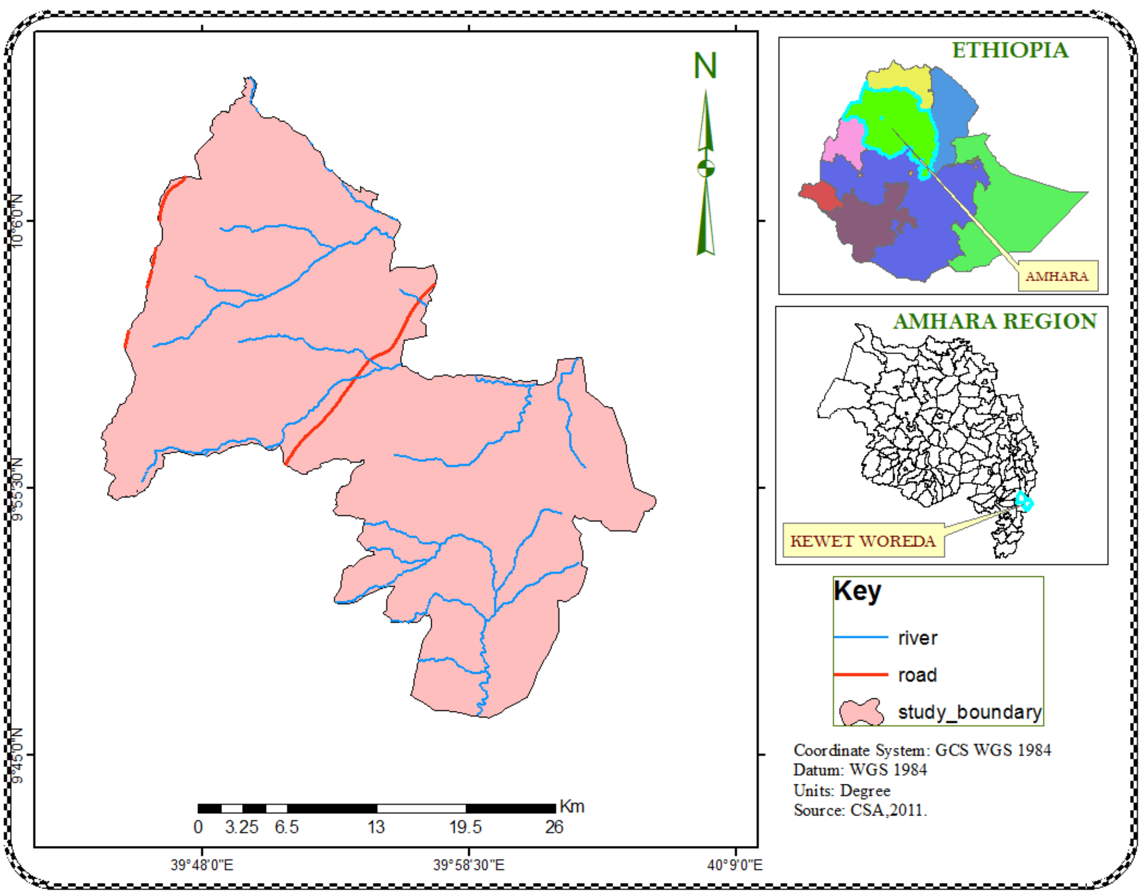

Figure 3.1: Location Map of the Study Area
Source: CSA, 2011. .

3.1.2. Demographic Characteristics

Based on the 2007 national census conducted by the Central Statistical Agency (CSA), Kewet *Woreda* has a total population of 118,381 with an increase of 9.97% from the 1994 census, of the total population, 60,934 are men and 57,447 women that comprise 51% and 49% of the total population respectively. About 17,575, (14.85%) of the population of the *woreda* live in urban area. It has a population density of 150.64 persons per square kilometer. The *woreda* is home of different ethnic group such as Amhara, Oromo, Argoba and others, of which Amhara is the dominant one.

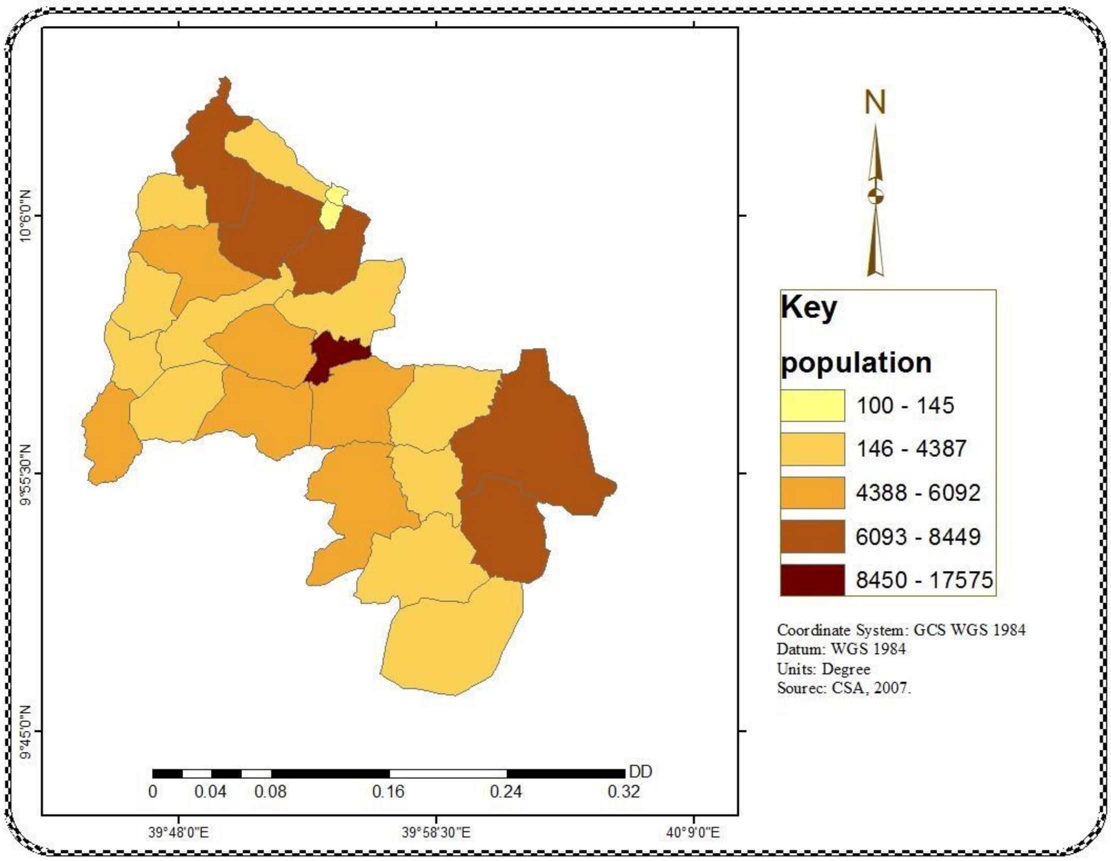

Figure 3.2: Population Density Map of the Study Area

Source: CSA, 2007.

3.1.3. Topographic Structure

The topography of Kewet *Woreda* constitutes flat, gentle and some mountainous landscapes. Its elevation ranges from 1047m.a.s.l to 3164m.a.s.l. as shown on figure 3.3. The Northern, Eastern and South tip of the *woreda* is dominated by low and flat laying areas where as, the Western tip are occupied by landscape with steep slope. Most parts of area are covered by flat land feature.

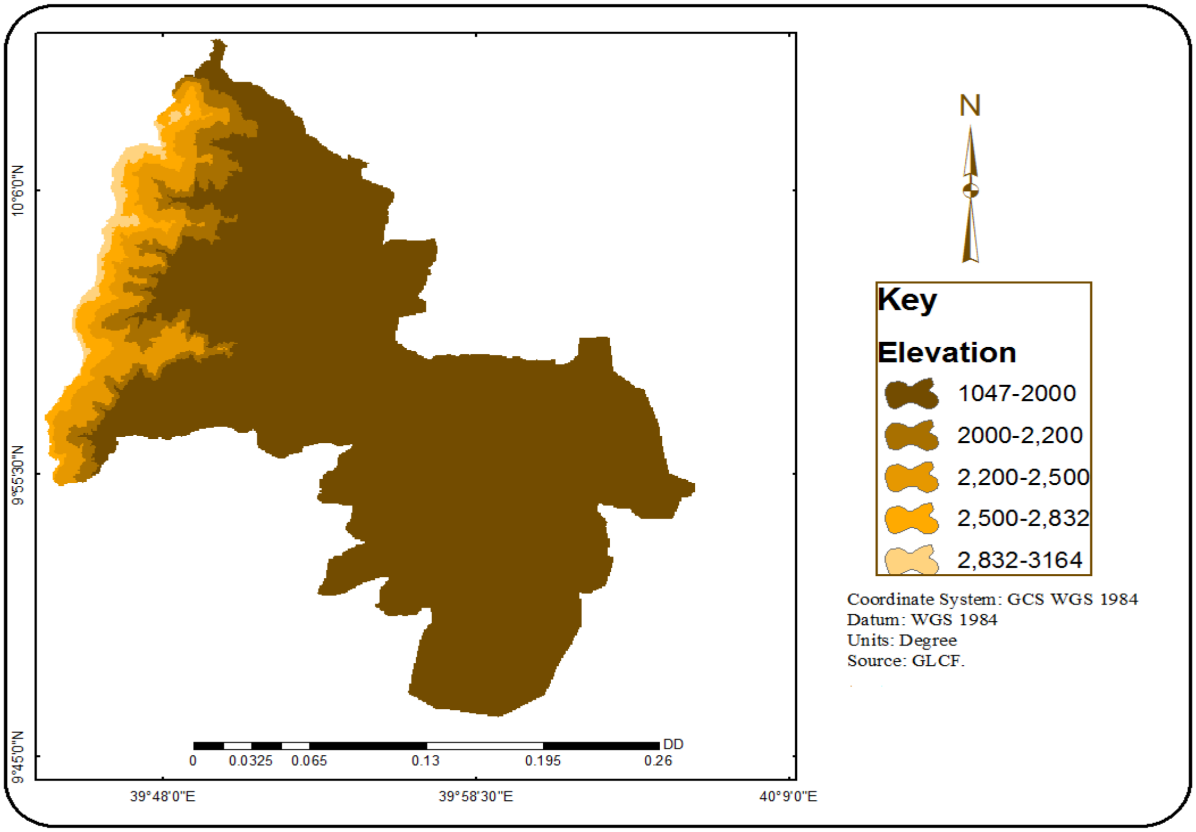

Figure 3.3: Elevation Map of the Study Area

Source: Global Land Cover Facility (http://glcf.umiacs.umd.edu/index.shtml).

3.1.4. Climate of the Study Area

3.1.4.1. Temperature

The climatic data of the study area was collected from National Metrological Agency in terms of monthly minimum and maximum temperature and rainfall. Then the monthly mean and annual climatic data was computed for the study area and other surrounding stations to carry out interpolation. Therefore, the mean minimum and mean maximum monthly temperature of the study area is in the ranges between 9.88^{o}C-17.62^{0}C and 28.25^{0}C-35.5^{0}C respectively as shown on figure 3.4. Its mean monthly temperature within a year ranges between 19.46^{0}C in December to 26.56^{0}C in the months of June. The yearly maximum temperature ranges from 30.7^{O}C to 31.9^{o}C while the minimum temperature ranges from 15.45^{O}C to 12.98^{O}C. Thus, from this one can understand that the temperature of Kewet *woreda* is favorable for the development of malaria.

Table.3.1.Mean Monthly Max, Min and Mean Temperature (^{O}C) of Kewet *Woreda* (2009-2015)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly min T^{o}	12.28	13.18	13.48	15.67	16.84	17.62	17.42	16.84	13.98	12.5	9.88	10.68
Mean T^{o}	20.33	21.71	22.69	23.92	25.49	26.56	25.23	24	22.56	21.53	20.34	19.46
Mean monthly max T^{o}	28.38	30.24	31.9	32.17	34.15	35.5	33.04	31.17	31.14	30.57	30.8	28.25

Source: National Meteorological Agency.

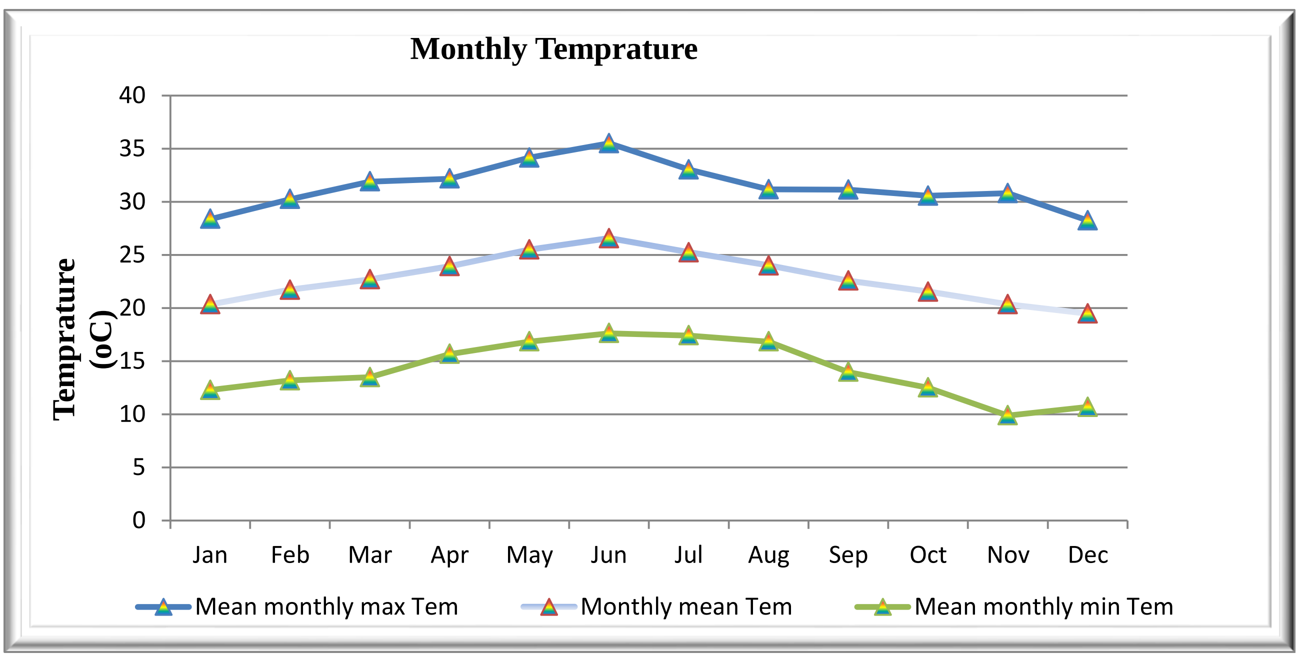

Figure 3.4: Mean Monthly, Mean Maximum and Mean Minimum Monthly Temperature of Kewet *Woreda* from 2009 to 2015.

Source: National Meteorological Agency.

3.1.4.2. Rainfall

The existence of rainfall plays an important role by providing suitable conditions for aquatic stages of mosquito. Thus, there is a positive relation between malaria cases and rainfall. This finding is in accordance with study made by Abebe et al. (2011) in which rainfall was reported to be a precipitating factor for malaria transmission. It plays an important role in malaria epidemiology because water not only provides the medium for aquatic stages of mosquitoes life but also increases the relative humidity and thereby the longevity of the adult mosquitoes. In addition, wet and humid environments provide the breeding sites and prolong the life of malaria mosquitoes (Mabratu, 2010).

Other studies also indicated that rainfall increases the breeding habitats for mosquitoes leading to increased population sizes and the rate of malaria transmission. Therefore, breeding increases radically in the rainy season when water collects in the area which has lower elevation and these provide plenty breeding site. Furthermore, the impact of rainfall on malaria transmission rate is very complicated, varying with the circumstances of a particular geographic region and depending on the local habits of mosquito breeding. It is beneficial if it is moderate, nevertheless, can destroy breeding sites and wash out the mosquito larvae when it is extreme (Reid, 2000).

Table.3.2. Average Monthly Rainfall Values (mm) of Kewet *Woreda* (2009-2015)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kewet Woreda	25.57	36.37	83.28	61.68	79.4	35.77	159.77	209.9	103.2	31.7	177.65	11.45

Source: National Meteorological Agency.

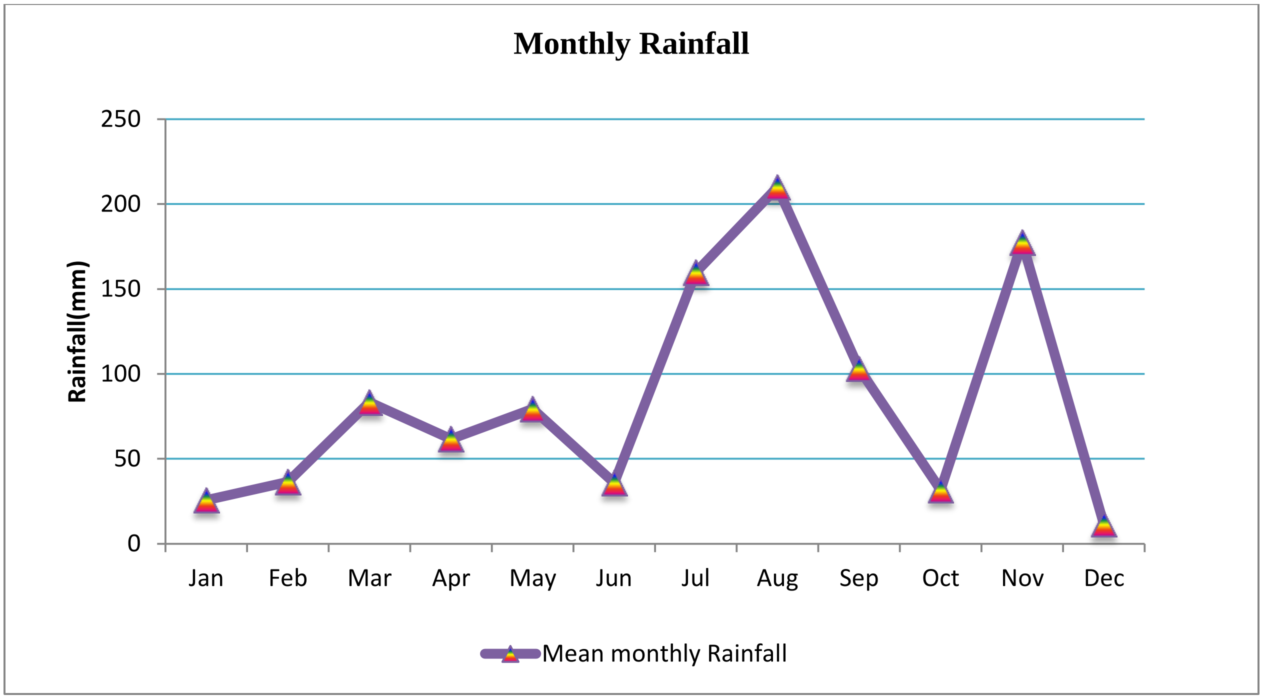

Figure 3.5: Mean Monthly Rainfall of Kewet *Woreda* from 2009 to 2015

Source: National Meteorological Agency.

The rainfall pattern of the study area, the mean annual rainfall is about 84.64mm with uneven and scarce occurring four or more times yearly. According to the data that collected from NMA, the rain fall of the area ranges from 11.45mm in December to 209.9mm in August. The study area has two rain seasons. The main rain season, which accounts for the largest total rainfall of the year occurs from June to August during summer season, the other rainfall season is from February to April (Belg) and during this time, the area receives small amount rainfall.

3.1.5. Trends of Malaria Infection in the Study Area

Kewet *Woreda* health office stated in 2016 that relative to the far past years malaria cases started to decrease over the last three years. This is due to the use of several preventive actions such as continuous yearly DDT spray and distribution of insecticide treated mosquito net by the governmental *woreda* health office and other non-governmental organization like USIAD and UNICEF. These activities combined with early diagnosis and treatment might have contributed for the decrease in number of malaria cases in the recent years. Even though, these actions were being undertaken, Malaria is still one of the major diseases in the area for the total mortality and morbidity rate due to the presence unplanned small scale irrigation practice and high temperature (20-25c^{o}) in the study area (NMA, 2016). In addition, there are many mosquito breeding areas that were created by river and rain water.

According to Kewet *Woreda* health Office, the peak malaria transmission season in the area is from September to December each year following the main rainy season from June to August, whereas the other highest malaria cases are recorded in the lowest rainfall months of March. Because of the presence of high temperature throughout the year and availability of water for breeding, malaria can occur frequently (Abebe et al., 2011).

The availability of permanent water that used for irrigated farming and high temperature are important factors for high evaporation. The relationship between malaria cases and evaporation shows relatively inverse relation. High evaporation occurs during high temperature period i.e., in March, April, and May. However, malaria cases decreases in April and May because of the reduction of surface water as the result of high evaporation (PMI, 2009). Figure 3.6 indicates that the numbers of malaria cases over years is being declining with some irregularities. In the last seven years, the maximum malaria case was recorded during the year 2011 followed by the year 2012 with number of cases 1763 and 1728 respectively.

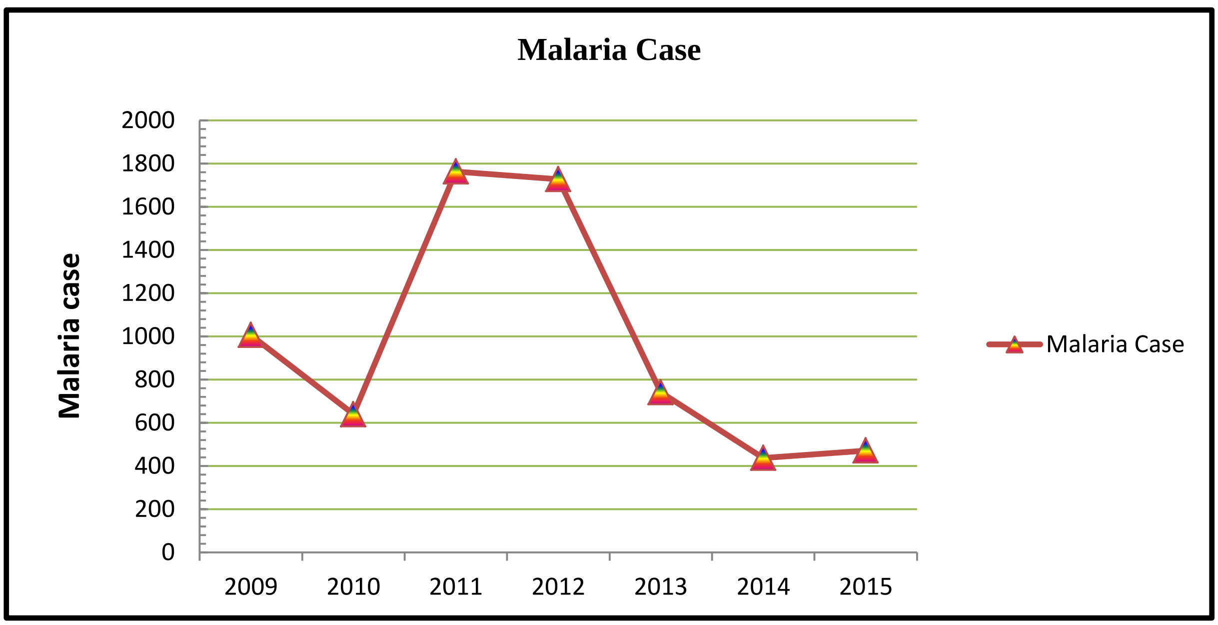

Figure 3.6: Number of Malaria Cases in Kewet *Woreda* for the Years 2009-2015

Source: Kewet *Woreda* Health Office.

3.1.6. Soil

Based on Food and Agricultural Organization (1984) soil classification system, the study area consists of six soil types namely Vertisols, Cambisols, Regosols, Lithosols, and Rock surface. Description of the soil types based on FAO (2006) is given below.

Vertisols: are churning, heavy clay soils with a high proportion of swelling and shrinking clays. These soils form deep wide cracks from the surface downward when they dry out, which happens in most years. They are almost impermeable, when saturated and very plastic and sticky when wet. Vertisols allow water stagnation during rainy season which are favorable for the breeding of mosquito, and found around depressions and level to undulating areas, mainly in tropical, subtropical, semi-arid to sub humid and humid climates with an alternation of distinct wet and dry seasons. The climax vegetation is savannah, natural grassland and/or woodland.

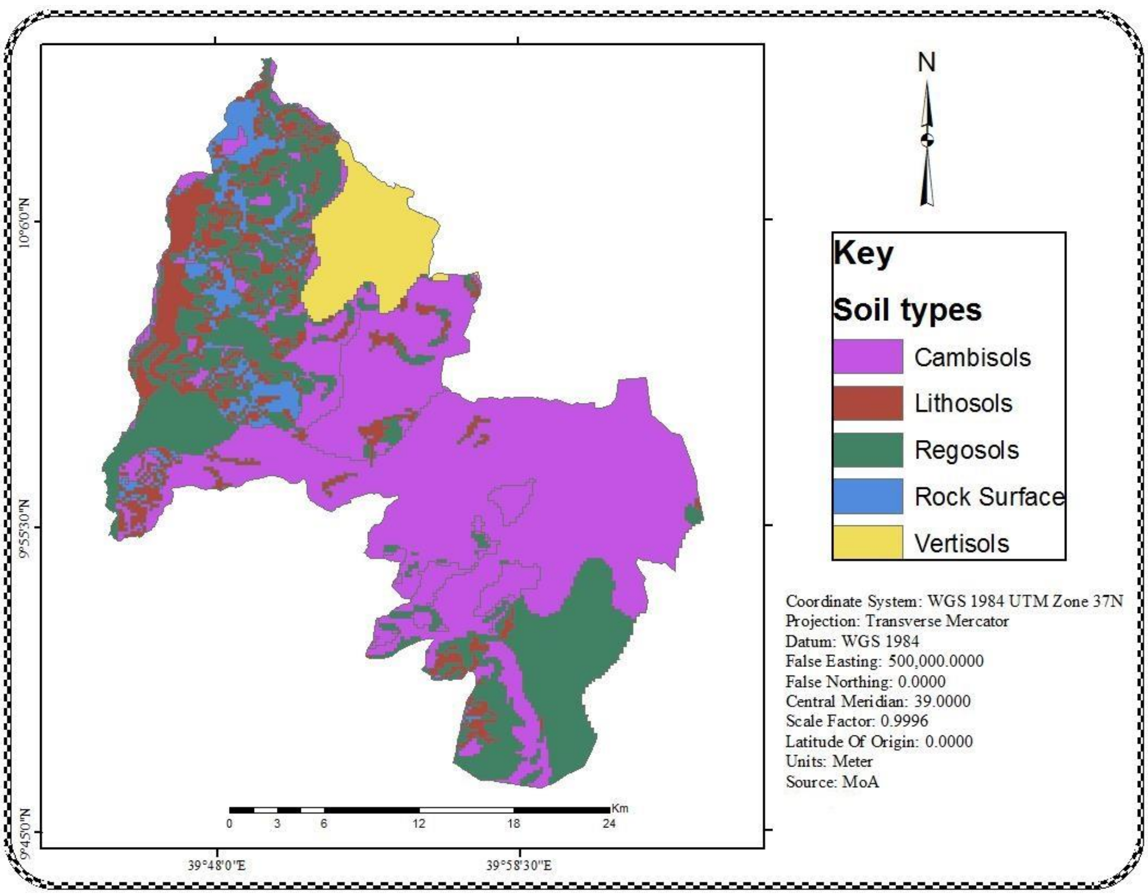

Figure 3.7: Soil Map of Study Area

Source: Ministry of Agriculture (FAO, 1984).

Regosols: are very weakly developed mineral soils in unconsolidated minerals of some depth, excluding coarse textured materials and materials with fluvic properties, and have no diagnostic horizons other than an ochric horizon. Regosols are extensive in eroding lands, in particular in arid and semi-arid areas and in mountain Regions.

Cambisol: is formed in the medium and fine textured material that derived from a wide range of rocks. It mostly developed in alluvial, colluvial and Aeolian deposits. Such types of soil are intensively used in agriculture and also the most productive soil in temperate climate.

Lithosols: are restricted in depth and have continuous, coherent rock within 10cm of the surface. Where developed, generally only mineral A, organic (O or H) horizons are found although some intermediate organic-rich humose horizons also occur. Such types of soils are very shallow, gravelly, and stony soils that are particularly good for wet-season grazing and forestland.

Rock Surface: is a coherent rock with no soil development. There are also three minor soils in the study area namly: Chromic, Eutric and Vertic.

3.1.7. Distribution of Health Institutions

It is obvious that, health creates a good condition for a nation to grow economically as well as progress in science and technology. To control spread of various diseases caused by insects, polluted water and poor hygiene and sanitation in the urban and rural area measures are being taking place through teaching and training community. This has been done through educating and training community how to take environmental sanitation by health workers those can reach up to rural population.

To enable the community to protect themselves from diseases caused by lack of clean water and environmental sanitation, health posts are constructed in different rural *kebeles.* The staffs from these health posts educate the rural community on how to keep the environment clean and free from diseases causing insects, like mosquitos. Therefore, those institutions play a great role in the reduction of disease, accessibility, awareness creation about various diseases and their means of prevention, and fair cost of treatment. These in turn influence the prevalence of a particular disease. Absence or distance from health center result in difficulties in accessibility and high cost of treatment.

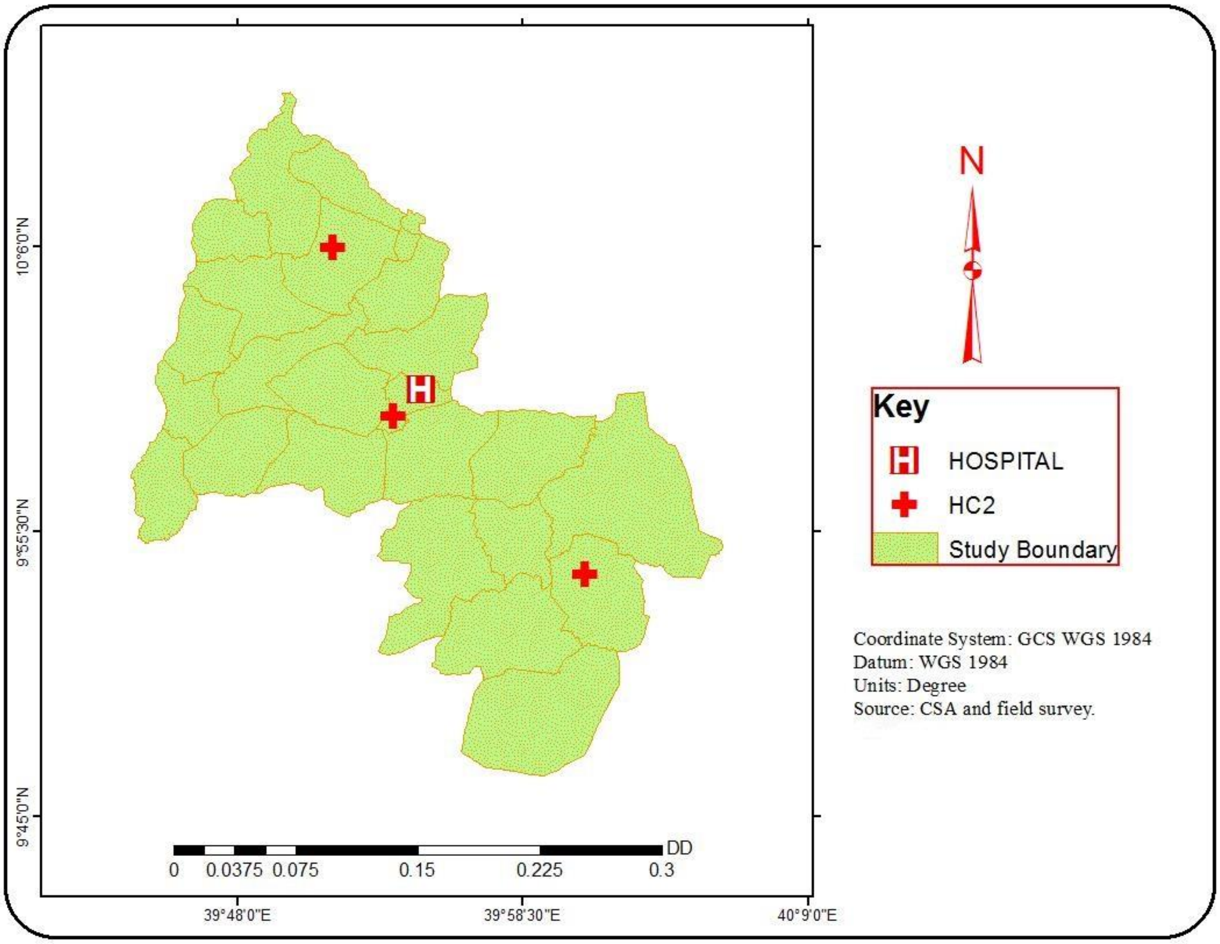

Figure 3.8: Spatial Distribution of Health Center in Kewet *Woreda*

Source: *Woreda* Health Office and Field Survey.

In Kewet *Woreda,* there are three governmental health centers and one hospital. From these, 2 health centers are found in the rural *kebeles* of the *Woreda* and the remaining 1 hospital and 1 health center are found in Shewa Robit town. Additionally, there are health extensions which are established in the rural part of the *Woreda*. But the researcher did not include them for malaria risk map of the study area because of their minimal contribution on the curative method of malaria in the study area.

To identify the spatial distribution of health centers within the study area, point data were collected using GPS on field survey. The type and spatial distribution of the health centers is illustrated in figure 3.8 above.

3.1.8. Land Use Land/Cover of the Study Area

The land use/cover map of the study area is, as it is indicated on figure 3.9. The map was derived from Land sat-5 (TM) imagery with 30m spatial resolution acquired on Feb, 2016. The land use/cover was divided in to six classes using supervised image classification techniques on ERDAS imagine 2013 environment. These are settlement, irrigated farm, water bodies, rain feed farm land, forest and bare lands. Among this land use/cover types, the main land use of the study area is dominated by rain fed farm lands, bare area and settlement area, which covers 34.9%, 31.5% and 13.3% respectively. The remaining area is occupied by forest, irrigated farm, and water bodies which cover 6.4%, 8.8% and 5.1% respectively (figure 3.9).

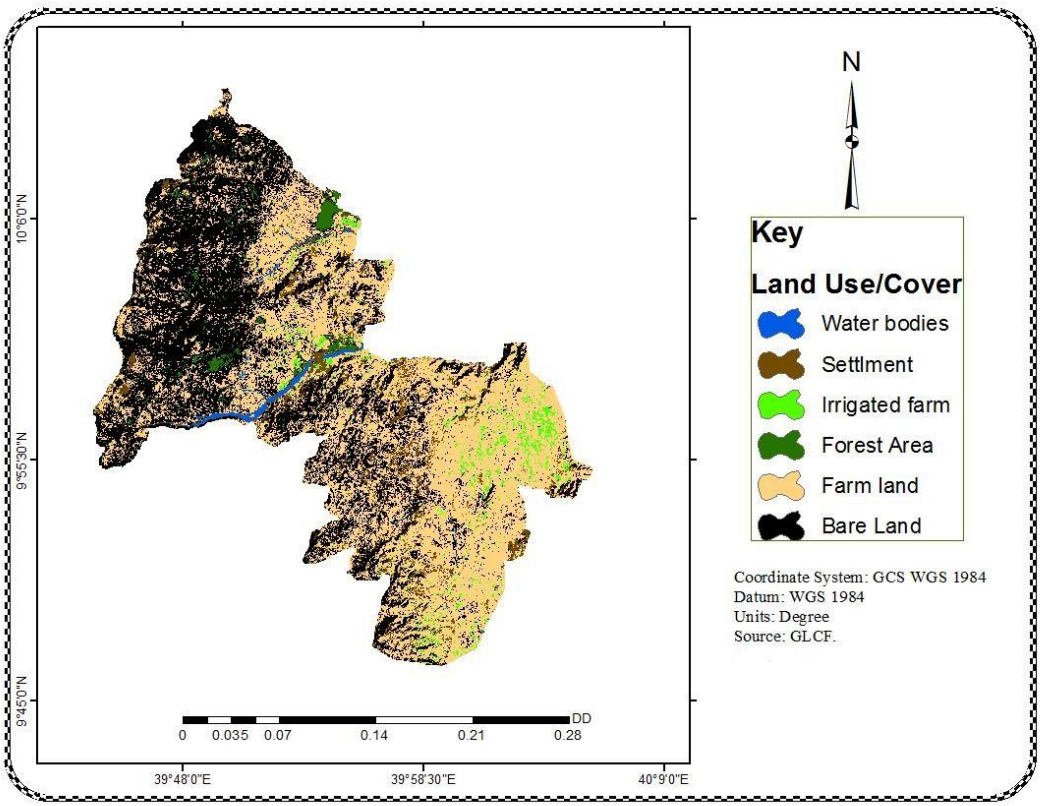

Figure 3.9: Land Use/Cover Map of the Study Area
Source: Global Land Covers Facility (http://glcf.umiacs.umd.edu/index.shtml).

Settlements: are built-up areas which are constructing largely from cement and concrete as in the case of the Shewa Robit town and some rural *kebele* settlements. In addition to this, there are houses which are built from mud, local grass and wood as construction materials input in the rural parts of the study area.

Farm Lands: is land that used for cultivation of various types of crops on rain feed agriculture. It is mainly used for the production of maize, teff and sorgum.

Irrigated Farmland: areas which are found around water bodies, farmers who have land around these areas produce some product like onion, maize, teff and others especially during non-rainy seasons.

Water Body: is describes water body laying over an extended land surface for long period of time.

Forest Land: an area or region covered with different type of trees or other woody vegetation. Bare Area is a section of the earth surface which is not covered by any natural vegetation.

Table 3.3: The Area that Covered by Different Land Use/Cover in the Study Area

Land use/cover class	Area (km^2)	Area (%)
Settlement	19.5	13.3
Irrigated farm	12.72	8.7
Rain fed farm	51.1	34.9
Water bodies	7.4	5.1
Forest	9.5	6.5
Bare land	46.1	31.5
Total	146.32	100

Source: Global Land Cover Facility (http://glcf.umiacs.umd.edu/index.shtml).

3.2. Research Methodology

The aim of the study is to assess and map malaria risk in Kewet *Woreda*, North Shewa Zone, Amhara National Regional State. To map the risk area, nine environmental and socio-economic factors were selected using the information collected from the Kewet *woreda* health office and related previous works. Accordingly, slope, elevation, rainfall, temperature, land use/cover, proximity to water bodies, population density and distance from health centers are taken as major environmental factors for malaria prevalence in the study area. For each environmental factors listed above maps were generated and then reclassified depending on their suitability for malaria breeding. In the course of the reclassification, new values 1, 2, 3, 4, and 5 were assigned and were labeled as very low, low, moderate, high and very high malaria risk level respectively and for some factors the researcher may use the revers. Then, weight was given to each risk factor in MCE on IDRISI software. To understand the influence of each factors, weighted overlay were carried out using Arc Map 10.1 to generate the final malaria risk map of the study area.

For socio-economic data analysis; before the data collection process ends, data edition and cleaning were take place side by side with the field work while collecting the data. In the course of data collection, completeness of the answers, accuracy of the answers and uniformity of the data in interpreting instruction were checked. The classification of the mass of data based on the main characteristics of the questionnaire, interview and objectives of the study have been made. To this end, both qualitative and quantitative methods of data analysis were employed. Quantitative data which gathered from questionnaire were analyzed in a descriptive way and presented using tables, verbal explanations and percentages to enable easy interpretation and quick visual comparisons of variables. The study mainly use SPSS (statistical package for social science) version 20 and Microsoft excel. On the other hand, information obtained from key informants in the study area was narrative and qualitative in nature and analyzed qualitatively to support the coded quantitative data.

3.2.1. Methods Used for Analysis of Factors

Different researches and articles have shown that malaria disease is influenced by environmental and climatic factors such as topography, temperature, rainfall; land-use/cover, population density, and proximity to water bodies have a profound influence on the temporal and spatial distribution of malaria vectors (Arega, 2009, Prosper, 2011, Aster, 2010). Especially, temperature and rainfall act as the major limiting factors on the development of Anopheles mosquitoes which are the intermediate hosts in the transmission of malaria parasites. Malaria transmission intensity, along with its temporal and spatial distribution in Ethiopia, is mainly determined by the diverse climatic conditions. Climatic factors including rainfall, temperature and humidity show high variability. These factors differ as a result of altitude (FMoH, 2009). Therefore, for this study relevant parameters which can be used for mapping malaria prone areas were extracted from the previous works, and data collected through interview and questioner. Their relevance for the mapping is described below in table3.4.

Table 3.4: Mapping Parameters and their Relevance

Mapping Parameter	Relevance for Mapping
Population Density	To Identify the Estimated number of population to malaria risk
Distance from Health centers	To identify areas those are close or far from Health Centers
Slope	For identifying of areas receptive to water logging
Proximity to River, Wet and Swamps	For identifying surface waters and swamps as are related to vector breeding
Elevation	To label the elevation of the area according to its suitability for malaria
Land Use/Cover	To detect vulnerable and receptive areas for malaria
T^o and Rainfall Conditions	To recognize the climatic condition

3.3. Sampling Techniques and Procedure for Collecting Socio-Economic Data

Even though the main target of the study was to assess and map the risk of malaria using GIS and remote sensing, to answer the last two specific objectives of the study as well as to confirm the results generated by GIS and remote sensing the researcher use questionnaires. Hence, multi stage sampling technique is used in this study. In the first stage, purposive sampling was used to select Amhara Region due to the presence of diversified climatic conditions as compared to other regions. Again in the second stage, the researcher selects North Shewa Zone purposively due to the existence of low land area than other surrounding Zones. In the third stage, Kewet *Woreda* was selected due to its favorable environmental conditions for mosquito breeding.

The ever increasing demand for research has created a need for an efficient method of determining the sample size needed to be representative of a given population. Thus, in the fourth stage, from Kewet *Woreda* five *Kebeles* were selected purposively due to the existence of high malaria case and their proximity to water bodies. i.e. (Shewa Robit 5873 HHs, Tere 1533 HHs, Agam ber 1510 HHs, Yelen 1596 HHs and Sefiberet 1743 HHs) (CSA, 2007) were purposively included to have better representation of sample respondents. Therefore, 12,255 of households are considered as sampling frame of the study.

Thus, the researcher was used sample size determination formula developed by (Jeff, 2001) to determine the total sample size for this inquiry.

$$S = \frac{X2NP(1-P)}{d2(N-1) + X2P(1-p)}$$

Where: S = required sample size.

X^2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841).

N = the population size

P = the population variability (assumed to be 0.10 since the population is homogeneous in terms of geography, similar social class and similar economic activity (cash economy) as urban economy is monetized economy).

d^2= the degree of accuracy expressed as a proportion (0.05).

When this formula is applied to the above sample, we get:

$$S = \frac{3.841x12255x0.1x(1-0.1)}{0.052(12{,}255-1) + 3.841x0.1x(1-0.1)}$$

$$= \frac{4236.43}{30.98} = 136.7 \approx 137$$

On the other hand, to determine the number of sample (respondents) in Shewa Robit (n_1), Tere (n_2), Agam ber (n_3), Yelen, ($n_{4)}$ and Sefiberet (n_5); the following formula were used:

Thus, $N_1 = S\ (N_1/N)$ and hence $n_1 = 137\ (5873/12{,}255) = 66$

Similarly, $N_2 = S(N_2/N)$, which is $n_2 = 137 (1533/12,255) = 17$

$N_3 = S(N_3/N)$ which is $n_3 = 137 (1510/12,255) = 17$

$N_4 = S(N_4/N)$ which is $n_4 = 137 (1596/12,255) = 18$

$N_5 = S(N4/N)$ which is $n_5 = 137(1743/12,255) = 19$

Table 3.5: Five Sampled *Kebeles*

No	List of selected *kebeles*	Total HHs per *kebeles*	Sample HHs from each *kebeles*	Method of selection
1	Shewa Robit	5873	66	PPS
2	Tere	1533	17	PPS
3	Agam ber	1510	17	PPS
4	Yelen	1596	18	PPS
5	Sefiberet	1743	19	PPS
Total		12, 255	137	Systematic sampling

The study use both probability and nonprobability sampling designs. Probability sampling was used to select respondents for the questionnaire through systematic sampling technique because it gives each element in the population an equal probability of getting into the sample (Kothari, 2004). Since non-probability sampling involves the selection of cases according to reasons other than mathematical probability, it was used in selecting the key informants for interview purposively. Because the researcher believed that they can provide enough information concerning the topic under study. Besides, systematic sampling was used in this study to distribute questionnaires evenly. Thus, the sample size was met by first selecting a random starting point and then picking every K^{th} element in the population for all household of independent *kebeles* in the sampling frame. Therefore, to compute k, the researcher uses the following formula;

$K = N/n.$

Thus, for *Shewa Robit Kebele* (n_1); K = 12,255/5873 = 2,

For *Tere Kebele* (n_2); K = 12,255 /1533 = 8,

For *Agam ber kebele* (n_3); k=12,255/1510 = 8, For *Yelen kekebele* (n_4); k= 12,255/1596 = 8, and

For Sefibert kebele(n_5); k= 12,255/1743 = 7.

Hence, every 2nd household from *Shewa Robit kebele*, every 8th household from each *kebeles* of *Tere, Agamber* and *Yelen* and every 7th house hold from *Sefiberet kebele* was selected by using their respective registers. The process of selecting continued until 137 households were selected.

3.4. Types of Data Used in the Study

Different primary and secondary data were used in the study area, which were obtained from field survey, questioner (structured questions), interview (semi-structured), and relevant institutions. The data used includes satellite imagery Land sat-5 Thematic Mapper (TM), Shuttle Radar Topography Mission (SRTM) 90m resolution data, climatic data (rainfall and temperature), socio-economic related data through questioner and clinical data (malaria cases) of the study area. Types of data used and their sources are described in Table 3.6 below.

Table 3.6: Types of Data and their Sources

No	Types of data	Source of data	Remark
1	Ground control points	Field survey	Point Data
2	Study area shape file	Central Statistical Agency	Shape file
3	Rainfall and T^o	National Meteorological Agency	Seven Years Data
4	DEM	GLCF	30mResolution
5	Land satellite image	GLCF	2012 Data
6	Malaria case data	*Woreda* health office	Seven Years Data
7	Topographic map	Ethiopia Mapping Agency	1:50,000m (Scale)
8	Socio-economic data	From sample respondents	

3.5. Materials/Soft wares

Different soft wares and materials have been used based on their relevance to this research. Namely: Arc GIS 10.1, ERDAS IMAGIN 2013, IDRISI, GPS, Microsoft Office Packages and Digital Camera. ,

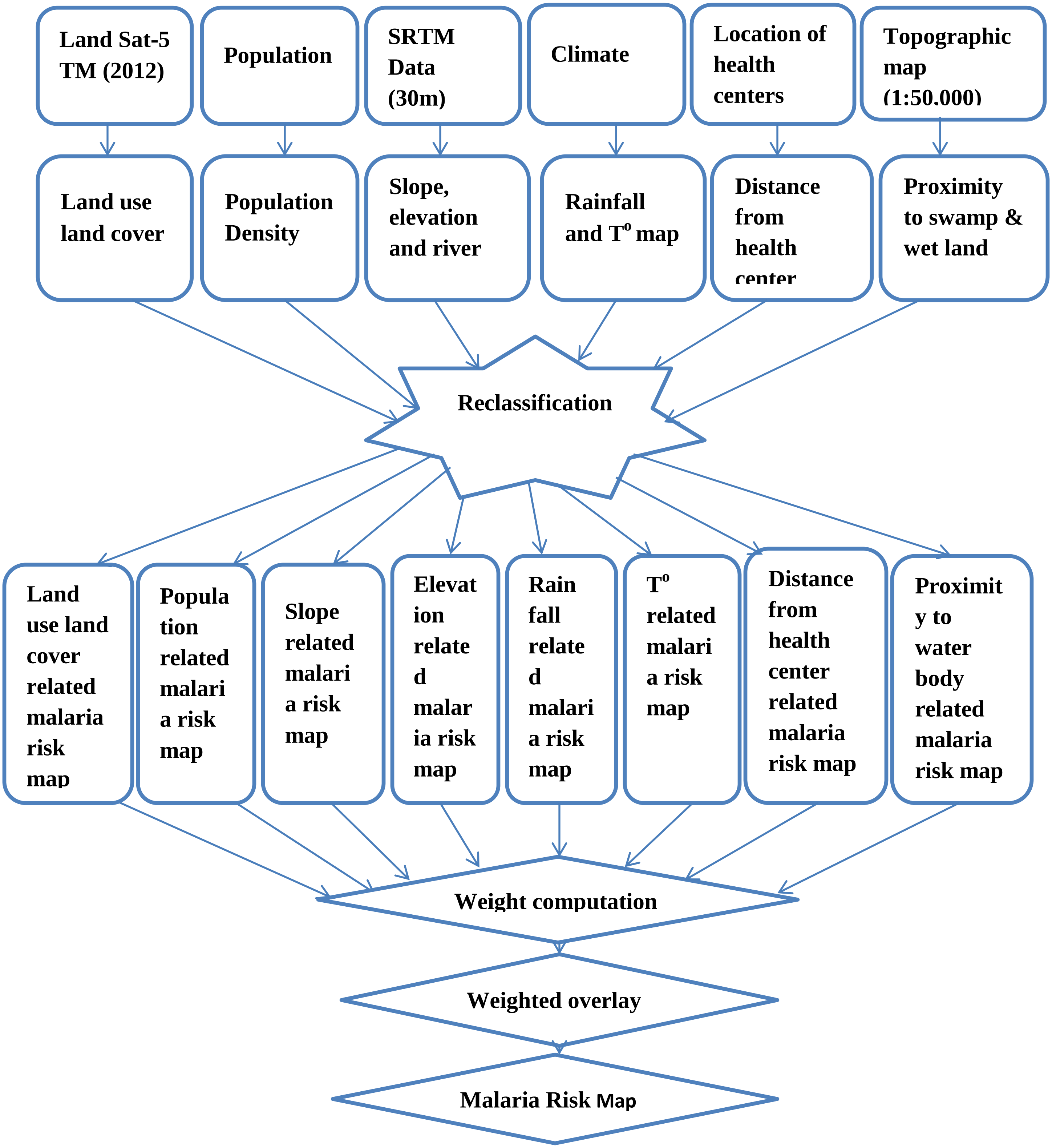

Figure 3.10: Procedural Flow Chart of Methodology

3.6. Criteria on Weighting

Multi criteria evaluation in GIS is focused on the allocation of land to suit for specific objective based on different attributes or factor. To carry out the MCE, weights of each criterion were given depending on their suitability for malaria prone area using IDRISI Selva 17.0 software. The weights were developed by providing a series of pairwise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. The procedure by which the weights of factors produced follows the logic developed by Saaty (1980) under the Analytical Hierarchy Process (AHP) which is utilized to determine the relative importance of the criteria in a specified decision-making problem. There are four different techniques when assigning the weights: Ranking, Rating, Pairwise Comparison and Trade of Analysis Methods.

1. Ranking Methods: This is the simplest method for evaluating the importance of weights which includes that every criterion under consideration is ranked in the order of decision makers' preferences. Due to its simplicity, the method is very attractive. However, the larger the number of criteria used, the less appropriate is the method.

2. Rating methods: It is based on allocating points ranging from 0 to 100, where 0 indicates that the criterion can be ignored, and 100 represents the situation where only one criterion need to be considered. Another method is ratio estimation procedure which is a modification of the point allocation method. A score of 100 is assigned to the most important criterion and proportionally smaller weights are given to criteria lower in the order.

3. Pairwise Comparison Method: The method involves creating a ratio matrix. It takes pairwise comparisons as input and produced relative weights as output. The pairwise comparison method involves three steps (Saaty, 2008).
   - ✓ Development of a pairwise comparison matrix: The method uses a scale with values range from 1 to 9.
   - ✓ Computation of the weights: The computation of weights involves three steps. First step is the summation of the values in each column of the matrix. Then, each element in the matrix should be divided by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix). Then, computation of the average of the

elements in each row of the normalized matrix should be made which includes dividing the sum of normalized scores for each row by the number of criteria. These averages provide an estimate of the relative weights of the criteria being compared

- ✓ Estimation of the consistency ratio: The aim of this is to determine if the comparisons are consistent or not. All the above methods were applied in this study with the help of IDRISI software.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. Climate Related Malaria Risk

To identify areas with high malaria risk in the study area, temperature and rainfall data were interpolated from seven nearest meteorological stations surrounding the study area. Among this one station is found within the study area while the remaining six stations are outside the study area within its surroundings. The closest among the six stations is found within 16km distance while the farthest within 178km distance. The data was collected from National Metrological Agency for each station namely: Ataye, Jeweha, Majete, Debre Sina, Debire Berhan, Mehal Meda, and Shewa Robit. The geographical distribution of the metrological station used is in this study is shown in figure 4.1 below.

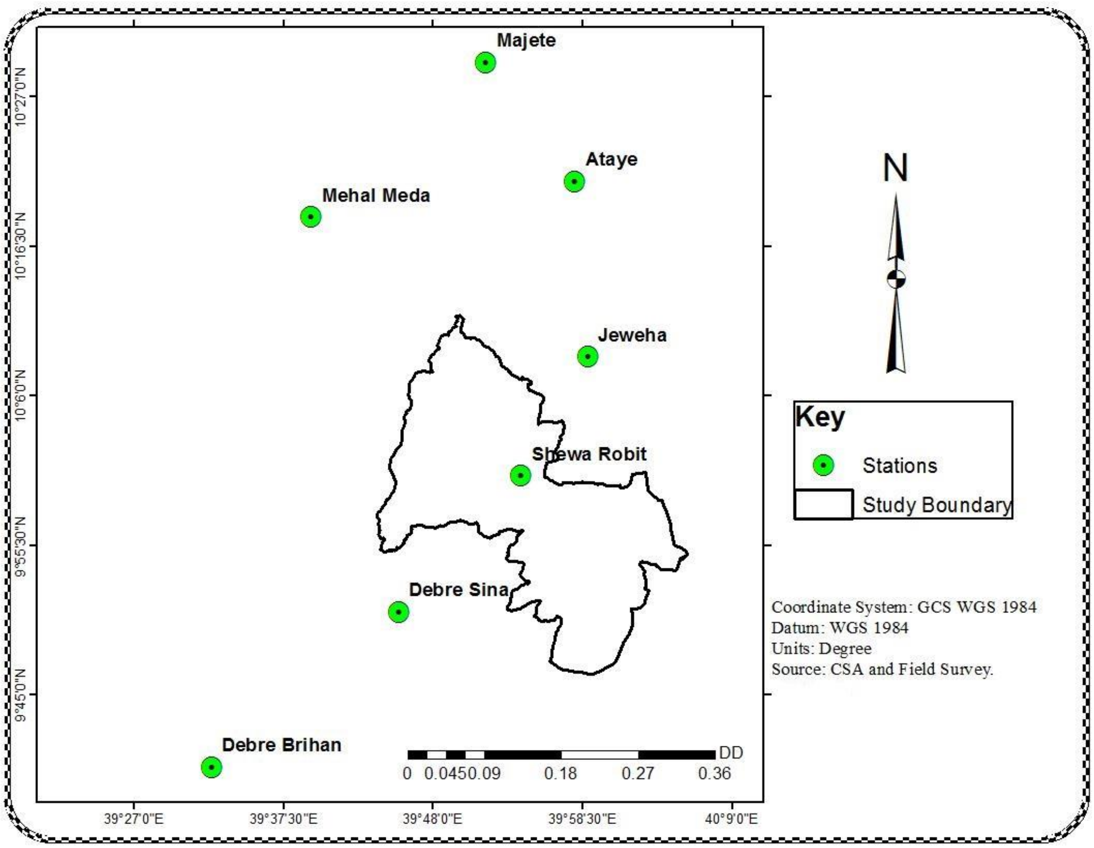

Figure 4.1: Map of Meteorology Stations Surrounding the Study Area

Source: CSA and Field Survey.

4.1.1. Temperature Related Risk of Malaria

In order to generate temperature map, seven years mean monthly maximum and mean monthly minimum temperature data of seven stations were analyzed. From the mean monthly maximum and minimum temperature of the stations, mean monthly temperature of each stations were calculated. Then, a single average value is computed for seven years. Finally, a single average value of each station used for surface interpolation in Arc GIS spatial analyst tools.

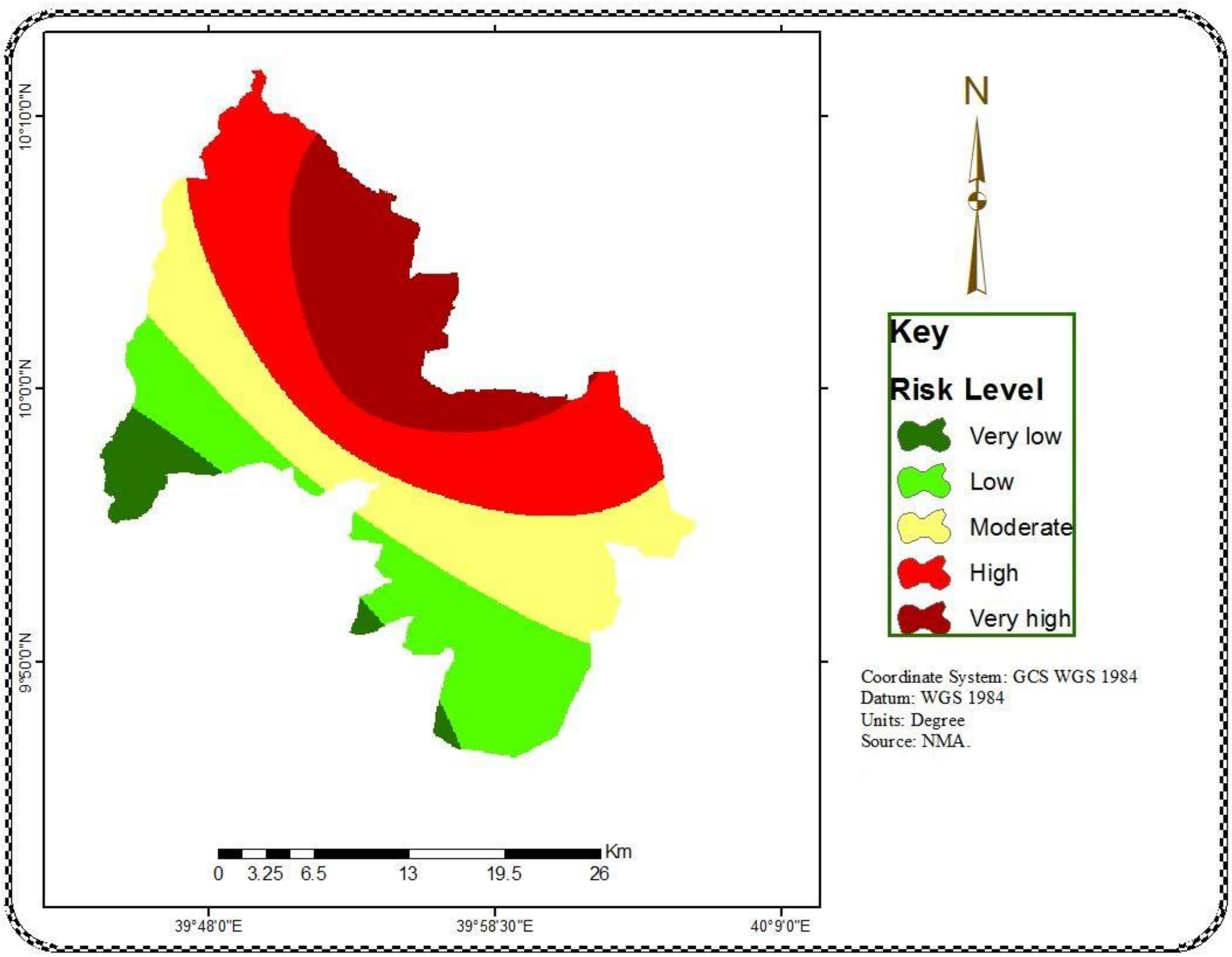

Figure 4.2: Temperature Related Malaria Risk Level Map

Source: National Meteorological Agency.

The technique used to interpolate the data was Kriging interpolation technique. The method is an advanced geo-statistical one, which estimates investigated area from dispersed set of meteorological stations with different altitudes (*z* value). The method involves interactive investigation of spatial behavior of data analyzed before selecting the best method of assessment for derivation of output area. It is more acceptable than other spatial interpolation methods, because of its fast data processing, high precision in calculating climatic data and adaptability to the relief configuration (Nusret and Dug, 2012).

The temperature map was reclassified by spatial analyst tools in Arc GIS. The study area was reclassified in to five classes based on its suitability to mosquito breeding. New values 1, 2, 3, 4 and 5 were assigned to temperature class 15-17, 17-19, 19-21, 21-22 and 22-23, respectively. Then, the classes were labeled as very low, low, moderate, high and very high malaria risk level respectively. Thus, the majority of the study area has temperature value between $18^{o}C$-$23^{o}C$, which indicates the area have conducive temperature for malaria breeding (Patz et al., 2008).

4.1.2. Rainfall Related Risk of Malaria

Rainfall, irrigation canals, rivers, swamps and other water bodies plays significant role in creating favorable ground for mosquito breeding. Thus, the area with high source of water is more comfortable for malaria breeding. Even though, an increase in temperature and rainfall increases mosquito breeding, it should be known that this is up to some maximum limit beyond which the relationship could be reversed. High rainfall may destroy mosquito larvae from its stable habitat or interrupt the process of breeding (Reid, 2000).

The rainfall map of the study area was also generated from seven (7) years monthly rainfall data of seven stations. Annual rainfall of each station calculated from monthly rainfall data and the average annual rainfall computed for each station. Then, a single seven years average value was computed for each station. This value was finally used for surface interpolation using Arc GIS spatial analyst tools. The technique used to interpolate the data was Kriging interpolation technique. The rainfall map was then reclassified to five classes based on its suitability to mosquito breeding. New values 5, 4, 3, 2 and 1 were assigned to rainfall class 133-144mm, 144-153mm, 153-163mm, 163-174mm and 174-193mm, respectively. Then the classes were labeled as very high, high, moderate, low and very low malaria risk level, respectively.

Based on their degree of vulnerability, in the weight overlay table also, the new scale values were given as 5, 4, 3, 2 and 1 for class very high, high, moderate, low and very low respectively.

The scale value ‘5’ given for class very low rain means that this amount of rainfall is ideally favorable for malaria breeding so that this is more vulnerable for breeding site where as the scale value ‘1’ given for class very high rain, this means that previous findings indicated that as rainfall is higher, it has probability of washing down the breeding sites so that it has no chance for malaria breeding rest. That is why the lowest scale value was given to those areas which are less vulnerable to malaria breeding sites.

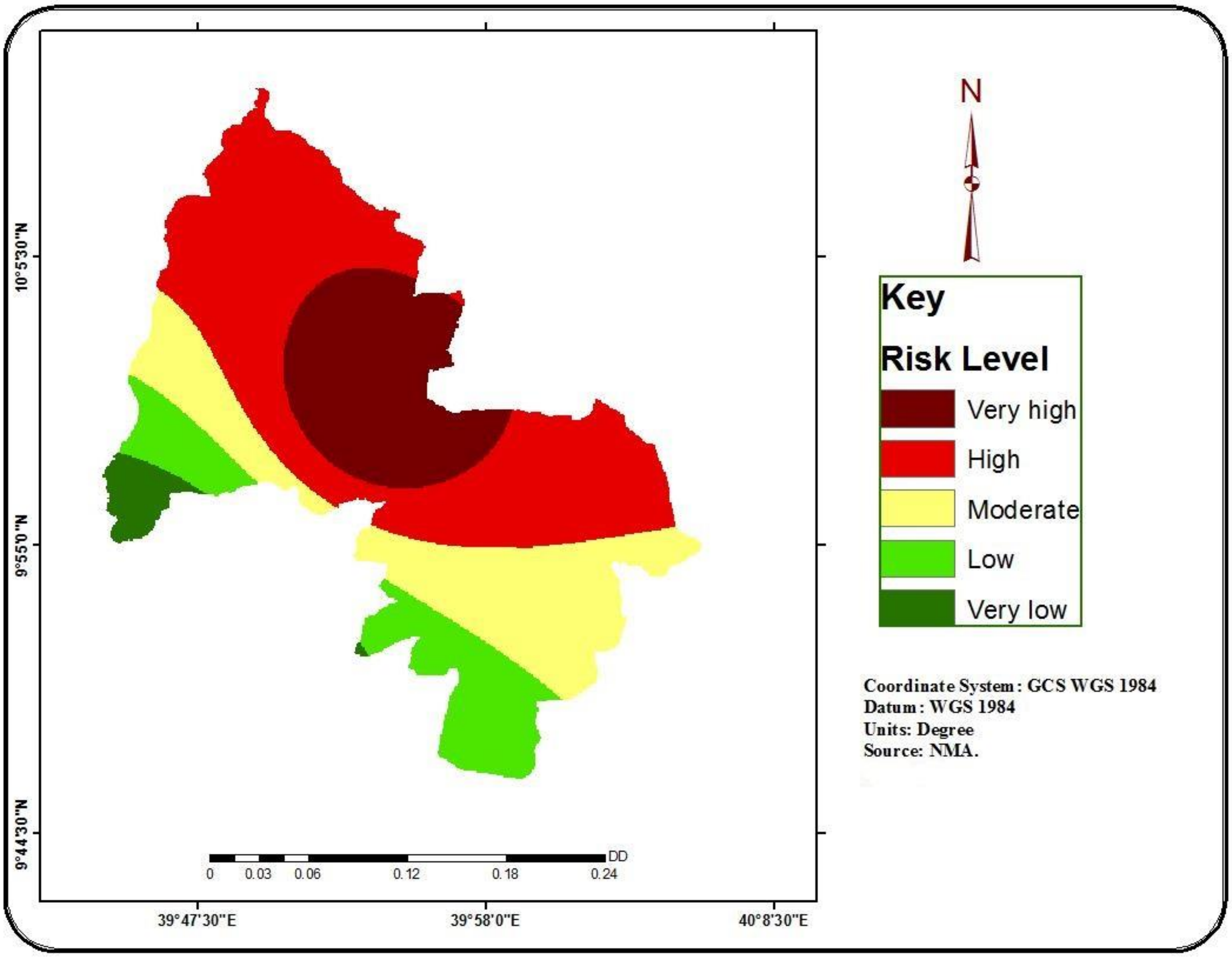

Figure 4.3: Rainfall Related Malaria Risk Level Map

Source: National Meteorological Agency.

4.2. Topographical Factors

4.2.1. Elevation

Elevation is an important factor for the development of malaria in a particular area, this is because of elevation highly determines the amount of temperature, and temperature in turn affect mosquito breeding as the length of immature stage in life cycle. In high temperature, the egg, larval and pupil stages will be shortened so that the turnover will be increased and also affect the length of the saprogenic cycle of the parasite with in the mosquito host i.e. when temperature increase, the period of the saprogenic cycle will be shorted (Patz et al., 2008).

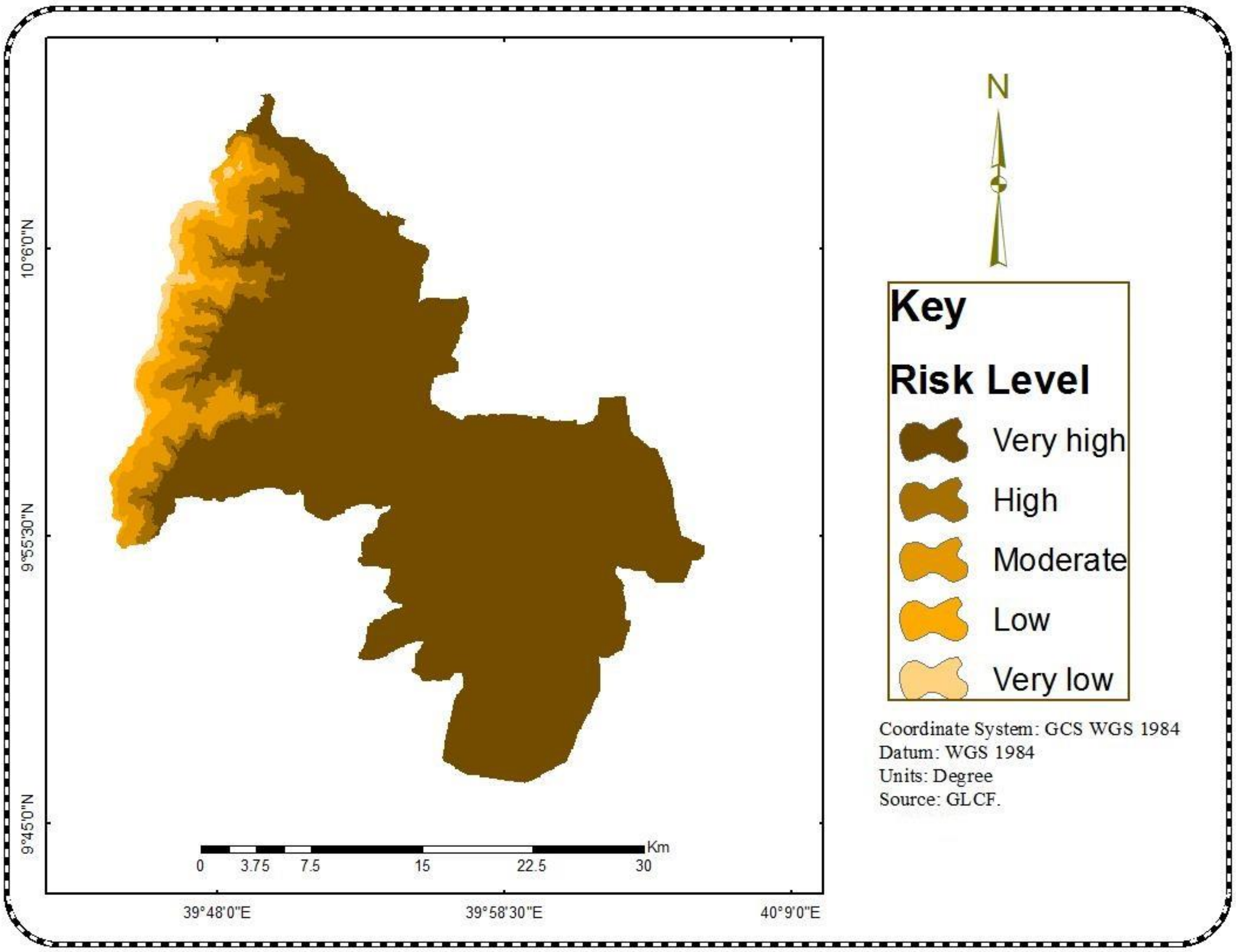

Figure 4.4: Elevation Related Malaria Risk Level Map

Source: Global Land Cover Facility (http://glcf.umiacs.umd.edu/index.shtml).

The area which are found below 2,200 a.m.s.l in Ethiopia, are highly affected by various type of vector born disease like malaria. UNICEF (2008) states that areas found above 2,200m are considered to be malaria free. But other researcher agreed that the areas located between 1000-2000m are mostly vulnerable for malaria (Tulu, 1993). Currently, the area up to 2,500m which were previously malaria free, are included under malarious (Negash et al., 2005).

Elevation of the study area was derived from SRTM data of 30m resolution and reclassified based on the extent of malaria prevalence at different altitudes given by UNICEF (2008). 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 value given to elevation ranges of 1047-2000m, 2000-2,200m, 2,200-2,500, 2,500-2,832 and 2,832-3164 respectively. These values were seen associated with elevation related malaria risk levels of very high, high, moderate, low and very low malaria risk level respectively as seen on figure 4.4.

4.2.2. Slope

Slope is also another topographic factor that may affect the existence of mosquito larval habitat in a certain area. Slope is the measurement of the rate of change of elevation of the land per unit distance. It affects the constancy of aquatic habitats; steeper slopes are slopes that allow the fast movement of water (Munga, 2006 and Burlando, 2012). Hence, they don't allow the development of stagnant water 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 suitable condition 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 reclassified in to five classes using natural break standard reclassification technique. The natural break (Jenks) method is a widely accepted method and it has the logic which is very most consistent with the purpose of data classification that is forming groups that are internally homogeneous while assuring heterogeneity among classes (Tsega, 2011).

Areas with gentle slope are usually typical characteristics of plain, plateau, and suitable physical area of the earth for malaria breeding's. This creates a favorable condition for mosquito breeding. It allows the formations of various pond areas that are comfortable for mosquitoes to lay eggs and progress to the next development cycle. Slope classes 0-5%, 5-8%, 8-15%, 15-30% and >30% are the correct classes to indicate the level of existence of water body or marshy area and vegetation within a particular area (FAO, 1976). So, the areas with slopes 0-5% have high probability to have water bodies and swamp areas and vegetation's whereas as the slope above this is not favorable for mosquito breeding.

Therefore, the new classes (0-5, 5-8, 8-15, 15-30, and >30), were seen associated with slope malaria risk levels of very high, high, medium, low and very low respectively based on the relative degree of suitability of the slope class for malaria incidence (see figure 4.5).

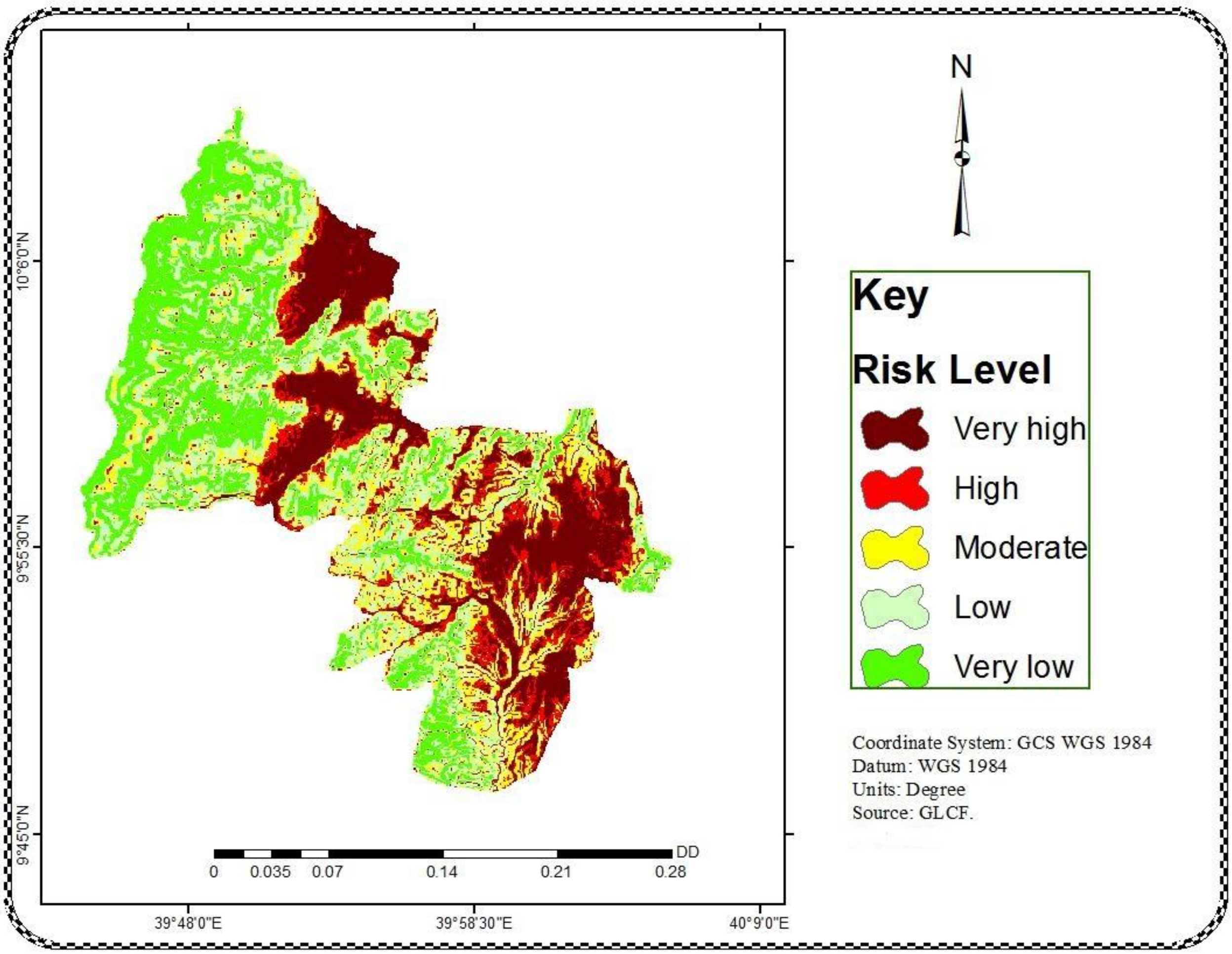

Figure 4.5: Slope Related Malaria Risk Level Map

Source: Global Land Cover Facility (http://glcf.umiacs.umd.edu/index.shtml).

4.3. Hydrological Factors

4.3.1. Proximity to Rivers

One of the various water bodies which are used for mosquito breeding is river (Negassi, 2008). For breeding, Mosquito needs stagnant or slow moving water to lay its eggs and to complete its life cycle to be an adult. Unlike other water bodies, river is not conducive for this since it disturbs and destroys the eggs and larvae during downslope movement. But when the water is diverted from rivers for different purposes and in case of flood inundations it decreases its speed and becomes comfortable for mosquito egg laying. This condition may affect a particular area by increasing mosquito breeding site and malaria prevalence (Kumar, Nathawat and Onagh, 2012).

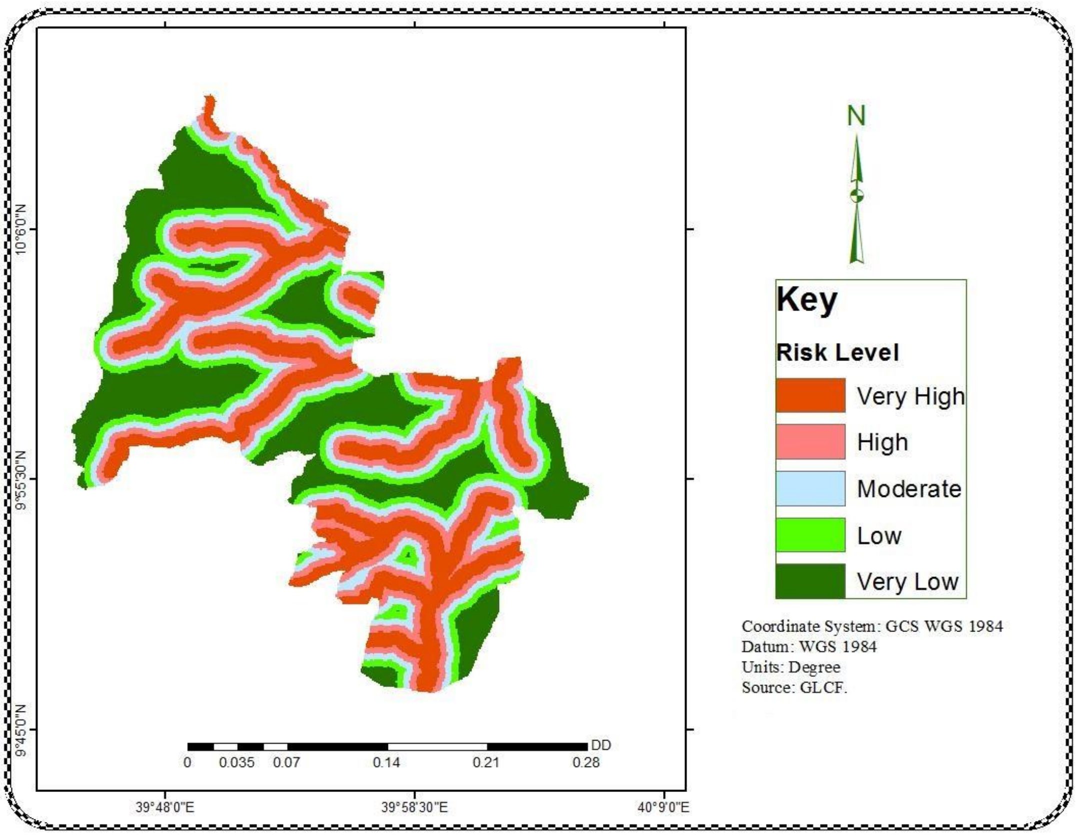

Figure 4.6: River Related Malaria Risk Level Map

Source: Global Land Cover Facility (http://glcf.umiacs.umd.edu/index.shtml).

As shown on map above, proximity to rivers is generated by using Euclidean distance in spatial analyst tools of Arc Map. According to Abdulhakim (2014) and Hoek et al. (2003) the maximum flight range of anopheles mosquitos is 2km. Thus, based on the flight range of mosquito the study area was reclassified in to five. i.e. < 500m, 500m – 1000m, 1000m-1500m, 1500m-2000m and above 2000m and these classes were assigned new value 5, 4, 3, 2 and 1 respectively. Based on malaria risk levels, these classes were designated as very high, high, moderate, low, and very low river related malaria risk levels respectively (see figure 4.6).

4.3.2. Distance from Wetlands and Swamps

Wetlands and swamp area are an important place for the development of malaria in a certain area. Therefore, identifying swamps or ponds and wetlands are useful to know the source of malaria vectors. Since the fly range of mosquitoes is limited and breeding should be done in water, the abundance of mosquitoes can be found around the places where there are patches of standing waters and wetlands (Boelee, 2003).

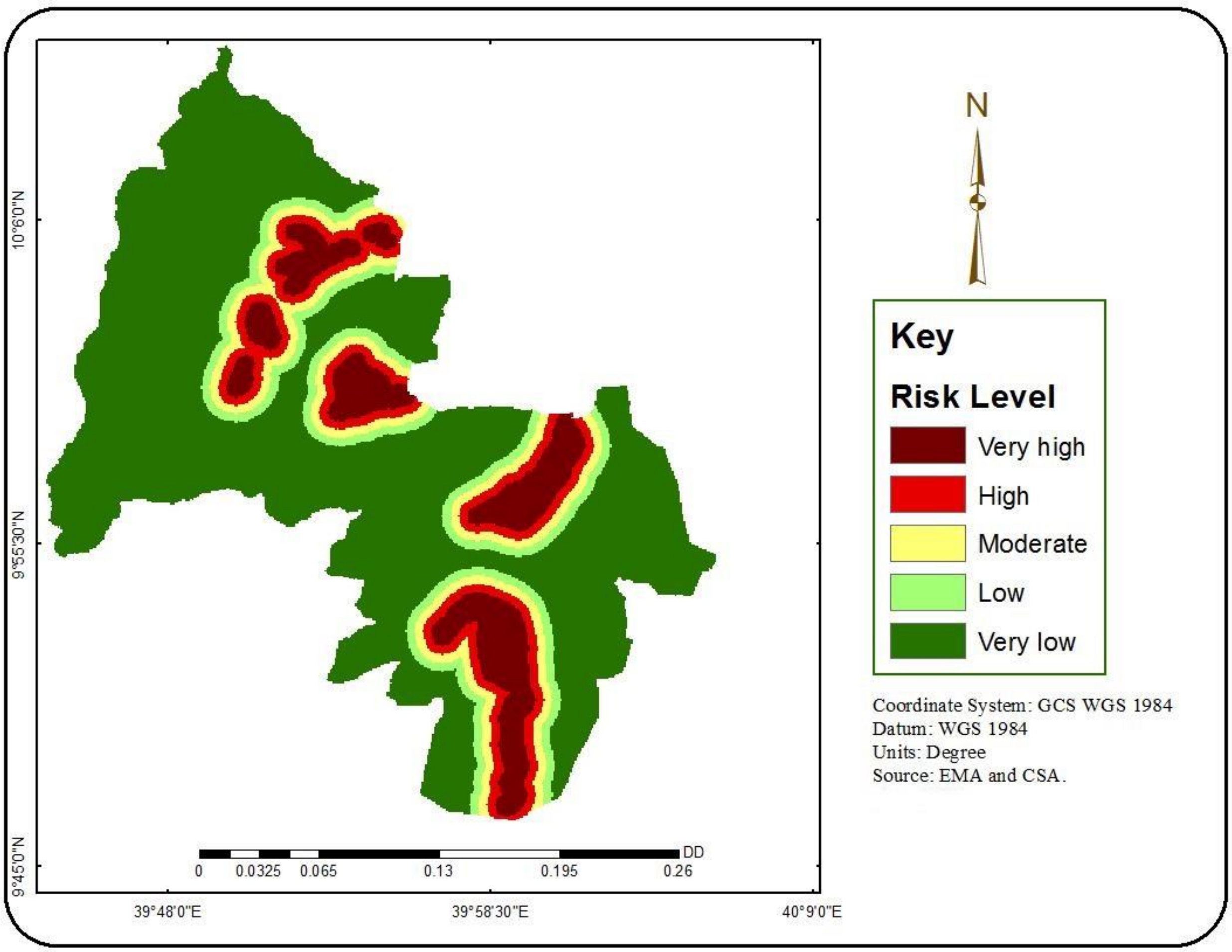

Figure 4.7: Wetland and Swamp Related Malaria Risk Level Map

Source: Ethiopia Mapping Agency, 1992.

The premise for assessing areas at risk of malaria infection is based on the maximum distance a malaria-carrying mosquito can travel from its breeding ground to infect human hosts. For this study, the swamp and wetland factors were considered to be the most favorable to mosquito larval breeding. Two-kilometer distances around swamps and wetlands larval breeding grounds were taken as an area with high malaria transmission with increasing transmission (Abdulhakim, 2014 and Hoek et al., 2003). With this evidence, new classes of the wet land and swamp layer were generated to show the highest mosquito density near these areas.

The layer was extracted from Topographic map of the study area and field data using GPS. Then, distance calculation from these area and reclassification was done on the layer in Arc GIS environment. Values were assigned for the reclassified map based on mosquitoes flying distance threshold value. Areas out of the maximum flying distance threshold were considered to be less malaria prone. Therefore, areas found within and outside the two kilometer distance was reclassified in to five classes as 0-500m, 500-1000m, 1000m-1500m, 1500m-2000m and > 2000m since all the area cannot have equal and uniform distribution of mosquitoes (figure 4.7).

4.4. Socio-Economic Factors

To fight malaria and to give attention for prevention of malaria, we need to map not only natural conditions but also socio-economic factors like health centers distribution, population density and land use/cover. One can better site the areas with high risk of malaria and in association with number of people at that can be affected and prevent measures taken by the nearby health centers.

4.4.1. Distance from Health Centers

Identifying the location and distribution of health centers is important, not only to map risky areas but also to uncover the potential needs and the location of existing health centers. The locations of health centers in the study area were obtained from Kewet *Woreda* health office and through ground survey. The map below illustrates the sphere of influence of health centers in the study area. This was done by calculating distance from each health center and by reclassifying the distances in to 5 classes based on the lowest easily accessible distance.

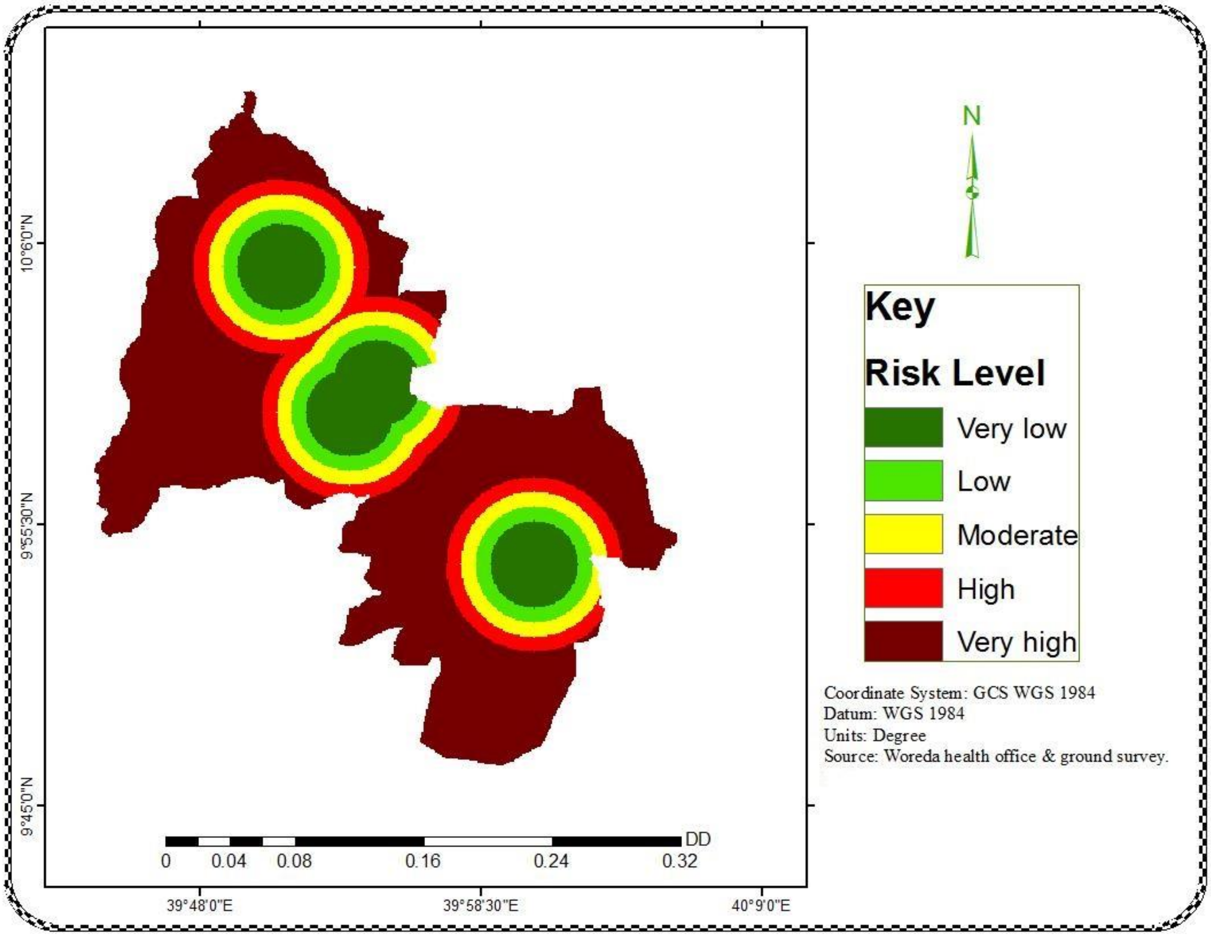

Figure 4.8: Distance From Health Centers Related Malaria Risk Level map

Source: *Woreda* Health Office and Field Survey

WHO (2003) States that areas found within 3 Km radius from a health centers are assumed to be at lesser malaria risk than areas found outside this distance. Hence, classes of distances; <3000m, 3000-4000m, 4000-5000m, 5000-6000m and >6000m were computed in figure 4.8. The classes were given values of 1, 2, 3, 4 and 5 were labeled as very low, low, moderate, high and very high malaria risk level respectively.

4.4.2. Population Density

Growth of population is another factor in the determination of health events such as epidemics of malaria. When population rapidly increases, it opens doors to new habitats for the malaria vector. Prakash (2014) also indicated that higher population density can lead to more efficient transmission of the virus and thus increased exposure to infection.

To map population at risk of malaria in the study area, population density of each *kebele* was computed on Arc map after the population of each *kebeles* were fill on Microsoft excel sheet. Then using layer property of population data the final population density map produced. The population density at *kebele* level was used because there is no detail population spatial data less than *kebele* level.

The population density layer was reclassified into five classes as very low, low, moderate, high, and very high. The value very high is assigned to the denser *kebeles* and the value very low was labeled to less dense *kebeles.* Therefore, the densely populated *kebeles* were labeled as highly susceptible in figure 4.9.

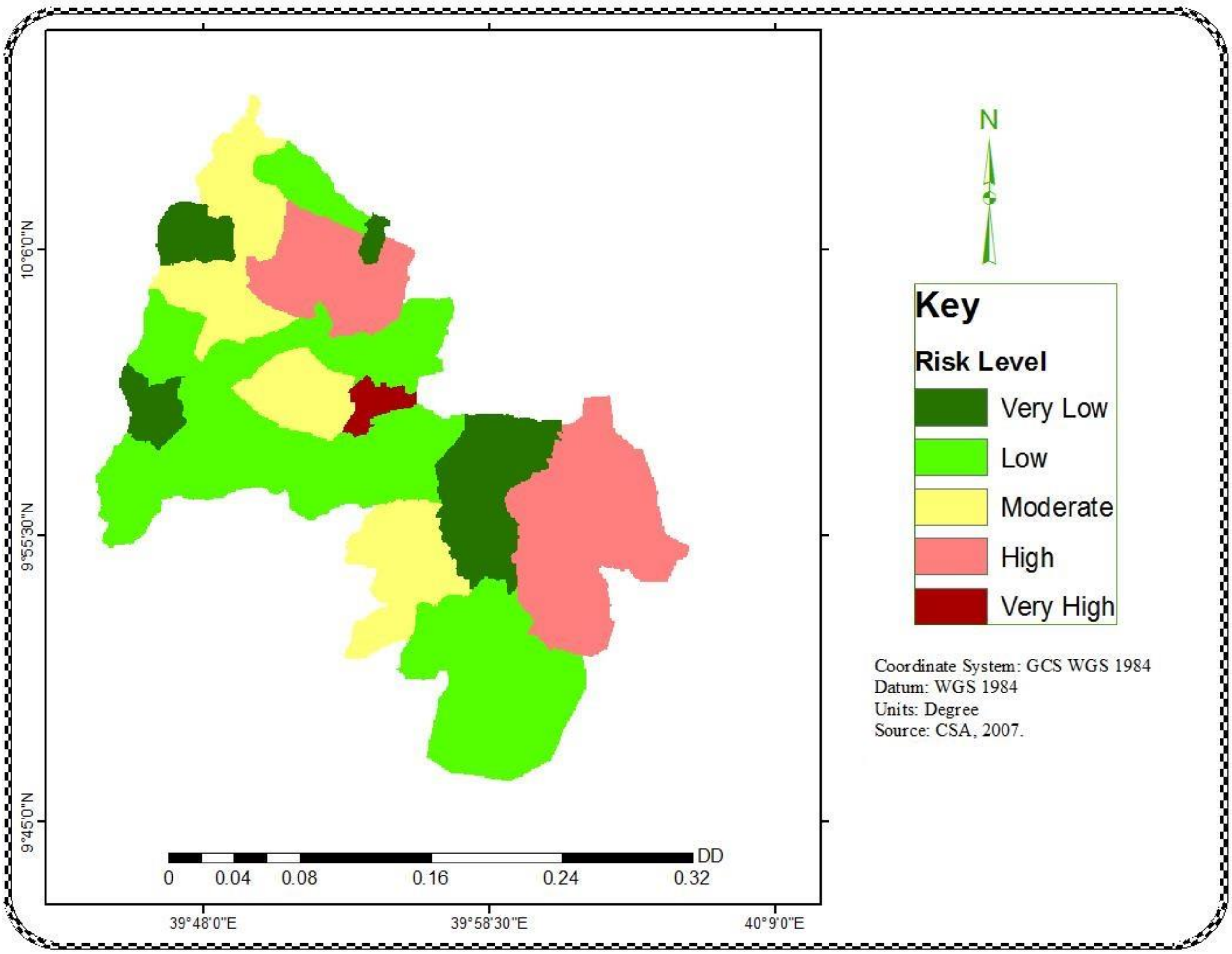

Figure 4.9: Reclassified Population Density Map

Source: CSA, 2007.

4.4.3. Land Use/ Land Cover

It is obvious that ecological disturbance is unavoidable. When the environment changes from one land use to another, favorable environments might be created for mosquito breeding. In the malaria-mosquito disease-vector combination, there is a association between land cover and vector density on the one hand, and vector density and disease risk on the other side. In the case of the land cover and mosquito population Munga et al. (2009) indicated that anopheles mosquito complex larvae were mainly confined to valley bottoms during both the dry and wet seasons. They were also located in man-made habitats where riparian forests and natural swamps had been cleared. The association between land cover type and occurrence of anopheles larvae was statistically significant. It is generally understood that proximity to water body is important, particularly in the breeding phase of mosquito. Afrane et al. (2005) stated that proximity to water body has been associated with increased vector density. Thus, the residences which are close to the water bodies are highly affected by malaria than the farthest one.

However, there are many other related land use/covers that make the spread of mosquito increase in a certain area. Such as: irrigated farm, settlement, forest area and others. Brooker et al. (2004) stated that settlement areas are open doors to new habitats for the malaria vector, because not only more people in the city, but also more places which are created by the residence for different purpose later which changes into ponds. Prakash (2014) also indicated that higher population density and interconnection of houses could lead to more efficient transmission of the virus and thus increased exposure to infection. Therefore, settlement is one of the major causes for the spread of malaria.

According to Boelee (2003), irrigation system can also lead to continuous availability of surface water where vectors can breed without restraint. In the irrigated fields mosquito abundance will increase and if these mosquitoes have enough food source in the breeding sites they can be increase in number. The resulting adult mosquitoes may live longer and allow malaria parasites to complete their life cycle so that they can be passed on to another host. Forested areas are areas with high humid conditions which favor the ecological reproduction and transmission of the malaria parasite (Afrane et al., 2005). Thus, from the above literatures one can understand that each land use/cover have their own contribution for the development of malaria in a certain area.

Therefore, based on these evidences, the land use/cover map of the study area was reclassified in to five sub-groups based on susceptibility and suitability for malaria risk. So, the reclassified version in figure 4.10 implies 5 to 1 values, where 5 stands for high prone land use/cover and 1 for less prone land use /cover of malaria risk. Due to their suitability for malaria, water bodies were considered as very high risk in terms of malaria breeding and resting sites in the study area and the remaining settlement and irrigated farm, forest land, rain feed farm land and bare land were labeled as high, moderate, low and very low malaria risk respectively.

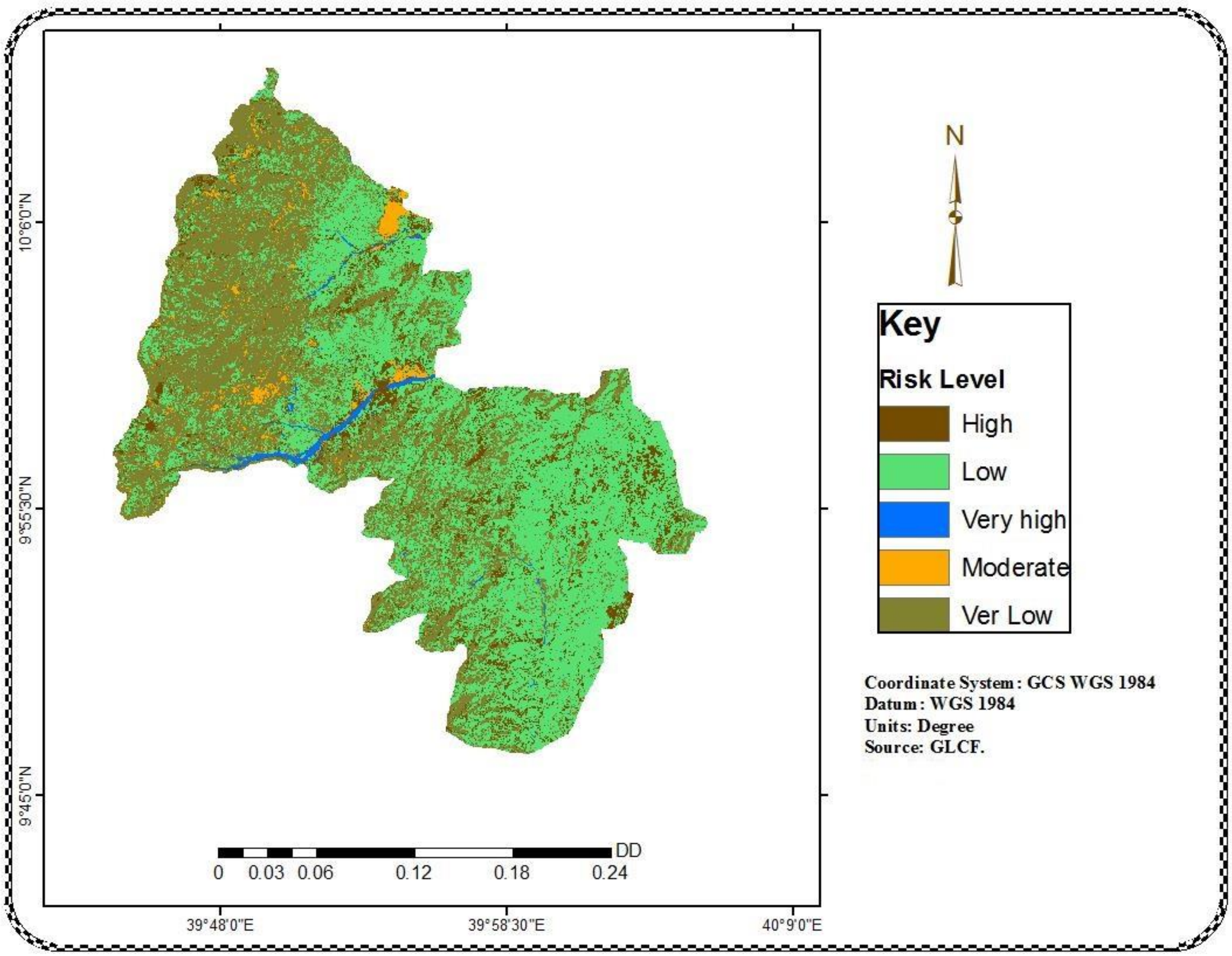

Figure 4.10: Reclassified Land Use/Cover Map

Source: Global Land Cover Facility (http://glcf.umiacs.umd.edu/index.shtml).

4.4.3.1. Accuracy Assessment

Accuracy assessment is an essential phase in the land use/cover classification process. The goal is to quantitatively determine how effectively pixels were grouped into the correct feature classes in the area under investigation. It is derived from map which produced from Land sat and field data. Additionally, a coefficient of agreement between classified image data and ground truth data were calculated using Kappa and its variance (Ismail & Jusoff, 2008).

It is important to measure the agreement between the land use/cover types derived from the Land sat-5 (TM) and the value observed from the field. Kappa statistics is an estimate to measure the agreement between the predicted value and the reference value. It varies between 0(no agreement) and 1(perfect agreement). A kappa value above 0.80 represent a strong agreement, value between 0.40 & 0.80 represent a moderate agreement, while the value below 0.40 represent a poor agreement. It might need reclassification (Phillips, Anderson & Schapire, 2006).

Accordingly, the confusion matrix was prepared using ground truth points which were collected during ground survey and the final classified land use/cover map. The result indicated that an overall classification accuracy of 77.9% and kappa statistics of 73%. Thus, the result of kappa coefficient revealed that, there is agreement between the classified map and the reality (see the table in the appendix II).

4.5. Weight Derivation

All factors which are causes for the breeding of malaria in a certain area must weight based on their influence. Therefore, the factors stated above are ranked based on the level of their impact on malaria breeding and their appropriateness for the development of mosquito. It is obvious that these factors are varying spatially. Thus, based on previous works and the information that collected through interview with *woreda* health office, weight were assigned for each factors. Weights are assigned by pairwise comparison 9 point continuous rating scale on IDRISI Selva 17.0 and factor weights were calculated by comparing two factors at a time depending on their importance.

4.5.1. Weight Derivation for Environmental and Socio-Economic Factors

The malaria risk level of the study area was recognized by assigning weight for all environmental and socio-economic factors. These are: temperature, elevation, rainfall, proximity to water bodies, slope, land use/cover, distance from health centers and population density. The significance of these factors for malaria breeding was explained in chapter two under literature review part. Therefore, based on their importance for the development of mosquito in the study area, weight is computed using pairwise comparison 9 point continuous rating scale on IDRISI Selva 17.0.

To assign weight for each factors, as already described in Criterion Weighting method in chapter three, the researcher use previous malaria related researches and current condition of the study area. To consider the current local condition, field observation and discussion with *woreda* health office were made. Therefore, based on this, elevation determines the incubation rate and breeding activity of mosquito given the highest weight followed by rainfall and proximity to wet and swamp area.

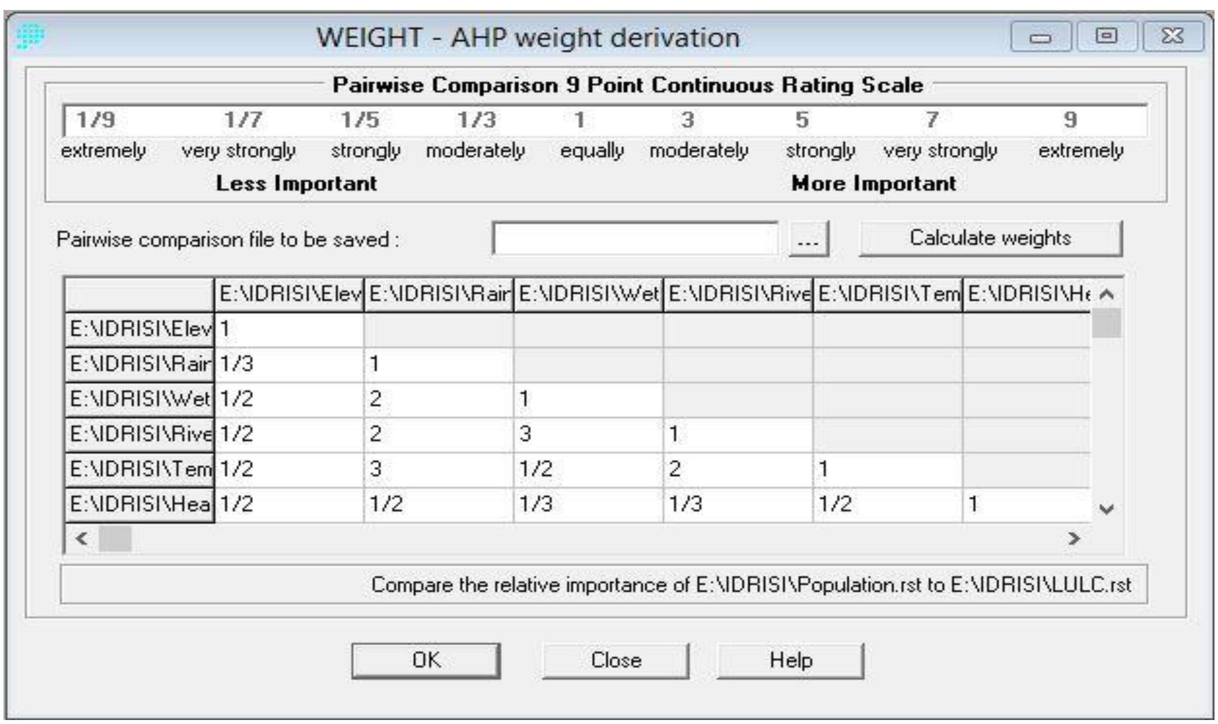

Figure 4.11: AHP Weight Derivation for Elevation, Temperature, Rainfall, Slope, Land Use/Cover and Proximity Related Factors

Most part of Kewet *Woreda* is dominated by lower altitude. The area is found in the altitude between 1047-3164, it make the area become the home of vector born disease including malaria and the remaining factors proximity to river, temperature, proximity to health facility, slope, land use/land cover, and population density were assigned as fourth, fifth, sixth, seventh, eighth and ninth factors respectively.

Figure 4.11 and 4.12 show weight derivation using Pairwise comparison matrix of environmental and socio-economic factors and consistency ratio was 0.06 which is acceptable (see Appendix III for detail).

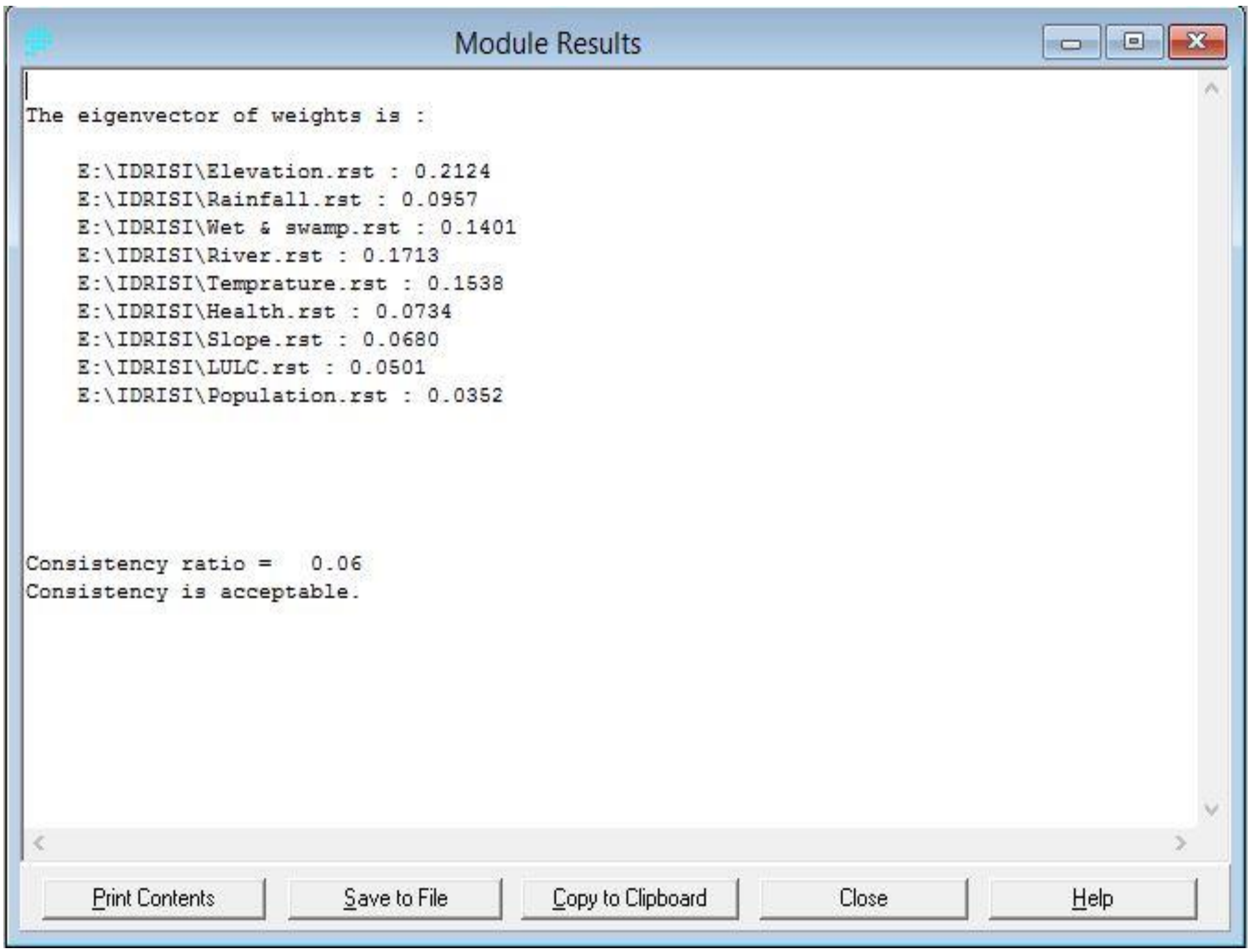

Figure 4.12: Module Result for Weight Derivation of All Environmental and Socio-Economic Factors.

The Weights that assigned for all environmental and socio-economic factors mentioned above described in the following table.

Table 4.1: Weights Assigned for all Environmental and Socio-Economic Factors

Risk Factor	Weight	(%)	Class	Suspectibility	Range
Elevation	0.2124	21.24%	1047-1470	Very high	5
			1470-1893	High	4
			1893-2317	Moderate	3
			2317-27140	Low	2
			2740-3164	Very low	1
Rainfall	0.0957	9.57%	140-147	Very high	5
			147-156	High	4
			156-170	Moderate	3
			170-193	Low	2
			>193	Very low	1
Proximity to Wetland and Swamp	0.1401	14.01%	< 500	Very high	5
			500-1000	High	4
			1000-1500	Moderate	3
			1500-2000	Low	2
			>2000	Very low	1
Proximity to River	0.1713	17.13%	<500	Very high	5
			500-1000	High	4
			1000-1500	Moderate	3
			1500-2000	Low	2
			>2000	Very low	1
Temperature	0.1538	15.38%	17-19	Very low	1
			19-20	Low	2
			20-22	Moderate	3
			22-23	High	4
			>23	Very High	5

Distance from Health centers	0.0734	7.34%	<3000	Very low	5
			3000-4000	Low	4
			4000-5000	Moderate	3
			5000-6000	High	2
			>6000	Very high	1
Slope	0.068	6.80%	<5	Very high	5
			5-12	High	4
			12-16	Moderate	3
			16-19	Low	2
			19-20	Very low	1
LULC	0.0501	5.01%	Water bodies	Very High	5
			Settlement & Irrigated farm	High	4
			Forest	Moderate	3
			Farm land	Low	2
			Bare area	Very low	1
Population	0.0352	3.52%	<145	Very low	1
			146-4387	Low	2
			4388-6092	Moderate	3
			6093-8449	High	4
			8450-17575	Very high	5

4.5.2. Malaria Risk Map

Malaria risk map of the study area was produced on Arc GIS 10.1 spatial analyses tools using weighted overlay. Therefore, all environmental and socio-economic factors mentioned above, proximity to water bodies, proximity to health facility, temperature, rainfall, elevation, slope, land use land cover, and population density overlaid based on their weights.

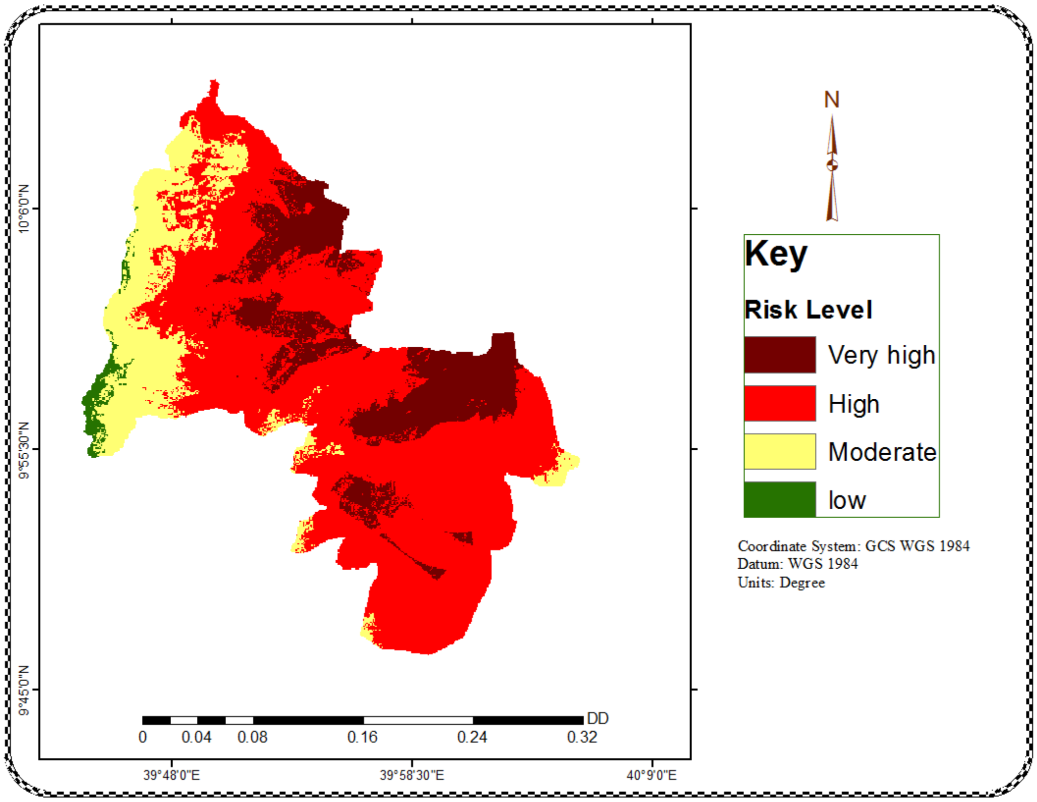

Figure 4.13: Final Malaria Risk Map

To identify malaria risk area, in this study; elevation, temperature, rainfall, distribution of health center, population density, proximity to river, swamp area and wetland, slope and land use/land cover were used as input factors for malaria risk mapping. Therefore, as showed in figure 4.13 around 36.5(25%) of the total study area is subjected to very high, 66.4(45.4%) labeled as high malaria risk, and the remaining 33.5(22.9) and 9.83(6.7%) area have moderate and low malaria risk level respectively. Thus, from this it is possible to conclude that more than 70% of the area is under high risk of malaria.

Table 4.2: Malaria Risk Level and their Area Coverage

No	Malaria Risk Level	Area in Km^2	Percentage (%)
1	Very high	36.5	25
2	High	66.42	45.4
3	Moderate	33.5	22.9
4	Low	9.9	6.7
Total		146.32	100

4.5.3. Comparing Malaria Risk Level among Kebeles

At *kebele* level, malaria risk map was generated by overlaying malaria risk level map of the study area and kebele boundary map. Thus, from the entire *kebele* of the study area Shewa Robit town, Deberena jegol, Yelen, and Yemegist den were labeled as very high malaria risk area, Abay atir, Kure beret, Jimderena gur, Medina, Korebeta, Mariyena insirt, Abomsana wuruba, Birbirina jegol, Alolo Wenberya, Jib Amba, Agam Ber, Sefibert and Mengisiti ena wodaj were subjected to high malaria risk and the remaining six and one *kebeles* were found to have moderate to low malaria risk respectively. Whereas the areas that fall under very high and high were highly vulnerable for mosquito breeding. Those areas fall under moderate and low exhibit less vulnerability due to the factors mentioned in the previous section.

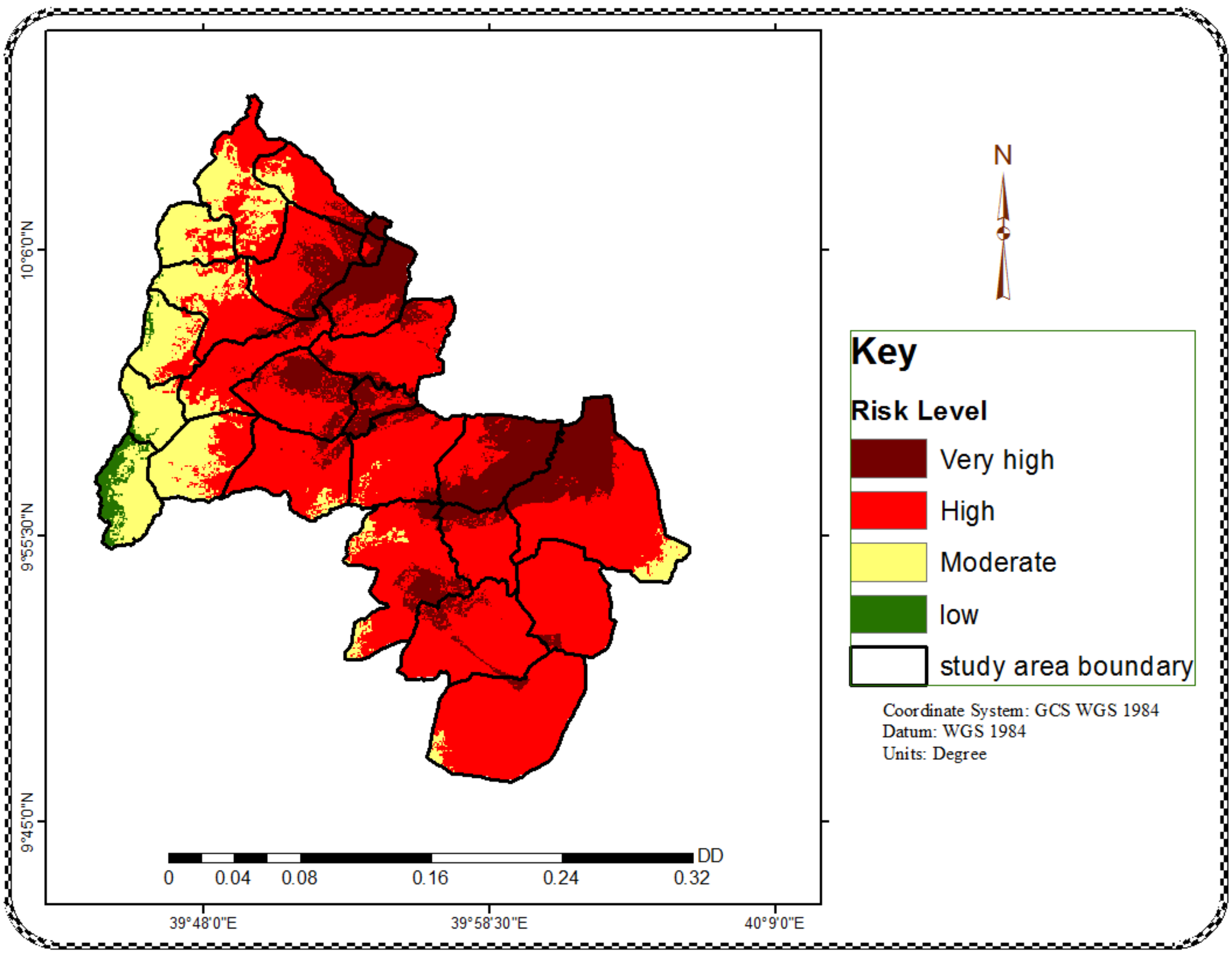

Figure 4.14: Malaria Risk at *Kebele* Level

Table 4.3: *Kebele* Wise Malaria Risk Level

No	Malaria Risk Level	Number of *Kebeles*	Number of *kebeles* in %
1	Very high	4	16
2	High	14	56
3	Moderate	6	24
4	Low	1	4
Total		25	100

4.6. Socio-Economic Analysis

To conduct the socio-economic analysis, the respondents were divided in to households and officials that were treated using questionnaires and interviews respectively. The total questionnaires being distributed for those households were 137. Out of the total questionnaires distributed for households, 130 of the respondents returned the questionnaire with their response on time. The remaining 7 respondents did not fill and return the questionnaires. Furthermore, interview was conducted with five (5) key health officials. Generally, this research was intended to have about 142 informants. However, the sum totals of respondents who have been involved in this research were 135. Therefore, the total of response rate of this research was about 95 %.

4.6.1. Socio-Demographic Characteristics of Sample Respondents in Kewet *Woreda*

The socio-demographic characteristics of sample respondent were summarized and presented in Table 4.4. From the total of 130 sample respondents, 86 (66.15%) were males and 44 (33.8%) were females. Therefore, both sex were included to get sample representative in this study, however, majority of the respondents were male because most of house hold heads were male. From the entire respondents 93 (71.5%) were married.

Regarding to the age of respondents, 33 (25.38%) of samples were between the age of 41-50 years and 73 (56.1%) were between the age of 31- 40 years; 13 (10%) were between the age of 20-30 years; and the remaining 11(8.4%) were at age above 50 years. Thus, from this we can conclude that most of the respondents found in the productive age (31-40).

The educational status of the respondent depicts as 84 (64.6%) of the study participants were illiterate; 21(16.15%) of them read and write; 14 (10.76%) attend primary school; 6 (4.6%) of sample respondent complete secondary education and the remaining 5 (3.8%) were attend college education. So, as it is shown below in table majority of respondents were illiterate and didn't attend formal education.

The occupation of respondents were dominated by farmers 96 (73.8%) from the total respondents, 13 (10) of them engaged in private business, 7(5.38%) were government employed, 9(6.8%) of sample respondents were casual workers and the remaining 5(3.84%) were house wife. Thus, since most of the study area was dominated by rural *kebeles*, majority of the respondents engaged in farming activity for their earnings, illiterate and in the age of adult. It shows that most of the respondents of the study area are vulnerable to malaria due to their educational level (illiterate) and economic activity (farming).

Table 4.4: The Socio-Demographic Characteristics of Sample Respondent in Kewet *Woreda*

Characteristics	Frequency (%)
Age (in years)	
20-30	13(10)
31-40	73(56.1)
41-50	33(25.38)
>50	11(8.46)
Sex	
Male	86(66.15)
Female	44(33.8)
Marital status	
Married	93(71.5)
Divorced	22(16.9)
Widowed	15(11.5)

Educational status	
Illiterate	84(64.6)
Read and writing	21(16.15)
Primary school	14(10.76)
Secondary school	6(4.6)
College and above	5(3.8)
Occupation	
Private business	13(10)
Government work	7(5.38)
Casual work	9(6.9)
Farmer	96(73.8)
House wife	5(3.84)

4.6.2. Assessment of the Impact of Malaria in Kewet *Woreda*

The survey result of impact of malaria in the study area were summarized and presented here under table 4.5 as follows. Accordingly, the result of this study indicated that majority of the respondents 118(90.76%) indicated that their families were affected by malaria and the remaining 12(9.2%) of the respondent families showed they were not affected by malaria. For those that indicated they were not affected by malaria the researcher asked them the reason behind and they respond that 6(50%) use insecticide net effectively, 5(41.7%) of the respondent can protect malaria by using the DDT that spayed on the wall of their home and few respondent control malaria using traditional methods such as by using garlic.

Other study that conducted around Hawassa town in Southern Nations and Nationality and peoples region stated that the olive tree smoke is used by the society as one of traditional method to prevent malaria (Ashenafi, 2008). Thus, in addition to the modern methods of prevention; traditional methods also used by the society to protect the disease.

Regarding the number of individuals affected by malaria in each household, 46 (39%) of the respondents answered as more than three of their family members were infected by malaria, 30 (25.4%) of sample respondent replied that three of their family members were infected, 27(22.9%) indicated two infections in each of their families and the remaining 15 (12.7%) of the respondents were replies that only one in each family was infected. Therefore, from the above data, we can understand that most of the respondent’s families in the study area were highly affected by malaria.

Besides, to be cure from malaria, 35(29.6%) of the respondents answered as it take more than one month to return back to their normal health, 34(28.8%) of sample respondent replied that it takes them one month, 30(25.4%) indicated two weeks to be cure from malaria and the remaining 19(16.1%) of the respondents were replies that it takes one week to cure from malaria. Therefore, from the above data, we can understand that most of the respondents waste a lot of time to be free from malaria. According to data obtained from key informants ineffective use of drugs and other necessary tools and absence of consultation by health workers were the main reason for the residents to live with malaria for a long period of time.

Regarding to the impact of malaria and its magnitude, 51(47.65%) of respondents answered as malaria has high impact on their economy, 33(30.8%) of sampled respondents replied that malaria has very high impact on their economy, 18(16.8%) indicated moderate impact of malaria and the remaining 4(3.7%) and 1(0.9%) of the respondents were replies that it has low and very low impact on their economy respectively. Therefore, from the above data we can conclude that most of the respondents’ economy was affected by malaria due to their infection.

Therefore, the result that extracted using GIS and remote sensing also confirmed by the questionnaire survey. Accordingly, both shows that most of the study areas are highly affected by malaria and malaria is one of top ten diseases in the area due to the presence of various facilitating factors for the development of anopheles mosquito.

Table 4.5: Impact of Malaria in Kewet *Woreda*

Question items	Frequency (%)
1. Is there any member of your family who has affected by malaria?	
Yes	118(90.76)
No	12(9.2)

2. If yes, how many members of your family affected by malaria?	
1	15(12.7)
2	27(22.9)
3	46(39)
>3	30(25.4)
3. If no, what is the reason behind?	
Effective use of insecticide net	6(50)
Effective use of sprayed DDT	5(41.7)
Using traditional methods	1(8.3)
4. What time it takes you to return back to normal condition?	
One week	19(16.1)
Two weeks	30(25.4)
One month	34(28.8)
>one month	35(29.66)
5. Is there any negative impact up on your overall activity that you face while you are encountered by malaria?	
Yes	107(90.7)
No	11(9.3)
6. If yes, how do you estimate the level of impact?	
Very high	33(30.8)
High	51(47.66)
Moderate	18(16.8)
Low	4(3.7)
Very low	1(0.9)

4.6.3. Coping Mechanisms to Eradicate Malaria in Kewet *Woreda*

There are many copying mechanisms employed for the protection of malaria incidence in the study area. Regarding to its survey results on table 4.6 show preventability of malaria and mechanisms used by the respondents in fighting malaria. Of the total, 128 (98.5%) believe as malaria is manageable disease while the remaining 2(1.5%) didn't agree on that. For those who said it malaria is preventable, the researcher asked the method that they use for protection.

Accordingly, majority of the respondents 98(76.6%) replied that insecticide treated bed net (ITBN) is major mechanism to control malaria; 25 (19.6%) indicated that they used insecticides and the remaining 5(3.9%) answered avoiding ponds as major mechanism to protect malaria. Therefore, from this we can understand that using ITBN is the number one prevention method that is used by the residence in the study area. The study conducted in Tanzania also shows ITBN as primary means of malaria protection (Mazigo et al., 2010). On the other hand, other studies conducted in central part of Ethiopia reported chemoprophylaxis as the major prevention method (Mengistu and Wakgari, 2009).

Even though, most of the respondents believe using ITBN could prevent malaria, due to their inefficient use and its limited distribution as well as their high number of family when compared to the supply, the whole family members were not use ITBN. The survey result indicated that from the total respondents, 35(35.7%) of them replied that the whole family use ITBN; while 33(33.7%) of sampled respondents answered that only father and mother in each family use it; the remaining 30(30.6%) of the respondents replies that only children use ITBN. From the above we can conclude that since the whole families were not using ITN, the possibility of being caught by malaria was high.

Regarding to the number of ITBN distributed to each household, 59 (60.2%) of respondents possess one ITBN; 15 (15.4%) had two ITBNs; 17 (17.3%) of respondents had three ITBN for each household and the remaining 7 (7.1%) of the respondent indicated they got more than three ITBNs per household. Having enough number of ITBN with effective usage plays a key role to prevent malaria. But, the above statistics shows that majority of the resident don't have acceptable number of ITBN which makes the prevention process difficult. Regarding the accessibility of ITBN distribution center, most of the respondents 95(96.9.2%) got ITBN from the nearby health center; and few of them 3(3.1%) bought from drug vendors. Thus, majority of the ITBN was delivered by the government- health centers in the study area.

Due to the presence low sewerage facilities in most parts of developing countries including Ethiopia, appropriate water treatment is very weak, unused water is removed wrongly by the households and rain water treatment also has a great problem. Due to this, different infectious diseases, particularly water related diseases are common. To avoid this problem, in some areas individuals themselves prepare surface water drainage. Nevertheless, there is a problem of unwise management of the existing drainage system that would expose the people to water-related diseases among which vector borne diseases like malaria are common.

This problem is common in Kewet *Woreda* too. During the fieldwork, it was common to see collected rain water or waste water in the unprotected drainage area from the houses. This condition in association with the favorable temperature creates good ground for the breeding and development of Anopheles mosquitoes that increase the risk of malaria in the study area. The result of the fieldwork shows that among 130 households, 93 (71.5%) of the respondents do not have properly managed drainage system. The remaining 37 (28.5 %) households have relatively well protected drainage. Proper management and wise use of drainage system allows continuous flows of waste water and hinder breeding of mosquitoes since the larva could be washed away easily.

Table 4.6 shows various eradication methods taken by the government in the study area. Accordingly, 45(34.6%) of sampled respondents answered as government give awareness to prevent malaria, 34(26.2%) of sampled respondents replied that strengthening the capacity of health centers as a prevention method used by government, 28(21.5%) indicated distribution of ITBN by government as the major preventive method for malaria, and the remaining 23(17.7%) of respondents were replies that providing yearly house spray was the method used by government to eradicate malaria in the study area. Thus, from the above data we can understand that, government use different methods in order to prevent malaria in the study area; however malaria still prevail.

Regarding to malaria controlling mechanism by society, 65(50%) of sampled respondents answered as they use ITBN in order to controlling malaria, 40(30.7%) of sampled respondents replied that they use house spray for method of preventing malaria, 22(16.9%) indicated avoiding ponds as the mechanism they employ to control malaria and the remaining portion of respondents were replies that effective usage of drainage as method they use for controlling malaria. From the above result we can conclude that using ITBN is the major mechanism used by the society for the prevention of malaria in the study area and followed by house spray, avoiding ponds and use of drainage respectively.

Table 4.6: Copying Mechanisms that Taken to Eradicate Malaria in Kewet *Woreda*.

Question items	Frequency (%)
1. Can we control malaria?	
Yes	128(98.5)
No	2(1.5)
2. What are the mechanisms that you use to control malaria?	
Insecticide treated bed net	98(76.6)
Insecticide spraying	25(19.5)
Avoid ponds	5(3.9)
3. If you use ITBN, who use it from your family?	
Whole family	35(35.7)
Father and mother	33(33.7)
Children	30(30.6)
4. How much ITN do you have?	
1	59(60.2)
2	15(15.4)
3	17(17.3)
>3	7(7.1)
5. From where do you get ITN?	
Governmental health centers	95(96.9)
From drug vendors	3(3.1)
6. Do have drainage in your home?	
Yes	37(28.5)
No	93(71.5)
7. What are the measures that taken by the government to control malaria in your kebele?	
Giving awareness	45(34.6)
Distribute ITN	28(21.5)
Strengthen the capacity of health centers	34(26.2)

Provide yearly house spraying	23(17.7)
8. What are the mechanisms that taken by the residence to control malaria?	
Avoid ponds	22(16.9)
Use ITBN effectively	65(50)
Use drainage	3(2.3)
House spraying	40(30.7)

There are different favorable environment for the expansion and spread of malaria in the study area. During the field observation the researcher has got a chance to observe the unplanned irrigation, swamps and slow moving waters which create favorable ground for the development of mosquito, climatic condition (high temperature and low rainfall), land feature, spatial distribution of health centers as well as population at risk of malaria. Thus, based on the observation, the result produced using GIS and remote sensing is reliable.

CHAPTER FIVE

5. SUMMARY OF THE FINDING AND RECOMMENDATIONS

5.1. Findings

The main objective of this study was to assess and map the risk of malaria using GIS and remote sensing in Kewet *Woreda*, North Shewa Zone, Amhara region. The study also involved questioner with sample population to examine the impact of malaria on the study community and identify coping of mechanisms in the study area using structured and pre-tested questionnaires to the systematically selected sample respondents.

To generate the malaria risk maps a number of factors like environmental factors (elevation. Slope, proximity to river, swamp and wet lands, climatic factors (rainfall and temperature) and socio-economic factors (proximity to health facilities, land use/cover and population density) were considered and the maps were reclassified based on their suitability for malaria breeding and incidence. Depending on the amount of influence of each factor, weight was computed for each factor by using pairwise comparison 9 point continuous rating scale on IDRISI. Then weighted overlay was undertaken on Arc GIS 10.1 environment to produce the final malaria risk map. The final malaria risk map of the study area indicated that, 25% of the study area is in very high malaria risk, 45.4% of the area in high and the remaining 22.9% and 6.7% of the area in moderate to low malaria risk respectively.

At *kebele* level, the entire area of Shewa Robit town, Yelen, Deberena Jegol and Yemengist Den are very highly affected by malaria and more than half area of 14 rural *kebeles* fall under high malaria risk. The remaining six and one *kebeles* were labeled as moderate and low affected area respectively. Therefore, the existence of suitable climatic condition, lower elevation, river, swamp and wetland plays a great role for the spread of malaria in the study area. Moderate and low risk levels are confined to areas which are far from water bodies.

This research confirmed that GIS and remote sensing technology are important tools for the analysis of malaria risk levels in an area taking number relevant factors in to consideration. In this study GIS played great role in the generation of maps for environmental factors, reclassification, overlaying and identification of risk level. Remote sensing also played a major role in generating data for one of the important factors (land use/cover) for the study area. Hence, GIS and remote sensing technology is vital tool for health sector, government and other concerned body to facilitate vector born disease control and prevention program.

Regarding the impact of malaria in the study area almost all respondents systematically selected from five *kebeles* indicated that their families were highly affected by malaria. Hence, they use ITBN and insecticide spraying as coping mechanisms. In addition to the above preventive method, there are also other preventive mechanisms that were carried out by the government such as: giving awareness, distributing ITBN, strengthen the capacity of health centers, and providing yearly house spraying; however, malaria still prevail and affect the health condition of the residents in the study area.

5.2. Recommendations

According to the result of this research, the study area is classified in to four malaria risk level as very high, high, moderate and low based on environmental and socio-economic factors which create favorable condition for malaria breeding. Therefore, based on the findings the following recommendations were given as follows:

- GIS and Remote Sensing technology enable the government and other concerned bodies to map the breeding habitat, identify various environmental and socio-economic factors, risk level and to make prediction in establishing early warning system for impending epidemics. Thus, it makes the prevention and control programs of this disease easy. Therefore, the *woreda* health office should develop the capacity to use GIS and remote sensing technology.

- The *Woreda* health office should plan to construct health center at very high and high risk area at reasonable distance away from the existing health centers. If so the people can easily access the service and control the disease easily.

- The *Woreda* should construct road for all inaccessible *kebeles* in connection with other non-governmental organization.

- The *Woreda* health office could aware people about the importance of drainage, use of ITBN, avoiding ponds from their *kebele* to prevent malaria.

- In order to improve the health condition of the society in the study area government alone didn't create malaria free area. Therefore, the society and stakeholders must be active participants in the task of preventing malaria. Like that of security command post, there should be healthy command post in each *kebeles* in parallel with healthy center and health extensions who is independent and responsible for its activity.

Reference

Abdulhakim, A. (2014). *GIS and remote sensing for malaria risk mapping.* Teri University, New Delhi, India.

Abebe, A., Wondwesen, T., Lemu, G., & Abebe, G. (2011). Urban Malaria and Associated Risk Factors in Jimma town, south-west Ethiopia. *Malaria Journal, 10 (173).*

ACIPH. (2009). *Qualitative study on malaria prevention and control in Oromia and Amhara regional state in Ethiopia.* Report submitted to academy for educational development (AED) and network.

Afrane, Y.A., Lawson, B.W., Githeko, A.K. & Yan, G. (2005). Effects of microclimatic changes caused by land use and land cover on duration of gonotrophic cycles of Anopheles gambiae (Diptera: Culicidae) in western Kenya highlands. *Journal of Medical Entomology, 42(6).*

Agarwal, S.A., Sikarwar, S.S., and Sukumaran, D. (2012). Application of RS and GIS in risk area assessment for mosquito born disease*:* A case study in a part of Gwalior city. *International journal of Advanced Technology and Engineering Research, 2 (1),250-3536.*

Akpala, E. (1994). Implementations for Malaria Control Strategies. *Bulletin of the World Health Organization* 74 (3):

Alemayehu, L. (2011). *GIS and remote sensing based malaria risk mapping in Fentale woreda. East Shoa zone.* Unpublished master's thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Amdie, Z. (2007). *Land use land cover dynamics and vegetation vulnerability analysis: A case study of Arsi Negele Woreda.* Un published Master's thesis, Addis Ababa University, Addis Ababa, Ethiopia.

American Public Health Association. (2010). *Malaria: Control of Communicable Diseases Manual,* An official report of the American Public Health Association.

Andagie, A., Abrham, D. and Berhanu, E. (2013). *Community knowledge, attitude and practice about malaria in low epidemic setting of* Shewa Robit Town. North eastern Ethiopia.

Arega, D. (2009). *Vulnerability Analysis and Malaria Risk Mapping in Awassa and Wondogenet Woredas.* Unpublished master's thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Ashenafi, M. (2003). "*Design and water management of irrigation systems to control breeding of Anopheles mosquitoes. Case study: Hara irrigation project, Arba Minch", Ethiopia.* M.Sc. Thesis. Wageningen University, Wageningen. Netherland.

Ashenafi, W. (2008). *Changes in the spread of malaria in Ethiopia*: *case study from Awassa and Hossana area 2006-2007*. Unpublished master's thesis, Telemark University College, Norway.

Aster, T. (2010). *GIS and remote sensing based assessment of malaria risk mapping for Boricha Woreda.* Unpublished master's thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Aynalem, A. (2008). Malaria in Ethiopia. www.EthioDemographyAndHealth.Org

Aynalem, A. (2011). *Malaria in Ethiopia.* Ethiopian Demography and Health.Org. http://www:EthioDemography And Health.org/MedVectored DiseaseMalaria.pdf. (Accessed on feb, 2016).

Boelee, E. (2003). *Water and Health in irrigated agriculture* .In: Mc Cornick, P. G.

Brooker, S., Clarke, S., Kiambo-Njag, J., Polark, S., Mugo, B., Estambale, B., Muchiri, E., Magnussen, P., Cox, J. (2004). *Spatial clustering of malaria and associated risk factors during an epidemic in a highland area of western Kenya.* Tropic Med Intern Health; 9(9).

Burlando, A. (2012). *The impact of malaria on education:* Evidence from Ethiopia. University of Oregon.

CDC. (2006). Department of Health and Human Services. *Schema of the Life Cycle of Malaria.* http://www.cdc.gov/malaria/diagnosis_treatment/diagnosis.htm, accessed Mar, 2016.

CDC. (2007). Department of Health and Human Services. http://www.cdc.gov/malaria/diagnosis_treatment/diagnosis.htm, accessed Feb 2016.

Ceccato, P., Connor,.J., Jeanne, I., and Thomson, M. (2005). *Application of GIS & RS technologies for assessing and monitoring malaria risk.* Parassitologia.

Cox, F. (2010). *History of the discovery of the malaria parasites and their vectors*. Bio med centeral, London.

CSA. (2007). Central Statistical Agency of Ethiopia. *Population and Housing Senses Report*. Addis Ababa, Ethiopia.

Cunnigham, P. (2005). *Environmental Science*: A global Concern. New York. McGraw Hill.

Dhiman, S., Gopalakrishnan, R., Goswami, D., Baruah, I., Singh, L. (2010). *Malaria epidemiology along Indo-Bangladesh border in Tripura state,* India. Southeast Asian J Trop Med Pub Health.

EMA. (1992).1:50,000 scale, *topographic map of Kewet Woreda* .Addis Ababa, Ethiopia.

FAO. (1976). *A framework for Land Evaluation.* FAO Soils Bulletin, ILRI Publication, International Institute for Land Reclamation and Improvement, Wageningen, Netherlands.

FAO. (1984). *Ethiopian geomorphology and soils. Assistance to land use planning*, Addis Ababa, Ethiopia.

FAO. (2006). *World reference base for soil resources*. *A framework for international classification, correlation and communication.* Rome: Italy.

FMoH. (2003). *Malaria prevention and control extension package.* Addis Ababa, Ethiopia.

FMoH. (2006). *National five-year strategic plan for malaria prevention and control in Ethiopia 2006-2007 report*. Ministry of Health, Addis Ababa, Ethiopia.

FMoH. (2008). *Ethiopian national malaria indicator survey 2007: Technical summary*. Addis Ababa, Ethiopia.

FMoH. (2009). *National Strategic Plan for Malaria Prevention, Control and Elimination in Ethiopia 2010 – 2015.* Federal Ministry of Health, Addis Ababa, Ethiopia.

FMoH. (2012). *Ethiopia malaria programme performance review.* Ministry of Health, Federal Democratic Republic of Ethiopia, Addis Abba, Ethiopia.

FMoH. (2014). *National strategic plan for malaria prevention, control and elimination in Ethiopia 2014-2020.* Federal Ministry of Health, Federal Democratic Republic of Ethiopia, Addis Abba.

Friesen, J., Silvie, O., Putrianti, E. D., Hafalla, J., Matuschewski, K., and Borrmann, S. (2010). *Natural immunization against malaria: Causal prophylaxis with antibiotics.* Sci. Transl. Med. 2,40ra49.

Giming, J.E., Hightower,A.W., and Hawley, W.A. (2005). *Application of geographic information systems to the study ecology of mosquitoes and mosquito-borne diseases.* Centres for Disease control and Prevention, Division of Parasitic Disease, Atlanta.

Haque, U. (2007). *Mapping malaria vector habitats in the dry season in Bangladesh N using Spot imagery*. Unpublished master's thesis, Royal Institute of Technology , Stockholm, Sweden.

Hempelmann, E., & Krafts, K. (2013). *Bad air, amulets and mosquitoes: 2,000 years of changing perspectives on malaria*. http://www.malariajournal.com/content, /12/1/232

Himeidan, Y., Hamid, E., Thalib, L., Elbashir, M., and Adam, I. (2007). *Climatic variables and transmission of falciparum malaria in New Hlfa, Eastern Sudan*. Health Journal 13(1).

Hoek, W., Konradsen, F., Amerasinghe, P., Perera. D., Piyaratne, M., and Amerasinghe, F. (2003).*Towards a Risk Map of Malaria for Sri Lanka: the Importance of House Location Relative to Vector Breeding Sites.* Great Britain.

Ifatimilehin, O., Laah, J., and Toluhi, O. (2009). An assessment of Malaria risk in Koton Karfe watershed catch, Nigeria. *Journal of Geography and Regional Plannin*g. 6(3).

Ismail, M. & Jusoff, K. (2008). Satellite data classification accuracy assessment based from reference dataset. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering*, 2 (3).

Jeff, W. (2001). *How to Determine a Sample Size*: Tip sheet #60, University Park, PA: Penn State Cooperative Extension. Retrieved December, 2015, from http://www.extension.psu.edu/evaluation/pdf/TS60.pdf

Kaya, S., Pultz, J., Mbogo. M., Beier. C., and Mushinzimana, E. (2002). *The use of Radar remote sensing for identifying environmental factors associated with malaria risk in coastal Kenya.* IGARSS, Toronto. Paper submitted to the International Geoscience and Remote Sensing Symposium (IGARSS '02), Toronto.

Kewet woreda health office. (2013). North shewa zone of Amhara National Regional State, Ethiopia.

Kothari, C.R. (2004). *Research Methodology; methods and Techniques.* New Age International (P) Ltd. New Delhi, India.

Kumar, P., Nathawat, S., and Onagh, M. (2012). *Application of linear regression model through GIS and RS for malaria mapping in Varanasi District*, INDIA.

Lindsay, S. W., and Birley, M. H. (1996). *Climate change and malaria transmission*: Annual Tropical Medicine. Parasitol.

Liu, X., Zeng, W., and Cui, X. (2006). *Remote Sensing and GIS for Identifying and Monitoring the Environmental Factors Associated with Vector-borne Disease*: An Overview, IEEE.

Mabratu, M. (2010). *Web GIS in Decision Support to Control Malaria: Case Study in Tiro Afeta Woreda, Oromia Region*. Unpublished master's thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Malakooti, M. A., Lindblade, K. A., Walke, E. D. R, Onapa, A. W., Katungu, J., and Wilson, M. L. (2000). *Land use change alters malaria transmission parameters by modifying temperature in a highland area of Uganda.* Tropical Medicine & International Health.

Martens, P., and Hall, L. (2000). *Malaria on the move: human population movement and malaria transmission.* Emerg. Infect. Dis.

Mazigo, H.D., Obasy, E., Mauka, W., Manyiri, P., Zinga, M., Kweka, E.J., Manyone, L.L., and Heukelbach, J. (2010). *Knowledge, attitude and practice about malaria and its control in rural Northwest Tanzania. Malaria Research and Treatment.*

Mendis, K. (2009). *Spatial technology & malaria control*. Indian Journal of Medical Research, 14 (7), 1-7.

Mengistu, L., & Wakgari, D. (2009). Community awareness about malaria, its treatment and Mosquito vector in rural highlands of central Ethiopia. *Ethiopian Journal of Health and Development*, 23 (1), 40-47.

MIS. (2011). *Ethiopian malaria indicator survey.* Ethiopia health and nutrition research institute. Addis Ababa, Ethiopia.

Munga, S. (2006). Landscape determinants and remoter sensing of Mosquito Larva habitats in the islands of Kenya. *Malaria Journal*, 44 (2), 758-64.

Munga, S., Laith, Y., Emmanuel, M., Guofa, Z., Tom, O., Noboru, M., Andrew, G. and Guiyun Y. (2009). Land Use and Land Cover Changes and Spatiotemporal Dynamics of Anopheline Larval Habitats during a Four-Year Period in a Highland Community of Africa. *American Journal of Tropical Medicine and Hygiene*, 81 (6), 521-538.

NMA. (2016). National Meteorological Agency. Addis Ababa, Ethiopia.

.Negash, K., Kebede, A., Medhen, A., Aragaw, D., Babaniyi, J., Guintaran, O. J., and Delacollette, C. (2005). Malaria epidemics in the highlands of Ethiopia. *East African Medical Journal,4(3, 44-53.*

Negassi, F. (2008). *Identifying, Mapping and Evaluating Environmental factors Affecting Malaria Transmission Using GIS and RS in Selected Kebeles of Adama district, Oromia Region*. Unpublished master's thesis, Addis Ababa University, Addis Ababa, Ethiopia.

NIAID. (2007). *Understanding Malaria: Fighting an ancient scourge.* National Institute of Health USA.

NIAID. (2008). *Efforts to Accelerate Control and Eradication of Malaria Through Biomedical Research.* USA.

Nusret, D. and Dug, S. (2012). *Applaying the invers distance weight and kriging methods of sapatial interpolation on the mapping the annual precipitation in Bosnia and Herzegovina.*

Nyika, A., Kilama, W., Chilengi, R., Tangwa, G., Tindana, P., Ndebele, P., Ikingura, J. (2009). Composition, training needs and independence of ethics review committees across Africa: are the gate-keepers rising to the emerging challenges? *Journal of Medical Ethics;35(3), 678-692.*

Patz, A., Mph, D., Olson, H., Uejio, K., and Gibbs, K. (2008). *Disease Emergence from Global Climate and Land Use Change.* Medical Clinics of North America.

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). *Maximum entropy modeling of species geographic distributions.* Ecological modeling.

PMI. (2009). *Malaria Operational Plan (MOP).* Ethiopia FYI 2012. US President's Malaria Initiative. http://www.pim.gov./Ethiopia.

PMI. (2012). *Malaria Operational Plan (MOP).* Ethiopia FYI 2012. US President's Malaria Initiative. http://www.pmi.gov/countries/mops/index.html.

Prakash, M. (2014). *Hotspot analysis of dengue fever cases in Delhi using Geospatial techniques. Unpublished master's thesis,* Teri University, New Delhi, India.

Prosper, L. (2011). *Spatial analysis of malaria epidemiology in the Amense West district.* Unpublished master's thesis, Kuamen Nkurumah University, Ghana.

Protopopoff, N., Van Bortel, W., Speybroeck, N., Van Geertruyden, P., Baza, D., Alessandro, U. (2009). *Ranking malaria risk factors to guide malaria control efforts in African highlands.* PLoS One.

Reid, C. (2000). *Implication of Climate change on Malaria in Karnataka-India.* Unpublished master's thesis, Brown University.

Reiter, P. (2008). Global warming and malaria: knowing the horse before hitching the Cart. *Malaria Journal, 6 (1),122-147.*

Robert, V., Macintyre, K., Keating, J., Trape, J., Duchemin, J., Warren, M., and Beier, J. (2005). Malaria transmission in urban sub-Saharan Africa. *American Journal of Tropical Medicine & Hygiene, 4 (3), 981-1012.*

Saaty, T.L. (1980). *The Analytic Hierarchy Process*, New York: McGraw Hill. International, Translated to Russian, Portuguese, and Chinese, Revised editions, Paperback (1996, 2000), Pittsburgh: RWS Publications.

Saaty, T.L. (2008). Decision making with the analytical hierarchy process. *International Journal of Service Science*, 5 (2), 269-278.

Saxena, R., Nagpal, B.N., Srivastava, A., Gupta, S.K., and Dash, A.P. (2009). *Application of spatial technology in malaria research & control:* some new insights, Indian.

Simoonga, C., Utzinger, J., Brooker, S., Vounatsou, P., Appleton, C.C., Stensgaard, A.S., Olesen, A., and Kristensen, T.K. (2009*). RS, GIS and spatial analysis for schistosomiasis epidemiology and ecology in Africa.* Parasitology.

SPSS. (2008). *Statistical Package for the Social Science.* Available online in www.spss.com Accessed on Feb 2016.

Srivastava, A., Nagpal, BN., Joshi, P., Paliwal, C., and Dash, A. (2009). *Identification of malaria hot spots for focused intervention in tribal state of India:* a GIS based approach. International Journal of Health and Geography, 3 (4), 569-581.

Tsega, Z. (2011). *GIS and Designing Maps for Malaria Management: The case of Tigray in Ethiopia.* Unpublished Master's Thesis, University of Oslo, Norway.

Tulu, A. (1993). Malaria In: Kloos, H and Zein, Z.A (Eds).*The Ecology of Health and Disease in Ethiopia.* West view Press, Boulder.

UNICEF. (2000). *The global malaria burden. Promoting Rational Use of Drugs and Correct Case Management in Basic Health Services*. UK.

UNICEF. (2008). *Malaria and Children: progress in intervention coverage*. Geneva.

Woyessa, A., Deressa, W., Ali, A., and Lindtjorn, B. (2012). Prevalence of malaria infection in Butajira area, South- central Ethiopia. *Malaria Journal*, 2 (5),123-131.

WHO. (2002). *World Malaria Report*. WHO Technique Report.

WHO. (2003). *World Health Report: Shaping the Future*. Geneva.

WHO. (2008). *World Malaria Report.* http://www.who.int/malaria/wmr2008/malaria2008.pdf accessed Feb, 2016.

WHO. (2009). *WHO Malaria Factsheet*. Retrieved 12 June 2010, from http://www.who.int/mediacentre/factsheets/fs094/en/index.htm

WHO. (2010). *Nepal Malaria Review Program*, 7-16 June 2010.

WHO. (2012).World malaria report fact sheet. http://www.who.int/malaria/publications/world-malaria-report-2012/wmr2012- factsheet.pdf. Accessed January, 2016.

WHO. (2013). *World Malaria Report*. http://www.who.int/iris/bitstream/10665/97008/1/9789241564694_eng.pdf.

WHO. (2014). *World malaria report.* http://www.who.int/malaria/visual-refresh/en/

Zeleke, G., Alemu, B., Hergarten, C., and Krauer, J. (2008). *Proceedings of Consultation Workshop on National Spatial Data Infrastructure and Ethio-Gis.* November 28, 2007, Addis Ababa, Ethiopia.

Zhou, G., Minakawa, N., Githeko, A., and Yan, G. (2004). *Association between climate variability and malaria epidemics in the East African highlands.* A review of National Academy of Sciences, USA.

APPENDIXES I

Household survey Questionnaire

Dear Sir/Madam,

I'm MA student at the Addis Ababa University and in my final year of study. As part of the requirement for the award of the degree of Master of Arts in GIS and remote sensing, I'm undertaking a research on malaria risk assessment: The Case of Shewa Robit town of Amhara National Regional State, Ethiopia.

In this regard, I'm kindly requesting for your support in terms of time, and by responding to the attached questionnaire. Your honest response will be crucial in ensuring the objective of research. The information gathered will only be used for the study and shall not be used to victimize any one and the respondents will remain anonymous and their names shall not be revealed to anyone.

It will not be necessary to write your name on this questionnaire and for your comfort, all information received will be treated in strict confidentiality. In addition, the findings of the study will surely be used for academic research purposes and to enhance knowledge in the field GIS and remote sensing.

Thank you for your valuable time on this.

Yours faithfully

Instructions:

For each of the following questions, please put a tick mark "✓" in the box or circle your answer that best describes the situation when you respond to the closed end questions (when necessary you may circle more than one options) and please also fill in the information in the blank space where required.

Questionnaire for Households

I. General Household Information

1. Age

   A. 20-30 B. 31-40 C. 41-50 D. above 50

2. Sex Male ☐ Female ☐

3. Marital status:

   A. Married

   B. Single.

   C. Divorce

   D. Widow

4. Educational status:

   A. Illiterate D. Secondary school

   B. Reading and writing E. College and above

   C. Primary school F. Others (Specify

5. Occupation of household head

   A. Private Business B. Gov't work

   C. Casual work D. Farmer

   E. House wife

II. Malaria and environment

1. Is there any member of your family who has affected by malaria?

   A. Yes B. No

2. If yes, how many members of your family affected by malaria?

   A. 1 B. 2 C. 3 D. Above 3

3. If no, what is the reason behind?

A. Effective use of insecticide net

B. Effective use of sprayed DDT

C. Using traditional methods

4. What time it takes you to return back to normal condition?

A. One week C. One month

B. Two weeks D. Above one month

5. Is there any negative impact up on your overall activity that you face while you are encountered by malaria?

A. Yes B. No

6. If yes, how do you estimate the level of impact?

A. Very high D. Low

B. High E. Very low

C. Moderate

7. Can we control malaria?

A. Yes B. No

8. What are the mechanisms that you use to control malaria?

A. Insecticide treated bed net

B. Insecticide spraying

C. Avoid ponds

9. If you use ITBN, who use it from your family?

A. Whole family

B. Father and mother

C. Children

10. How much ITN do you have?

A. 1 B. 2 C. 3 D. above 3

11. From where do you get ITN?

A. Governmental health centers

B. From drug vendors

12. Do have drainage in your home?

A. Yes B. No

13. What are the measures that taken by the government to control malaria in your *kebele*?

A. Giving awareness

B. Distribute ITN

C. Strengthen the capacity of health centers

D. Provide yearly house spraying

14. What are the mechanisms that taken by the residence to control malaria?

A. Avoid ponds

B. Use ITBN effectively

C. Use drainage

D. House spraying

Interview guideline questions

Interviewer: Date: *Kebele*: Interviewee: Position: Qualification:	
Which diseases are the most top diseases that prevail in this area?	
What are the main environmental factors that are responsible for the occurrence of Malaria?	
During which months (season) do you attend high number of Malaria patients?	
What general preventive methods do you take to control Malaria?	

APPENDIXES II

Table 1: Accuracy assessment matrix

Classified data	WB	SA	IF	FA	FL	BL	Raw Total	Commission error (%)	User Accuracy (%)
Water Bodies	16	0	3	1	6	0	26	38.46	61.5
Settlement Area	1	35	0	2	0	1	39	10.25	89.7
Irrigated farming	0	3	18	0	3	0	24	25	75
Forest area	0	0	11	23	0	2	36	36	63.8
Farm Land	10	2	0	2	49	0	63	22.2	77.7
Bare Land	0	0	1	0	0	29	30	3.33	96.6
Column Total (%)	27	40	33	28	58	32	218		
Omission Error	40.74	12.5	45.45	17.85	15.5	9.37	Overall accuracy $= \frac{16+35+18+33+95+62}{27+40+33+38+104+65}$		
Producer Accuracy (%)	59.2	87.5	54.5	82.21	84.4	90.6	$=OA = \frac{170}{218}$= 0.779= 77.9% K= 73%		

APPENDIXES III

Table 2: AHP Weight Derivation for Elevation, Rainfall, Temperature, Slope, Land Use/Cover and Proximity Related Factors.

	Elevation	RF	Wet and swamp	River	T^o	Health	slope	LULC	Population
Elevation	1								
Rainfall	1/3	1							
Wet and swamp	1/2	2	1						
River	1/2	2	3	1					
Temperature	1/2	3	½	2	1				
Health	1/2	1/2	1/3	1/3	1/2	1			
Slope	1/2	1/2	½	1/2	1/2	1/2	1		
LULC	1/5	1/2	½	1/2	1/3	1/2	1/2	1	
Population	1/3	1/5	1/3	1/7	1/3	1.2	1/2	1/2	1

Consistency= 0.06.

APPENDIXES IV

Health Centers Coordinate Points

Table 3: Health Station Coordinate Points

Kebeles	X-Coordinate	Y-Coordinate	UTM Zone (Adindan)
Tere health centers	594455	1115695	37
Abay Atir health center	611707	1093241	37
Shewa Robit health center	598913	1105558	37
Shewa Robit hospital	599003	1106262	37

APPENDIXES V

Photographs taken during field survey

Photo 1: Malaria breeding site that created by irrigation

Photo 2: Malaria breeding site that in the study area created along river in the study area.