

Addis Ababa
University
(Since 1950)



GIS and Remote Sensing Based Assessment of Malaria Risk Mapping for Boricha Woreda, Ethiopia

**Dissertation submitted for Partial Fulfillment of the Requirements for the
Award of the Degree of**

MASTER OF SCIENCE

**In
Remote Sensing and Geographical Information Systems (GIS)
of Addis Ababa University, Addis Ababa, Ethiopia.**

By

ASTER TIRUNEH

Department of Earth Sciences
Faculty of Science
Addis Ababa University, Addis Ababa

JUNE, 2010

GIS and Remote Sensing Based Assessment of Malaria Risk Mapping for Boricha Woreda, Ethiopia

**Dissertation submitted for Partial Fulfillment of the Requirements for the
Award of the Degree of**

MASTER OF SCIENCE

In

**Remote Sensing and Geographical Information Systems (GIS)
of Addis Ababa University, Addis Ababa, Ethiopia.**

Under the guidance of

**Dr. Dagnachew Legesse
Department of Earth Sciences
Addis Ababa University, Addis Ababa**

By

Aster Tiruneh

JUNE 2010

**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES**

GIS and Remote Sensing Based Assessment of Malaria Risk Mapping for Boricha Wereda, Ethiopia

By
ASTER TIRUNEH

Faculty of Natural Science
Department of Earth Sciences
Remote Sensing and GIS

Approval By Board of Examiners

Dr. Balemual Atnafu
Chairman, Department
Graduate Committee

Dr. Dagnachew Legesse
Advisor

Advisor

Dr. -----
Examiner

Dr. -----
Examiner

DECLARATION

I here by declare that the dissertation entitled “GIS and Remote Sensing Based Assessment of Malaria Risk Mapping for Boricha Wereda, Sidama Zone, SNNP Region” has been carried out by me under the supervision of Dr. Dagnachew Legesse, Department of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2009-2010 as a part of Master of Science programme in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa
Date: June, 2010

(Aster Tiruneh)

C E R T I F I C A T E

This is certified that the dissertation entitled “GIS and Remote Sensing Based Assessment of Malaria Risk Mapping for Boricha Wereda, Sidama Zone, SNNP Region” is a bonafied work carried out by Aster Tiruneh under my guidance and supervision. This is the actual work done by Aster Tiruneh for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

Dr. Dagnachew Legesse

Department of Earth Sciences

Addis Ababa University

Addis Ababa

Acknowledgment

I have no words to thank my advisor Dr. Dagnachew Legese, not only for his advice but also for his willingness to consult me at any point of time, his patience and experience he shared with me, many thanks to you for confidence you build inside me. I record my gratitude to Dr. K.V. Suryabhadgavan, Dr. Mohammed Umer and staff members of Earth Science for their encouragement and cooperation they made to me.

My home organization Ethiopian Mapping Agency (EMA) must be thanked for giving me full sponsorship to attend this programme and for the necessary assistance I received during my research work. I am so great full to Ato Sultan Mohamed Director of EMA, for the sponsorship I was granted to pursue my study. I greatly acknowledge Ethiopian Metrology Agency, Sidama Zone Health Bureau, Sidama Zone BOFED, Famine Early Warning Network System, Science Faculty of Addis Ababa University and Boricha Woreda Health Bureau for giving me, free access to their document and support for the accomplishment of this study.

The encouragement and support from my family has always been with me throughout my studies. My brothers and sisters are great partners who always earnestly encourage me and enthusiastically follow up the progress of my work. I would like also to thank from Awassa Ato Shitaye Hordofa, Ato Abebe, Ato Abnet, Ato Kiya and his friend, from Boricha Ato Legese Yawre, Ato Boriso Bulasho, Ato Tebeje Misganaw, Ato Talo Hilo, Ato Milkano Sakuma and Ato Negash Teka from EMA W/t Genet Lema, Ato Kerlos Latebo, Ato Degelo Sendabo, Ato Grmay Kassa, Ato Tegene Wodageneh, Ato Sime Ayano and W/o Mebrate Samuel, from AAU4 all my classmates and Ato Biniyam Tezera whose supports have been useful to prepare this document.

It is also my pleasure to express my deepest gratitude to my friends W/t Mekiya Defar, AtoBechaye Tesfaye, and Dr. Asayehegn Tekeste for their invaluable comment, enriching support and encouragement through out the research.

Almighty God, thank you. You make every thing possible for me. God bless Ethiopia and its people. Save my family and help me to realize my next dream.

Table of contents

DECLARATION.....	iv
Acknowledgment.....	vi
List of Tables.....	ix
List of Figure.....	ix
List of Acronyms.....	x
Abstract.....	xi
1. Introduction.....	1
1.1 Background.....	1
1.2 Problem Statement.....	2
1.3 Objective.....	3
1.3.1 General Objective.....	3
1.3.2 Specific Objectives.....	3
1.4 Contribution of the Thesis.....	3
1.5 Limitation of the Study.....	4
2. Review of Literature.....	5
2.1 Global Distribution of Malaria.....	5
2.2 Distribution of malaria in Ethiopia.....	6
2.3 Why We Need to Map Malaria Risk Areas?.....	8
2.4 The Vector Mosquito and the Disease Malaria.....	9
2.5 Factors Influencing Malaria Incidence.....	10
2.5.1 Temperature.....	10
2.5.2 Rainfall.....	10
2.5.3 Humidity.....	11
2.5.4 Altitude.....	11
2.5.5 Slope.....	12
2.5.6 Land Cover.....	12
2.5.7 Depth to Ground Water.....	12
2.5.8 Irrigation Practice.....	12
2.5.9 Migration.....	12
2.5.10 Soil Type.....	13
2.6 GIS and Remote Sensing Techniques to Monitor and Control Malaria.....	13
3. Description of the Study Area, Materials and Methods.....	16

3.1 General Description of the Study Area.....	16
3.1.1 Location.....	16
3.1.2 Size and Population.....	17
3.1.3 Topography	18
3.1.4 Landuse/ Landcover	18
3.1.5 Soil	20
3.1.5.1 Luvisols	20
3.1.5.2 Nitosols	20
3.1.5.3 Vertisols	21
3.1.5.4 Leptosols	22
3.1.6 Major Climatic Variables (Temperature and Rainfall)	22
3.2 Data Used for the Analysis	22
3.3 Software and Hardware Utility	23
3.4 Methodology	23
3.4.1 Analysis Flow Chart.....	25
3.5 Data Analysis.....	26
3.5.1 Parameters for Identifying Malaria Hazard Areas	26
3.5.1.1 Temperature	26
3.5.1.2 Rainfall.....	28
3.5.1.3 Altitude.....	29
3.5.1.4 Slope.....	30
3.5.1.5 Distance from Ponds and Swamp Areas	31
3.5.1.6 Distance from Rivers.....	33
3.5.1.7 Soil	34
3.5.1.8 Land Use Land Cover	35
3.5.1.9 Population Density	36
4. Results and Discussion	38
4.1 Malaria Cases versus Temperature	38
4.2 Malaria Cases versus Rainfall	39
4.3 Identifying Areas of Malaria Hazard	40
4.4 Identifying Areas of Malaria Risk	42
4.5 Comparing the Extent of Malaria Risk Map with Kebeles Which Were Labeled as Malarious	44
5. Conclusion and Recommendation	46
5.1 Conclusion	46
5.2 Recommendation	47
Reference	48
APPENDIX I.....	51

List of Tables

Table 3. 1 Monthly Average Temperature in °C at Bilate station (1996-2009)	22
Table 3. 2 Monthly Average Rainfalls in mm at Yirba Dibancho and Belela Stations (1996-2009)	22
Table 3. 3 Data and Their Sources.....	23
Table 3. 4 Software and Hardware to be Used for the Study	23
Table 4. 1 Weight of Malaria Hazard Factors	40
Table 4. 2 Weight of Malaria Risk Factors.....	42

List of Figure

Figure 2. 1 The Malaria Belt of the World	5
Figure 2. 2 The Malaria Epidemiological Strata in Ethiopia.....	8
Figure 3. 1 Location of the Study Area	16
Figure 3. 2 Population Density Map	17
Figure 3. 3 Altitudinal Variation Map	18
Figure 3. 4 Landsat ETM+ Image of the year 2005 at Bands 6, 4 and 2.....	19
Figure 3. 5 Landuse/ Landcover Map	20
Figure 3. 6 Soil Map	21
Figure 3. 7 Schematic Representations of Malaria Hazard Analysis	25
Figure 3. 8 Schematic Representations of Malaria Risk Analysis.....	25
Figure 3. 9 Reclassified Temperature Map.....	27
Figure 3. 10 Reclassified Rainfall Map	29
Figure 3. 11 Reclassified Elevation Map.....	30
Figure 3. 12 Reclassified Slope Map	31
Figure 3. 13 Reclassified Pond and Swamp Map	32
Figure 3. 14 Reclassified River Map	33
Figure 3. 15 Reclassified Soil Map.....	34
Figure 3. 16 Reclassified Land use Land Cover Map.....	35
Figure 3. 17 Reclassified Population Density Map	36
Figure 4. 1 Annual Patterns of Temperature and Malaria Cases in Boricha (2004 - 2009)	38
Figure 4. 2 Annual Patterns of Rainfall and Malaria Cases in Boricha (2004 - 2009).....	39
Figure 4. 3 Malaria Hazard Map.....	41
Figure 4. 4 Malaria Risk Map	43
Figure 4. 5 Malaria Risk Map with Kebele Boundaries	44

List of Acronyms

AAU	Addis Ababa University
BOFED	Bureau of Finance and Economic Development
B.W.H.B.	Boricha Woreda Health Bureau
DEM	Digital Elevation Model
ERDAS	Earth Resources Data Analysis System
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agricultural Organization
FMoH	Federal Ministry of Health
GIS	Geographic Information System
GPS	Global Positioning System
IDW	Inverse Distance Weight
ITNs	Insecticide Treated Nets
km	Kilo Meter
m	Meter
m.a.s.l	Meter Above Sea Level
MCE	Multi Criteria Evaluation
mm	Mile Meter
NDVI	Normalized Difference Vegetation Index
NMA	National Meteorological Agency
P.	Plasmodium
RS	Remote Sensing
SNNPR	Southern Nations, Nationalities and Peoples Region
sq. km	Square kilo meter
WHO	World Health Organization
WMR	World Malaria Record

Abstract

Ethiopia is a predominantly malaria prone country like most sub Saharan African countries with about 75% of the landscape being favorable for the breeding of malaria vector. This study aims to explore how the interplay between environmental factors, GIS and Remote Sensing could be applied for the identification, mapping of malaria risk and contribute to the prevention and control efforts of malaria in Boricha Woreda of Sidama Zone. The study reveals that ability of GIS and remote sensing to deal with large data sets and incorporate satellite images makes it easy to analyze the environmental determinants of malaria. For mapping malaria hazard areas at Boricha Woreda seven parameters were selected. The parameters include rainfall, temperature, altitude, soil, slope, distance from swamp areas, and distance from rivers. These layers were combined by using weighted multi criteria evaluation. Similarly, risk map was developed depending on the malaria hazard layer, land use/land cover, distance from ponds and population density layers of the study area. The resulting malaria hazard map depicts that 14.5percent, 74.3percent and 11.2percent of the total area is subject to moderate, high and very high level of malaria hazard. The risk map produced from the overlay analysis of the four parameters shows as a result 5.0percent, 46.5percent, 24.3percent and 24.2percent of the total area is subject to very high, high, moderate and low to malaria risk respectively. In general, most of the kebeles in the study area are subject to moderate, high and very high risk of malaria. Among them Konsore Chefa is almost fully in very high malaria risk. Most part of Hanja Chefa, and Elawo Orfe and some part of Etawo Dawale, Alawo Siso, Dila Arfe, Hanja Goro and Belela are subject to very high risk of malaria, moreover the remaining part of these Kebeles is under high risk of malaria. In conclusion, more than 85percent of the total area is highly exposed to malaria hazard and over 51percent of the total area is under high and very high risk of malaria. Since maps of malaria risk are considered as one of the very vital input it is therefore, critical to use them in every aspect of planning, implementation, monitoring and evaluation of any development processes as well as malaria eradication and prevention program in the Woreda.

Key words: GIS, Malaria, Remote Sensing, Risk and Weighted Overlay

1. Introduction

1.1 Background

Malaria is one of the vector born diseases in the world. In 2008, there were 243 million estimated cases of malaria worldwide. The vast majority of cases (85percent) were in the African Region, followed by the South-East Asia (10percent) and Eastern Mediterranean Regions (4percent). In the same year, it accounted for an estimated 863,000 deaths, of which 89percent were in the African Region, followed by the Eastern Mediterranean (6percent) and the South-East Asia Regions (5percent) (WMR, 2009).

Malaria also a major public health problem in Ethiopia, every year it is the leading cause of out patient consultations, admissions and death. It is seasonal in most parts of Ethiopia, with unstable transmission that lends itself to the outbreak of epidemics. According to many researchers including FMOH (2008) report, the transmission patterns and intensity vary greatly due to the large diversity in altitude, rainfall, and population movement within the areas below 2,000 meters are considered to be malarious. Those areas are home to approximately 68percent (52 million) of the Ethiopian population and cover almost 75percent of the country's landmass.

According to Getachew (2006), in 2003 the disease was the primary cause of reported morbidity and mortality accounting for 15.5percent of out patient visits, 20percent of hospital admissions and 27percent of hospital deaths. Malaria transmission in Ethiopia is unstable and characterized by frequent and often large-scale epidemics. In 2003, large scale malaria epidemics occurred from April to December resulting in 2 million clinical and confirmed cases and 3000 deaths, affecting 3,368 localities in 211 districts. When we see in the years between 2001 and 2005 proportion of malaria in out patient department, admission and in-patient deaths have been increasing with the highest being recorded in 2003 and 2004 while a slight reduction was observed in 2005. In 2005, malaria was still the first leading cause of health problem accounting for 48percent of out patient consultation, 20percent admissions and 24.9percent inpatient deaths. The impact of malaria, in addition to its health consequences, it is a significant barrier to social and economic development of the country. It

causes debilitating and loss of work force and , reduction of income as well as school absenteeism for both of the sick and the family members who serve as a care taker.

Malaria is a Vector borne disease. The vector Anopheles mosquitoes are particularly influenced by environmental conditions. Indeed, arthropod vectors in general, and insect vectors in particular are very sensitive to their environments, which in turn determines their presence, and development. As a consequence, climatic as well as landscape and land cover factors greatly influence the spatial distribution of vectors and the diseases they transmit (Wim *et al.*, 2003).

Nowadays Remote Sensing techniques provide valuable information on such environmental conditions. Several studies have used Remote Sensing imagery and Geographical Information System (GIS) techniques to map the distribution of vector species at different spatial scales such as the entire world, continent, national, regional, even at small village level. According to Tran *et al* (2008), in endemic areas, mainly in tropical and subtropical regions, these vector maps are designed to improve vector control, which is currently one of the essential methods in limiting the burden of important vector-borne diseases such as malaria or dengue fever. In disease free areas, analyzing the link between the environment and potential vector distribution may help evaluate the risk of emergence of the disease, and lead to better mitigation and control measure of the invasive vector species.

As we observed in the previous studies of Remote Sensing and GIS use in combination as a tool to map the distribution of vectors at different spatial scale. Therefore, this study identifying and mapping the malaria risk areas by considering many geographical and environmental factors that make condition suitable for breeding site of mosquito in the study areas. The final output makes it possible to plan the control measures to be implemented by giving priority to high risk areas. This situation greatly increases the cost, time and energy efficiency of the malaria control and prevention program.

1.2 Problem Statement

The Ethiopian government policy towards malaria control and eradication has given due consideration to communicable diseases like malaria, free diagnosis especially at lower health facilities level free anti-malarial drugs, free distribution of ITNs to all and free indoor residual spraying of houses (Daddi, 2008). But, in this study area many people are suffering

from malaria. If all the above efforts could be supported by the output of malaria risk map, the result of prevention and control of malaria would be better than today's situation.

Environmental factors that make condition suitable for breeding of mosquito were not identified for this study area. This has resulted in failure of identifying areas severely affected by malaria, and this in turn resulted in improper utilization of scarce financial and human resource for the places which are not given top priority.

1.3 Objective

1.3.1 General Objective

The main aim of this study is to develop map of malaria risk, which integrates environmental factors that make condition suitable for breeding and habitat site of mosquito in the study areas by using Remote Sensing and GIS as a tool.

1.3.2 Specific Objectives

- To show the relationship between malaria incidence and climatic variables such as temperature and rainfall of the study area;
- To identify environmental factors that contribute for malaria hazard and identify areas of malaria hazard in the woreda
- To identify, classify and map areas at risk of malaria that subsequently will help the decision-makers to better allocate limited resources in the fight against the disease;
- Comparing the extent of malaria risk with Kebles of Borecha Woreda which were labeled as malarious using the produced malaria risk map

1.4 Contribution of the Thesis

This study is expected to enable decision makers use and ensure that the scarce resource implemented to the most high risk areas and can make the eradications and prevention task successful. It also shows way for the application of GIS and Remote Sensing to the broader public health field.

1.5 Limitation of the Study

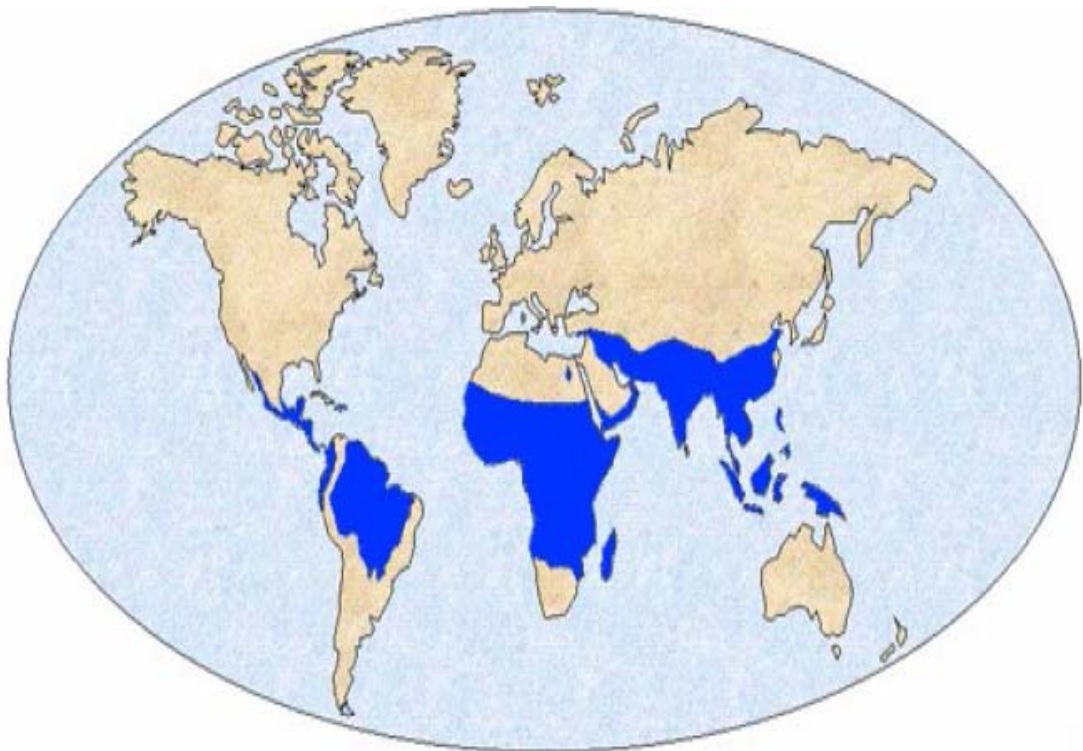
The main limitation of the study included lack of satellite images taken at different seasons for some years which can help to map seasonal variation of climatic variables in relation with malaria epidemics. There was also lack of the necessary climate data (relative humidity). Lack of well documented monthly malaria case data at Kebele as well as at Woreda level over extended years, and lack of a spatial population distribution data of the study area were also encountered, which made analysis of risk map with malaria case at Kebele levels difficult.

2. Review of Literature

2.1 Global Distribution of Malaria

Malaria is a serious vector borne disease affecting a greater proportion of the world's population than any other vector transmitted disease. About 41percent of the world population is living in malaria endemic regions (WHO, 2002). Over two hundred million cases of malaria occur every year. According to WMR (2009), the global numbers of malaria cases in 2008 were an estimated 243 million. The vast majority of cases (85percent) were in the African Region, followed by the South-East Asia (10percent) and Eastern Mediterranean Regions (4percent). And it accounted for an estimated 863,000 deaths, of which 89percent were in the African Region, followed by the Eastern Mediterranean (6percent) and the South-East Asia Regions (5percent). As shown in the figure2.1 malaria has been recorded from 64° North latitude to 32° South latitude and in altitude ranges of 400m below sea level up to 2,800m.a.s.l. According to Gilles and Warrell (1993) which is cited by Getachew (2006) within these limits of altitude and latitude, there are large areas free of malaria. It illustrate that the transmission of malaria depends greatly on local environmental and other conditions.

■ Global Distribution of Malaria



Source: WHO, 2005

Figure 2. 1 The Malaria Belt of the World

2.2 Distribution of malaria in Ethiopia

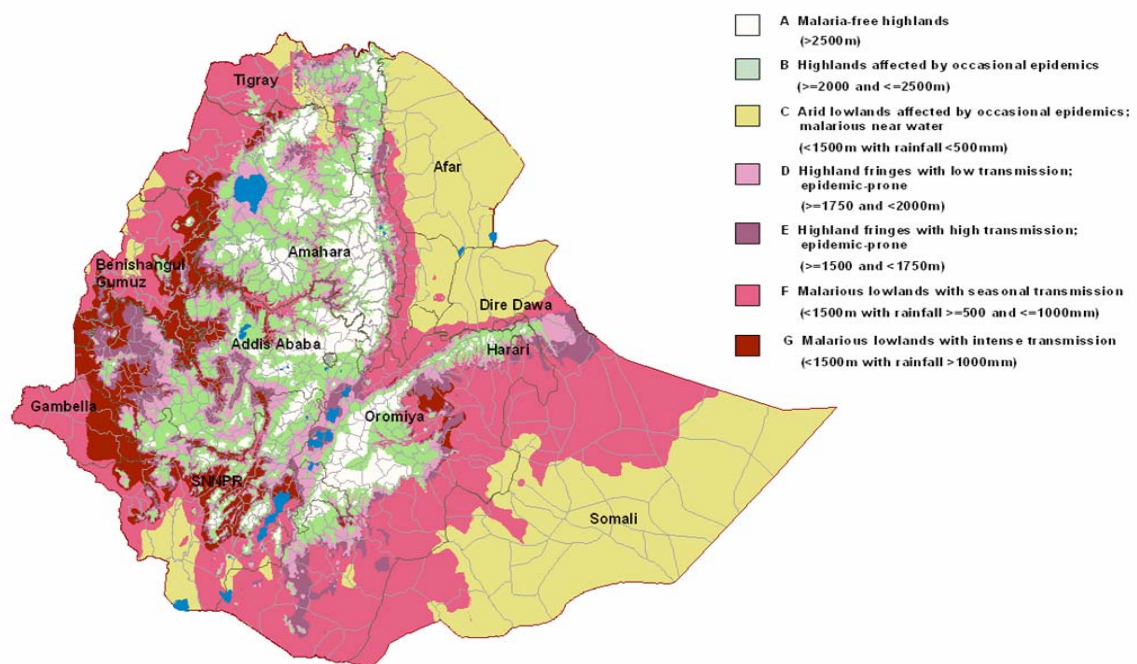
Malaria is a major concern in Ethiopia since it is one of the leading causes of morbidity and mortality. Annual malaria mortality is about 70,000 and in a non-epidemic year, 5-6 million clinical malaria cases and over 600,000 confirmed cases are reported from health facilities. However, the actual number of malaria cases in the country is expected to be more than ten fold of those captured through the routine public health surveillance system (Tilahun, 2009).

Ethiopia has experienced daunting effects of malaria epidemics. The most notable epidemic of malaria occurred in 1958. That was a devastating epidemic as there were an estimated three million cases out of which 150,000 people died. The epidemic covered about 100,000 square miles of highland areas between June and December 1958. Since 1958, major epidemics of malaria occurred at intervals of approximately 5-8 years, but recently there is a trend of more frequent small- or large-scale epidemics occurring in the same or different parts of the country. Currently, there are a number of epidemic precipitating factors in addition to natural environmental or climatological factors including high-scale population movement (due to resettlement and labor forces in agro-industrial development areas) and expansion of developmental activities such as irrigation schemes. In 1998, a large-scale and severe malaria epidemic occurred in most highlands as well as lowland areas in the country. In 2002, localized but severe and widespread outbreaks of malaria occurred in Amhara and SNNP regions that ended up in large-scale epidemics in 2003. In 2003, widespread epidemic malaria (somewhat similar to the 1958 and 1998) had occurred in highland and highland fringe areas (up to 2500 m) between the months of April and December. In this year more than 2 million clinical malaria cases and 3,000 deaths were reported from 3,368 villages in 211 districts. The epidemic was associated with climate abnormalities, which were also amplified by low immunity and drought during the preceding year (2002), including an increased therapeutic failure rates to the anti-malarial drug, Sulphadoxine-Pyrimethamine (FMoH, 2009).

According to FMoH (2008) the epidemiological pattern of malaria transmission in Ethiopia is generally seasonal and highly unstable due to spatial variations in topography and rainfall patterns. Because of this unstable and seasonal pattern of malaria transmission, the protective immunity of the population is generally low, and all age groups are at risk of infection and disease.

The distribution of malaria in Ethiopia is mainly determined by the diverse eco-climatic conditions. Climatic factors such as temperature, rainfall, and humidity show high variability mainly as a function of altitude and are the most important variables that influence malaria transmission. Based on this altitudinal variation and associated climatic characteristics, areas of the country are categorized into climatic zones, locally named as, “Dega” represent the cold zone; “Kolla” the hot zone; and “Weyna Dega” areas of average climatic conditions. The cold zone, which covers areas higher than 2,500 m.a.s.l has a mean annual temperature of 10–15⁰C. This highland area is considered free of local malaria transmission. The midland area, ranging in altitude from 1,500–2,500m with a mean annual temperature between 15–20⁰C, has diverse malaria transmission patterns. In the hot lowland zone, located in areas below 1,500m.a.s.l, where the mean annual temperature varies from 20–25⁰C, malaria transmission is endemic, and its intensity and duration are mainly dictated by the amount and duration of rainfall. In the midland zone, where temperature is a determining factor, malaria transmission often occurs in areas below 2,000m, while areas between 2,000 and 2,500m may become affected during epidemics. Mean annual precipitation, in general, ranges from 800 to 2,200 millimeters (mm) in the highlands (>1,500m) and varies from less than 200 to 800mm in the lowlands (<1,500m). The major malaria transmission season in Ethiopia is from September to December, following the main rainy season from June to September and a shorter transmission season from April to May following the short rainy season from December to February (FMoH, 2009).

Figure 2.2 is attempts to show the epidemiological classification of Ethiopia by Woreda level, which is the second smallest administrative unit. It is composed of seven epidemiological strata that have been done using elevation and precipitation datasets. In this map the study area is found within three epidemiological strata. The major area is with in 1750 - 2000 m.a.s.l. it represent highland fringes with low transmission epidemic prone. Small area with in 1500 – 1750 m.a.s.l. and it represent areas of highland fringes with high transmission epidemic prone. And very small area is between 2000 and 2500 m.a.s.l. This corresponds to areas of highlands affected by occasional epidemics.



Source: WHO Country Office for ETHIOPIA, 2005

Figure 2. 2 The Malaria Epidemiological Strata in Ethiopia

2.3 Why We Need to Map Malaria Risk Areas?

Recently there has been keen interest in mapping malaria distribution and risk. Such maps would make it possible to target control measures at high-risk areas and greatly increase the cost efficiency of malaria control programs. Most risk maps that have been developed so far have used as key inputs climatic models and information on weather data such as rainfall, temperature, and relative humidity, which to a large extent determine the survival and reproduction of the mosquito and the development of the parasite in the vector. Other studies have used different indicators of vector presence, reproduction, and survival, such as vegetation patterns, land use, and soil moisture. The environmental and climatic variables are then linked with entomological and epidemiological information to identify geographical areas at high risk for malaria. These have covered either vast areas, such as the efforts to map the malaria risk in Africa or a relatively limited number of villages (Wim *et al*, 2003). GIS and Remote Sensing offers powerful tools to present spatial information on malaria risk areas. Such information has important implications for the disease eradication strategy to be employed. GIS allows policy makers to easily understand and visualize the problems in relation to the available resources and target resources to those communities in need.

2.4 The Vector Mosquito and the Disease Malaria

Malaria is usually transmitted when a person is bitten by an infected female *Anopheles* mosquito. The *Anopheles* species breeds in stagnant water, in fallow fields, rice fields, irrigation channels, field channels, and seepage water collection sites etc (Malhotra and Aruna, 1995). The feeding habits of adult mosquitoes are quite unique. The male mosquitoes feed only on plant juices but female mosquitoes feed animal blood. Only female *Anopheles* mosquitoes transmit malaria and to do so the mosquito must have been infected by having drawn blood from a person already infected with malaria.

The mosquito goes through four distinct stages of life cycle namely egg, larva, pupa, and adult. According to David *et al* (1995), the days needed for the process from egg to adult mosquito has a seasonal contraction and expansion. In winter the vector population is localized, and the larval cycle of the mosquito population increases from approximately eight days in summer to 44 days in winter. The adult mosquitoes depending on their species lay their eggs in different water bodies.

The cause of malaria is a protozoan parasite belonging to the genus *Plasmodium* which is introduced in to a persons' blood while a mosquito bites him. According to Beanland T, which is cited by Negassi (2008), there are over 120 species of the parasite genus *Plasmodium*. However, only four of these infect humans to cause malaria. The four species of the parasite in human are *Plasmodium* (*P.*) *falciparum*, *P. vivax*, *P. malariae* and *P. ovale* (MMV, 2010). *P. falciparum* and *P. vivax* account for more than 95 percent of cases of malaria in the world (Adamu, 2004).

In Ethiopia, *P. falciparum* and *P. vivax* are the two most dominant malaria parasites, distributed all over the country and accounting for 60percent and 40percent of malaria cases, respectively. *P. malariae* accounts for less than 1percent and *P. ovale* is rarely reported. This proportion varies from place to place and from season to season. *P. falciparum* accounts for 69percent of confirmed malaria cases in SNNPR, while in Harari accounts 84percent. *Anopheles arabiensis* is the main vector and *Anopheles pharoensis*, *Anopheles funestus* and *Anopheles nili* are considered secondary vectors (Getachew, 2006). In malaria epidemic situations, *P. falciparum* is the cause for the severe form of the disease and almost all malaria deaths happen due to infection by this parasite (FMoh, 2004).

People who get malaria are typically very sick with high fevers, shaking chills, sweats, head aches, nausea and vomiting, body aches and general malaise. Malaria is not only a cause for illness but also a cause for death (FMoH, 2004).

The incidence of Anopheles mosquito differs in space and time. Environmental factors that influence malaria incidence by their impacts on the Anopheles mosquito positively or negatively. According to many researchers including WHO (2005), and Malhotra and Aruna (1995), mosquito vectors affected by the environmental factors that make favorable condition increase the incidence of the vector mosquito as well as the disease malaria, while unfavorable conditions resulted in the opposite/reverse.

2.5 Factors Influencing Malaria Incidence

According to Molineaux (1988) which is cited by Immo *et al* (2001), explain that distribution of malaria is governed by a large number of factors relating to the parasite, the vector and the host. Predominant among these are climatic and environmental factors, particularly those that affect habitat and breeding sites of the Anopheles mosquito vectors such as temperature, precipitation, humidity, presence of water, vegetation, migration and man to vector contact etc. Specifically, temperature and rainfall act as limiting factors on the development of Anopheles mosquitoes which are the intermediate hosts in the transmission of malaria parasites. Additionally the anthropogenic changes in the environment, in land use, deforestation, in hydraulic network, induce continuous changes in the intensity of malaria transmission.

2.5.1 Temperature

Ambient temperature plays a major role in the malaria vector cycle. The development of the parasite within the mosquito depends on temperature (Yazoume *et al.*, 2008). Vector species adapts to different temperature threshold depending on the area it occurs. Low temperature, when duration of parasite development in mosquitoes exceeds 30 days that is beyond average life span of mosquitoes, limits active malaria transmission. At higher temperatures the longevity of mosquitoes is reduced.

2.5.2 Rainfall

Malaria vectors depend on rainfall, since it provides breeding sites for the mosquitoes to lay their eggs. The amount and the seasonality of rainfall are important parameters in determining the location of mosquito breeding habitats as well as the total density of adult mosquitoes.

During periods of heavy rainfall, breeding may be hampered due to the excess water resulted from heavy rain make the streams and the pools move fast and torrential, so it flushing away the eggs and larvae. Excessive rains may also have the opposite effect increase vector populations in many circumstances by increasing available Anopheles breeding sites. According to Yazoume *et al.* (2008), the 1958 malaria epidemic out break in Ethiopia was associated with unusual high amount of rain. Similarly in Nairobi, Kenya outbreaks of malaria occurred in 1940 after heavy rain. Periods with low rainfall may induce mosquito breeding by turning rivers into a string of pools in which mosquito can breed. Apart from creating mosquito breeding sites, rainfall also affects malaria transmission through increasing humidity, which in turn will help to increase the longevity of the adult vectors (FMoH, 2004).

Malaria vector survival is also affected by the distribution of rainfall throughout the year, whether in the wet or dry season. Rainfall during wet season, rainwater remains on the surface and provides a place for mosquitoes to breed and a chance for the larvae to complete their development cycle. In contrast, rainwater during the dry season evaporates rapidly and does not stay long enough to provide mosquito larva habitats.

2.5.3 Humidity

Humidity also makes condition suitable for transmission, because it affects the survival rate of mosquitoes. Rainfall apart from creating mosquito breeding sites, affects malaria transmission through increasing humidity, which in turn will help to increase the longevity of the adult vectors. The optimum temperature for development of malaria parasite is between 25⁰C to 30⁰C and average relative humidity at least 60percent. These temperature and relative humidity conditions increase the longevity and density of mosquitoes and thus initiate malaria transmission, if parasite load exists in the community (Yazoume *et al.*, 2008).

2.5.4 Altitude

Elevation m.a.s.l is known to define the ecology of malaria transmission through temperature. At certain altitudes malaria transmission does not occur because of extreme temperatures that inhibit the mosquito and parasite life cycle. Study on mapping of malaria risk in Malawi shows that topography remains a single most important factor that defines large-scale differences in malaria risk because climatic variables change little over the limited range of latitude (Lawrence *et al.*, 2006).

2.5.5 Slope

Generally flat topography characterized by restricted natural drainage. It is more pronounced with the type of soils. Therefore, without the existence of efficient water drainage systems can led to the creation of stagnant water pools and used as a crucial factor of water stagnates, which in turn, encourage the breeding and survival of mosquito (Malhotra and Aruna, 1995).

2.5.6 Land Cover

Land cover, in particular vegetation has been associated with malaria transmission, because it provides suitable environment for mosquito breeding. According to Alen (2002), the type and distribution of vegetation can influence mosquito populations. The presence of vegetation creates microclimatic conditions which are moderate temperature and humidity, it is suitable for mosquitoes. Land cover can be measured directly by field observation or indirectly by satellite imagery. Satellite imagery can quantify the amount of vegetation by Normative Difference Vegetation Index (NDVI) (Yazoume *et al*, 2008). NDVI greenness values higher than normal can indicate that habitat on the ground are beneficial to vector populations increasing beyond normal levels. If this greater than normal greenness is maintained for a second and third month, conditions are likely to remain highly favorable to mosquito breeding (Michael *et al*, 2004).

2.5.7 Depth to Ground Water

Subsoil water is an important factor for the creation of stagnant water pools. Shallow ground water can result in stagnant, humid marshy areas, which encourage mosquito breeding and survival (Malhotra and Aruna, 1995).

2.5.8 Irrigation Practice

An increased area under irrigation may increase the density of malaria transmitting mosquitoes by increasing the area favorable to breeding resulting from pooling within the fields, seepage from canals, or stagnant water in the drainage. Also dry season irrigation may extend the transmission season, where the irrigation water supplied to an area is the only breeding source available (Mutuwatte, 1997).

2.5.9 Migration

Movements of people can be dangerous for malaria epidemics. People with malaria coming into an area where malaria has been under control or even eliminated from the local population can cause an epidemic. Non-immune people moving to an area of higher

transmission may also cause an epidemic since they will be more susceptible than the local population. Such movement could be migrant workers, refugees or resettlement. Refugees with substandard housing and few resources are particularly at risk (FMoH, 2009; Getachew, 2006).

2.5.10 Soil Type

Impermeable soil allows water stagnation and creates grounds for mosquito breeding and thus favors malaria. Porous soil is devoid of stagnant water bodies, hence unfavorable for Anopheline mosquito breeding (Aruna, 1995).

2.6 GIS and Remote Sensing Techniques to Monitor and Control Malaria

According to Alen (2002), before the development of GIS technology, the only way to assess human risk was manually monitor larval and adult mosquito populations. This time consuming and tiresome fieldwork has been costly and not frequently put in practice especially in countries with fewer resources.

Many researchers agree that the location and population of mosquitoes is associated with environmental factors, such as elevation, temperature, precipitation, humidity and the type and distribution of vegetation, which can influence mosquito populations. If we understand these factors and their relation to mosquito survival, and if Remote Sensing data containing these elements are available in digital format, GIS can help identify human populations at risk for disease transmission. It is clear that this approach can help to target malaria vector control much more cheaply and efficiently than older manual field methodologies.

The power of GIS is its ability to integrate and manipulate multiple layers or themes of spatial data for a large area and from different sources at different scales. The data source of GIS are paper maps, aerial photographs, satellite images, Geographical Positioning Systems (GPS) as well as censuses data, epidemiological surveys data, environmental data, health data and any other data with spatial component.

GIS characterized by the strict link between a feature's geographical position or coordinate and its attribute data. It permits dynamic link between databases & maps so that data updates are automatically reflected on the maps. It can also help to generate thematic maps, ranged colour maps or proportional symbol maps to denote intensity. In comparison with tables and

charts, maps developed using GIS are more effective means for communicating messages clearly even to those who are not familiar with the technology. GIS makes the manipulation and possible combination of several data layers from the different data sources easy and it allows the rapid display and analysis of multivariate spatial data. For this combined display layers, data have to be registered geographically to a common coordinate system. Therefore, GIS is a potentially powerful tool for epidemiology, in mapping diseases and their determinants, quantifying risk, linking diseases and their potential risk actors, and creating databases for further statistical and epidemiological analyses. For malaria research and control, GIS has great potential since it has the capacity to integrate information on all aspects of malaria including the environmental factors, infrastructure and demography. GIS has been intensively used in malaria research to examine the link between environmental factors and malaria transmission risk (Yazoume *et al*, 1988).

As malaria is a complex disease related to the interaction among parasites, vectors, human hosts and environment, it is fundamental to study these factors together to try to control it. The combination between human factors and relevant environmental information to the malaria biology might indicate a predominant epidemiologic situation, making the action of health services easier. Thus, Remote Sensing and GIS techniques can help epidemiologists to identify vector focuses. These technologies, allow them to relate disease occurrence indexes and environmental characteristics, enabling the exact observation of geographic area and the determination of how some physical factors (rivers, mountains, vegetation) can influence the spreading or controlling of the disease. Besides that, the use of these techniques can improve the ground data acquisition and information accuracy (Cintia and Evlyn, 2004).

According to Awash (2005) the national malaria control programs are now using a comprehensive GIS system

- To identify population at risk
- To assess access of communities to health care
- To target and monitor implementation of interventions, including use of insecticide treated nets and larvicides
- To monitor resistance to first line medicines
- To integrate environmental data (such as rainfall amounts and their variability) to serve as an early warning system for epidemics
- To assess the impact of irrigation and other environmental factors on transmission

Moreover potential benefits of GIS in public health are to:

- Determine the geographical distribution & variation of diseases.
- Analyze spatial & temporal trends of diseases.
- Identify gaps in immunizations.
- Map populations at risk and stratify risk factors.
- Document community health care needs and assess resource allocations.
- Forest epidemics.
- Plan and target interventions.
- Monitor diseases and interventions over time.
- Manage patient care environments, materials, supplies and human resources.
- Monitor the utilization of health centers.
- Route health workers, equipments and supplies to service locations.
- Publish health information maps on the internet.
- Locate the nearest health facility.

(Negash *et al.*, 2005; Tulu, 1993)

3. Description of the Study Area, Materials and Methods

3.1 General Description of the Study Area

3.1.1 Location

The study area is found in Sidama Zone, Ethiopian Southern Nations Nationalities and Peoples Regions (SNNPR), which is located at 311km south of Addis Ababa. Its geographical location extends from 6° 46'N and 38°04'E to 7°01'N and 38 °24'E. Before 2003 Boricha is administrated under Shebedino as one of the 77 kebeles within it. It has got its name from the nearby ridge Boricha Ridge (B.W.H.B., 2001). Boricha has an estimated area of 588.05 sq. km. Administratively the Woreda comprises 39 Kebeles of which 3 kebeles are semi-urban towns and the others are rural (figure 3.1). The woreda is labeled as malarious since the altitude falls below 2000m.a.s.l (FMoH, 2008). As far as road network is concerned, as it is indicated in figure 3.1, there are three all weather gravel roads and their total length is about 55.62km.

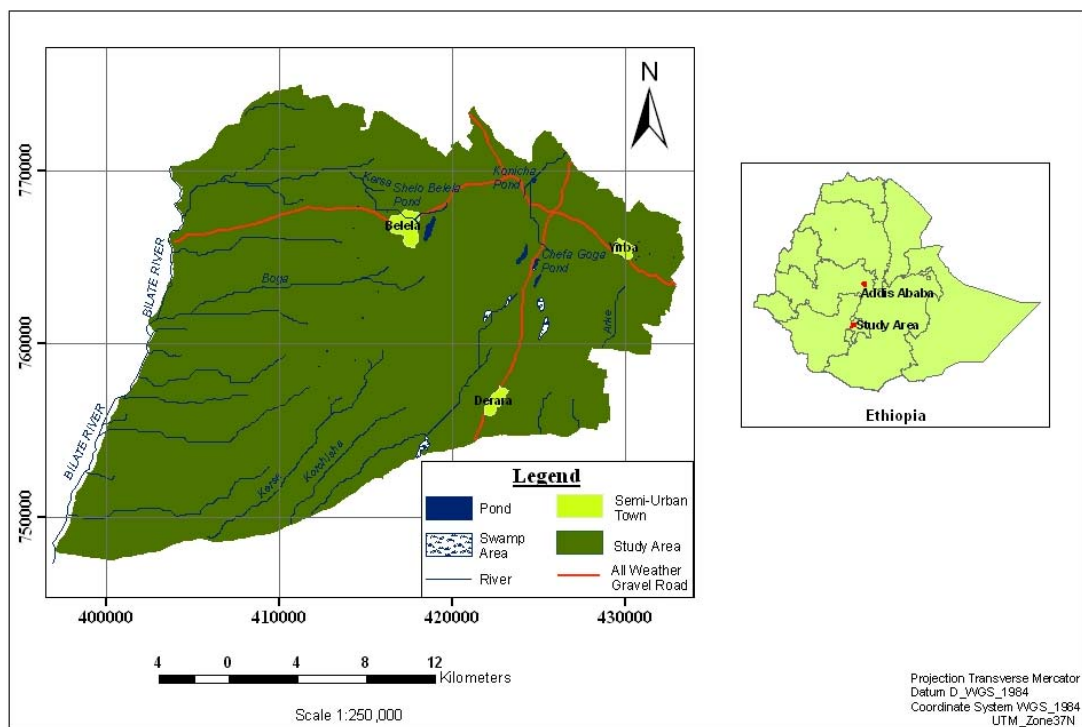


Figure 3. 1 Location of the Study Area

The drainage pattern of the study area is found in a poorly drained catchment. In some places the rain water stays for several days lying on the ground. All the rivers in this Woreda are seasonal rivers and are tributary's of Blate River. These tributary rivers are running from east to west in the Woreda. In addition, there are swamp areas and many ponds in the study area.

Most of the ponds were quarried by the dwellers in order to fight scarcity of water during the dry seasons. The dwellers use this water for drinking, household purpose and for their cattle through out the year. The swamp area dries out within a few weeks after the end of major rainy season.

3.1.2 Size and Population

Based on the information BOFED of SNNPR, Boricha Woreda has an estimated total population of 236,341 of whom 118,566 were men and 117,775 women. 225,944 or 95.6 percent of the population are estimated to be rural inhabitants, while 10,397 or 4.4 percent are urban. It has an estimated density of 401.9 people per square kilometer.

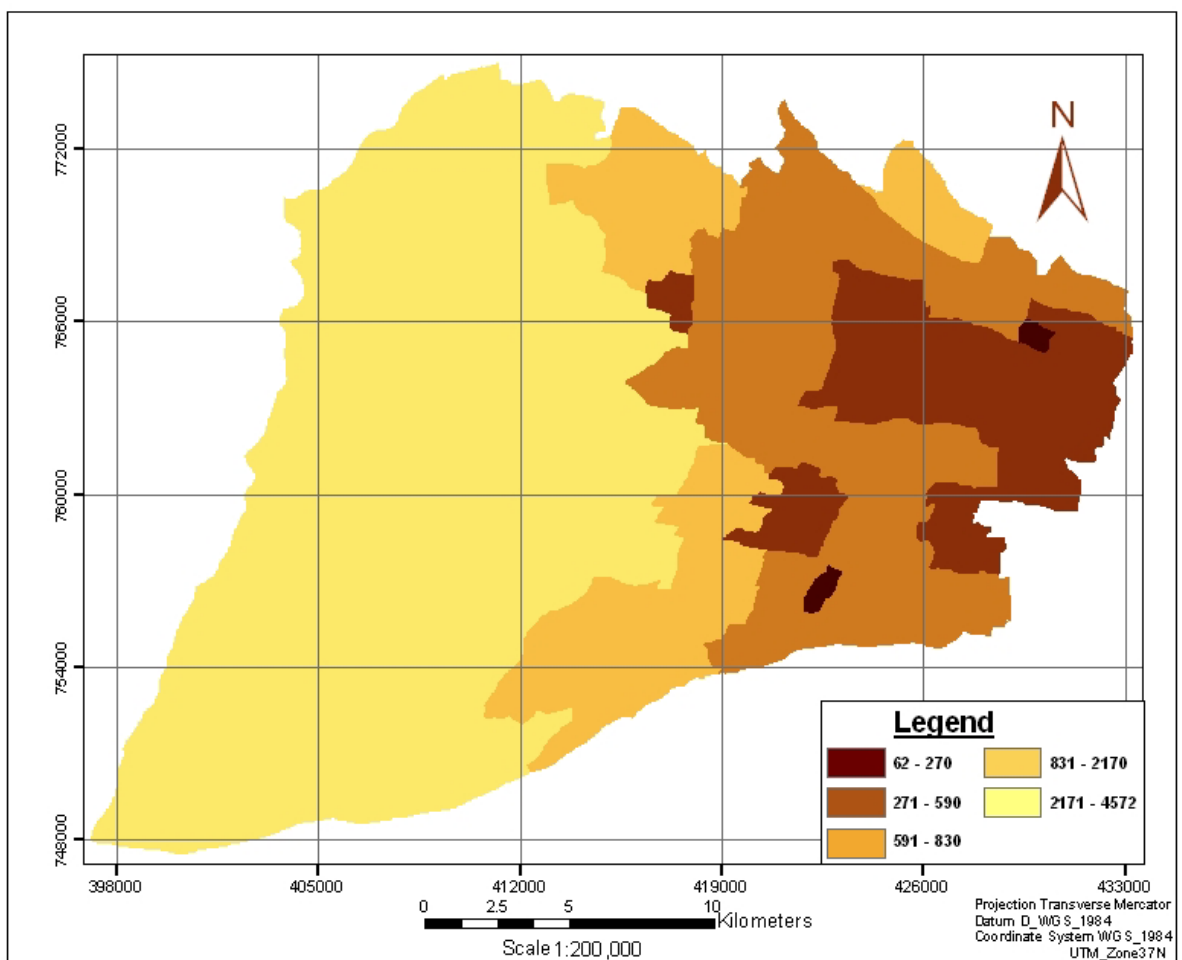


Figure 3. 2 Population Density Map

As it is indicated in figure 3.2, areas colored dark brown are areas of high population density. These areas are dense because they are areas of rural town settlement. The second dense areas are areas surrounding the rural towns. The very sparsely populated areas of the woreda are at

lower altitude where there is barren land which is highly degraded and very fragile ecosystem prevails.

3.1.3 Topography

Most of the study area is characterized by flat lying topography. As far as the altitudinal variation of the region is concerned, as it is indicated in figure 3.3, it extends from the lowest point at south west of the mouse of tributary of Bilate river 1320m.a.s.l to north east 2080m.a.s.l with some scattered ridge in between such as Boricha Ridge 2040m and Siso Ridge 2020m.a.s.l.

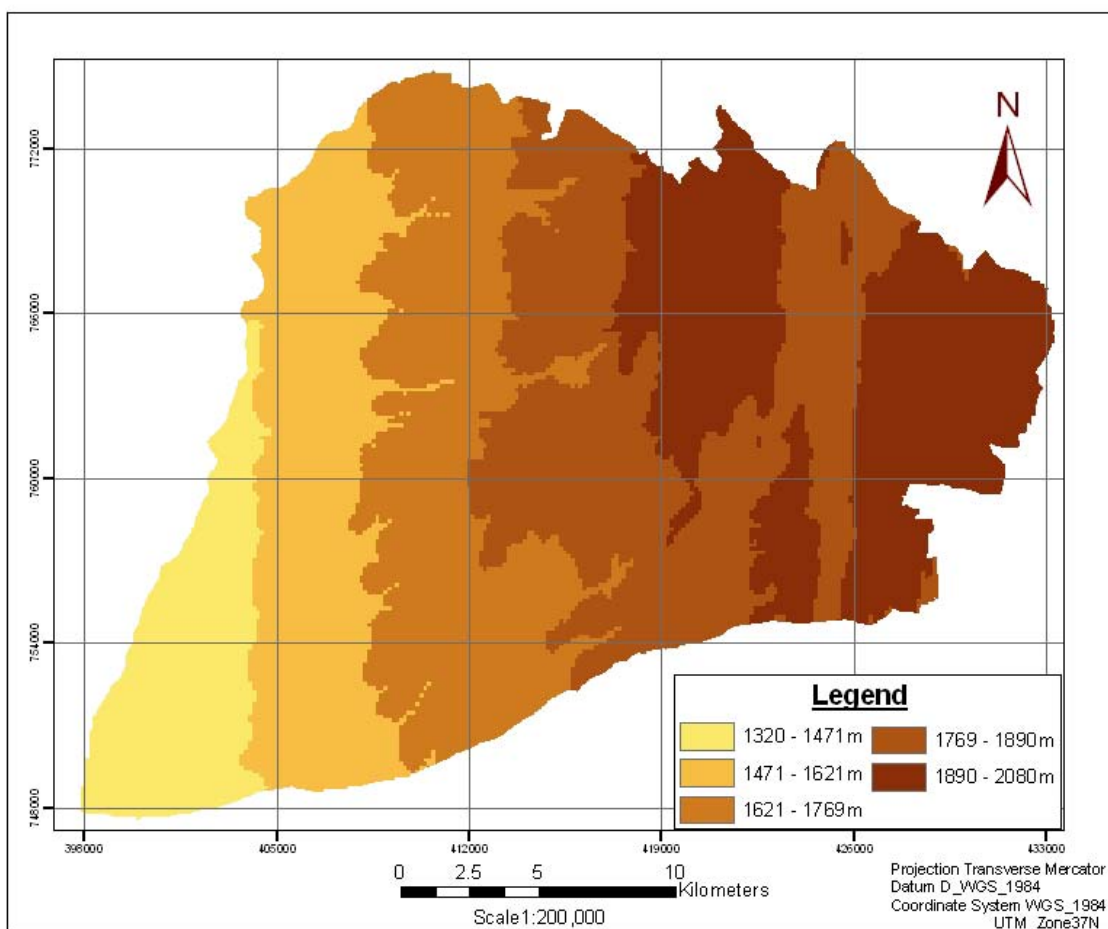


Figure 3. 3 Altitudinal Variation Map

3.1.4 Landuse/ Landcover

The main land use of the Woreda is dominated by rain fed agriculture which is owned by small holding farms. The major production of them are maize, enset, coffee, chat, potato, sweet potato, sugarcane plantations used for household consumption and also serves as the means to earning money. The towns in this woreda are rural towns thus the settlement area is

insignificant but, the farm land covered a considerable large area than others land use land cover types. Especially the areas to the lower altitude are severely degraded. Riverine trees are growth by follow the pattern of the rivers. The other dominant land use land cover type is the scattered trees. These are found mixed with farm land and planted by the dwellers. The scattered trees covers the ridge are planted by the cooperation of GOLF with the dwellers. The classification was done on Landsat ETM+ image of year 2005. It is shown in figure 3.4 with combination of bands 6, 4 and 2 and the classified land use land cover map is presented on figure 3.5.

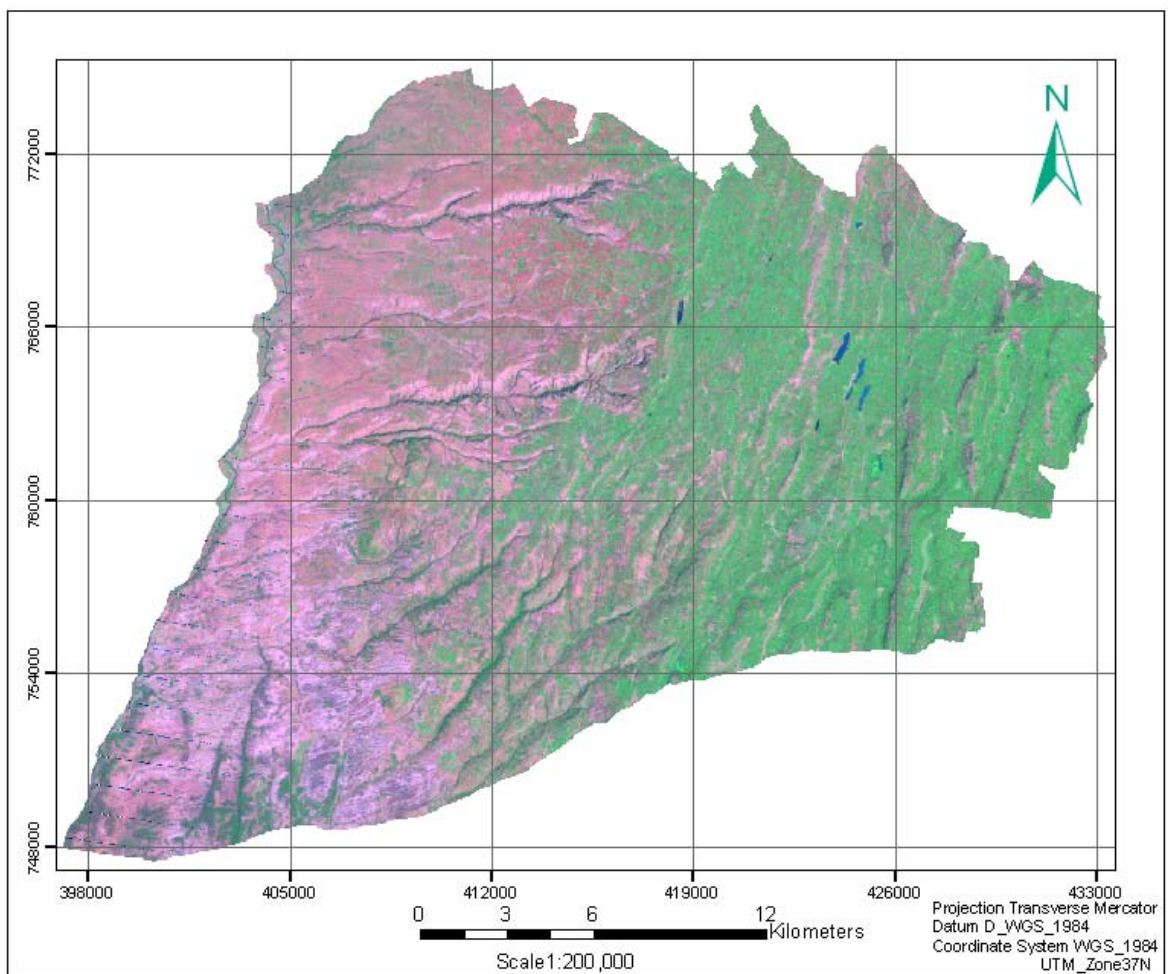


Figure 3. 4 Landsat ETM+ Image of the year 2005 at Bands 6, 4 and 2

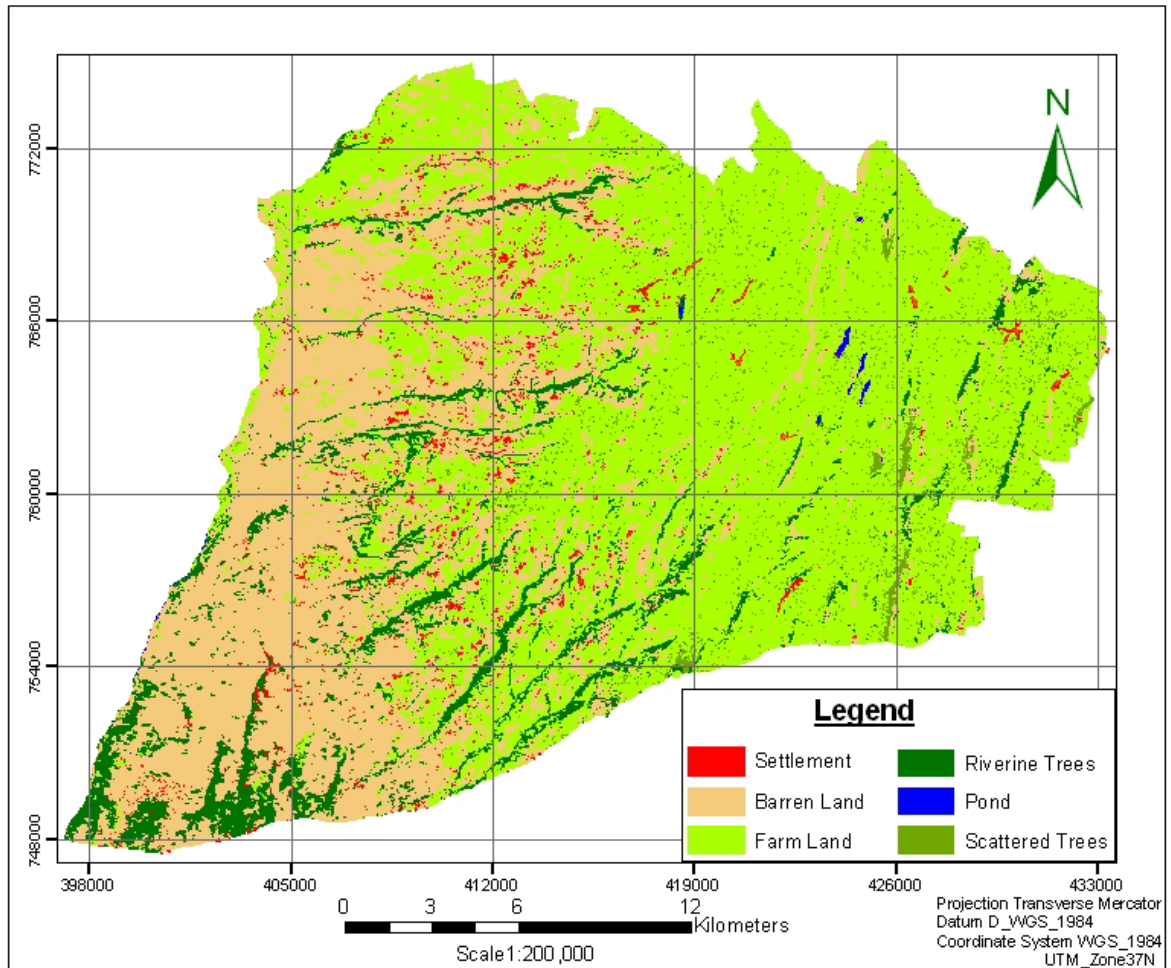


Figure 3. 5 Landuse/ Landcover Map

3.1.5 Soil

According to FAO soil classification, the study area has four types of soil, namely; chromic luvisols, lithic leptosols, eutric vertisols, humic nitosols (figure3.6). As can be seen in the figure, the Woreda is mostly covered by the chromic luvisols and eutric vertisols.

3.1.5.1 Luvisols

Most Luvisols have good agricultural potentialities. In soils with a heavy textured B horizon, permeability might be low, and drainage and good root distribution can be hindered.

3.1.5.2 Nitosols

Nitosols are deep, clay red soils with an argillic B horizon. They have rather good potentialities for agriculture. These soils have very good physical properties. They have a uniform profile, are porous, have a stable structure and a deep rooting volume. Their moisture storage capacity is high.

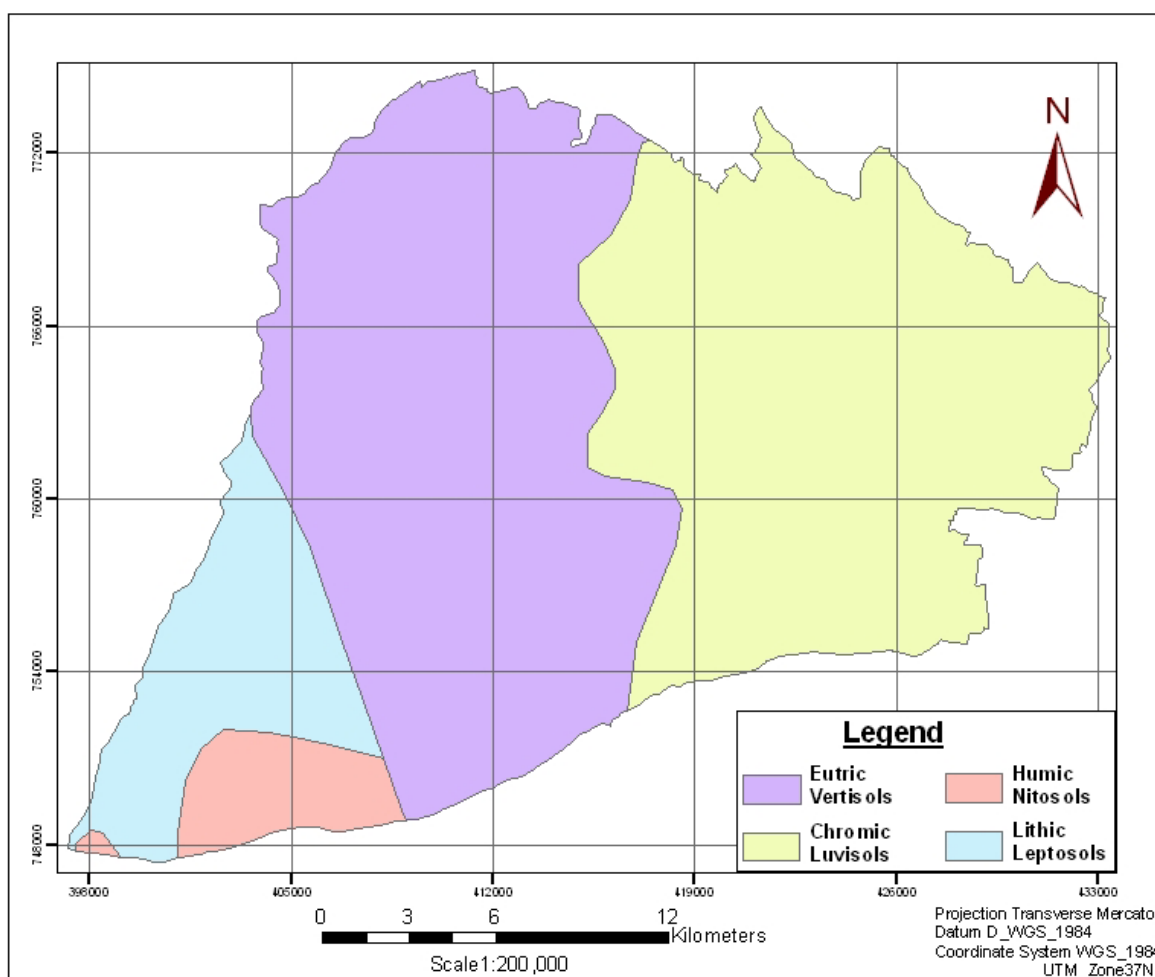


Figure 3. 6 Soil Map

3.1.5.3 Vertisols

Vertisols are heavy clay soils in flat areas. During dry season they shrink and have deep cracks in a polygonal pattern, but on the contrary during the wet season the clay swells and causes pressure in the sub-soil. Chromic vertisols are brownish and better drained. But, in general, vertisols have fairly good, but limited agricultural potentialities. Land preparation is difficult, dry soils are hard and wet soils are sticky. The moisture condition of the surface layer is only during for a short period favorable to prepare land. Another difficulty is that the permeability of the subsoil is very low. Very often these soils are flooded or have stagnant water during the rainy season. The soil has high water retention, but relatively a small amount of water is available for plant growth. Rooting depth might be restricted because of the swelling and shrinking properties of the soil.

3.1.5.4 Leptosols

Leptosols are very shallow its thickness is around 10cm. These types of soils are found on hard rocks or where erosion exceeding soil formation. Leptosols are unattractive soils for agriculture.

3.1.6 Major Climatic Variables (Temperature and Rainfall)

Climate features such as rainfall, humidity, and temperature have a direct influence on the propagation of mosquitoes and their survival. Malaria requires an intermediate living agent for their transmission. Their epidemiology is influenced by attributes of their vectors, which in turn are closely linked to environmental factors such as topography, temperature, rainfall, land-use, population movements, and degree of deforestation have a profound influence on the temporal and spatial distribution of malaria vectors and malaria. 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 vary as a function of altitude (FMoH, 2009).

Concerning the monthly average temperature of the study area, it varies between 21.93°C in July and 25.36°C in February (table 3.1). And the rainfall pattern of the study area, according to table 3.2 varies from 27.82mm mean minimum rainfall in December to the mean maximum rainfall 128.58mm in October.

Table 3. 1 Monthly Average Temperature in °C at Bilate station (1996-2009)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
24.61	25.36	25.14	24.15	23.17	22.47	21.93	22.24	22.65	22.84	23.00	23.89

Table 3. 2 Monthly Average Rainfalls in mm at Yirba Dibancho and Belela Stations (1996-2009)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
35.9	34.88	87.3	126.94	131.03	92.03	92.26	105.72	127.96	128.58	38.2	27.82

3.2 Data Used for the Analysis

For this study, both primary and secondary data were used and their sources are described in the following table.

Table 3. 3 Data and Their Sources

Data	Sources	Remarks
Map of the study area	BOFED	Shape File
Population data	BOFED	Shape File
Malaria patients data	Boricha Woreda Healthy Bureau	6 Years Data
GPS data	Collected from field	
Topographic maps	EMA	Scale 1 : 50,000
Satellite rainfall data	Famine Early Warning System Network	6 Years Data
Satellite images	GIS lab and EMA	2005 p168 r55, 2006
Meteorological data	National Meteorology Agency	14 Years Data

3.3 Software and Hardware Utility

The following table shows the soft wares and hard wares utilized during the various stages of the study.

Table 3. 4 Software and Hardware to be Used for the Study

Type	Name	Utility
Software	ERDAS IMAGIN 9.1	Image processing and data analysis
	ArcGIS 9.2	Data base creation, land use/cover, contour, overlay analysis, map preparation
	MS Office	Documentation, statistical analysis and presentation
	IDRISI	Multi Criteria Evaluation (MCE)
Hardware	Computer (RAM 1GB)	For storage, software and internet support

3.4 Methodology

The main aim of this study is to identify and categorize the malaria risk areas of Boricha Woreda. To map malaria hazard some environmental factors were selected by consulting a malaria expert and depending on related previous works and reports including FMOH (2004, 2009). These factors include temperature, rainfall, elevation (altitude), slope, soil, distance from swamp areas, and distance from rivers. The malaria hazard areas mapping is done using Multi Criteria Evaluation (MCE) by reclassifying all the above factors and giving weight. To

conduct this MCE, in IDRISI software the selected factors are weighted according their suitability for the vector mosquito and the prevalence of malaria. And then the overlay analysis is carried out using ArcGIS 9.2 spatial analyst tool. The result of these gives us the malaria hazard map (figure 3.7). The main output of this study is the malaria risk map. The basis for this map is the risk computation model which is developed by Shook (1999).

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

$$R = H * E * V$$

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

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

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

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

The malaria risk map (Figure 3.8) was produced from malaria hazard layer, computing and reclassifying the population density map which is the element at risk layer and vulnerability map that is produced by reclassifying land use/land cover layer and distance from ponds. The other out put is the graphs show the trend of malaria cases who are attending healthy centers versus rainfall and temperature.

3.4.1 Analysis Flow Chart

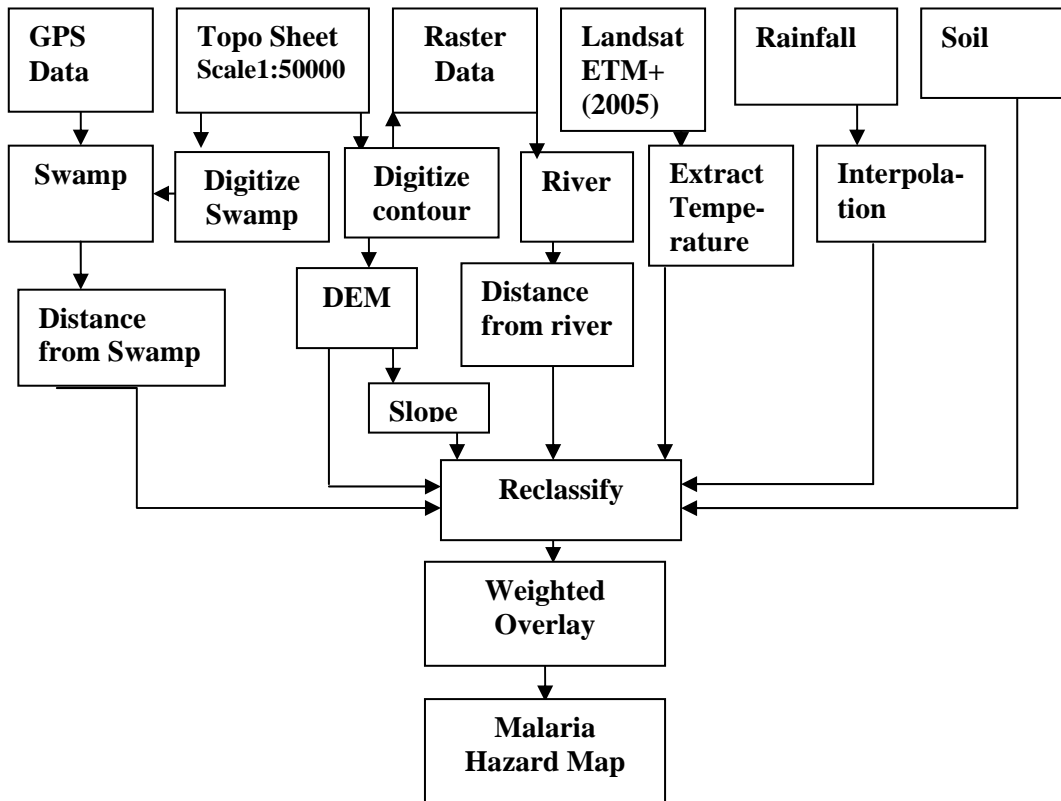


Figure 3. 7 Schematic Representations of Malaria Hazard Analysis

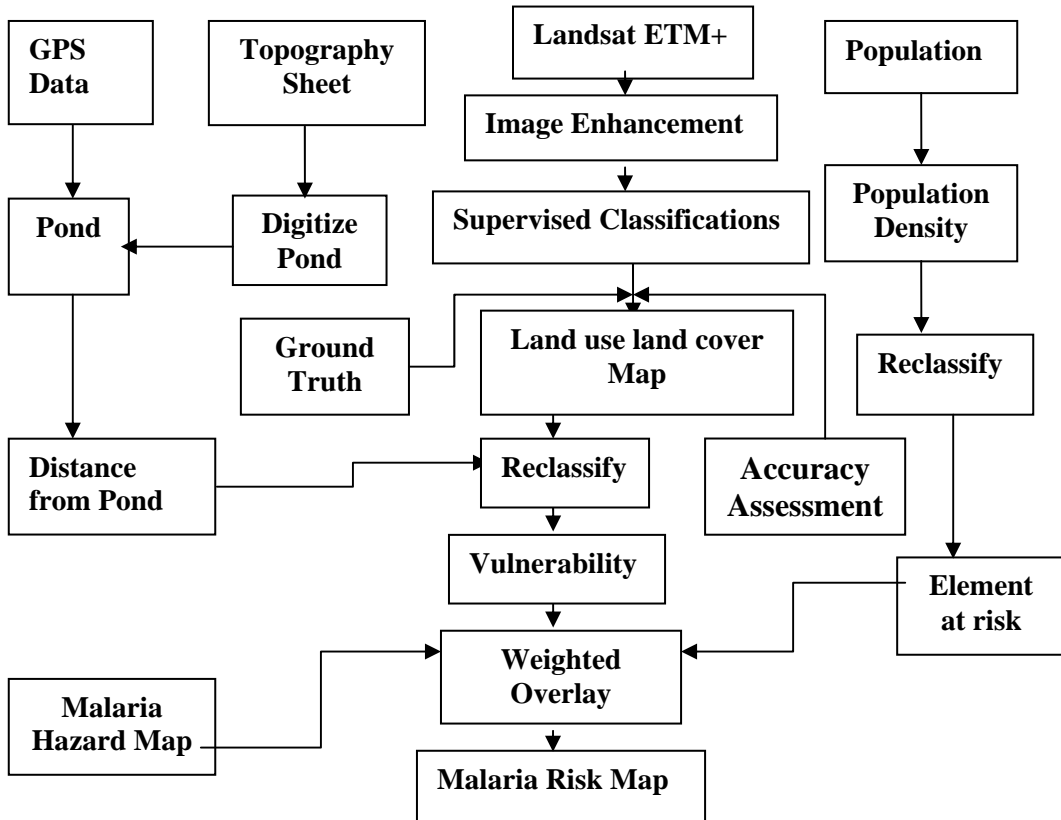


Figure 3. 8 Schematic Representations of Malaria Risk Analysis

3.5 Data Analysis

3.5.1 Parameters for Identifying Malaria Hazard Areas

Several studies have shown that malaria infection is influenced by environmental and climatic features such as topography, temperature, rainfall, land-use, population movements, and degree of deforestation have a profound influence on the temporal and spatial distribution of malaria vectors and malaria. Specifically, temperature and rainfall act as limiting factors on the development of *An. 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 vary as a function of altitude (FMoH, 2009).

The assessment of vulnerability risk indicators is identification of areas at highest risk of malaria epidemics based on regular monitoring of climatic and non climatic factors and the incidence of previous malaria epidemics. Since vulnerability is not static due to changes in risk factors over time, regular monitoring of the following risk indicators is of great importance. These include increase and spread of drug resistance, migration of non-immune populations to high malaria endemic areas such as resettlement programmes, migration of labour forces or displaced population due to war or civil unrest and environmental changes that increases the risk of transmission such as construction of dams, agricultural projects, and flooding or drying out along river margins

3.5.1.1 Temperature

The development of the parasite within the mosquito as well as the life cycle of the vector depends on temperature. The rapid decrease of the sporogonic cycle length is observed with increase in temperature. The number of mosquitoes surviving the sporogonic cycle show a bell shaped relationship with temperature. At low temperatures the vector needs to survive long enough for the sporogonic cycle to take place and at high temperature the mosquitoes survive less (Yazoume *et al*, 2008). However, the temperature should be combined with the availability of rainfall for this to be flourishing.

Studies have indicated that *P. falciparum* cannot be transmitted when the average daily temperature is below 18°C; likewise *P. vivax* transmission is usually impossible if the average

daily temperature is below 16°C. An average daily temperature of above 30°C is lethal to the sporogonic stages of the parasite within the mosquito vector. An average daily temperature of above 30°C is also unfavorable to the vectors, as adult longevity may be reduced especially in arid environment (FMoH, 2004).

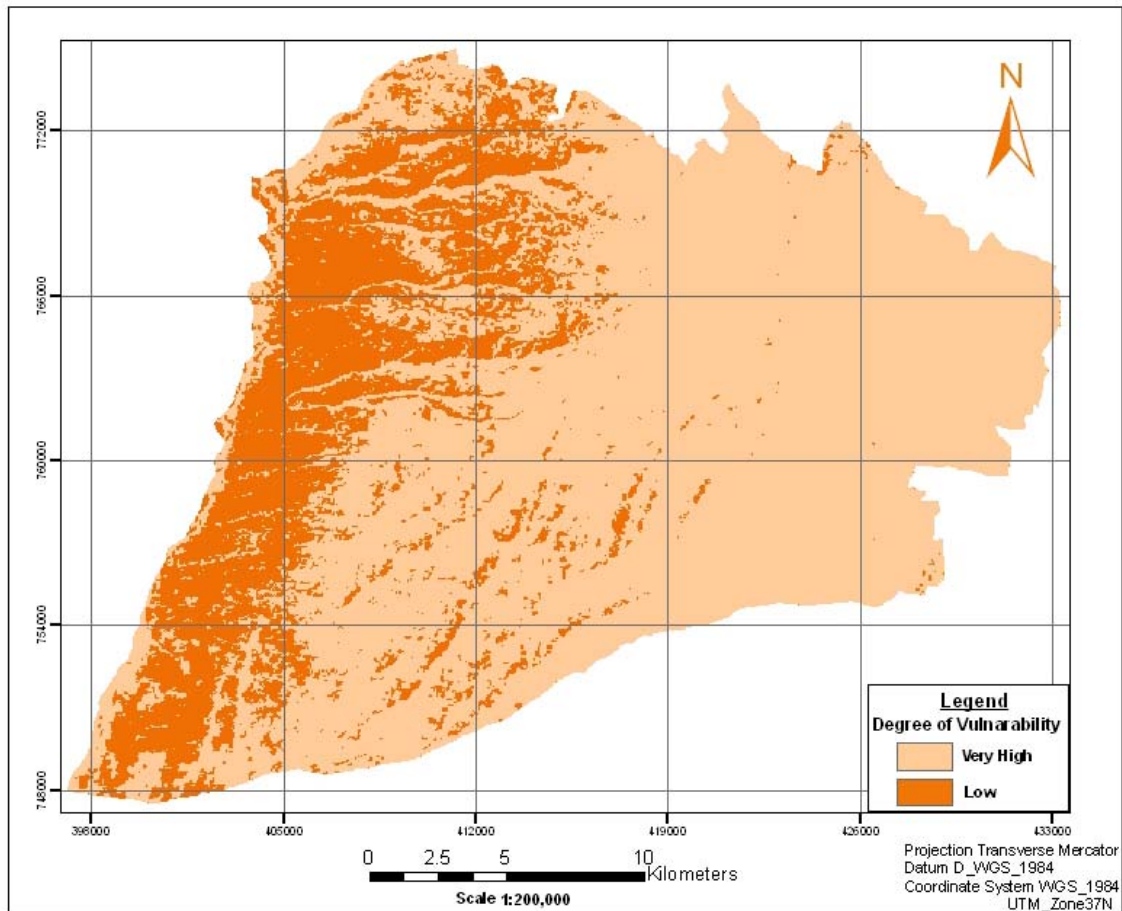


Figure 3. 9 Reclassified Temperature Map

The land surface temperature of the study area was estimated from LANDSAT ETM+ image of year 2005 thermal band by using different models. The first model is used a radiative transfer equation to correct the at-sensor radiance to surface radiance, followed by an emissivity model used for conversion of radiance to temperature. This model separates the surface radiance into temperature and emissivity. But the emissivity of a surface is controlled by such factors as water content, chemical composition, structure, and roughness. There are different techniques use to estimate emissivities for ground object such as the NDVI method. To implement this NDVI model was used. Then use another model to calculate surface kinetic temperature. Lastly I use conversion model to convert degree Kelvin to degree Celsius. The surface temperature layer used to this study is the output of the last

model. This layer was reclassified based on the most conducive temperature limit for malaria multiplication FMOH (2009). The layer was reclassified in to two classes and new values were assigned to each class and based on this classification, 5 and 1 values were given to the area with temperature below 30⁰C above 30⁰C, respectively. Hence, the classes were labeled in the figure 3.11 as very high, and low based on the level of vulnerability of those areas to malaria incidence.

3.5.1.2 Rainfall

According to many research works in many malaria areas the peak of transmission is known to follow the rainy season and the length of transmission may be determined, among other things, by the balance between precipitation and evaporation. When there is a continuous and heavy rainfall, most water collections are disturbed and thus mosquito breeding is unfavorable during the rainy period since excessive rains cause flushing, thus killing immature stages. However, as soon as the frequency and intensity of rainfall decreases, it is likely that numerous favorable mosquito-breeding sites will be created. In addition, it affects malaria transmission through increasing humidity, which in turn will help to increase the longevity of the adult vectors (FMOH, 2004).

A study conducted in Southern Sri Lanka show that, malaria cases were mapped for the smallest administrative Division, Grama Niladhari. One of the variables used in this study is rainfall data. Its grids were interpolated based on rainfall point data from rainfall stations and covering the whole Division using kriging technique and aggregate with other variables in geographical information system (Eveline *et al*, 2003).

The rainfall data of the study area was collected from NMA. It includes nine stations two of them are found in the Boricha Woreda and the other stations are found in the surrounding Woredas and the layer was created by Inverse Distance Weight (IDW). The layer was reclassified based on the favorable amount of rainfall extent for the prevalence of malaria at different altitudes given by FMOH (2009). It was reclassified in to two classes and new values were assigned to each class and based on this classification, 5 and 4 values were given to the mean annual rainfall above 800mm and below 800mm, respectively. Hence, the classes were labeled in the figure 3.10 as very high, and high based on the level of vulnerability of those areas to malaria incidence.

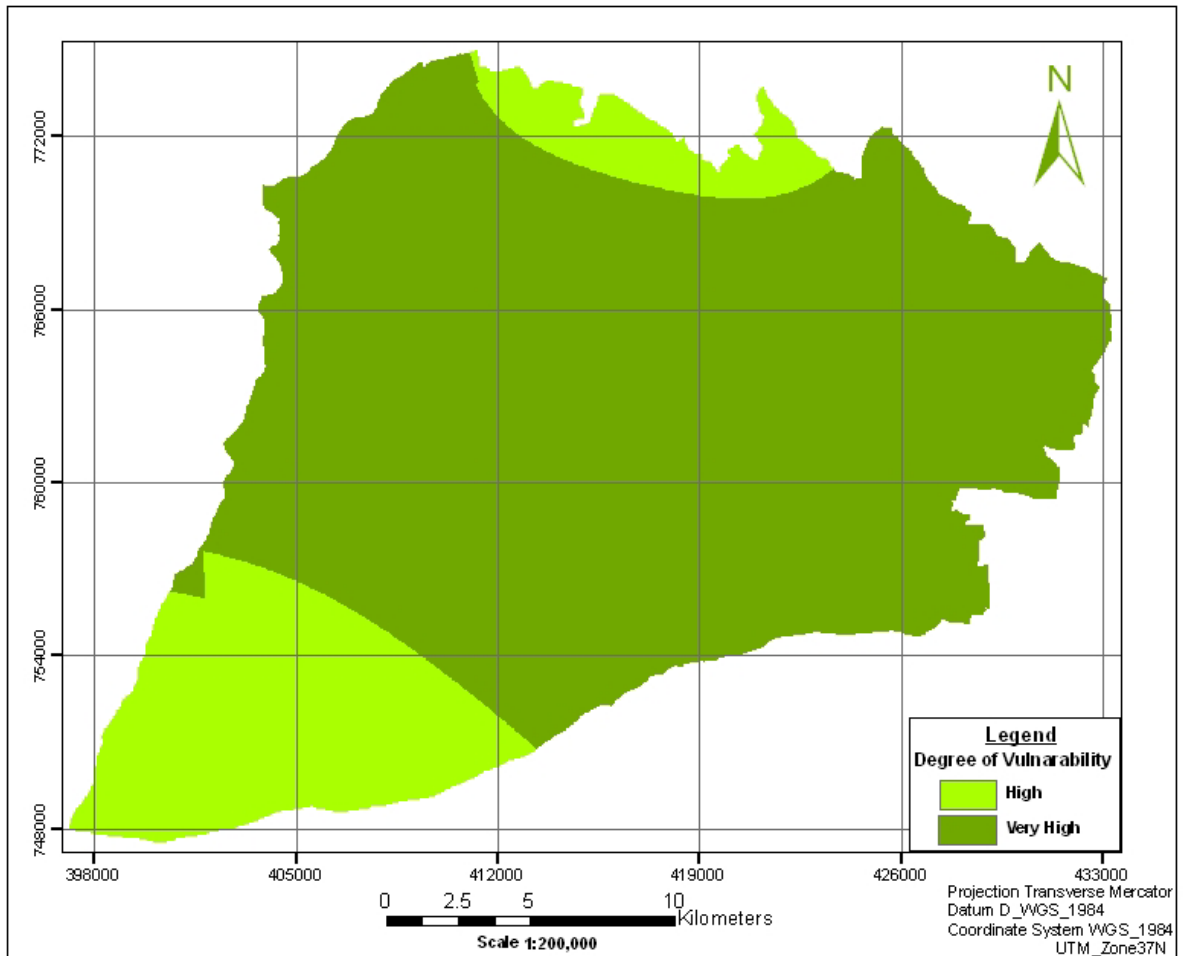


Figure 3. 10 Reclassified Rainfall Map

3.5.1.3 Altitude

Elevation above mean sea level is known to define the ecology of malaria transmission through temperature. At certain altitudes malaria transmission does not occur because of extreme temperatures that inhibit the mosquito and parasite life cycle (Lawrence *et al*, 2006).

The elevation layer of the study area was derived from digitized contour. This contour was digitized from scale 1: 50,000 topography sheet of the study area which was prepared by Ethiopian Mapping Agency. The elevation layer was reclassified based on the extent of malaria prevalence at different altitudes given by FMOH(2008). The layer was reclassified in to two classes and new values were assigned to each class based on this classification as 5 and 3. The values were given to elevation below 2000m.a.s.l, and above 2000m.a.s.l. respectively and the classes were labeled in the figure 3.11 as very high, and moderate based on the level of vulnerability of those areas to malaria incidence.

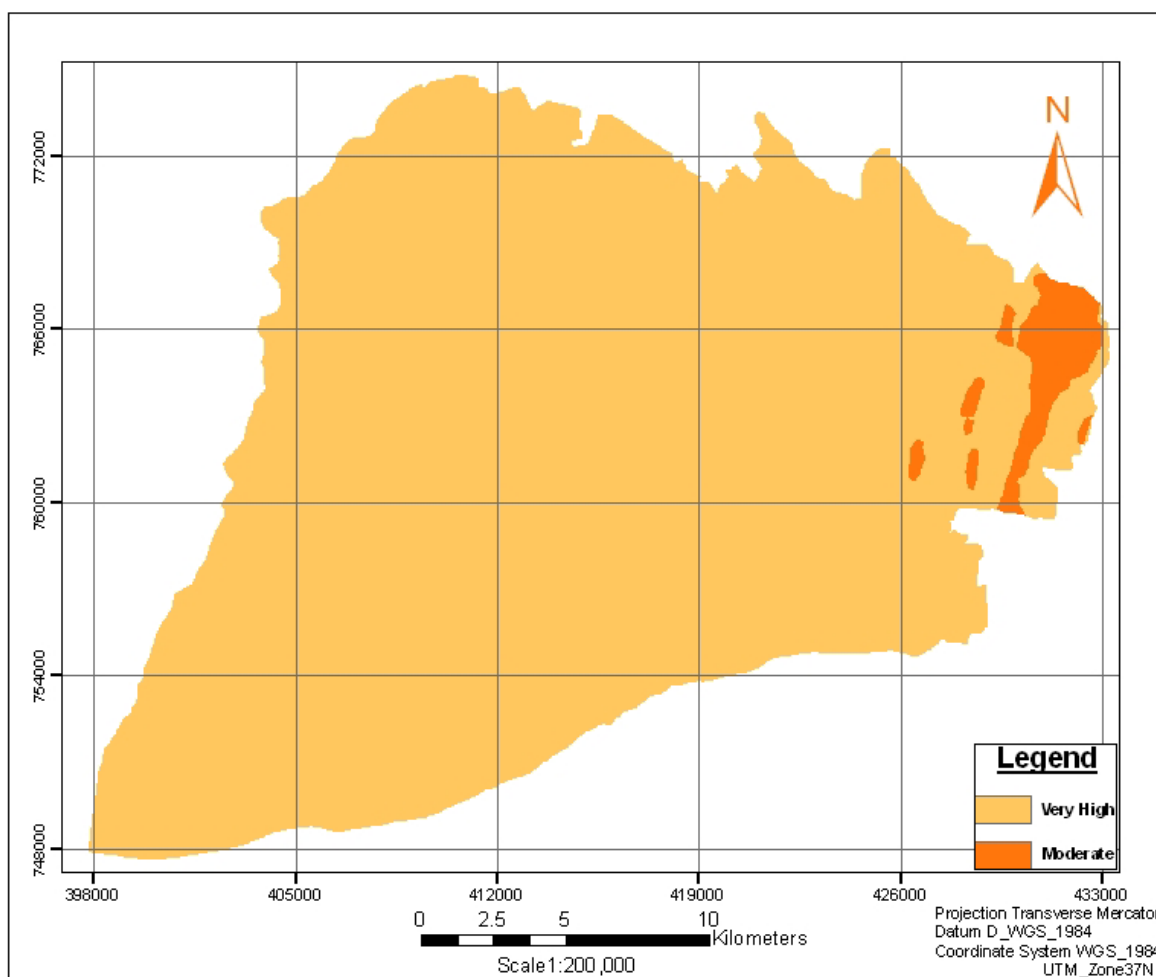


Figure 3. 11 Reclassified Elevation Map

3.5.1.4 Slope

The slope was used as a crucial factor of water stagnates. This is because in areas with low slopes, water tends to be dammed, this condition aggravated by the physical soil properties which are lodged or impermeable. The slope layer of the study area was derived from digitized contour. This contour was digitized from scale 1: 50,000 topography sheet of the study area which was prepared by Ethiopian Mapping Agency. This layer was classified according to FAO classification and reclassified in to three classes. The new values were assigned to each class based on this classification as 5, 3 and 1. The values were given to slope was below 8percent, 8percent-15percent and above 15percent, respectively and the classes were labeled in the figure 3.12 as very high, moderate, and low based on the level of inclination.

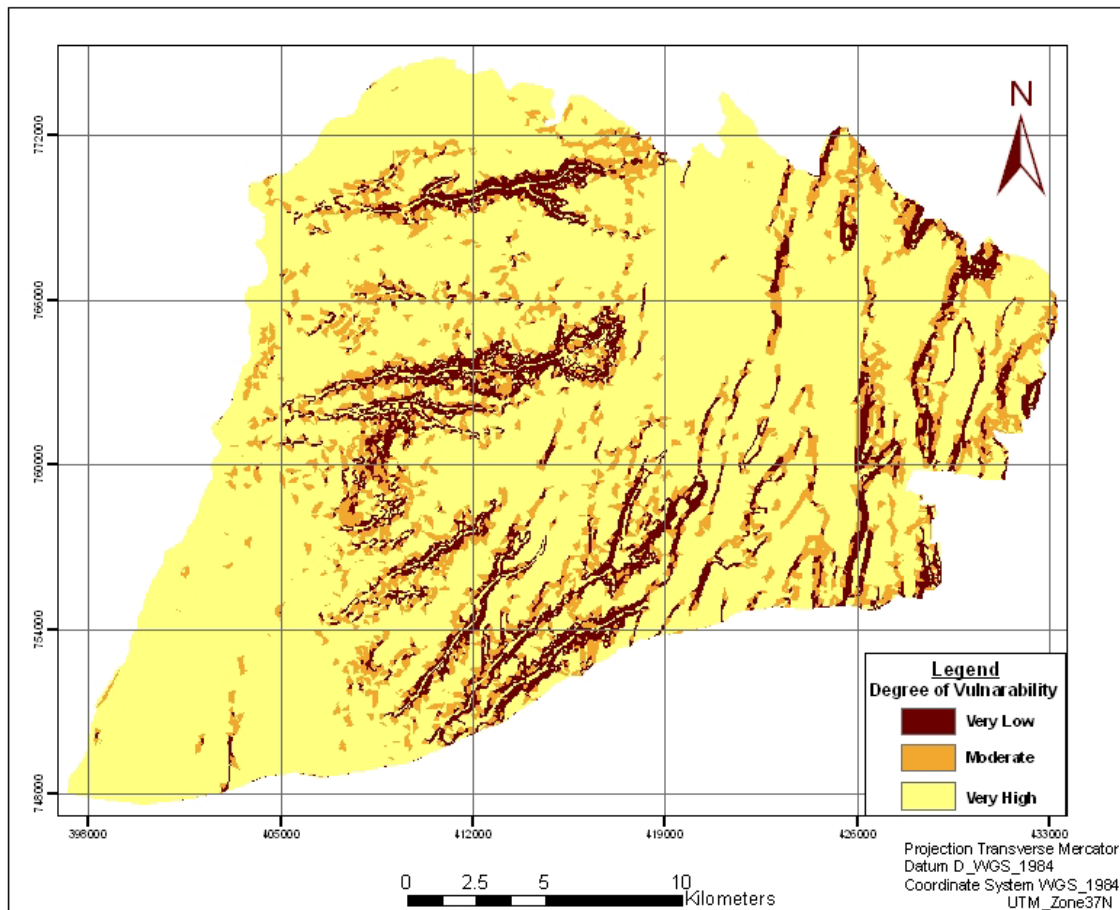


Figure 3. 12 Reclassified Slope Map

3.5.1.5 Distance from Ponds and Swamp Areas

Researchers at the NASA Ames Research Center, the University of California at Davis and the Mexican Ministry of Health, have used a combination of Remote Sensing and GIS software to characterize the landscape in and around villages in southern Mexico. Comparing these landscape characteristics to local mosquito abundance data, they found that villages surrounded by more transitional swamp and unmanaged pasture support greater numbers of Anopheline mosquitoes (Jeffrey, 2005).

In the study area there is shortage of water. In order to fight this condition the dwellers practice water harvesting system. So most of the villages have ponds and the water was gathered from rain water. In attempt to fight famine in the area, the village ponds were some are deepened and most of the harvested water is open air can access easily by the mosquito. While this has created a year round supply of water, it has also created a high local humidity level which is conducive to heavy vector breeding. This situation facilitates the continuous

availability of surface water where vectors can breed without restraint. If mosquitoes have enough food source around the breeding sites, the resulting adults may live longer and allow malaria parasites to complete their developmental cycle inside the mosquito so that they can be passed on to another host. Therefore, the presence of ponds allows year round transmission of the disease malaria in the study area. There are also swamp areas in the concerned Woreda. The swamp areas are dry out within a few weeks to more than a month after the end of major rainy season. But before drying, these areas can be used as a seasonal breeding site for the vector mosquito. This can be the reason for the increase in number of patient after major rainy season.

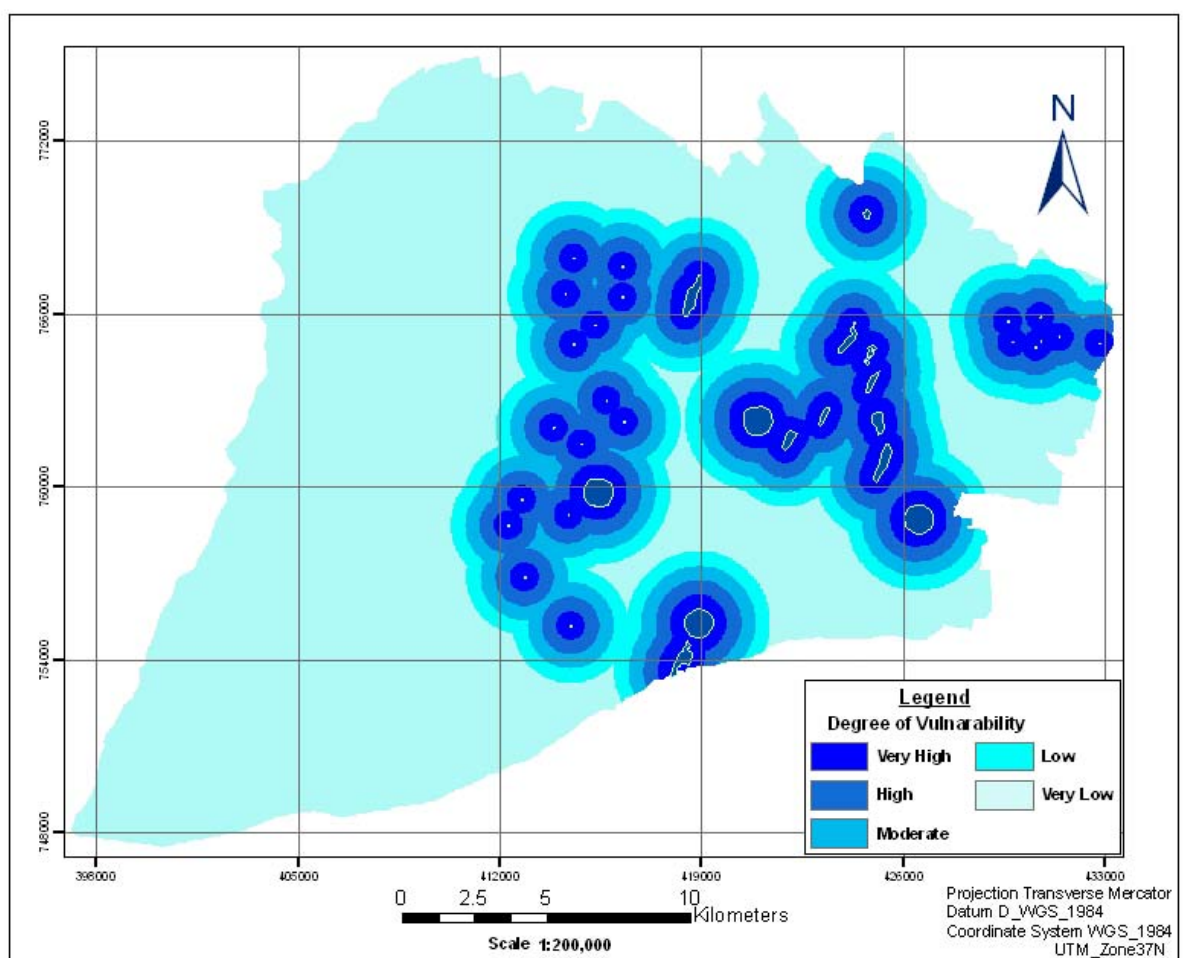


Figure 3. 13 Reclassified Pond and Swamp Map

The pond and the swamp layer were extracted from topographic and land use land cover map of the study area and from the field data. Then, distance calculation and reclassification was done on the layer in GIS environment. The maximum flight range of the vector mosquito can be considered to be 2 km (Wim *et al*, 2003). The reclassification class was assign according to mosquitoes flying distance. Areas found within the two kilometer distance was reclassified

in two five classes. Thus, new values were assigned as 5, 4, 3, 2, and 1 in order to show the relative susceptibility of the class ranges of 0-500m, 500-1000m, 1000m-1500m, 1500m-2000m and > 2000m which is reassigned as very high, high, moderate, low, and very low susceptibility to malaria respectively (figure 3.13).

3.5.1.6 Distance from Rivers

Study in Sri Lanka, shows that, the major malaria vector mosquito breeds in pools formed in streams and river beds and it is likely that people living close to such breeding sites are at higher risk of malaria than people living further away, this condition aggravated if the house was poorly constructed and provided easy access to mosquitoes (Wim *et al*, 2003). As we all know, the housing condition of rural Ethiopia is not much secured, easily accessed by the mosquito vector. The rivers in the study area are seasonal therefore; there is a tendency to create innumerable sites for malaria vector breeding after the end of rainy season. This condition can result by the occurrence of abundance of mosquitoes found around rivers where there are still waters.

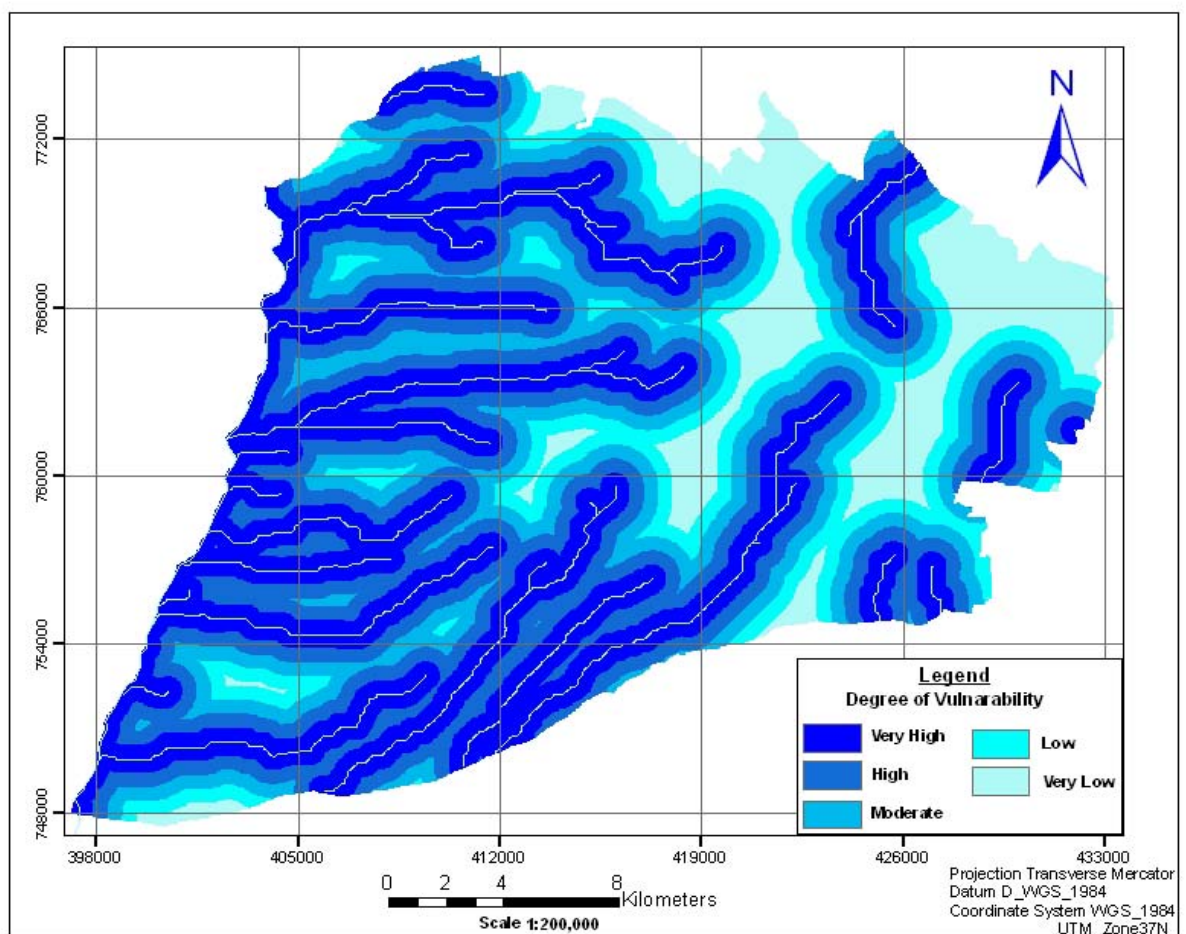


Figure 3. 14 Reclassified River Map

The river network of the study area was derived from the digitized contour. Distance was computed from every river and reclassified in the same fashion with the pond and swamp layer. Hence, new values were assigned as 5, 4, 3, 2, and 1 in order to show the relative vulnerability of the classes ranges of 0-500m, 500-1000m, 1000m-1500m, 1500m-2000m and > 2000m which is reassigned as very high, high, moderate, low, and very low susceptibility to malaria respectively (figure 3.14).

3.5.1.7 Soil

The study conducted in India with the title of mapping malaria, considering the close association of vector biology with ecological parameters, rainfall, soil, altitude and temperature were taken in the study to map areas of occurrence of the vector mosquito. In this study the soil is classified as impermeable and permeable. Impermeable soil allows water stagnation and creates grounds for mosquito breeding and thus favors malaria. Porous soil is devoid of stagnant water bodies; hence unfavorable condition is created for Anopheline breeding (Aruna, 1995).

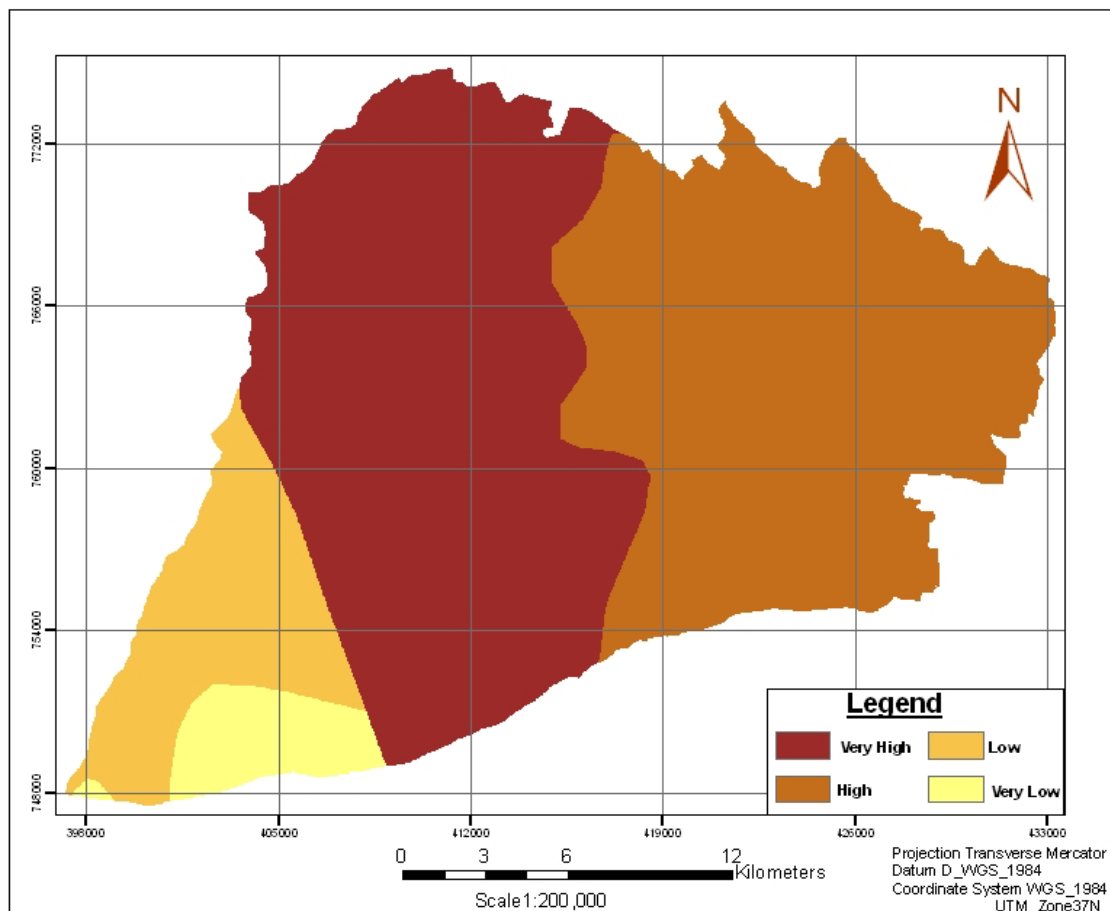


Figure 3. 15 Reclassified Soil Map

The soil layer of the study area is classified according to their degree of permeability. As shown in figure 3.15 the new values were assigned to eutric vertisols, chromic luvisols, lithic leptosols, humic nitosols as 5, 4, 2, and 1 respectively in order to show the relative permeability of the soil.

3.5.1.8 Land Use Land Cover

Land use land cover of an area play an important role in the abundance of malaria insect differs in space and time. This variability is influenced by environmental conditions, such as deforestation, which is ultimately a land use and land cover change process, detectable by orbital sensors systems (Malhotra and Aruna, 1995). The type of land use land cover especially type of vegetation which surrounds the breeding sites basically supply sugar feeding for adult mosquitoes, and provided ideal sites for resting and protection from climatic conditions this enhancing longevity of the vectors.

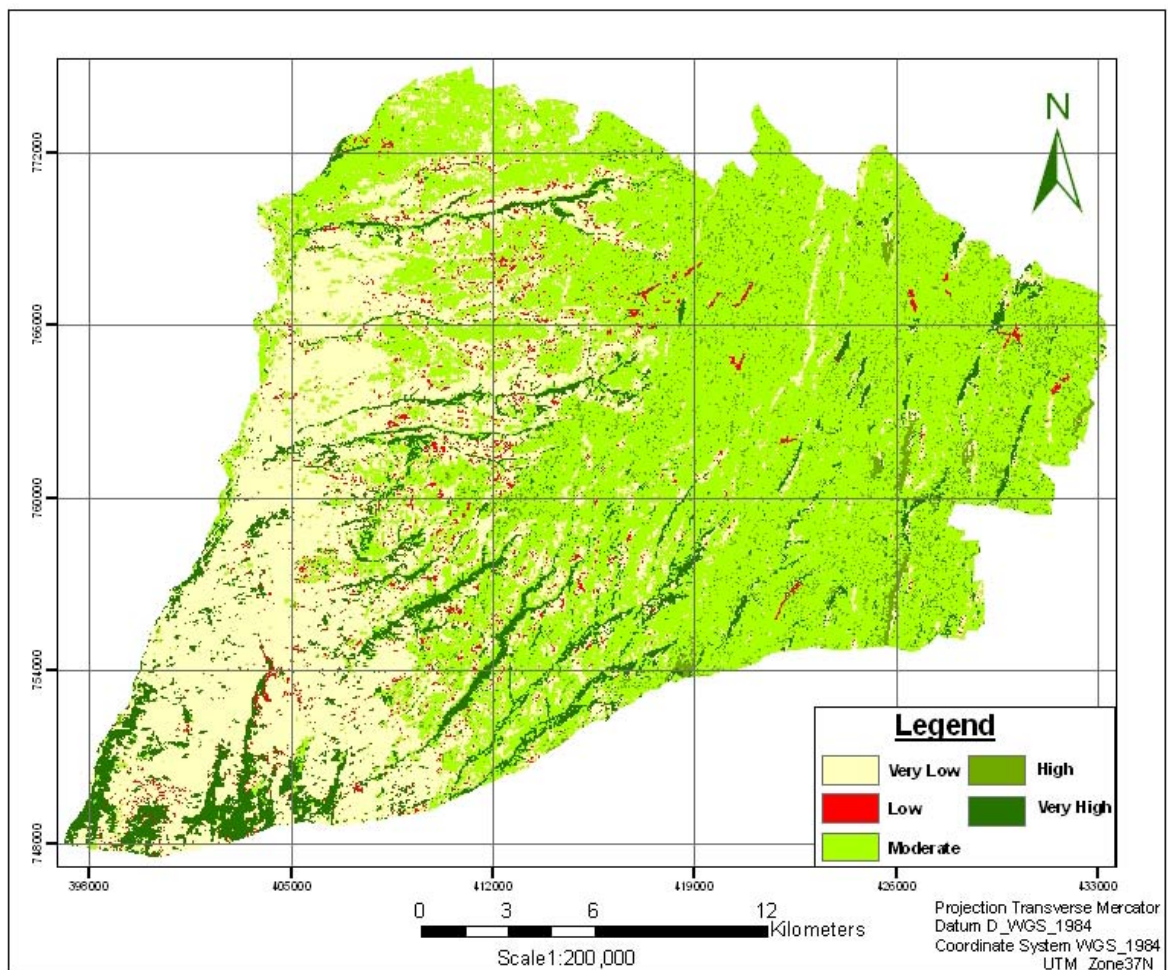


Figure 3. 16 Reclassified Land use Land Cover Map

To identify the land use and land cover of the study area, Landsat ETM+ satellite image of the year 2005 was classified using a supervised classification method. The GPS reading that was collected from field used as ground truth in the classification process. In addition to this the accuracy assessment was performed for the classification. The assessment was resulted as an overall accuracy of 91.11 percent and overall kappa coefficient of 0.8535 was achieved. All classes have higher producer and user accuracy (Appendix I). In addition to the inspection of field, topography map of the study area were used as collateral information. As shown in figure 3.16 a total of six classes were identified by this classification that is pond, settlement, farmland, bare land, scattered trees and riverine tree. This layer was reclassified in to five classes based on the order of susceptibility to be suitable breeding site, source of food and use as a shelter from climatic condition for the vector mosquito. Thus, the new values were assigned to each class based on this classification as 5, 4, 3, 2 and 1. The value 5 is assigned to pond and riverine tree which is highly prone land use land cover type for the vector mosquito, 4 for scattered trees, 3 for farm land, 2 for settlement and 1 for bare land.

3.5.1.9 Population Density

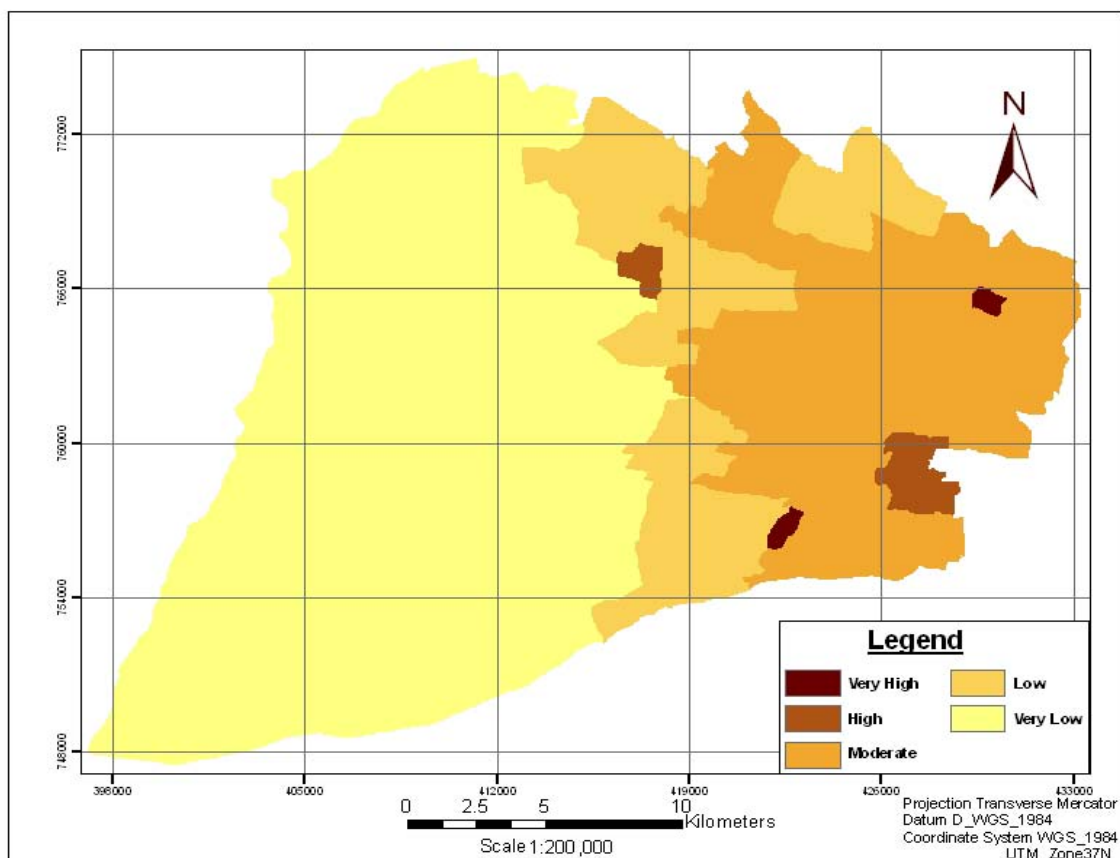


Figure 3. 17 Reclassified Population Density Map

To map population at risk of malaria, population density of each kebele was computed. 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 5, 4, 3, 2, and 1. The value 5 is assigned to the denser kebele and the value 1 was assigned to less dense kebele. The in between values were assigned in their order respectively in figure 3.17.

4. Results and Discussion

4.1 Malaria Cases versus Temperature

Temperature affects their rate of multiplication in the insect mosquito. In turn, this affects the rate at which the salivary secretions become infected, and thus the likelihood of successful transmission to another host. If the development time of the pathogen exceeds the life span of the insect, transmission cannot occur. It is the complex interplay of all these factors that determines the overall effect of climate on the local prevalence of mosquito borne diseases (Diriba, 2008).

As shown in figure 4.1, there is a positive relationship between malaria case (patients came to the health facilities in the woreda and confirmed that they are positive to malaria with laboratory tests) and temperature in March, May and the months between July and October. The negative relationship was seen in February, April, June, and the months between November to February. When the temperature reaches its maximum and minimum reading the malaria case is show almost its minimum number. When the temperature reading is in between the two extremes the malaria case reached its maximum number. This shows that the temperature is not the only determinant factor for the incidence of malaria epidemics in the study area.

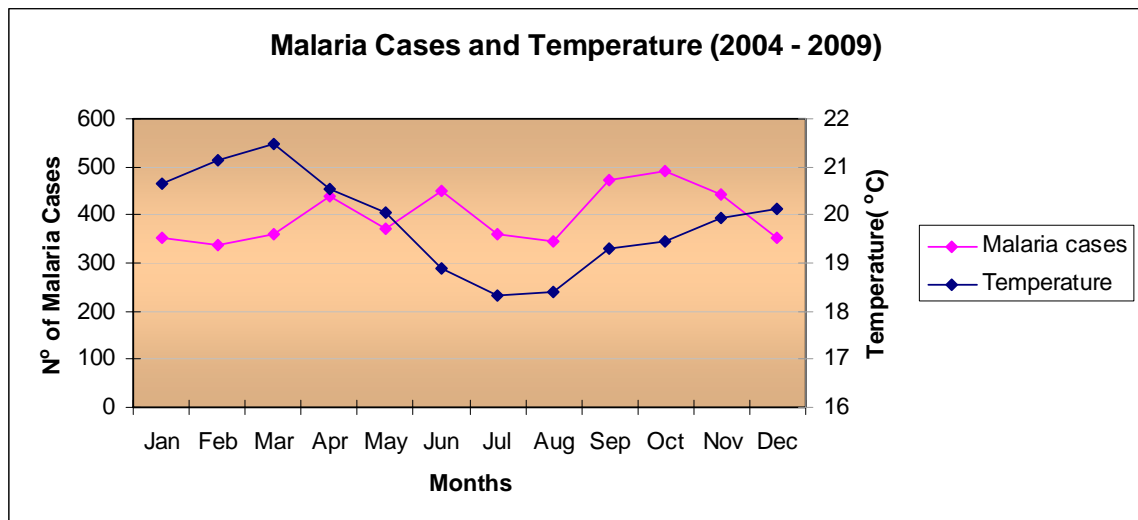


Figure 4. 1 Annual Patterns of Temperature and Malaria Cases in Boricha (2004 - 2009)

4.2 Malaria Cases versus Rainfall

Rainfall can promote transmission of malaria by creating ground pools and other breeding sites, but heavy rains can have a flushing effect by cleaning the breeding sites of the mosquitoes.

Figure 4.2 shows the malaria cases (patients came to the health facilities in the woreda and confirmed that they are positive to malaria with laboratory tests) and rainfall of the study area. There is a positive relationship between malaria case and rainfall between the months January to April and in the months September and November. However, the relationship becomes negative between the months May to October and in the month December. There is a dramatic decreasing and increase in malaria case before and after the peak rainy season in May. During periods of heavy rainfall, breeding may be hampered due to the excess water resulted from heavy rain make the streams and the pools move fast, so it flushing away the eggs and larvae thus killing mosquito in its immature stages, so that the turnover was decreasing in malaria case. Conversely after the pick rainy season the intensity of the rain declines and the temperature increase therefore progressive dryness beginning, so it creates a favorable environment for mosquito breeding in areas where water has been accumulating from the main rain season. This condition resulted by increasing the number of malaria cases. The malaria transmission can not be explained only by the rainfall but by the lag time in mosquito breeding and parasite life cycle inside the mosquito, which are dependent on air temperature and humidity together with rainfall.

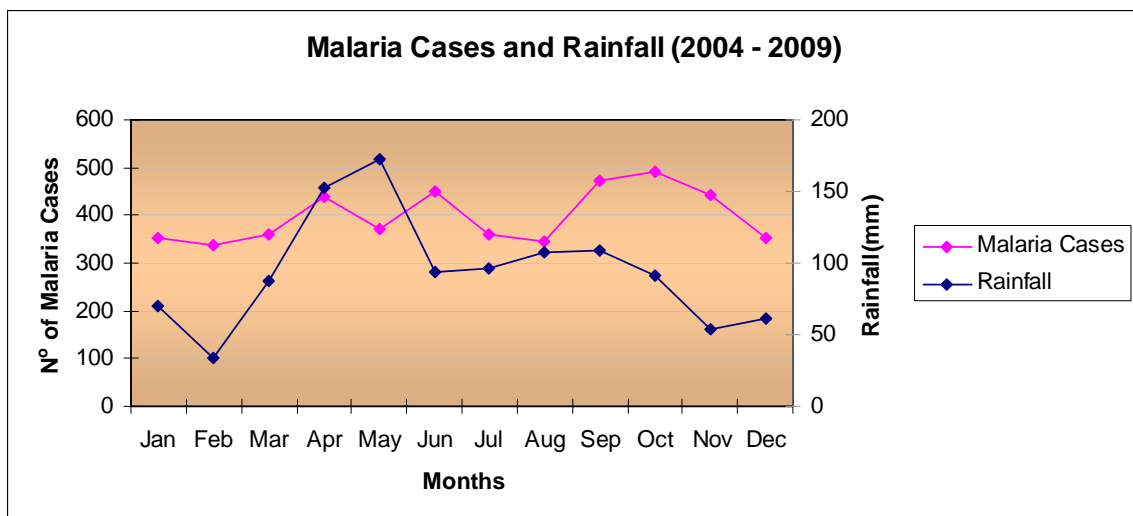


Figure 4. 2 Annual Patterns of Rainfall and Malaria Cases in Boricha (2004 - 2009).

4.3 Identifying Areas of Malaria Hazard

Hazard is the probability of occurrence of a potential damaging natural phenomenon within a specified period of time and in a given area. As a hazard, malaria incidence is mapped by depending on environmental factors that create favorable condition for the survival of the vector *Anopheles* mosquitoes. These variables are including rainfall, temperature, altitude, soil, slope, distance from swamp areas, and distance from rivers aggregated in ArcGIS environment using spatial analyst tool after each factor was given the appropriate weight.

Table 4. 1 Weight of Malaria Hazard Factors

Factors	Weight	Class	Rank	Degree of Vulnerability
Rainfall	34	< 800mm	4	High
		> 800mm	5	Very High
Temperature	21	< 30 ⁰	5	Very High
		> 30 ⁰	2	Low
Elevation	15	< 2000m	5	Very High
		> 2000m	3	Moderate
Swamp	11	0–500m	5	Very High
		500–1000m	4	High
		1000-1500m	3	Moderate
		1500-2000m	2	Low
		>2000m	1	Very Low
River	8	0–500m	5	Very High
		500–1000m	4	High
		1000-1500m	3	Moderate
		1500-2000m	2	Low
		>2000m	1	Very Low
Soil	6	Eutric Vertisols	5	Very High
		Chromic Luvisols	4	High
		Lithic Leptosols	2	Low
		Humic Nitosols	1	Very Low
Slope	5	< 8%	5	Very High
		8 - 15%	3	Moderate
		> 15%	1	Very Low

The process of weighting each factor was performed in IDRISI in order to control the consistency of weighting. The pair wise comparison of the seven parameters was carried out

to develop the pair wise comparison matrix in IDRISI. The factors were ranked in table 4.1, according to the degree of importance that they have for the incidence of malaria in this study. This was done based on the previous studies and by consulting the malaria expert. After the overlay analysis of the above seven factors, the malaria hazard map was produced.

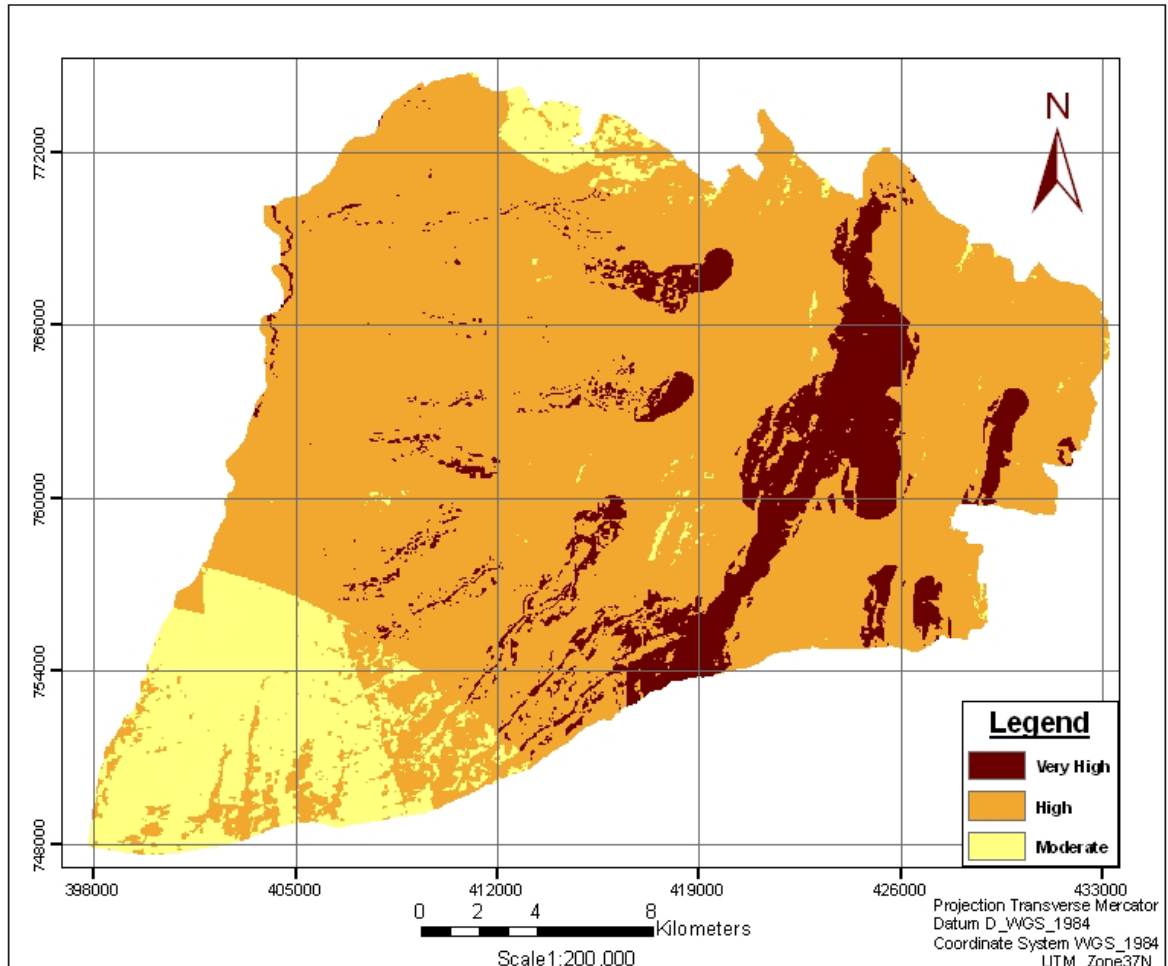


Figure 4. 3 Malaria Hazard Map

The malaria hazard map, in figure 4.3 illustrates that 66.0 km² very high, 436.7 km² high and 85.4 km² moderate level of malaria vulnerability, that are representing from the total area 11.2percent, 74.3percent and 14.5percent of the study area respectively subject to very high, high and moderate level of malaria susceptibility. Hence, from these figures it is possible to conclude that over 85percent of the total area are in high and very high malaria hazard and the remaining area was moderately exposed. This finding shows higher hazard to malaria than reported studies in Wondogent and Awassa Zuria Woredas which is 68percent (Arega, 2009). This difference is as such significant as compare the area of the two study areas but it could be due to altitude of the study area which is below 2000m.a.s.l, with annual rainfall of more than

800mm and temperature that is highly favorable for multiplication of the malaria vector. Moreover most of the study area is nearly level to gentle slope which challenges the drainage system. This combined with the fact that most of the soil is impermeable; it aggravates the availability of surface water and the creation of swampy area which is a favorable breeding pool for the mosquito vector.

4.4 Identifying Areas of Malaria Risk

The malaria hazard mapping which is based only on natural conditions is not sufficient to locate the malaria risk area but need to include socio economic factors that have the profound effect for the survival of the vector *Anopheles* mosquitoes. These factors including population density, distribution of ponds, land use land cover as well as the hazard map of the study area. The basis for the calculation of the map was the risk computation model (Risk = Hazard * Element at Risk * Vulnerability) developed by Shook (1997).

Table 4. 2 Weight of Malaria Risk Factors

Factors	Weight	Class	Rank	Degree of Vulnerability
Hazard	40		5	Very High
			4	High
			3	Moderate
Pond	35	0-500m	5	Very High
		500-1000m	4	High
		1000-1500m	3	Moderate
		1500-2000m	2	Low
		>2000m	1	Very Low
Land use land cover	15	Pond and Riverine tree	5	Very High
		Scattered trees	4	High
		Farm Land	3	Moderate
		Settlement	2	Low
		Bare Land.	1	Very Low
Population Density	10	>2178	5	Very High
		1081-2177	4	High
		681-1080	3	Moderate
		351-680	2	Low
		<350	1	Very Low

A malaria risk map was produced in an overlay weighted process in ArcGIS environment indicating the potential risk of malaria at any point within the study area in relation to pond and land use land cover (Vulnerability layer), population density (Element at Risk layer) and malaria hazard. To create the malaria risk map of the study area, each variable were reclassified as shown in table 4.2. The corresponding weight assigned to each of the factors was computed in IDRISI which is based on the pair wise comparison of the four parameters.

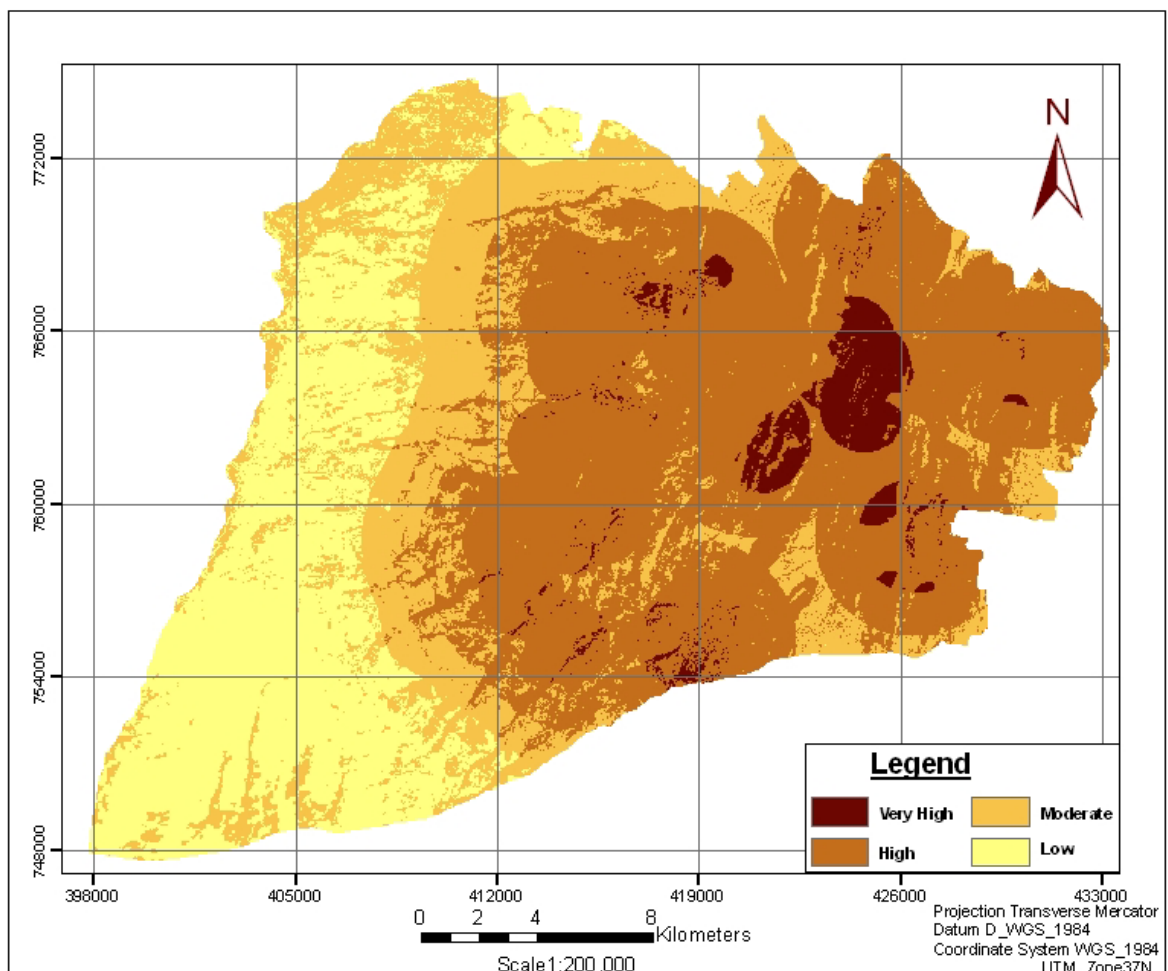


Figure 4. 4 Malaria Risk Map

For the purpose of identifying malaria risk areas; this study focused on malaria hazard, population density, distribution of ponds and land use land cover were used as input factors for malaria risk mapping. As a result, the risk map in figure 4.4 shows 29.3 km² (5.0percent), 273.7 km² (46.5percent), 143.0 km² (24.3percent), 142.1 km² (24.2percent) of the total area is subject to very high, high, moderate and low to malaria risk respectively. Hence, it is possible to conclude that the most of the area (over 51percent) is under high and very high risk of malaria. The risk level in this study was relatively lower than reported by Arega in Awassa Zuria and Wondogenet woredas, which was more than 62 percent of the total area (Arega, 2009). This

difference is not as such significant as compare the area of the two study areas but, could be due to the higher presence of wetlands and swampy areas and irrigation activities prevalent in the above mentioned study area.

4.5 Comparing the Extent of Malaria Risk Map with Kebeles Which Were Labeled as Malarious

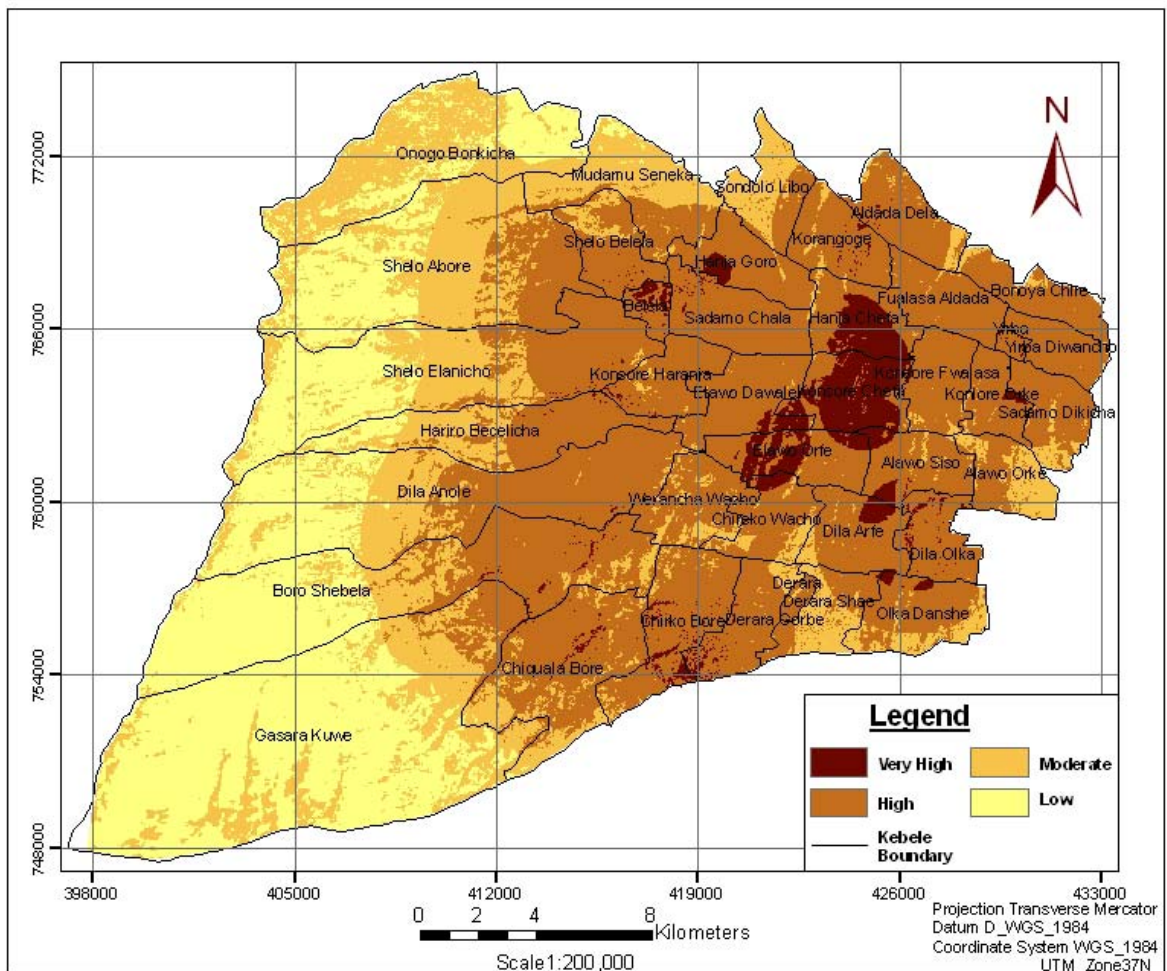


Figure 4. 5 Malaria Risk Map with Kebele Boundaries

In general, as shown in figure 4.5 the whole wereda is in risk of malaria. Most of the kebeles in the study area are subject to high and very high risk of malaria. Among them Konsore Chefa is almost fully in very high malaria risk. Most part of Hanja Chefa, and Elawo Orfe and some part of Etawo Dawale, Alawo Siso, Dila Arfe, Hanja Goro and Belela are subject to very high risk of malaria moreover the remaining part of these Kebeles is under high risk of malaria. This seems due to the availability of favorable climatic condition to the vector mosquito, the presence of swamp for the reason that the type of soil is low permeable additionally the degree of slope for this area nearly level to gentle slope, absence of significant drainage system, the existence of

many ponds which are created for the purpose of water harvesting but, it aggravated the condition by create a year round supply of water for the vector to breed and it has also created a high local humidity level conducive to heavy vector breeding, and the presence of large number of people in the area. Moreover, the existence of green area might have provided food and more shelter for resting for adult mosquitoes, which extends their longevity and density. It should be noted that the population of these very high risk kebeles is 51,899, which is about 22percent of the total population in the Woreda.

In contrast, low risk area are found in some part of Onogo Bonkicha and Hariro Bedelicha, and most part of Shelo Abore, Shelo Elanicho, Dila Anole, Boro Shebela, and Gasara Kuwe kebeles. This seems due to the permeability of the soil, the presence of high slope resulted with no stagnant water in the area. This part of the Woreda is highly degraded so most of its area is bare land additionally there is no swamp area as well as pond, these conditions together make uncomfortable situation for the vector malaria. In some part of Dila Anole, Boro Shebela, Gasara Kuwe, Chiquala Bore, Derara Shae and Alawo Orke, and most part of Sondolo Libo, Mudamu Seneka, Onogo Bonkicha, Shelo Abore, Shelo Elanicho, and Hariro Bedelicha kebeles are kebeles under moderately risk of malaria. This is mainly attributed to availability of favorable climatic condition, absence of pond and swamp, and the presence of green land cover. These situations make the condition moderately favorable for the vector mosquito to get conducive environment for breeding and resting the adult mosquito. In addition to this the presence of low population makes the degree of risk moderate.

5. Conclusion and Recommendation

5.1 Conclusion

The initial purpose of the thesis was achieved by identifying possible environmental conditions that exacerbates malaria spread in Boricha Woreda of Sidama Zone. Further more, the study produced mapping of malaria risk area which can be used as an input for policy makers and other responsible bodies. Besides these groups, the experts in the field will benefit more by acquiring ready made information which serves as a spring board for national malaria eradication and prevention program.

In this study, application of GIS provided the necessary infrastructure for identifying and combining different variables. Remote Sensing was also shown to play an important role by providing environmental information and supporting large scale malaria risk map could significantly enhance the ability of local communities, government and non government organizations to conduct contingency planning for prevention and eradication.

According to malaria case number of the study area, the Woreda has an all year round malaria transmission.

According to malaria hazard analysis out of the total area of the study Woreda 11.2percent, 74.3percent and 14.5percent of the study area respectively subject to very high, high and moderate level of malaria hazard.

Additionally according to malaria risk analysis out of the total area of Boricha Woreda 5.0percent, 46.5percent, 24.3percent and 24.2percent of the study area identified as very high, high, moderate and low level of malaria risk.

The presence of swampy areas and unmanaged ponds at large predisposed inhabitants of the Woreda to be affected by the vector mosquito. Thus over 51percent of the study area was high and very high malaria risk area. This reveals that Boricha Woreda has an all year round malaria transmission and needs very coordinated and timely responses to fight against the vector.

5.2 Recommendation

As the Woreda is mainly classified as malaria risk, it is necessary to draft strategy and program that considers the difference in risk. The strategy to be crafted to address malaria disease must be changed to plan of action for prompt prevention and control of malaria. Since maps are considered as one of the very vital input it is therefore, critical to use them in every aspect of planning, implementation, monitoring and evaluation of any development processes as well as malaria eradication and prevention program in the Woreda.

Therefore the following are recommended:-

- Planners and decision makers should specifically apply the findings of this study to prioritize risk areas and make sure adequate resources are allocated to the high and very high malaria risk areas of the Woreda. They could also use these maps to monitor and communicate progress of interventions.
- The Woreda should develop the capacity to use GIS and remote sensing technology for the effective identification of ecologies of mosquito and use such maps for eradication planning.
- Distribution of malaria nets, insecticide spraying and environmental measures must follow priority set by malaria risk map.
- The ponds which are used as a source of water for the dwellers should be covered when that is feasible and stirring of the ponds by mechanical means whenever possible for the larger ponds to disrupt the mosquito breeding and larval development.
- Identified environmental factors that are known very conducive for the multiplication of the vectors such as clearing of bushes around the house, drainage of swampy areas and laying rainfall water, keeping environmental sanitation to eradicate old vessels, tires, cans, pots etc from the residential areas. These have to be done through promoting voluntary participation of the community at large.
- Proper data bases about detail patient data, the seasonal incidence of epidemics and about other related aspects of the malarious kebeles should be made using GIS
- It is also vital to increase the awareness of the community with respect to malaria prevention and control
- Based on malaria risk map it is essential to establish strong early warning system

Reference

- Adamu Addissie (2004) Malaria and HIV Co-infection in Hadya Zone, Southern Ethiopia. AAU, Addis Ababa, M. Sc. Thesis
- Alen L. Melnick (2002) Introduction to Geographic Information Systems in Public Health. An Aspen Publication, Mary Land, USA
- Arega Degife (2009) Vulnerability Analysis and Malaria Risk Mapping in Awassa and Wondogenet Woredas. AAU, Addis Ababa, M. Sc. Thesis
- Aruna Srivastava, B. N. Nagpal, Rekha Saxena and S. K. Subbarao (2001). Predictive Habitat Modeling for Forest Malaria Vector Species An. Dirus in India – A GIS-Based Approach. Malaria Research Centre, India
- Aruna Srivastava (1995) Mapping Malaria.
URL:<http://www.gisdevelopment.net/application/health/planning/healthp0002.htm>
- Awash Teklehimanot (2005) Coming to grips with malaria in the new millennium. UN Millennium Project 2005, Task Force on HIV/AIDS, Malaria, TB, and Access to Essential Medicines, Working Group on Malaria Earth Scan, UK
- Boricha Woreda Health Bureau 2002 Planning, June 2001, Boricha Woreda Health Bureau, Yirba
- Cintia and Evlyn, (2004) Remote Sensing and GIS to Analyze the Vulnerability to Malaria in Face of Deforestation Processes Held in the Urban Fringe of Human Settlements in the Amazon Forest. National Institute for Space Research, Brazil
- Daddi Jima Dr (2008). Malaria Prevention and Control in Ethiopia. National Malaria Control Program, Ethiopia
- David le Sueur, Siphon Ngxongo, Maria Stuttaford, Brian Sharp, Rajendra Maharaj, Carrin Martin, and Dawn Brown (1995). Towards a Rural Information System. GIS for Health and the Environment. pp. 23 – 24, (Don de Savigny and Pandu Wijeyaratne, Eds). International Research Center, Ottawa
- Diriba Korecha (2008). Factoring Climate Information for Malaria Risk Mapping. National Meteorological Agency. Addis Ababa, Ethiopia
- Eveline Klinkenberg, Wim van der Hoek, Felix P. Amerasinghe, Gayathri Jayasinghe, Lal Mutuwatte and Dissanayake M. Gunawardena (2003) Malaria and Land Use: A Spatial and Temporal Risk Analysis in Southern Sri Lanka. Research Report 68, International Water Management Institute, Colombo, Sri Lanka

- FMoH (2004). Source Malaria Diagnosis and Treatment Guidelines for Health Workers in Ethiopia. 2nd Edition Addis Ababa, Ethiopia
- FMoH (2008) Ethiopia National Malaria Indicator Survey 2007. Federal Ministry of Health, Addis Ababa, Ethiopia
- FMoH (2008) Ethiopia National Malaria Indicator Survey 2007: Technical Summary. Federal Ministry of Health, 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
- Getachew Alemu (2006). Prevalence of Malaria and its Influencing Factors in Awassa District, Southern Ethiopia. AAU, Addis Ababa, M. Sc. Thesis
- Gilles, H.M. and Warrell, D.A. (1993). Bruce- Chewatt's Essential malariology. 3rd edition. Arnold, London.
- Immo Kleinschmidt, Judy Omumb, Olivier Briet , Nick van de Giesen, Nafomon Sogoba, Nathan Kumasenu Mensah, Pieter Windmeije, Mahaman Moussa³ and Thomas Teuscher (2001). An Empirical Malaria Distribution Map for West Africa. Tropical Medicine and International Health, Durban, South Africa.
URL: http://www.geotimes.org/may05/feature_malariamap.html#top
- Jeffrey Shaman (2010). Malaria Mapping and Prevention. American Geological Institute
- Lawrence N Kazembe, Immo Kleinschmidt, Timothy H Holtz and Brian L Sharp (2006) Spatial analysis and mapping of malaria risk in Malawi using point-referenced prevalence of infection data. International Journal of Health Geographic
URL: <http://creativecommons.org/licenses/by/2.0>
- Malhotra M.S. and Aruna Srivastava (1995), Diagnostic Features of Malaria Transmission in Nadida Using Remote Sensing and GIS
- Michael D. Thomas, DO, MPH&TM, Arthur D. Desch, Holly D. Gaff, PhD, Suzanne K. Scheele, MS, Richard K. Jordan, MS, PhD, Jonathan R. Davis, PhD, MS, (2004). Estimating Infectious Disease Risk in the Absence of Incidence Data. ESRI International Health GIS Conference, Washington DC
- MMV (2010) Curing Malaria Together. Medicines for Malaria Venture. The US Institute of Medicine(IOM), USA
- Mutuwatte L. P. (1997) Geographic Information System Technology to Monitor and Control Diseases, Water Related Environmental Factors and Malaria Transmission in Mahi Kadana. Gujarat, India, International Irrigation Management Institute, Working Paper N° 41. Colombo, Srilanka

- 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 Africa Medical Journal* 82: 186-192.
- Negassi Fisseha (2008) Identifying, Mapping and Evaluating Environmental factors Affecting Malaria Transmission Using GIS and RS in Selected Kebeles of Adama Woreda, Oromia Region. MSC Thesis, AAU.
- Shook, G (1997), An assessment of disaster risk and its management in Thailand, *Disasters* 21(1): 77-88
- Tilahun Nigatu, Berhane Haileselassie, Samuel Hailu and Dawit Seyum (2009) Involving communities in the Fight Against Malaria in Ethiopia. AMREF Case Study. African Medical and Research Foundation
- Tran Annelise, Nicolas Poncon, Céline Toty, Catherine Linard, Helene Guis, Jean Baptiste Ferre, Danny Lo Seen, Francois Roger, Stephane de la Rocque, Didier Fontenille and Thierry Baldet (2008) Research Using Remote Sensing to Map Larval and Adult Populations of *Anopheles Hyrcanus* (Diptera: Culicidae) a Potential Malaria Vector in Southern France. *International Journal of Health Geographics*, BioMed Central Ltd, France
- Tulu, A. (1993). Malaria In: Kloos, H and Zein, Z.A (Eds). *The Ecology of Health and Disease in Ethiopia*. West view Press, Boulder.
- Wim van der Hoek, Flemming Konradsen, Priyanie H Amerasinghe, Devika Perera, MK Piyaratne, and Felix P Amerasinghe (2003). Towards a Risk Map of Malaria for Sri Lanka: the Importance of House Location Relative to Vector Breeding Sites. *International Journal of Epidemiology* 2003, Great Britain
- WHO (2002). *World Malaria Report*. WHO Technique Report. WHO
- WHO (2005) *Roll Back rt. Ethiopia, Country Profile*. WHO
- World Malaria Report*. (2009). Global malaria situation. In: *World Malaria Report /WMR/*.
- Yazoume Ye, Osman Sankoh, Bocar Kouyate and Rainer Sauerborn (2008) *Environmental Factors and Malaria Transmission Risk Modeling the Risk in a Holoendemic Area of Burkina Faso*. Ashgate Publishing Company, USA

APPENDIX I

Error Matrix

Classified Data	Reference Data						Row Total
	Bare Land	Farm Land	Scattered Trees	Pond	Settlement	Riverine Tree	
Bare Land	17	0	0	0	1	0	18
Farm Land	0	21	0	0	0	2	23
Scattered Trees	0	0	1	0	0	0	1
Pond	0	0	0	1	0	0	1
Settlement	0	0	0	0	1	0	1
Riverine Tree	0	0	1	0	0	0	1
Column Total	17	21	2	1	2	2	45

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Bare Land	17	18	17	100.00%	94.44%
Farm Land	21	23	21	100.00%	91.30%
Scattered Trees	2	1	1	50.00%	100.00%
Pond	1	1	1	100.00%	100.00%
Settlement	2	1	1	50.00%	100.00%
Riverine Tree	2	1	0	0.00%	0.00%
Totals	45	45	41		

Overall Classification Accuracy = 91.11%

KAPPA (K[^]) STATISTICS

Overall Kappa Statistics = 0.8535

Conditional Kappa for each Category

Class Name	Kappa
Bare Land	0.9107
Farm Land	0.837
Scattered Trees	1
Pond	1
Settlement	1
Riverine Tree	-0.0465