ADDIS ABABA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

Spatial and Temporal Distribution of Malaria Risk: Geographic Information System and Remote Sensing Mapping Using Environmental Factors: a Case of Humbo Woreda, Cewkare kebele, Southern Nations Nationalities and Peoples' Regional State

BY

ENDRIAS TEGA

ADDIS ABABA, ETHIOPIA

June, 2015

Spatial and Temporal Distribution of Malaria Risk:

Geographic Information System and Remote Sensing Mapping Using Environmental Factors: A Case of Humbo Woreda, Chewkare kebele, Southern Nations Nationalities and Peoples' Regional State

By

Endrias Tega

Advisor

Yohanis G /Micael (PhD)

A thesis submitted to

The Department of Geography and Environmental Studies Presented in Partial Fulfillment of the Requirements for the Degree of Master of Art in Geography and Environmental Studies (GIS, Remote Sensing and Digital Cartography)

June, 2015

ADDIS ABABA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

This is to certify that a project prepared by Endrias Tega entitled: GIS and remote sensing based on Malaria risk mapping using environmental factors in Humbo Woreda Specially Chewkare kebele, SNNPRS, Submitted to the partial fulfillment of the requirements for the degree of Master of Arts in Geography and Environmental Studies with specialization GIS, Remote Sensing and Digital Cartography compiles with the regulation of the university and meets the accepted standards with respect to originality and quality.

Signed by: examining committee

External examiner________________________Signature_____________Date________

Internal examiner_________________________Signature______________Date_______

Advisor________________________________Signature_____________Date_________

____

Chair of the department or Graduate program coordinator

Abstract: Ethiopia is a predominantly malaria prone country like most sub Saharan African countries, the landscape being favorable for the breeding of malaria vector. This study ai 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 Humbo Woreda of Wolaita Zone particularly Chewkare kebele. 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 Chewkare kebele 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 15%, 74 % and 11.2% 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 5.0%, 46.5%, 24.3% and 24.2% of the total area is subject to very high, high, moderate and low to malaria risk respectively. In conclusion, more than 85% of the total area is highly exposed to malaria hazard and over 51% 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 kebele.

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

Acknowledgements

Above all, I would like to thank 'Almighty God' who made it possible for me, to start and finish my study successfully.

I would like to extend my heartfelt thanks and appreciation to my advisor, Dr Yohanis G/Micael for his valuable, unreserved and constructive comments and guidance at each phase of this study.

I would also like to thank those people who are working at Wolaita Finance and Economy Developmental Berue, Humbo Woreda health office and Wolaita health center for their cooperation and provision of the required data.

My special thanks go to my lovely wife Yabsira Yohanes, my father Tega Kanedo and my mother Ribika Woticho for their encouragement and moral support throughout my study.

Table of Contents Page

LIST OF FIGURE

List of Tables

List of Appendixes

AHP Analytic Hierarchy Processes

AVHRR Advanced Very High Resolution Radiometer

BOFED Bureau of Finance and Economic Development

CDC Centers for Disease Control and Prevention

CSA Central Statistical Agency

DEM Digital Elevation Model

EMA Ethiopia Mapping Agency

ERDAS Earth Resources Data Analysis System

ESRI Environmental Science Research

ETM+ Enhanced Thematic Mapper Plus

FAO Food and Agricultural Organization

FMoH Federal Ministry of Health

GIS Geographic Information System

GPS Global Positioning System

HSDP Health Sector Development Program

ITN Insecticide Treated Net

Km Kilometer

m.a.s.l. Meter above sea level

MCE Multi Criteria Evaluation

MFI Malaria Foundation International

Mm Millimeter

MOA Ministry of Agriculture

NOAA National Oceanic and Atmospheric Administration

NMSA National Meteorological Services Agency

NIAID National Institute of Allergy and Infectious Diseases

RH Relative Humidity

RS Remote Sensing

SNNPR Southern Nations Nationalities and Peoples Region

SRTM Shuttle Radar Topography Mission

TM Thematic Mapper

WHO World Health Organization

WMR World Malaria Record

1. INTRODUCTION

1.1. General Background

Malaria is 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 epidemic. 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 is considered to be malaria's. Those areas are home to approximately 68percent (52 million) of the Ethiopian population and cover almost 75percent of the country's landmass. FMoH (2008).

Malaria transmits through 3 possible mediums; malaria parasite, human hosts, and *Anopheles* mosquito. The way to solve the malaria problem is to intervene these mediums. One of the interventions mechanisms includes identifying possible potential malaria prone areas. First predicting and analyzing potential mosquito reproduction areas. The characteristic of heterogeneous space is an important factor to predict the mosquito densities. The heterogeneous space is called "land cover" (Abose *et al.,* 2003).

There are about 400 different species of *Anopheles* mosquitoes throughout the world, but only some 60 of these are vectors of malaria under natural conditions, and only 30 are vectors of major importance. Each species have different behavioral pattern. Several species of *Anopheles* can be found in most malarial areas, and different species occur in different parts of the world. Highly efficient species, such as *A. gambiae*, *A. arabiensis* and *A. funestus*, predominate in sub Saharan Africa, while less efficient vectors, such as *A. stephensi* and *A. minimus*, predominate in Asian countries. *A. dirus* is an efficient vector in the forests of South-East Asia (WHO, 2005).

The large, round numbers that delineate the immense and persistent burden of malaria have become a familiar part of discussions in the global public health forum: 3 billion people at risk of infection in 109 malarias countries and territories and around 250 million cases annually, leading to approximately 1 million deaths (WHO, 2009). Every year nearly 350-500 million clinical disease episodes are caused by malaria parasites and3.2 billion people in the world are living under the risk of malaria (WHO, 2005). Malaria essentially an environmental disease since the vectors require specific habitats with surface water for reproduction, humidity for adult mosquito survival and the development rates of both the vector and parasite populations are influenced by temperature (Ashenafi, 2003). Although it is preventable, Malaria is a leading cause of morbidity and mortality in the developing world, especially sub-Saharan Africa where the transmission rates are highest and where it is considered to be a major impediment to economic development (Robert *et al.,* 2003).

According to Getachew (2006), in 2003 the disease was the primary cause of reported morbidity and mortality accounting for 15.5percent of outpatient 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 outpatient 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 outpatient consultation, 20percent admissions and 24.9percent inpatient deaths.

During the last twenty years, the development of Geographical Information Systems (GIS) and satellite development of Geographical Information Systems (GIS) and satellites for earth observation have made it possible to make important progress in the monitoring of the environmental and anthropogenic factors which influence the reduction or there-emergence of the disease. Analyses resulting from the combination of GIS and Remote Sensing (RS) have improved knowledge of the biodiversity influencing malaria. This knowledge can help decision-makers to better allocate limited resources in the fight against the disease (Robert *et al.*, 2003).

All GIS packages have the ability to produce high quality thematic or topographic maps from the feature data stored within the system. Datasets such as topographic maps, aerial photographs, satellite imagery and complex databases can be combined and visualized concurrently (Wyatt and Ralphs, 2003). With GIS tools it is also possible to overlay accurate spatial maps of an area which can display disease events, climatic and topographic variables and land-use patterns and simultaneously examine the relationship between these, enabling new and critical insights to be made to the disease and its transmission localities (Mendis, 2009).

As we observed in the above, a 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 of the study area.

1.2. Statement of problem

In Sub-Saharan Africa the pattern of malaria transmission varies markedly from region to region depending on climate and biogeography, and broad ecological categories have been widely used to describe variations in the observed epidemiological patterns (MFI, 1997).

In Ethiopia epidemics occur in 5–8 year cycles; several epidemics have been reported in recent years, for example, in 2003 and 2005. Accordingly, there is a pressing need to develop malaria early warning to enhance public health decision making for control and prevention of malaria epidemics. A malaria early-warning system that provides predictions of the temporal and spatial pattern of epidemics could help to control and prevent malaria epidemics. If an effective malaria early-warning system were operational, it could assist public health decision makers in prioritizing scarce resources to areas and periods most at risk. One approach to developing a malaria early-warning system is to use statistical forecasting models based on historical malaria cases and environmental risk indicators.

Malaria transmission is seasonal in Ethiopia and varies across the country depending on climatic and ecological factors favorable to disease-transmitting vector and parasite development, including elevation, rainfall, and temperature. The major malaria transmission season occurs primarily during September to December following the main rainy season, which occurs from June to September with peak precipitation in July and August. Large-scale malaria epidemic outbreaks occur particularly in the Ethiopian lowland where transmission is unstable, immunity of the population is low, and almost all age groups of the population are at risk of severe morbidity and mortality from malaria.

According to Humbo Woreda health office, in 2012 malaria was the second top disease responsible for high morbidity and mortality in the Woreda. Seasonal rain, over flow of Blate River during high rainy season, impounded water and the geographic location which is typical for the breeding of mosquito contributed a lot for the prevalence of malaria. Presence of large and small scale irrigation schemes in the area associated with lower water management skill of the local people also favor breeding of mosquito which will aggravate malaria prevalence in the area. Severity of malaria increases at the rainy seasons putting higher pressure on the activity of the local people whose livelihood is totally dependent on crop production and livestock rearing. It reduces labor, time for on farm follow up, livestock supervision and children school attendance consequently resulting in decline of agricultural production, economic dependency, high school dropouts and social crisis.

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. To feel this gap, this study tried to identify environmental factors facilitating conditions for mosquito breeding and malaria risk map is generated, which will make malaria prevention and control exercise cost and time efficient.

Climatic and topography factors, particularly rainfall, temperature, altitude, and slope are known to have a strong influence on the biology of mosquitoes. GIS and remote sensing can be used to associate such variables and the distribution of mosquito responsible for malaria transmission. Other factors like population density, land-use/land-cover and proximity to different malaria causing or preventing factors can be also associated with the effect they do have on malaria prevalence using the same tools. Therefore, GIS and remote sensing are the appropriate tools to aid malaria control and prevention system through assessing potential malaria risk level of an area. With GIS and remote sensing it is possible to produce different thematic and attribute maps for each malaria supporting factors and malaria risk level for the study area. This in turn helps in the malaria control and prevent.

In order to design and implement cost-effective appropriate interventions, knowledge on local prevalence, distribution malaria and its influencing factors are nevertheless paramount importance. Therefore, this study was initiated as to assess prevalence of malaria and its predisposing factors in Humbo Woreda. Thus, remote sensing and geographic information systems (GIS) technologies have been used to describe local and landscape-level features that influence the patterns and prevalence of disease and then model the occurrence of the health event in space &time(Ashenafi, 2003).

In the study area although malaria is prevalent, risk analysis is not yet done and potentially prone areas are not delineated based on environmental factors. This has created a problem to target at high risk areas and has substantial increased costs of prevention. This study therefore apply the combined use of GIS and remote sensing which provides a strong tool for monitoring environmental conditions that are conducive to malaria and mapping the disease risk. GIS and remote sensing tools are used to analyze and in component of vector-borne disease situation in the study.

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

i. To investigate the trend of malaria infestation in the study area.

ii. To analyze the spatial distribution of malaria risk in the study area

iii. To assess factors influencing malaria spread in the study area

iv. To evaluate the impact of malaria incidences

1.4. Research questions

Basic questions answered by this Thesis work are:

i. What is the temporal dynamics of malaria infestation in the study area?

ii. How is the malaria infestation distributed in space?

iii. What are the major environmental factors that contribute for mosquito breeding?

iv What is the impact of malaria in the study area?

1.5. Significance of the Study

This research is aimed at using GIS and RS tools for identification of malaria prone areas. The ability of identifying risk areas will greatly enhance the effectiveness of prevention efforts and will substantially reduce costs of prevention with efficient targeting of high risk areas. Applying GIS and RS for visualizing and analyzing epidemiological data, revealing trends, dependencies and interrelationships will provide valuable information for evaluation and monitoring.

1.6. Scope of the study

The scope of this study is delimited both in geographical area and issue of concern. Geographically, it is delimited to Humbo Woreda, which is one of the Woredas in Wolaita Zone of the Southern Nation's Nationalities and Peoples Region. Regarding the area of concern, the main focus of the project was developing malaria risk map for the Woreda. Thus, this study is restricted to develop GIS and remote sensing based malaria risk map of HumboWoreda using environmental factors.

1.7. Limitations of the study

The major limitations of this study include lack of adequate meteorological stations closer to the study area to make accurate interpolation or to reduce generalization in the process of interpolating temperature and rainfall maps, lack of well documented malaria case data for the Woreda of as well as kebele based data. There was also lack of relative humidity data for the study area to include it as one factor.

1.8. Organization of the thesis

This study is organized in five chapters. Chapter one provides introduction, problem statement, objectives, significance, scope and limitation of the thesis. Chapter two presents review of related literatures of concept and distribution of malaria, environmental factors, GIS and remote sensing application on malaria control and risk mapping. Chapter three provides description of the study area and methodology. Chapter four describes results and discussions and finally chapter five is about summary, conclusions and recommendations.

2. REVIEW OF RELATED LITERATURE

2.1. Some Concepts: Malaria and its Behavior

Malaria is a mosquito-borne disease caused by a parasite. The geographic distribution of malaria depends mainly on climatic factors such as temperature, humidity, and rainfall. It is transmitted in tropical and subtropical areas. Malaria is responsible for over 300 to 500 million clinical cases and more than one million deaths each year. Approximately 20% of the world population is living under risk of malaria, mainly in tropical areas and in the poorest countries of the world (CDC report, 2006). Scientists have observed significant correlations between malaria epidemics and seasonally warm semi-arid and highland areas. Several tools, such as, GIS, GPS, remote sensing and spatial statistics were used for malaria surveillance and malaria control programs.

2.2. Using RS and GIS Technology to Study and Control Malaria

Historically several attempts have been done to study and control malaria by using different technologies and ideas that the body of knowledge has produced. Satellite sensors developed in US, Europe, Canada, and India have contributed to a better understanding of malaria vector ecology. The history of RS and its application to malaria and other vector-borne diseases has been recorded over time in a series of review papers (Hay *et al.,* 2000). Yet, despite 30 years of research on the potential applicability of remote sensing technologies to malaria control, these tools are only now beginning to have an impact on policy and practice in operational control of malaria in affected countries. In 1971, NASA scientists first identified larva habitat sites using CIR photography. Manually they identified forest coverage, open wetlands, marshy lands and residential areas from CIR photography and, by calculating mosquito flight range from settlements, produced a risk map for malaria control. Pope *et al.* (1992) used Land-sat TM imagery over the Pacific coastal plain of Chiapas, Mexico and by integrating GIS, RS and field research tried to predict *Anopheles* mosquito population dynamics. TM proved its usefulness by identifying *Anopheles* larva habitat sites in California and mapping rift valley fever vectors in Kenya, East Africa (Pope *et al.,* 1992). In that study, they classified TM image and identified roads, water and vegetation. They also colour coded the homogeneous vegetation types and water bodies on classified TM images. Their study result revealed that habitat types were divided in low, medium and high larva producing groups. Many disease vectors cannot be observed directly. Wood *et al.* (1992) identified high mosquito producing fields in California using GIS and Land-sat TM imagery. They also detected the reflectance of canopy growth in early season and correlated with

Anopheles larva density. Distances between rice fields and source of blood meal for mosquitoes, i.e. pastures with livestock, were measured using GIS. Their study result revealed that rice fields situated very close near pastures had more larva production compare with rice fields far from pastures. Kaya *et al*. (2001) carried out another study in Bangladesh. They used GIS technology to understand the spatial distribution of houses and incidence rates. In that study, GIS was used to generate the nearest distance between houses, water bodies and forest edges, and to create a buffer zone around water bodies. Finally, the findings were used to estimate the impact of malaria risk reducing interventions. In order to identify the environmental risk factors associated with malaria risk, a study was carried out by Kaya *et al*. (2001) in coastal Kenya. In that study risk areas were identified based on the highest mosquito flight carrying capacity from breeding sites. Wetlands were considered suitable for larva breeding sites and a two-kilometer buffer zone was created around mosquito breeding sites. With that information a risk map was generated that showed which settlements were situated very close and within the buffer zones. That study demonstrated the potential of using SAR images for identification of land cover types that may be associated with malaria carrying mosquito breeding.

2.3. Importance of Land-use/ Land-cover Classification for Malaria Study

In different parts of the world different landscape elements were identified for different types of malaria breeding. Beck et al. (1997) demonstrated how landscape elements can be used to predict mosquito availability and subsequently malaria outbreaks in Mexico. Land cover maps were produced from Land-sat imagery to identify different classes of land. Land type was then correlated with malaria incidence to identify the landscape elements that are most suitable for mosquito breeding. Research was carried out by Bian *et al.* (2003) in the Kenyan highlands to understand mosquito larval habitats. Remote sensing images were classified for land cover types using a supervised classification method. A total of seven land cover classes were used: farmland, pasture, natural swamp, forest, river/stream, road and suburbs. DEM was used to investigate topographic parameters that can be related with mosquito larva habitat sites such as elevation, wetness index, and distance from stream, land surface and curvature. They used Land-sat TM images and their study results revealed that transitional swamps and unmanaged pastures were the most suitable land types for mosquito larva breeding. To see the spatial distribution of *Plasmodium vivax* in Afghanistan a study was carried out by Broker *et al.* (2002). Afghanistan is divided into four ecologic zones on the basis of differences in elevation, temperature and land cover type. Epidemiologic data were obtained from a nationwide survey of 269 villages. They used logistic regression analysis to investigate the relationship between environmental variables and the probability of transmission. No transmission occurred in those villages higher than 2000 meter above sea level because of variation of temperature. Prevalence rate was higher in river valleys and no transmission occurred in settlements farther than 10 km away from rivers.

2.4. The relationship Between Major Climatic Variables and Malaria Incidence

Rainfall in tropical areas creates an opportunity for anopheles mosquitoes to lay eggs, which can reach adulthood. 9-12 days are needed for that process. The anopheles mosquito transmits the causative agent, plasmodium species, when the environmental parameters (such as water availability, temperature and humidity) permit. In many parts of the world where temperature is not a limiting factor, seasonal malaria transmission takes place during peak rainfall periods (Daniel, 1999). It is already established that vector abundance, distribution and pattern of vector behaviors changes because of climate change. In order to develop malaria early warnings based on seasonal climate forecasts in Botswana, research was carried out in 1996. Malaria incidence data, precipitation data, DEMETER (Development of European Multi-Model Ensemble System for Seasonal to Inter-annual Climate Prediction) climate predictions were used for probability forecasts. Study result revealed that high incidence malaria years were associated with above average precipitation, while the lowest malaria years were associated with below average precipitation. To understand climate change and its relation to vector borne disease a review was carried out by Githeko *et al.* (2000) on the whole world. Literature suggests inter-annual and inter-decadal climate variability has a direct influence on vector-borne disease epidemics. Broker *et al.* (2002) studied to see the spatial distributions of Helminthes (one type of parasites) in Cameroon. They collected epidemiological and population data. Land surface temperature was derived from NOAA-AVHRR. They used a Logistic regression model to identify significant environmental variables which affect the transmission of infection. The variables used in the regression analysis were mean, minimum and maximum land surface temperature; total annual rainfall and altitude. The result revealed that maximum temperature was an important variable in determining Helminthes distribution.

2.5. Factors Affecting the Emergence of Malaria

The severity of malaria is a function of the interaction between the parasite, the *Anopheles* mosquito vector, the human host and the environment. Vector abundance, duration of the extrinsic incubation period and survival rate of the vector, combined with the probability of the vector feeding off a susceptible human host determine the risk of malaria infection, the stability of disease transmission, and seasonal patterns. Many factors are involved in determining the evolution of the parasite, the vector, the human and the environment (WHO, 2005). Hackett wrote 'Everything about malaria is so molded by local conditions that it becomes a thousand epidemiological puzzles'. Like chess, it is played with few pieces, but is capable of an infinite variety of situations'. If we are to see order within the chaos we must consider that most of the factors are interrelated and it is necessary to take into account these inter-relationships in a holistic approach to understand the components which influence the development of malaria; we must also understand the differing scales at which each factor play out its influence on the overall game. According to many researchers including WHO (2005), Githeko *et al.* (2000), and Broker (2002), the natural principle that govern malaria emanate from the natural conditions that are favorable to it.

A. Rainfall

Different malaria vectors use a variety of sites in which to lay their eggs (irrigation canals, tire ruts, mangrove swamps, pools, etc.) as long as the water is clean, not too shaded and, for most species, relatively still. In many semi-arid areas these sites are only widely available with the onset of the seasonal rains unless dry season irrigation is undertaken. The association between rainfall and malaria epidemics has been recognized for many decades (WHO, 2005) but while increasing precipitation may increase vector populations in many circumstances by increasing available anopheles breeding sites, excessive rains may also have the opposite effect by flushing out small breeding sites, such as ditches or pools or by decreasing the temperature, which in regions of higher altitude can stop malaria transmission.

B. Temperature

Temperature has an effect on both the vector and the parasite. For the vector, it affects the juvenile development rates, the length of the gonotrophic cycle and survivorship of both juvenile and adult stages with an optimal temperature and upper and lower lethal boundaries. For the parasite it effects the extrinsic incubation period *Plasmodium falciparum* (the dominant malaria parasite in Africa) requires warmer minimum temperatures than

Plasmodium vivax. This helps account for the geographic limits of *Falciparum malaria* transmission in Africa At 26ºC the extrinsic incubation period of this malaria species is about 9-10 days whereas at 20- 22ºC it may take as long as 15-20 days. In highland areas, where cold temperatures preclude vector and/or parasite development during part/or all of the year, increased prevalence rates may be closely associated with higher than average minimum temperatures (Bouma *et al.*, 1994).

C. Humidity

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

D. Surface Water

Surface water provides the habitat for the juvenile stages (egg, larvae, and pupae) of malaria vectors. Monitoring the state of small water bodies and wetlands using satellite data is therefore very useful to identify the source of malaria vectors. The Short Wave Infrared (SWIR) is a wavelength (1.55-1.75 µm) absorbed by water and therefore can be used to retrieve information on the presence of water bodies and vegetation water content (Gond *et al.*, 2004)

E. Vegetation

Vegetation type and growth stage may play an important role in determining vector abundance irrespective of their association with rainfall. The type of vegetation which surrounds the breeding sites, and thereby provides potential resting, sugar feeding supplies for adult mosquitoes, and protection from climatic conditions, may also be important in determining the abundance of mosquitoes associated with the breeding site (Broker 2002). Furthermore, vegetation type may influence mosquito abundance by affecting the presence or absence of animal or human hosts and thereby affecting the availability of blood meals.

F. Seasonality of Climate

The combined influence of rainfall, temperature and humidity, re-grouped underneath weather (short-term) and climate (long-term) on malaria is very complex, especially for extreme weather conditions. Direct effects of climate on vector and parasite development are easy to see but indirect effects may also be important such as the effects of previous exposure (related to direct effects), nutritional status, and co-infection may help determine the disease outcome. Just as climate is one of the determinants of malaria endemicity, climate variability is one of the main factors behind inter-annual fluctuations of malaria. Literature abounds with examples of how unusual, anomalous or extreme weather conditions have led directly and indirectly (through destructive crop pests and diseases) to human malnutrition and in turn to health problems or to both at the same time (Ashenafi, 2003). In recent years there have been significant scientific advances in our ability to predict climate on the seasonal timescale (Goddard *et al.*, 2001). The skill associated with these predictions varies from region to region, but is generally higher within the tropics. The World Health Organizations Technical Support Network for Malaria Epidemic Prevention and Control has suggested that such forecasts may be relevant to malaria early warning (WHO, 2005). Recently, the information provided by regional forecasters in Southern Africa has been presented and used by decision makers to forecast an increase in malaria risk in epidemic prone areas during seasonal Outlook Forums (Daniel, 1999). The importance of the factors influencing malaria is not only limited to climatic factors. Anthropogenic changes in the environment, in land use, deforestation, in hydraulic network, also induce continuous changes in the intensity of malaria transmission.

2.6. Anthropogenic Factors Affecting Malaria Transmission

Consequences of demographic and technological developments during the last century have considerably modified the environment. Forest and swamp regions were shifted to agriculture to feed an ever-increasing population. Water requirements for many crops have led to modifications of surface waters. Development of urban areas has also modified the spatial distribution of populations and lead to high concentrations of population in restricted areas. Already more than 50% of the total global population lives in cities. These demographic changes in cities can impact malaria, either by increasing the potential for malaria transmission where the development of irrigated cultures surrounding the city increases the vector population or by decreasing it, if adequate measures are taken to reduce the vector and parasite population in the cities. In some countries, and in particular in Africa, movements of population for political or economical reasons create another risk factor to the spread of malaria. Migrants and refugees may bring new parasites (including drug resistant parasites) to an area and increase transmission in the settled population, or because they come from a low, no transmission area migrants and refugees may be highly vulnerable to severe disease when the enter a malaria endemic area (Giada *et al.,* 2003). Development of urban cities (Small, 2003) can be monitored with high spatial resolution images such as Ikonos and QuickBird (respectively, 1m and 0.61m for the panchromatic channel).

2.7. Global Malaria Distribution and Burden

Malaria has been recorded as far North 64ºN latitude and as far South 32ºS latitude and in altitude ranges of 400m below sea level up to 2800m above sea level. Within these limits of latitude and altitude, there are large areas free of malaria (figure: 1), which is essentially a focal disease, since the transmission of malaria depends greatly on local environment and other conditions (Gilles and Warrell, 1993). The World Health Organization estimates that 300 to 500 million people are diagnosed with malaria annually, causing 1.1 to 2.7 million deaths (WHO2000; WHO, 2003).

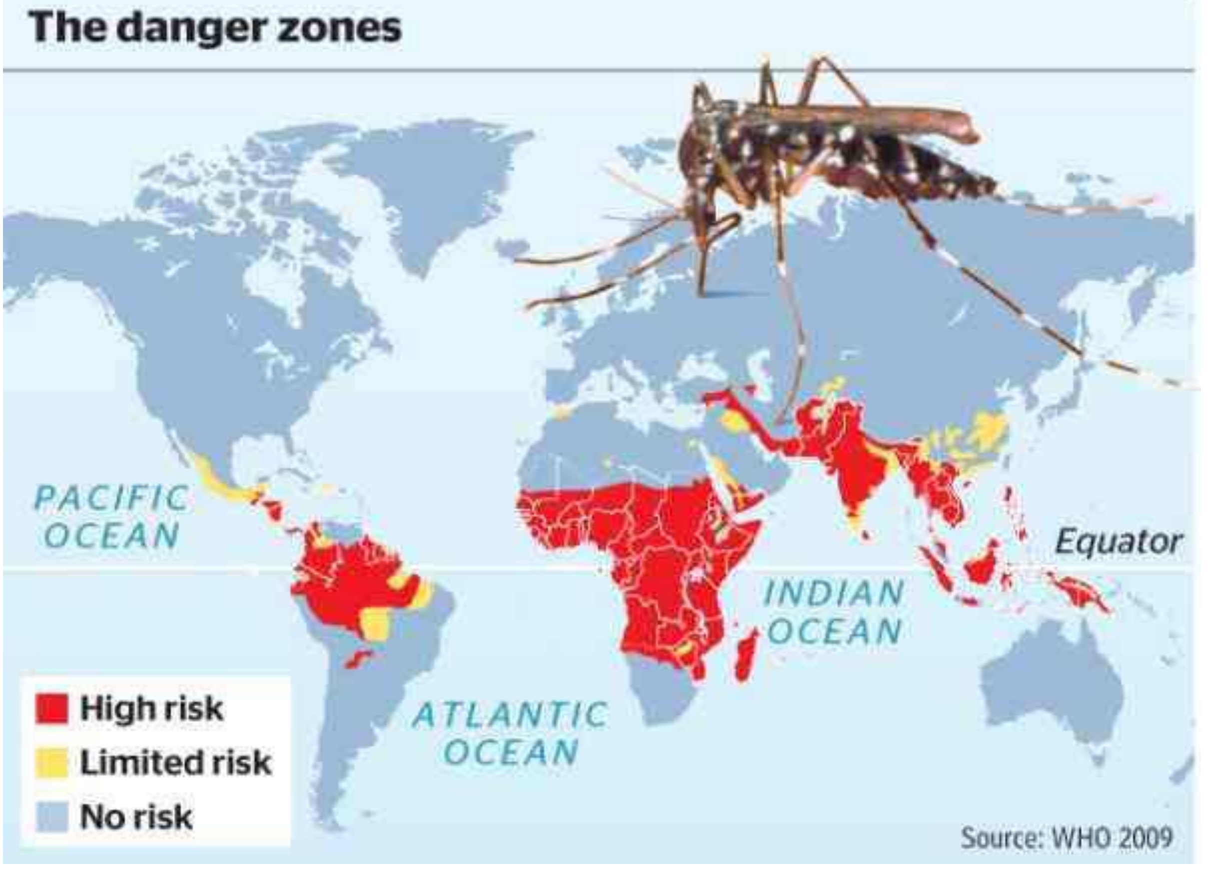


Figure1. The Malaria Belt of the world (Source: WHO, 2005)

Malaria has a major place among the endemic tropical diseases (Gilles and Warrell, 1993). Reports as for 2004 indicate that 107 countries and territories have reported as areas at risk of transmission. This number is considered less than the 1950s report where 140 endemic countries and territories were accounted, but still in these 107 countries there are 3.2 billion people at risk of infection (WMR, 2005). Around 60 % of the cases of clinical malaria and over 80% of deaths occur in Africa, south of the Sahara. In addition to acute disease episode and deaths in Africa, malaria also contributes significantly to anemia in children and pregnant women, adverse birth outcome and overall child mortality. Financially, it is estimated to be responsible for 3% in average annual reduction of economic growth in countries with high disease burden (WMR, 2005). Malaria extracts an enormous toll in lives, medical costs, and days of labor lost. Educational systems also suffer as large numbers of children miss several weeks of school each year in endemic regions (MFI, 1997). In addition to the direct economic cost of malaria such as costs related to transportation to health service facility, consultation fee, laboratory test fee, and more importantly, drug cost, malaria mortality and morbidity sluggish economic growth by reducing the capacity, and efficiency of the labor force. The economic loss due to malaria is very high, with an annual loss of growth estimated at 1.3% and loss of approximately 12 billion US dollars every year in Africa (WHO, 2005). The wide variation seen in the burden of malaria between different regions of the world is driven by several factors (WMR, 2005). The presence of the most serious parasite, accompanied by the potent vector species and vulnerable human population (Parasitevector- human transmission dynamics) is the one amongst the factors that favor or limit the transmission of malaria and the associated risk of disease and death (Gilles and Warrell, 1993; Konradsen *et al.,* 1990; cited by Joshi *et al.,* 2005). The severe malaria parasite *P. falciparum* and the most efficient malaria vector mosquitoes *Anopheles gambiae* occur exclusively in tropical and sub tropical part of the world, especially in Africa (Gilles and Warrell, 1993; WMR, 2005). Tropical areas of the world have the best combination of adequate rainfall, temperature and human host allowing for breeding and survival of malaria vector mosquitoes (WMR, 2005). The other major factor contributing to regional and local variability in malaria burden is differences in level of socio-economic development. Determinants include general poverty, quality of housing and access to health care and health education, as well as existence of active malaria control programmes providing access to malaria prevention and treatment measures (Gilles and Warrell, 1993; WMR, 2005). The poorest nations generally have the least resource for adequate control efforts (WMR, 2005). The combination of all these factors put down a heavy toll on malaria burden in Africa. In fact, the population groups at risk of malaria also differ between regions. The majority of death in tropical Africa occurs in areas of stable transmission of *falciparum* malaria (WMR, 2005). In these areas the two groups at high risk are the very young children, who have not yet acquired clinical immunity (Gilles and Warrell, 1993), and pregnant women, whose immunity to malaria is temporarily impaired (WMR, 2005). Whereas in areas of unstable or highly seasonal *falciparum* malaria transmission, which is mostly common outside Africa, the lack of frequent exposure to malaria infection early in life delay the acquisition of clinical immunity, and thus older age groups remain at relatively higher risk for malaria disease when exposed (WMR, 2005). More recently, there is evidence that compared with the 1980's, the burden of malaria increased during the 1990s in several areas in terms of population at risk, the severity of infection and the number of deaths (WMR, 2005). Malaria re-emerged in several countries of central Asia with an increased frequency of epidemics and with the re-establishment of stable endemic transmission. Factors contributing to the increase in malaria include (i) resistance of parasite to commonly used anti-malaria drugs; (ii) breakdown of control programs; (iii) complex emergencies; (iv) collapse of local primary health services; (v) resistance of mosquito vectors to insecticides (WMR, 2005). In addition, there are other variables that expand malaria endemicity such as, deforestation, introduction of different irrigation schemes, swamp drainage and specific crop intensification (Patz and Lindsay, 1999; Boelee *et al,* 2002; ICMR, 2002; Kebede *et al*, 2005). Within the same period, however, malaria was well controlled in the five northern African countries and elimination or a very low level of transmission was maintained in some of the islands of the cost of Africa. Throughout the decades, malaria was generally less intense in central and South America than in Africa and South East Asia (WMR, 2005). From the available information, it is not yet possible to determine with sufficient confidence whether the global burden of malaria has changed substantially, for better or worse, since 2000 when Roll Back Malaria (RBM) implementation began in many countries. In some areas, fluctuations in malaria transmission from year to year potentially confound evaluation of broader trends. Therefore, a final conclusion typically requires analysis of epidemiological data over multiple years. For the high burden in Africa, reliable data will only become available after a time lag of several years. Nevertheless, for some countries and areas throughout the world, there is evidence that successful control has got an impact on malaria disease burden (WMR, 2005).

2.8. The Situation of Malaria in Ethiopia

Malaria is a major public health problem in Ethiopia (Abose *et al.,* 1998). Its occurrence in most parts of the country is unstable mainly due to the country's topographical and climatic features (Abose *et al.,* 2003). Although the two epidemiologically important malaria parasite species in the country are *P. falciparum* and *P. vivax*, the other two species, *P. malariae* and *P. ovale*, are also reported to occur. *Anopheles arabiensis* is the major malaria vector; *An. pharoensis, An. funestus a*nd *An. nili* are deemed as secondary vectors (Abose *et al.,* 1998). Approximately 4-5 million cases of malaria are reported annually in Ethiopia (in a normal transmission year) (WHO, 2005). Malaria is found in about 75% of the total area of the country, and 40-50 million (>65%) of the total population is at risk of infection (Tulu, 1993; WHO, 2005). Malaria accounts for seven per cent of outpatient visits and represents the largest single cause of morbidity. It is estimated that only 20 per cent of children less than five years of age that contract malaria are treated at existing health facilities. Large-scale epidemics occur every 5-8 years in certain areas due to climatic fluctuations and drought-related nutritional emergencies. There are also areas of stable transmission in some low-lying western regions of the country (WHO, 2005). Transmission usually occurs at altitudes <2000 meters above sea level. The two main seasons for transmissions of malaria in Ethiopia are September–December, after the heavy summer rains, and March–May, after the light rains. *P. falciparum* and *P. vivax* are the dominant human malaria parasites, which account for about 60% and 40% of cases, respectively (Tulu, 1993). Malaria epidemics are frequent and widespread in the country. Most of the areas affected by epidemics are highland or highland fringe areas (mainly areas 1000–2000m above sea level), in which the population lacks immunity to malaria (Tulu, 1993). Occasionally, transmission of malaria occurs in areas previously free of malaria, including areas >2000m above sea level, in which the microclimate and weather conditions are favorable for malaria. According to Negash *et al.* (2005) true explosive epidemic malaria was recorded at exceptionally high altitude (around 2500 m above sea level). Resulting from human activities, aggravated transmission in the country was also observed (Negatu *et al*., 1992).

2.9. Potential Applications of GIS in Public Health

The recognition and employ of GIS technology in public health is significantly growing. GIS is gradually being accepted and used by public health administrators and professionals, including policy makers, statisticians, epidemiologists, regional and district medical officers. Some of its potential applications in public health are listed below:

Determine the geographical distribution and variation of diseases.

Analyze spatial and 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).

The main aim of this study is to identify and categorize the malaria risk areas of Humbo Woreda. To map malaria hazard some environmental factors were selected by consulting a malaria expert and depending on related previous works and reports. 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. 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 Arc GIS 10.2 spatial analyst tool. The result of these gives us the malaria hazard map. The main output of this study is the malaria risk map.

3. Materials and Methods

3.1. Geographic location

Humbo is one of the Woredas in the Southern Nations, Nationalities and Peoples' Region of Ethiopia. Part of the Wolayita Zone located in the Great Rift Valley, Humbo is bordered on the southeast by Lake Abaya which separates it from the Oromia Region, on the south by the Gamo Gofa Zone, on the west by Offa, on the northwest by Sodo Zuria, on the northeast by Damot Weyde, and on the east by the Bilate River which separates it from the Sidama Zone. The administrative center of Humbo is Tebela. According to a 2004 report, Humbo had 25 kilometers of asphalt roads, 24 kilometers of all-weather roads and 51 kilometers of dry-weather roads, for an average road density of 118 kilometers per 1000 square kilometers. Its distance from Addis Ababa country capital 322km&from Hawassa Regional capital 200km and also from soddo wolaita zone capital 22km.chewkare is one of Humbo Woreda kebel its distance from Tebla 35km around lake Abaya.

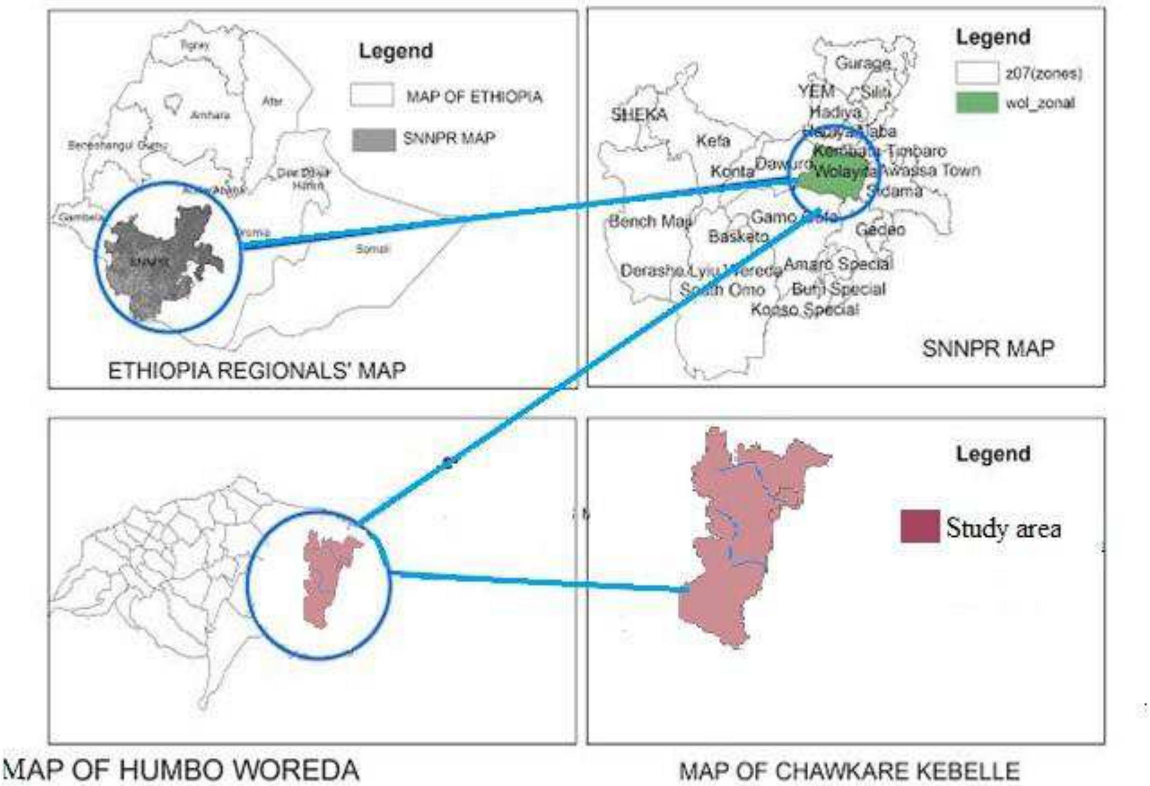


Figure2. Map of study area

3.2. Demography

Based on the 2007 Census conducted by the CSA, this kebel has a total population of5689, of whom 2842are men and 2847women. The majority of the inhabitants were Protestants, with 87.15% of the population reporting that belief, 7.87% practiced Ethiopian Orthodox Christianity, and 4.07% were Catholic.. The three largest ethnic groups reported in kebele were the Wolaita (96.33%), the Amhara (1.28%), and the Sidama (0.86%); all other ethnic groups made up 1.53% of the population. Wolaita is spoken as a first language by 96.8%, 1.5% Amharic, and 0.88% speak Sidama; the remaining 0.82% spoke all other primary languages reported.

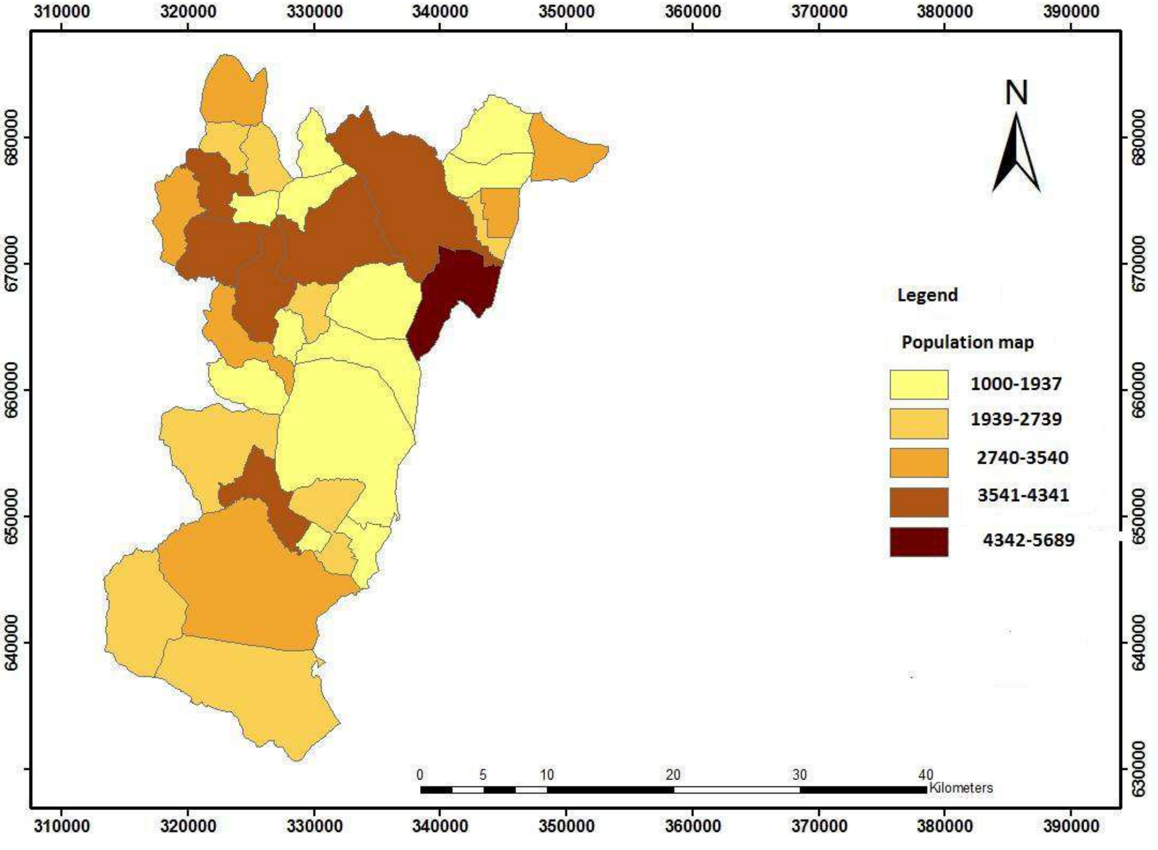


Figure 3: Population density map of the study area

3.3. Sample collection

The pre-test of the questionnaire was carried out in the kebele which is selected for the study in Humbo Woreda of the selected kebeles that has similar socio-demographic and agro-climatic characteristics with the people. Both the interviews and supervisors assessed clarity, understandability and completeness of the questions, and the others. The survey was conducted in one Kebele (among 15 Homogenus kebeles) out of total 41 kebeles selected from all kebeles in the Woreda. The number of households to be selected from Kebele was determined by dividing the sample size to the average number of family size per household (Statistical Report of Population and Housing Census of Ethiopia, 2007). The list of households for the selected Kebeles, knowing that the list did not contain any hidden order was obtained from the Kebele leaders and it was used as a sampling frame. Simple random sampling method was employed to select households from the Kebele from household registry using a table of random numbers and when the selected household was inconvenient, the households before or after the indicated one was sampled for replacement. All individuals who were members of randomly selected households and who slept there In the previous night were included in the study and any relatives who come to those households during study and any individuals who were not willing to participate in the study were excluded from the study.

3.3.1 Sample size and sample selection

The sample size for the study was estimated using the formula for estimating single proportion at 95% confidence interval (CI) level (Z (1-ά/2) = 1.96), an expected prevalence of 10.3% reported by Woreda health office(2010)around Humbo, 2.0% margin of error, and 5% level of significance. A sample of 30, better off individuals,30 medium &40poor= 100 total of (~100 households) was estimated as the minimum number required for malaria parasite prevalence testing in the kebel.

According humbo woreda health office From total 41kebeles, out of total kebeles(15 kolla agro-ecology) meaning malaria infested area selected. among those kebeles one pilate kebele the most proved was selected for study. In the study area kebele an average of 200-300/year people affected by malaria. From the pilote the community classified in to wealth rank it used for the production of safety net programs.

Table 1. Interviewed respondent in wealth Rank

Name of selected kebele	Agro-climate	Wealth rank	The number of selected	Expected number in percent
Chewkare	kolla	better-of	30	30 (100%)
		medium	30	30 (100%)
		poor	40	40 (100%)
total			100	100%

3.3.2. Focus group discussion

For the qualitative the kebeles administrator, the head of the health office, and the supervisors, with principal investigator will used to identify eligible discussant. A total of two and FGD each holding 7 to 10 discussants was carry out. FGD discussion will be conducted with malaria infestation, health workers, elders, women, youth, Das, experts and community leaders. Causes about the main reasons for the malaria infestation issues discussed during the FGD.

3.3. Climate

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, is different from month to month. The same is true in the rainfall.

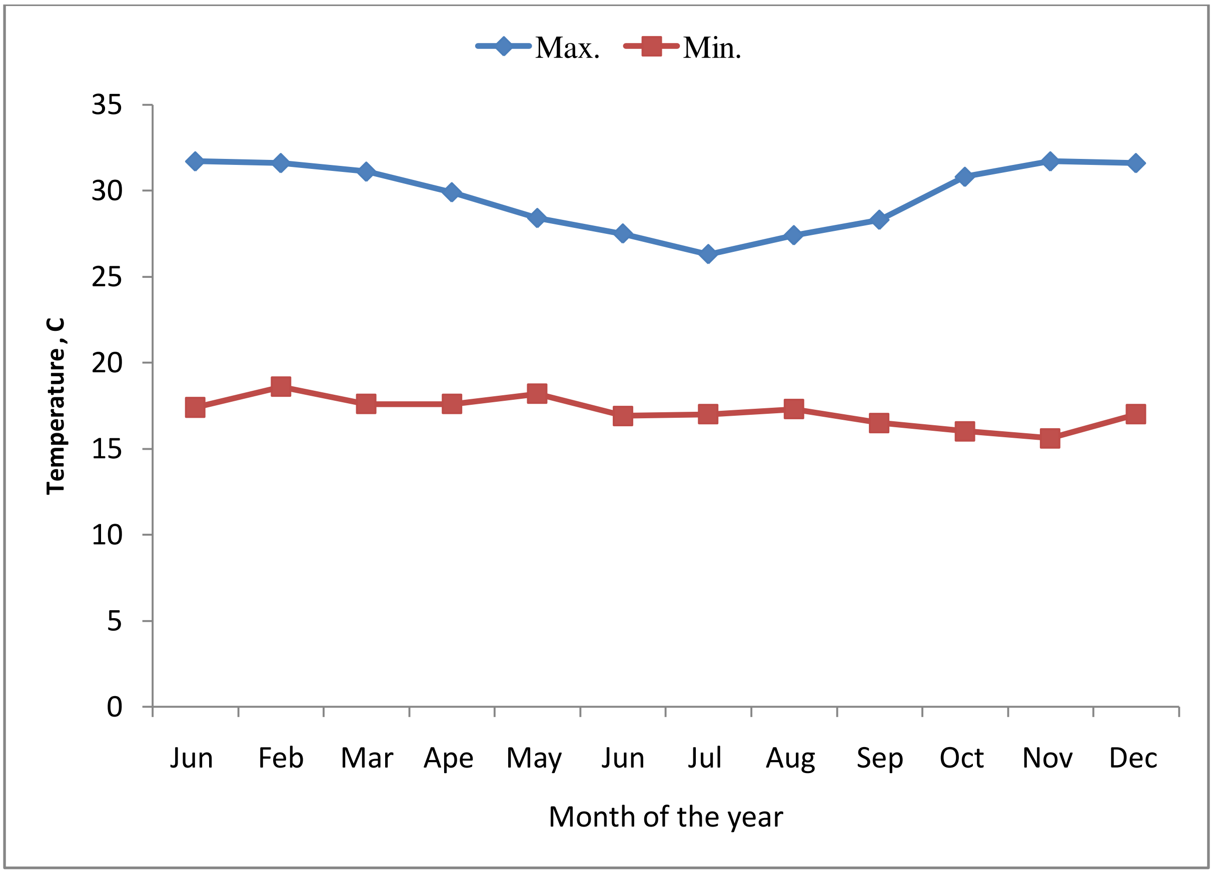


Figure 4. Monthly mean temperature distribution of Humbo Woreda (Source: Humbo meteorological station)

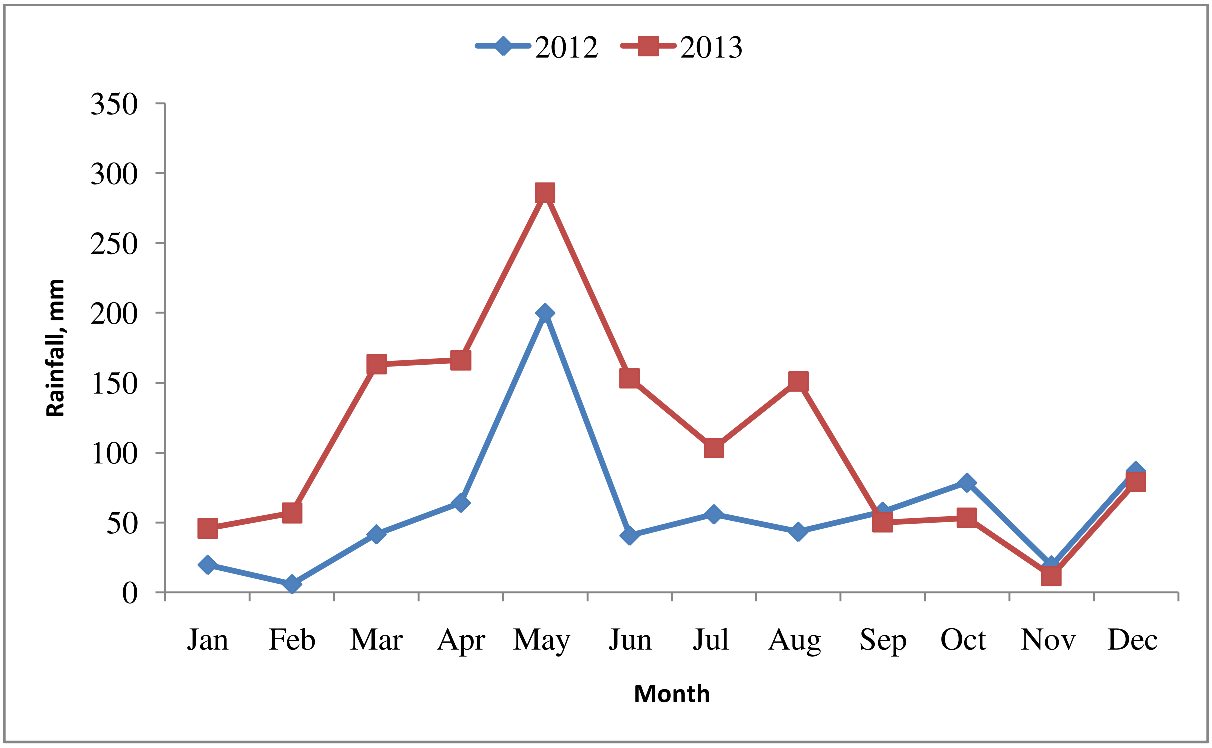


Figure 5. Monthly mean of rainfall in Humbo Woreda (Source: Humbo meteorological station)

3.4. Topography of the study area

Topography of the study area constitutes plain, gentle sloppy lands and mountains. Its elevation ranges from 1001 meters above sea level around eastern part to 2000 meter above sea level in north western part. Eastern part of the study area is dominated by flat lying topography, while the northern and north western parts constitute areas with high altitude.

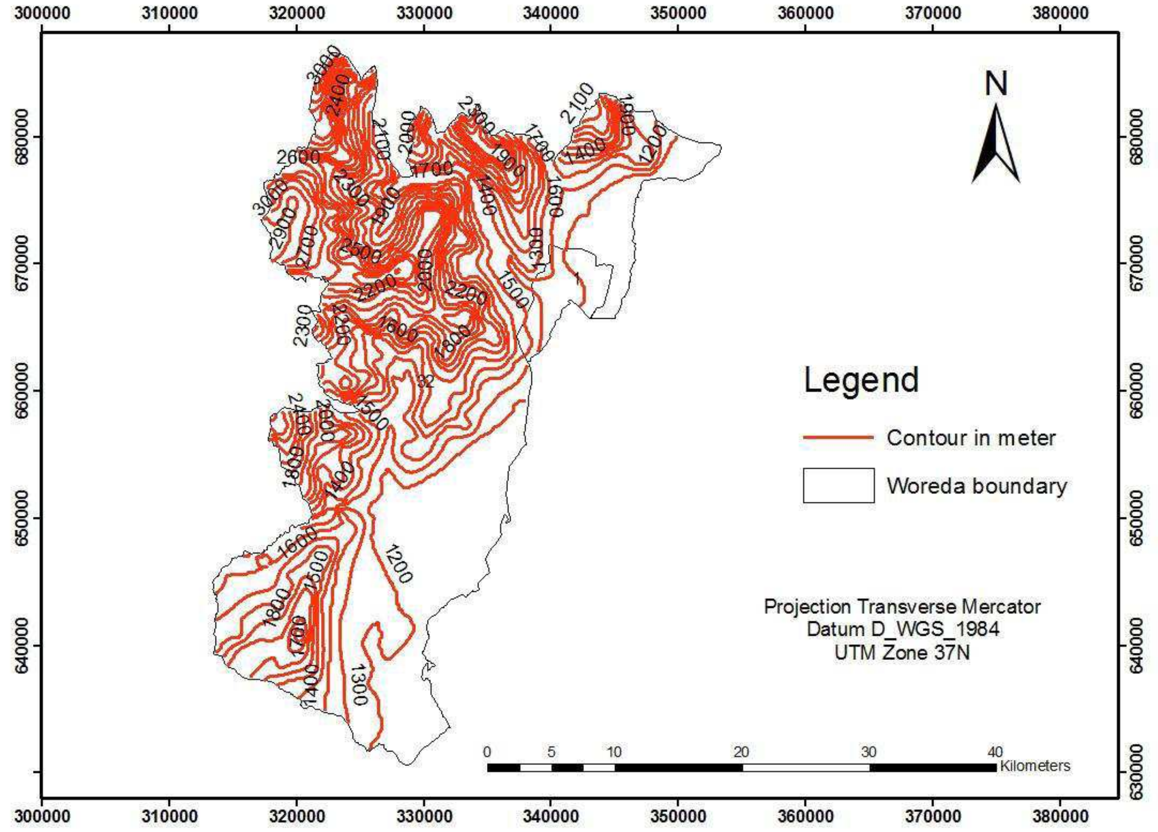


Figure 6. Contour map of the study area (Source: Researcher)

3.5. Drainage of 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 north east to south east 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.

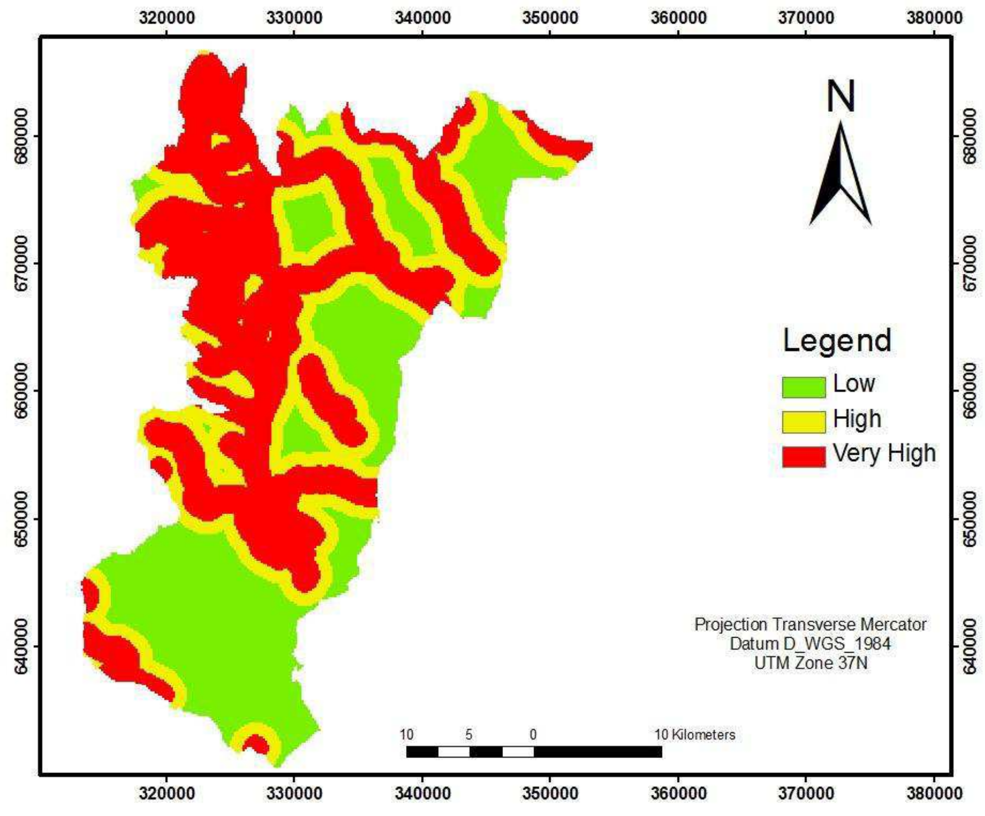


Figure 7. Drainage map of the study area (Source: Researcher)

3.6. Soil

On the basis of Food and Agricultural Organization (FAO) soil classification system, the study area consists of five soil types. These are Fluvisols, Vertisols, Xerosols,Leptosols& Nitosols.

Fluvisols: are genetically young soils. They are zonal soils in alluvial deposits, which found in alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones. Many Fluvisols under natural conditions are flooded periodically. Most Fluvisols are wet in all or part of the profile due to stagnating groundwater and/or flood water from rivers or tides. So they are poorly drained soils.

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

Xerosols: are arid desert soils containing low organic matter; the top layer is of a light color, and underlying layers may contain clayish and/or salt minerals such as carbonates and sulphates. They have low water storage capacity, thus they have good drainage.

Leptosols: are very shallow soils less than 30 cm thick over continuous rock or conglomeratic materials (which have over 75% coarse fragments). Due to high gravelly/stony and/or contact with lithic material at shallower depth, they have high water drainage/percolation. Leptosols are zonal soils and particularly common in mountainous regions.

Nitosols: are deep, well-drained, red, tropical soils. Nitisols have high moisture storage capacity. They are finely textured weathering products of intermediate to basic parent rock. Nitisols are predominantly found in level to hilly land under tropical rain forest or savannah vegetation.

Table 2. Level of malaria infestation based on soil type

Type of soil	Level of infestation		
	High	Medium	Low
Fluvisols	x		
Vertisolsv	x		
Xerosols			x
Leptosols		x	
Nitosols	x		

3.7. Land use land cover of the study area

The study area involves six major types of land use - land cover. These are settlement, farm land, water bodies, forest, bush lands and bare lands. It is dominated by farm lands account 46% of the total area, and wide farmers owned farm lands. The second dominant land use land cover type is bush land area 34.1%, which includes short trees and shrubs found in different parts of the study area. The study area also includes settlement areas account 12.5%, which are the kebel of Chewkare and small village settlements, dense 32 forest 5.7% of the total area found around the

Abaya Lake, water bodies 0.85%, part of lake and major rivers in the study area and bare lands account 0.85% found in different parts of the Woreda, which left fallow.

3.8. Temporal Malaria trend of the study area

Based on ten years data obtained from Humbo Woreda health office, the number of malaria cases in the Study area is very high. The trend of malaria in Kebel is irregular showed decrease between 2005 and 2007 and increased between 2008 and 2011. But since 2012, it showed decreasing trend due to several preventive actions taken by the Woreda health office and other concerned bodies. Even though, these actions have been undertaking, malaria is still major health problem in the study area.

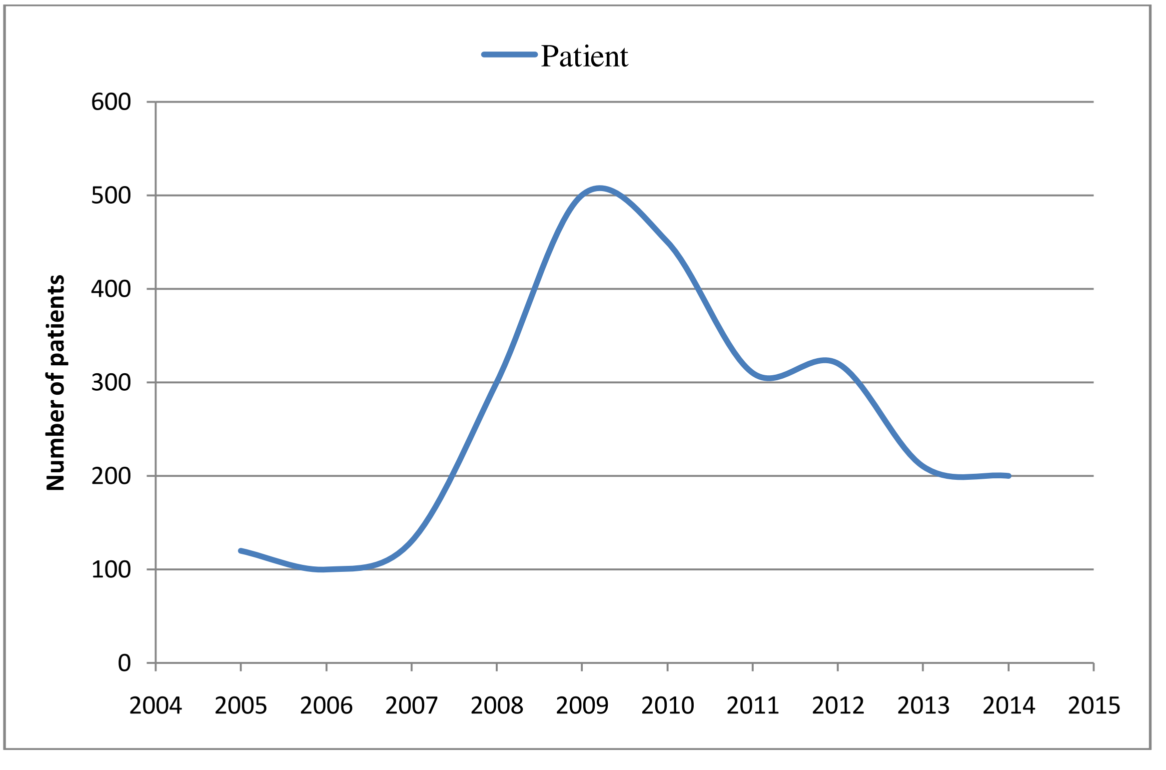


Figure8. Dynamics of Malaria infestation in Humbo Werda (Source: Humbo Woreda Health Office)

Malaria cases in the years 2005 and 2007 started to increase in the month June and reached the highest at the month of October. This is associated with the main rainy season of the area which starts at may and stays up to September. But in 2011 it started to increase at July and reached the maximum in the month of September. there is malaria case increment after the rain stopped. This is due to land-use land-cover existing during these times favor mosquito breeding through providing shade, moisture, and even food for the male mosquito as the effect of last gone rain retains. But after the harvest of agricultural production and continues dry season it starts to decline due to no suitable condition like enough amount of moisture within vegetations. According to the report of Woreda health office, child, pregnant women, and old ages were the most affected groups.

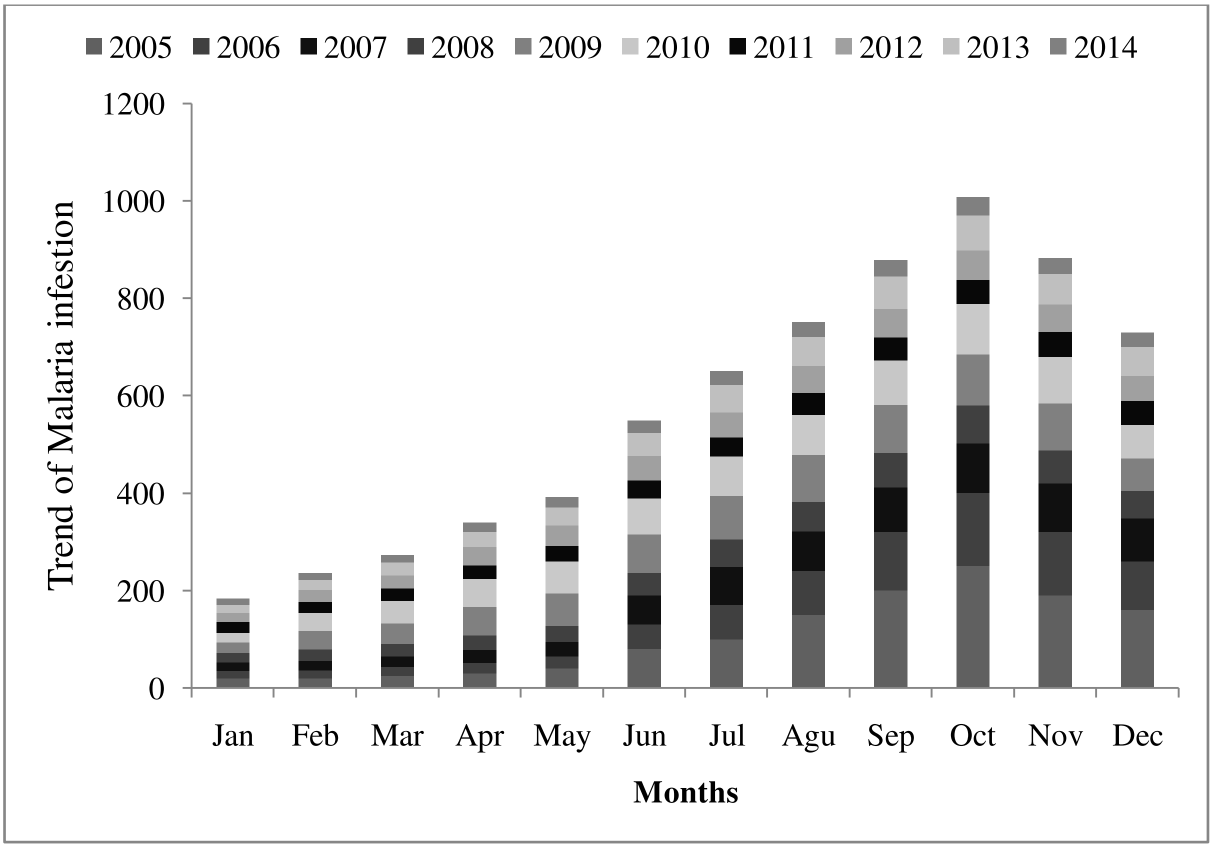


Figure 9 Trends of malaria infestation in study area (source: Humbo Woreda Health Office)

Table 3. Malaria infestation in months

Month	High	Medium	Low
Jan			×
Feb			×
Mar			×
Apr		×	
May		×	
Jun	×		
Jul	×		
Aug	×		
Sep	××		
Oct	××		
Nov	×		
Dec		×	

Source: Humbo Woreda Health Office

Both primary and secondary data were used for the malaria risk mapping of the study area, which were obtained from field survey and concerned institutions. The data and materials used include satellite imagery Landsat Thematic Mapper (TM), climatic data (rainfall and temperature), Shuttle Radar Topography Mission (SRTM) 30 m resolution data, topographic map (1:50,000 scale), soil map and clinical data (malaria cases) of the study area.

Table4. Procedure followed during the analysis of data in GIS.

	Sources	Remarks	Remark
Map of the study area	BOFED	Shape File	
Population data	BOFED	Shape File	
Malaria patients data	Humbo Woreda Healthy Bureau	10 Years Data	
GPS data	Collected from field		
Topographic maps	EMA	Scale1 : 50,000	
Satellite rainfall data	Famine Early Warning System Network	6 Years Data	

3.9. Software and Hardware Utility

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

Table 5. Software and hardware to be used for data analysis in GIS

	Name	**Utility**
Software	ERDAS IMAGIN 2013	Image processing and data analysis
	ArcGIS 10.2	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 4 GB)	For storage, software and internet support

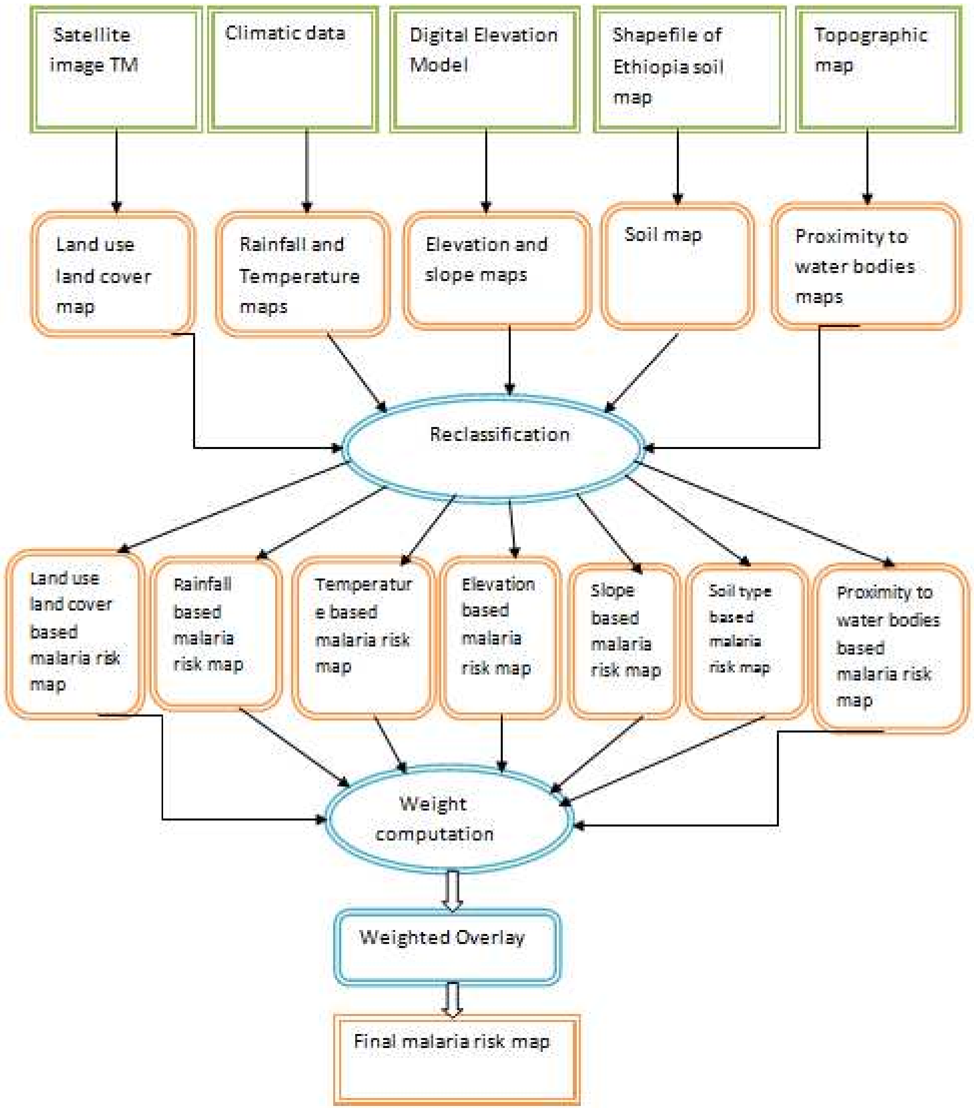


Figure 10. Methodological frame work of the study

3.10. Methods used for analysis of factors

3.10.1. Climatic factors

The temperature and rainfall maps of the study area generated from fifteen years mean monthly temperature and mean annual rainfall data collected from the national meteorological services agency. The data was collected from Eleven stations, one of them is found in the study area and the rest ten stations are surrounding the study area. The data was collected with the geographical location of stations as a point data. These stations are, bilate, Humbo, areka, Bombie ,Gesuba ,Bedesa ,Gununo, Wolayta Soddo, Boditi and Shanto .

Temperature

To generate temperature map, fifteen years mean monthly maximum and mean monthly minimum temperature data of eleven stations were analyzed. From the mean monthly maximum and minimum temperature of the stations, mean monthly temperature of each stations were calculated. Then, a single average value is computed for ten years. Finally, a single average value of each station used for surface interpolation in Arc GIS spatial analyst tools. The technique used to interpolate the data was rigging interpolation technique. The temperature map was reclassified by spatial analyst tools in Arc GIS. The study area is reclassified in to three classes based on its suitability to mosquito breeding.

Rainfall

The rainfall map was also generated from ten years monthly rainfall data of eleven stations. Annual rainfall of each station calculated from monthly rainfall data and the average annual rainfall computed for each station. In the same fashion as temperature map, by using rigging interpolation technique continuous surface was created. The reclassification of rainfall map of the study area was done in Arc map spatial analyst tools. Accordingly, the rainfall map of the study area was reclassified in to two classes on the basis of the rainfall amount suitability for mosquito breeding.

Elevation

Elevation of the study area was derived from STRM data of 30m resolution. This were classified into three classes of 862-1000m, 1000-1500m and 1500-1997m based on the relationship between elevation and malaria stated in to and assigned values of 1, 2 and 3 respectively. These values were seen associated with elevation related malaria risk levels of very high, high and medium respectively.

Slope

Slope map of the study area was generated from SRTM 30 meter resolution Digital Elevation Model. Then, the slope map was reclassified based on suitability of the slope for mosquito breeding by using spatial analyst tools in Arc GIS. The slope is classified in to five classes as: 0 – 1.8%, 1.8-3.7%, 3.7 – 5.8%, 5.8 – 8.5%,8.5-11.7%,11.7-15.8%,15.8-21.1%21.1-28.0%,&28.0-48.2% .

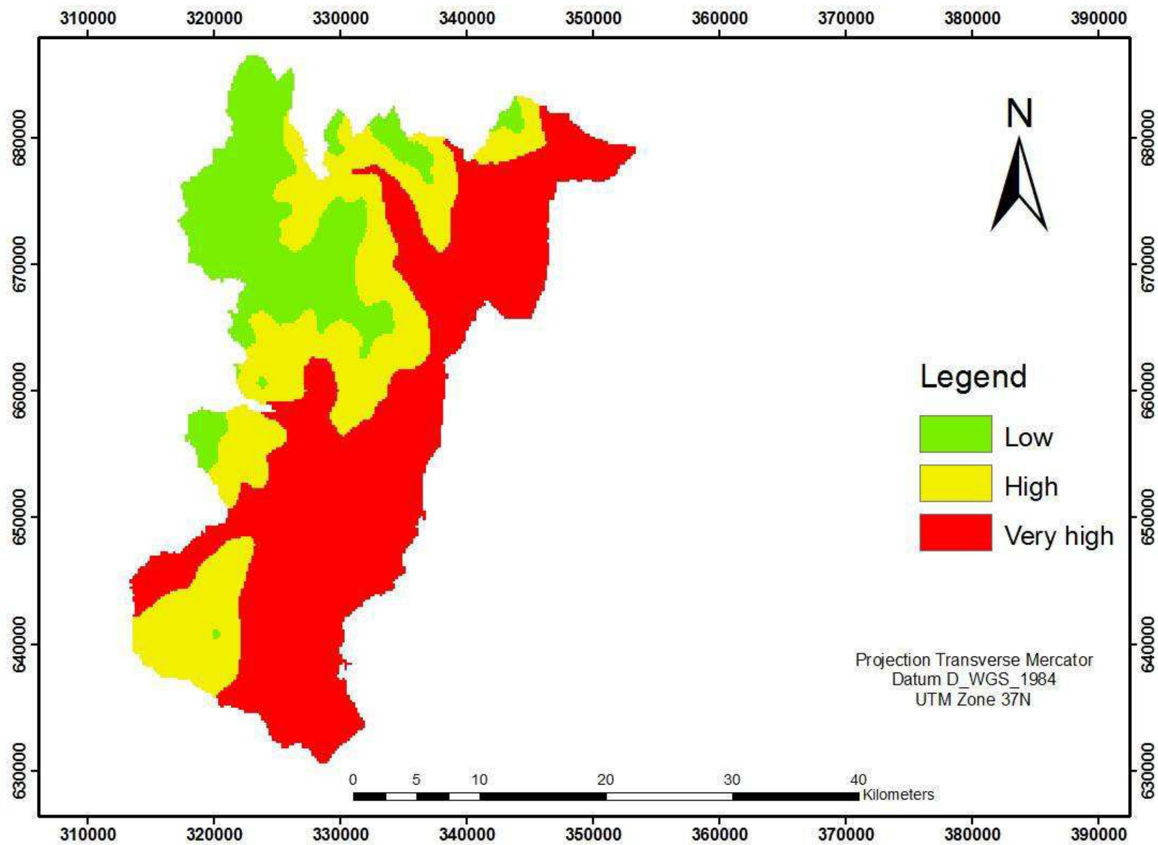


Figure11. Slop map of the study area (Source: Researcher)

3.10.2. Proximity to water bodies related factors

The map which shows proximity of the study area to water bodies such as rivers, lakes and swamps generated from 1:50,000 scale topographic map of the area (EMA, 1980). The scanned topographic map was geo-referenced and rivers, lakes and swamps are digitized by Arc GIS. The distance calculation from water bodies and the reclassification processes was also done in Arc GIS.

Proximity to Rivers

The map showing proximity to rivers and canals is generated by using Euclidean distance in spatial analyst tools of Arc Map from digitized rivers and canals. The reclassification of rivers map is based on flight range of mosquito. Areas found < 1 km, 1 - 2 km and above 2 km from rivers and canals assigned new values as 5, 4 and 2 and classified as very high, high and low malaria risk level, respectively.

Proximity to Lakes

Proximity to lakes map is generated and reclassified in Arc GIS by using Euclidean distance calculation in spatial analyst tools. New values were assigned for regions located within < 1 km, 1 - 2 km and above 2 km as 5, 4 and 2.Then reclassified as very high, high and low malaria risk areas, respectively.

Proximity to swamps

As it was mentioned above, swamps are digitized from1:50,000 scale topographic maps obtained from Ethiopia Mapping Agency (EMA) and the map was generated in Arc GIS environment by using Euclidean distance calculation. The reclassification was done on the basis of mosquito flight range. Areas found below1 km, 1 - 2 km and above 2 km distances are given new values 5, 4, and 2 and reclassified as very high, high and low malaria risk level, respectively.

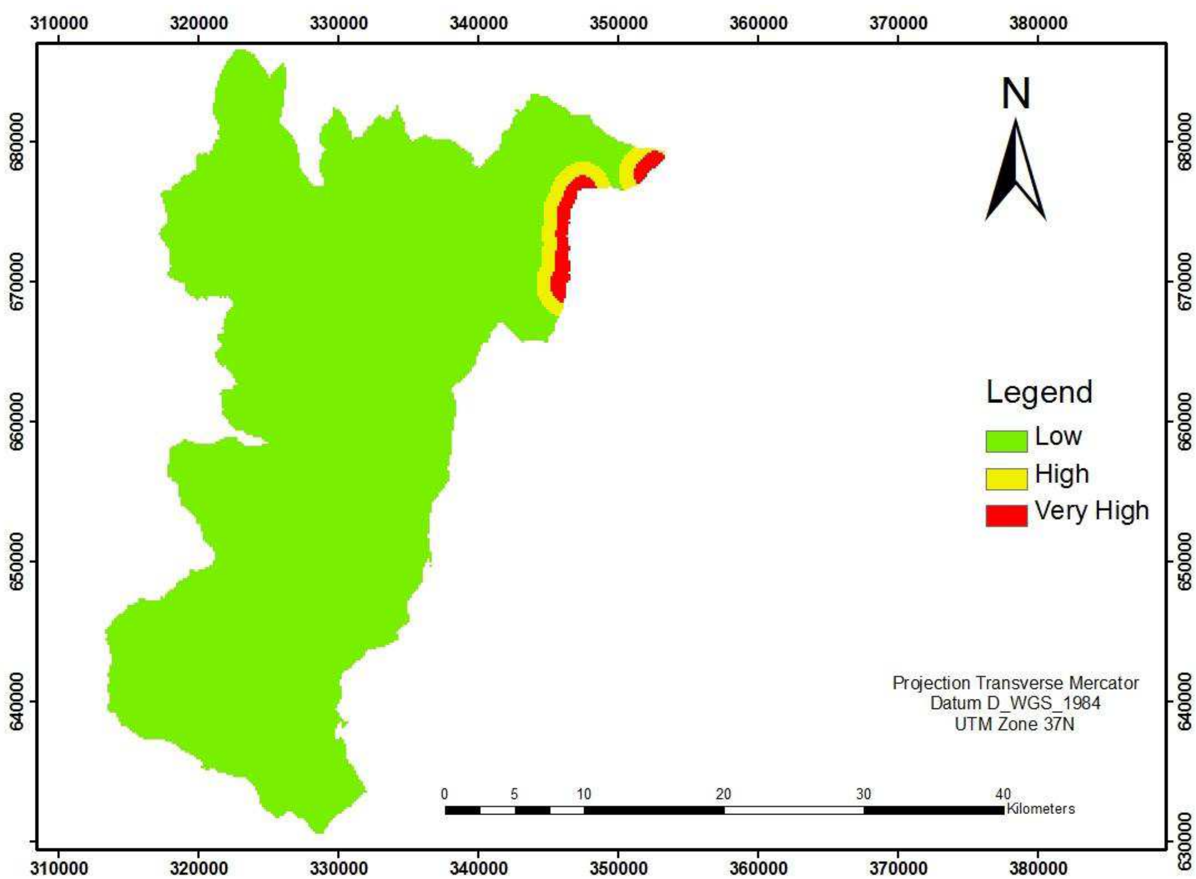


Figure 12.Reclassified proximity to Swamps based malaria risk map

3.10.3. Land use land cover

The land use land cover map was produced from Land Sat (TM) image of the year 2010, which is obtained from EMA. Supervised classification technique was used to classify the image in ERDAS IMAGINE 2010. The land use land cover classification was verified by ground truth data (ground control points) collected for each land use land cover types by field survey. From all land use land cover types, a total of 203 ground control points were collected from the field by GARMIN GPS and simple random sampling technique was used for collection of ground control points. By using ground control points collected from the field, accuracy assessment for the algorithm/computer based classification was conducted for the classified image. The land use land cover map was reclassified in to four classes depending on its suitability to mosquito breeding. According to literatures and previous works, farmlands are most suitable for mosquito breeding so, they classified as very high, forests and water bodies as high, because wet lands around the lakes create favorable conditions, settlement areas and bush lands are classified as moderate and bare lands are classified as low malaria risk level.

3.10.4. 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).

Soil types of the study area reclassified based on their ability to hold moisture or based on being permeable or impermeable. As it was mentioned above in description part, Vertisols are very sticky poorly drained soils and Fluvisols are found along tidal marshes and alluvial plains allow water stagnation. So they reclassified as very high malaria risk level and assigned new value. Nitosols, those have also high moisture storage capacity are given new value and reclassified as high malaria risk level. Leptosols poorly drained soils are given new value and classified as moderate risk level. Xerosols and those have good drainage leveled as low malaria risk level and assigned new value.

3.10.5. Drainage

Drainage density refers to the average length of streams within each unit area. A number of factors influence drainage density. It tends to be highest in areas where the land surface is impermeable, where slopes are steep, and where rainfall is heavy and prolonged (Waugh, 1996). Steeper slopes inhibit the development of still aquatic body; thereby inhibiting mosquito breeding habitats. In addition, heavy rains may have a flushing effect, cleaning breeding sites of mosquitoes. Therefore, calculating drainage density helps to identify the potential areas for mosquito breeding by identifying areas of water-logging. A.W. Sweeney (1999) stated that, there is a negative correlation between mosquito habitat and drainage density. This means that the lower the drainage density, the higher an area is suitable for water logging and the better suitable the area is for mosquito breeding.

3.10.6. Population

The growth of population and urbanization is another factor in the determination of health events such as epidemics of malaria. Issues related with urbanization include open water storage and the inadequate disposal of water (Reiter, 2001). When population is rapidly expanding, it opens doors to new habitats for the malaria vector, because not only are there more people in the city, but there are more places to breed in the city as well. Also of importance is the movement of people, infected people traveling to non-endemic areas can introduce disease where it would not normally occur. Conversely non-immune people are at a high risk if they move to a region where transmission is high. Malaria as a disease is closely bound to conditions which favor the survival of the anopheles mosquito. For malaria to occur in a person, *Anopheles* mosquitoes must be present, which are in contact with humans, and in which the parasites can complete the "invertebrate host" half of their life cycle. In addition, humans must be present, who are in contact with *Anopheles* mosquitoes, and in whom the parasites can complete the "vertebrate host" half of their life cycle. Finally, malaria parasites must be present. For *Anopheles* mosquito to survive, it has to feed on human blood. The frequency with which the vector takes blood meals is directly related with rising temperature at optimal range of temperature (20-30 C^0) and the presence of people exposed to *Anopheles* mosquitoes. The larger the population, the greater it is exposed to the risk of malaria in areas where malaria hazard is prevalent. Because, it increases the human-vector interactions, and enhances transmission by increasing the frequency with which the vector takes blood meals. This causes an increase in malaria incidence in the human population.

Therefore, for the purpose of mapping the population at risk of malaria, population density of each kebele was computed. The population density at Keble level was used because there is no detail population data or map that can depict the detail spatial distribution of the population in an area less than Keble level. Then, the population density map is reclassified in to 5 classes and the densely populated areas were labeled as highly susceptible.

3.11. Weight derivation

Environmental factors mentioned above are rated based on the level of their influence on mosquito breeding and their suitability for mosquito habitat. Since the aforementioned factors vary spatially, discussion was made with malaria experts of the Woreda to give weight for the factors. So the rating or assigning weights for the factors depends on previous works and literatures and the influence of the factors in the study area. Weights are assigned by pair-wise comparison 9 point continuous rating scale in IDRISI 32. Factor weights are calculated by comparing two factors at a time depending on their importance.

3.11.1. Weight computation for proximity to water bodies related factors

Proximity to rivers, lakes and swamps rated based on their level of influence. Weight is calculated by pair-wise comparison 9 point continuous rating scale in IDRISI 32. Since water body, particularly not moving is a typical place for mosquito breeding, swamps which provides best vector habitats are given high weight followed by lakes. Rivers, which are not stagnant and able to wash away mosquito habitats, are given less weight.

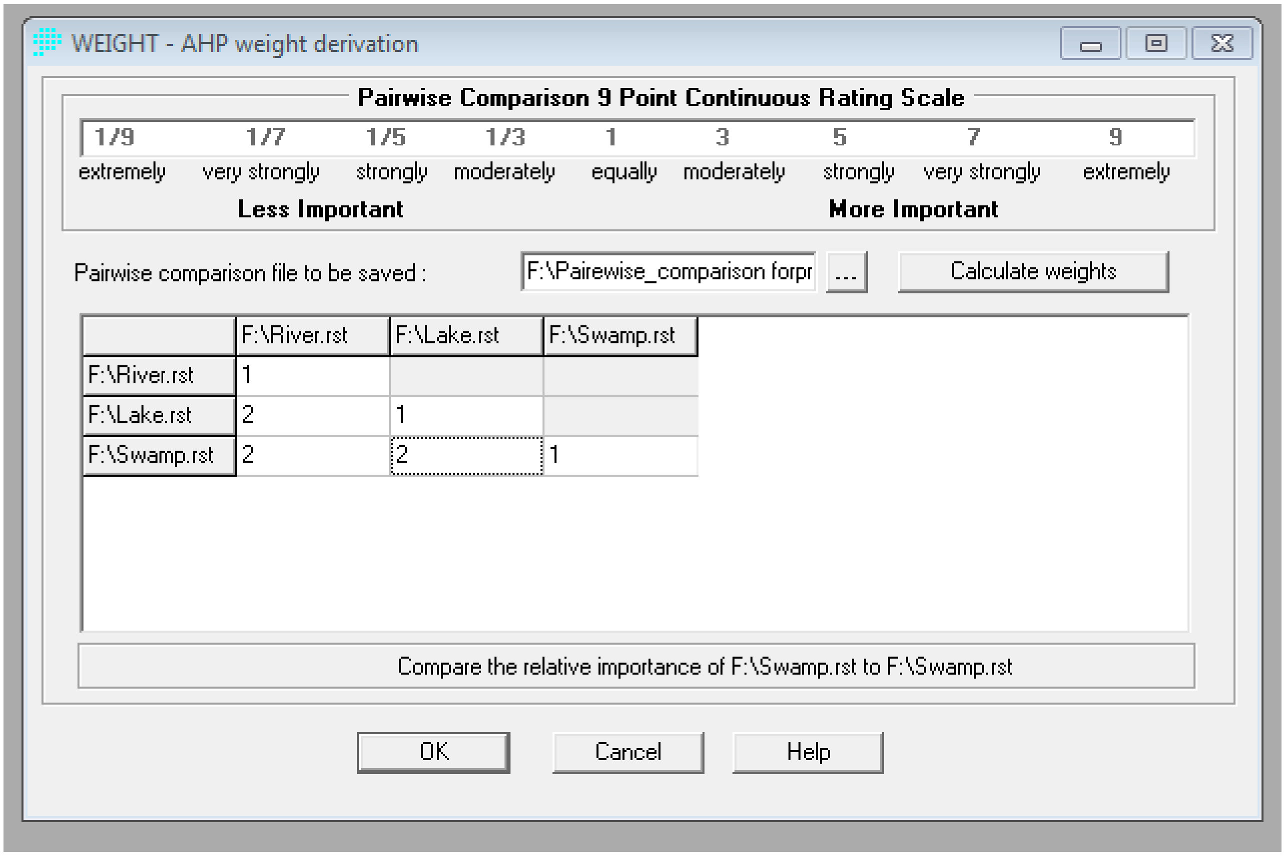


Figure 13. AHP weight derivation for proximity to rivers, lakes and swamps

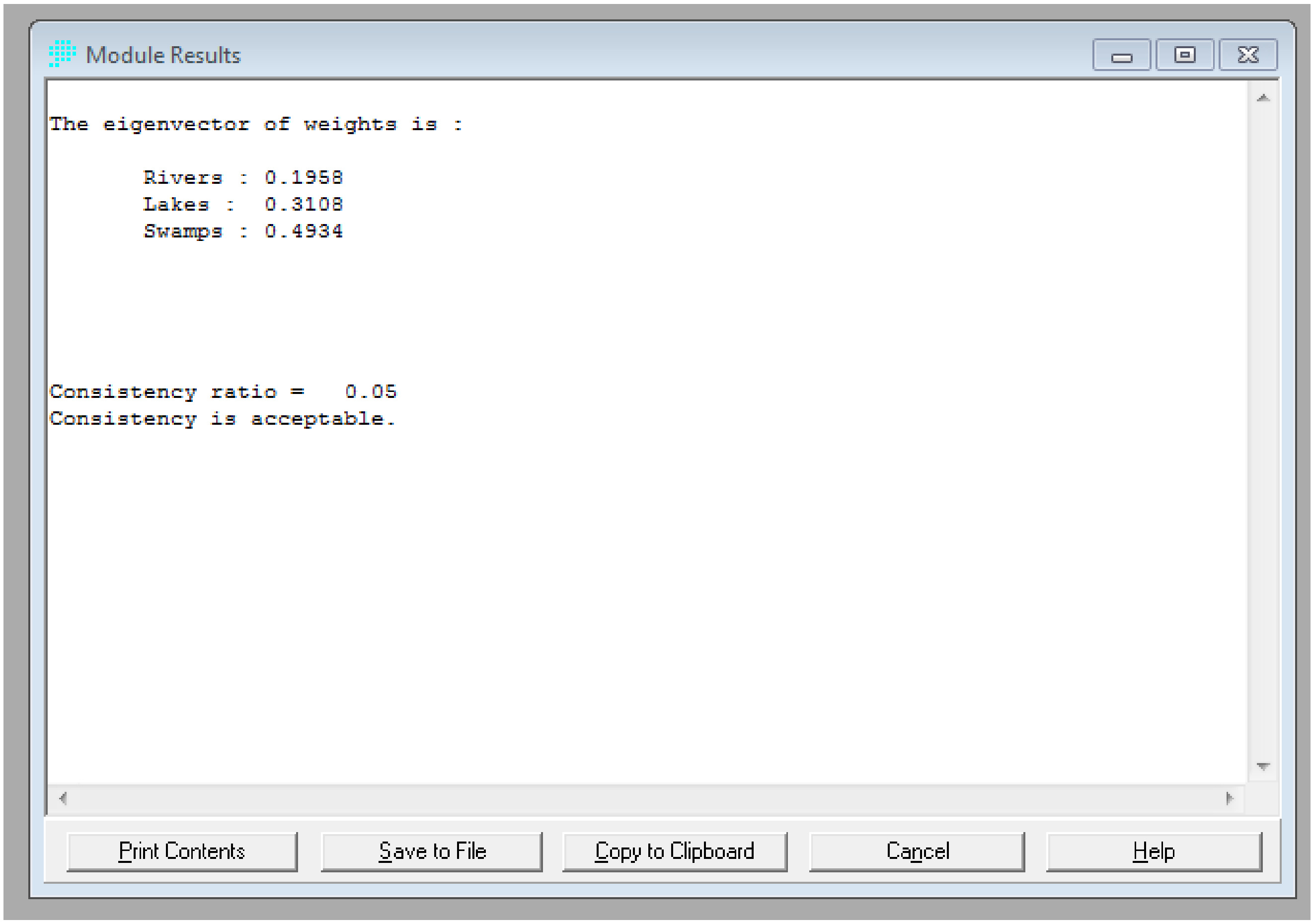
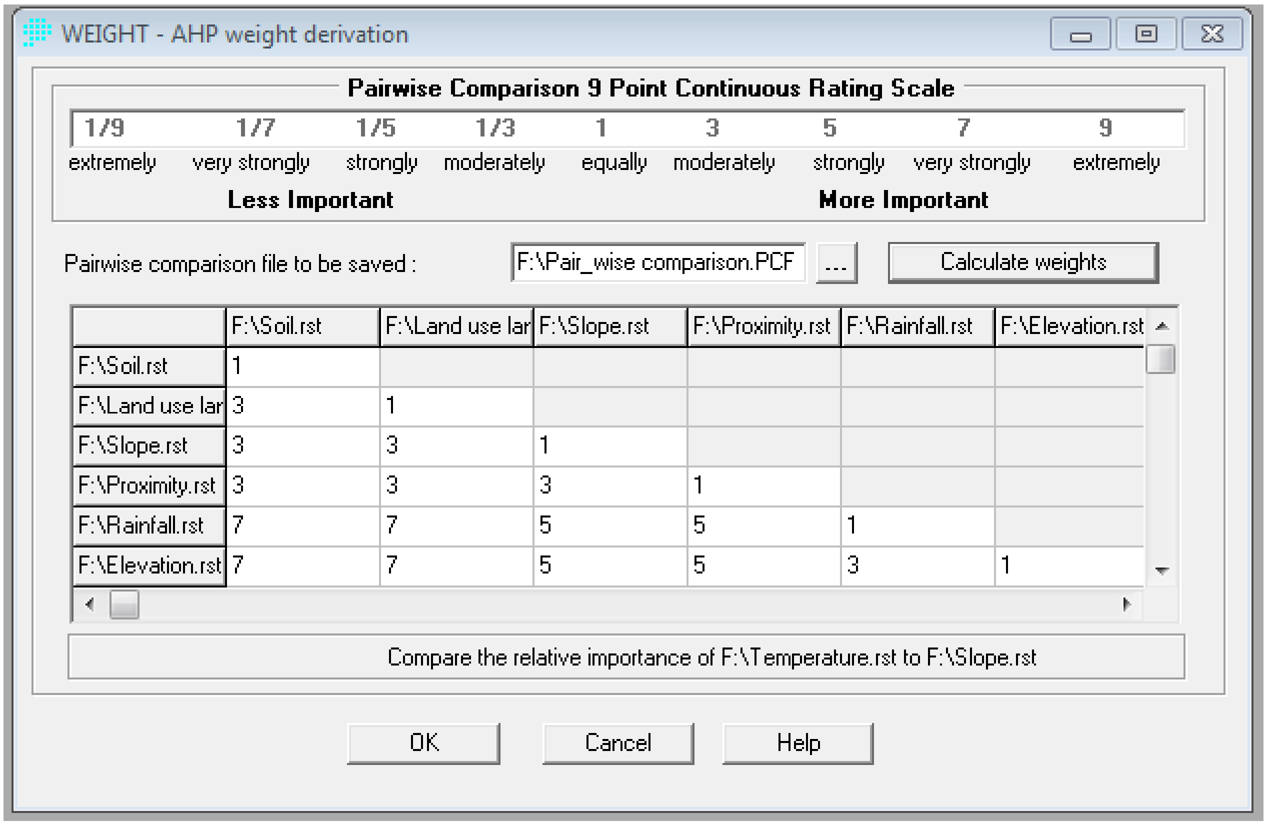


Figure 14. Module result for weight derivation of proximity to rivers, lakes and swamps

3.11.2. Weight derivation for all environmental factors under consideration

Malaria risk level of the study area is finally identified by assigning weights for previously discussed seven environmental factors. These are temperature, elevation, rainfall, slope, soil, land use land cover and proximity to water bodies. The importance of these factors for malaria incidence was discussed in chapter two, in the literature review part. These factors are rated based on their degree of importance that they have in mosquito breeding and malaria incidence. Weight is calculated by pair wise comparison 9 point continuous rating scale in IDRISI 32. Regarding the weights assigned for the factors previous researches and local condition of the study area were taken in to consideration. As it was mentioned above to consider local condition, discussion was made with malaria experts of the Woreda. Depending on this temperature which determines the incubation rate and breeding activity of mosquito given the highest weight followed by elevation. Rainfall which provides *anopheles* breeding sites by causing soil saturation is given the third weight. Since the study area consists of lakes, swamps, rivers and canals, proximity to water body related factors leveled as fourth factors and followed by slope, land use land cover and soil as fifth, sixth and seventh factors, respectively (Wilder,2007; Afrane *et al.,* 2011; Kumar *etal.*2012;Burlando, 2012; Woime, 2008; Munga *et al.,* 2006; Srivastava, 1995).



.

Figure 15. AHP weight derivation for elevation, temperature, rainfall, slope, soil, land use land cover and proximity to water bodies

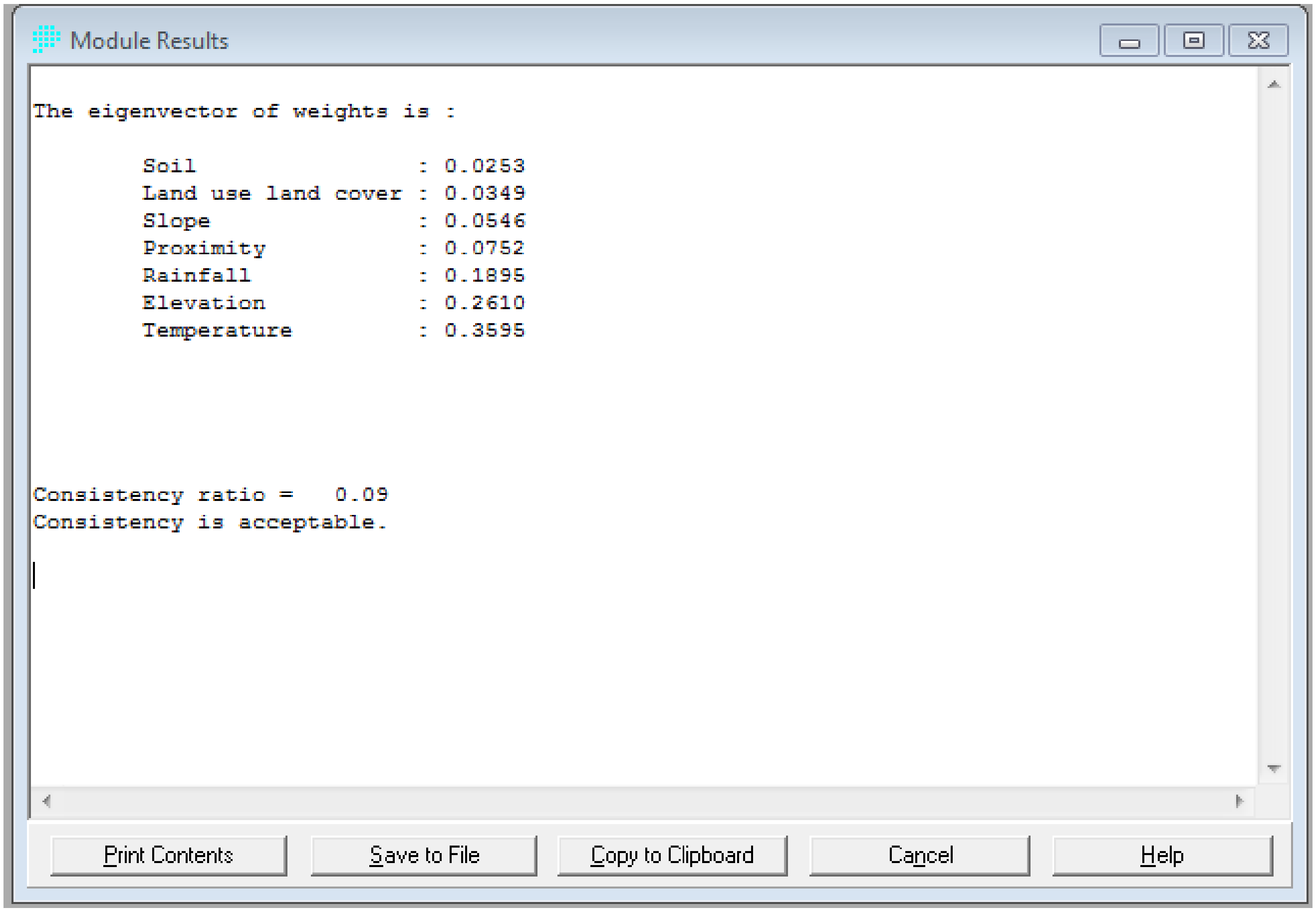


Figure16. AHP weight derivation for elevation, temperature, rainfall, slope, soil, land use land cover and proximity to water bodies

Module result for weight derivation of all environmental factors Weights assigned for all environmental factors mentioned above described in the following table.

Table 6. Show weight derivation of environmental factors and its consistency ratio

No	Factors	The Eigenvector of weights	Percentage of weights (%)
1	Temperature	0.3595	35.95
2	Rainfall	0.1895	18.95
3	Elevation	0.2610	26.10
4	Slope	0.0546	5.46
5	Soil	0.0253	2.53
6	Land use land cover	0.0349	3.49
7	Proximity to water bodies	0.0752	7.52
Total		1	100

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. The relationship of malaria risk with climatic factors

4.1.1. Relation of temperature with malaria infestation

In the area where temperature amount is less than 20°C *Plasmodium falciparum* that causes severe malaria, cannot complete its life cycle in the Anopheles mosquito. On the other side, places with temperature amount >30°C are difficult for larval survivorship (Afrane *et al.,* 2011). So the average temperature between 20°C to 24°C is suitable for malaria incidence thus leveled as high and very high risk level of malaria. the condition which is happened in chewkare is between in the above mentioned.

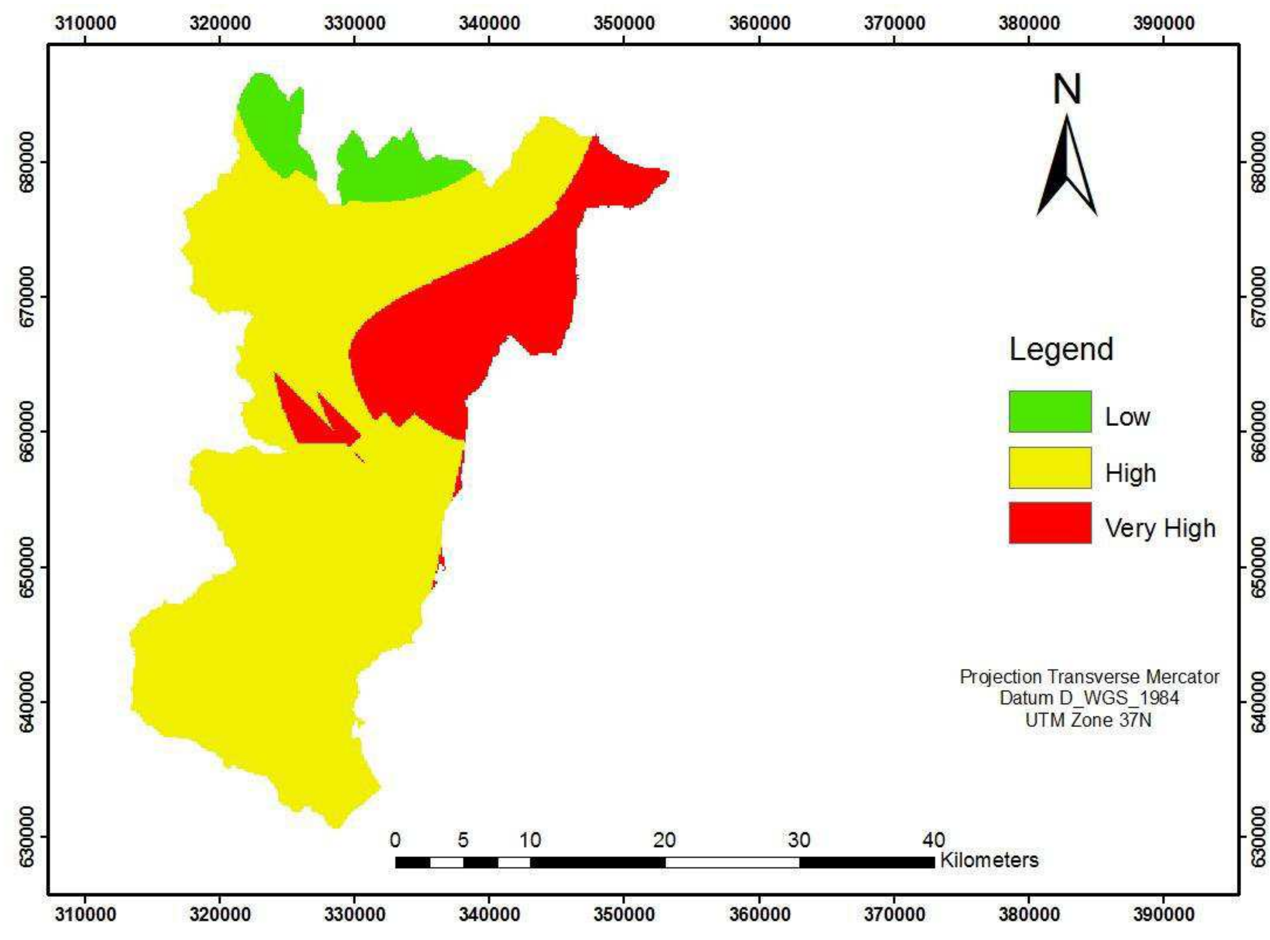


Figure 17. Reclassified temperature based malaria risk map

4.1.2. Rainfall and malaria risk level

Based on the distribution of rainfall, the whole study area is in very high and high risk of malaria. This is due to the annual rainfall distribution, ranges between 820 mm to 1600 mm conducive for mosquito breeding.

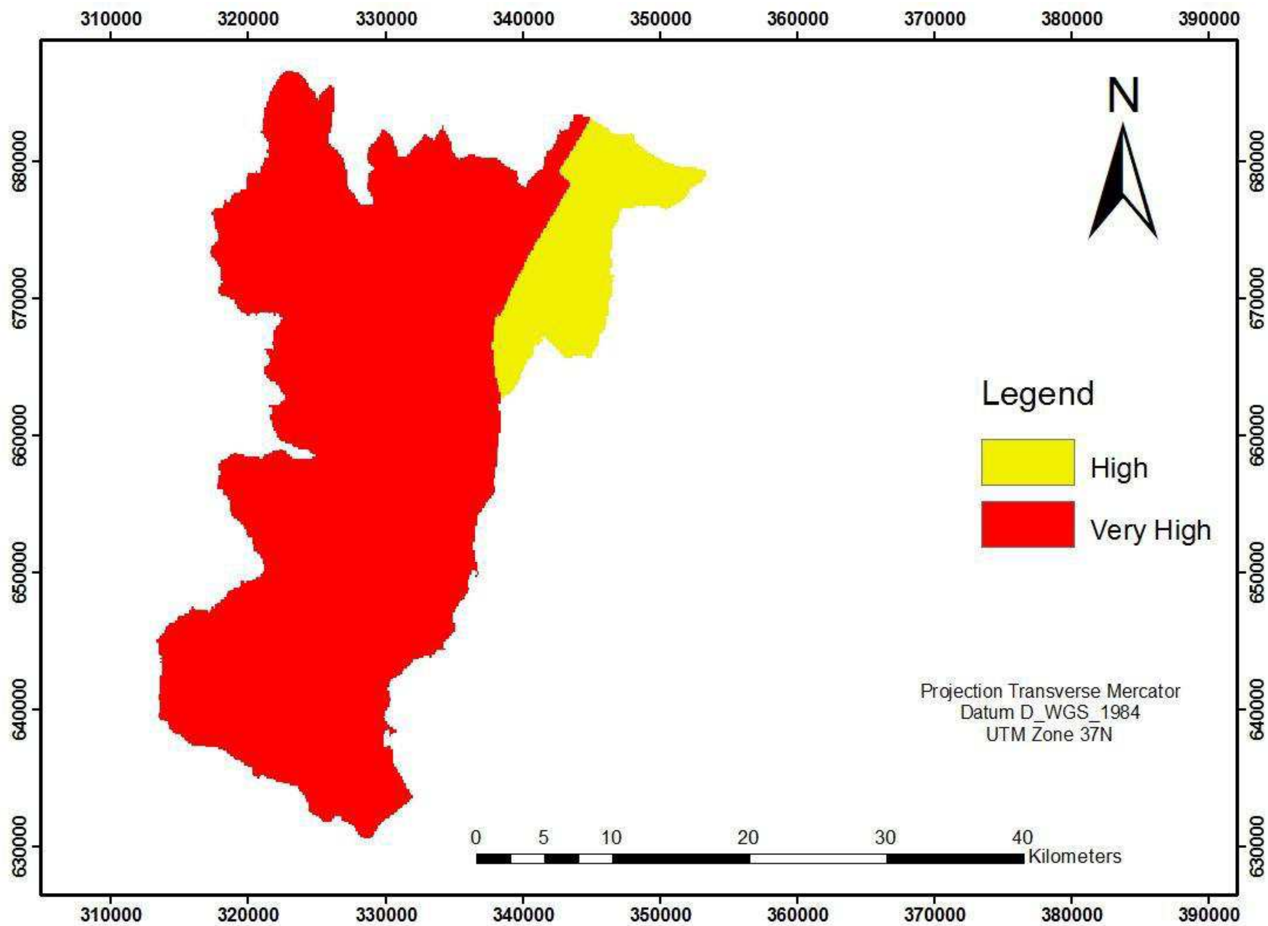


Figure 18. Reclassified rainfall based malaria risk map

4.2. Relationship between topographic factors and malaria incidence level

4.2.1. Elevation and malaria risk level

In Ethiopia malaria frequently occurs in areas with elevation below 2000 m above sea level and its transmission is very intense below 1500 m. So, area's elevation ranges between 1149 to 2000 m above sea level, which is potentially malarias. So that location of Chewkare 1001-1500 m.a.s.l. so it makes the situation suitable for malaria breeding.

4.2.2. Relation of Slope and malaria incidence

Of the total area, 40.9% is in high and very high malaria risk level, while the rest (59.1%) area is in moderate, low and very low risk level. Areas leveled as high and very high risk level have, slope less than 1.8% and 1.8-3.7% that allow water stagnation and create suitable conditions for mosquito breeding.

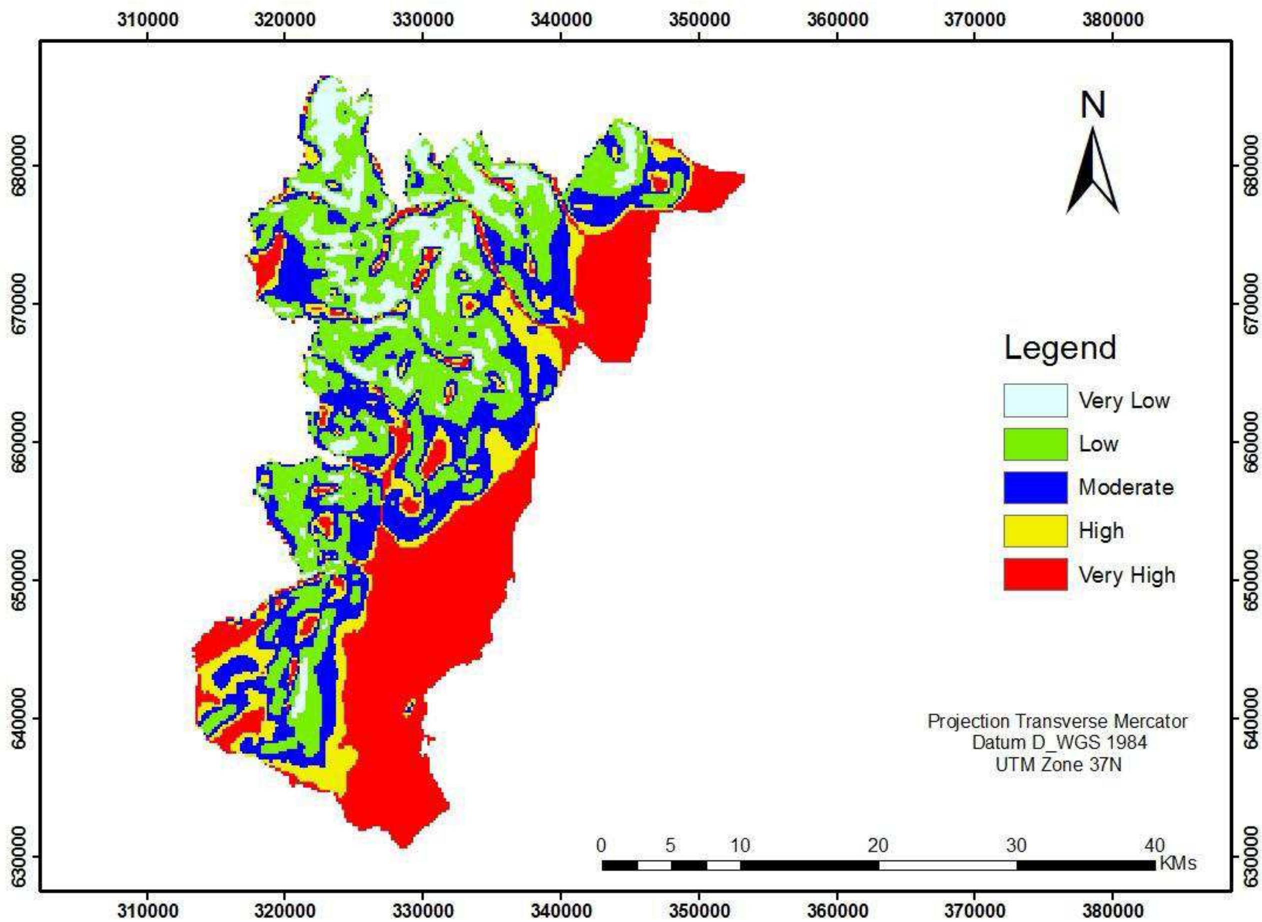


Figure 19. Reclassified map of Slope and malaria incidence

4.3. Proximity to water bodies and malaria risk level

The proximity to water bodies map is the result of overlaid proximity to rivers, lakes and swamp maps. This shows that 477 km2 have low, 488 km2 have moderate, while the remaining 29km2 and 7km2 have high and very high malaria risk level, respectively. This implies that very high and high malaria risk level cover only 4% of the study area. This is the result of small area coverage of swamps and lakes, those are given higher weights. Very high and high malaria risk observed in few areas located within 1 km and 2 km distance from lakes and swamps. Since rivers are given less weight compared to swamps and lakes due to their non-stagnant characteristics, areas located closer to rivers are mapped as moderate risk level. Areas located above 2 km distance from rivers, lake and swamps are mapped as low malaria risk level.

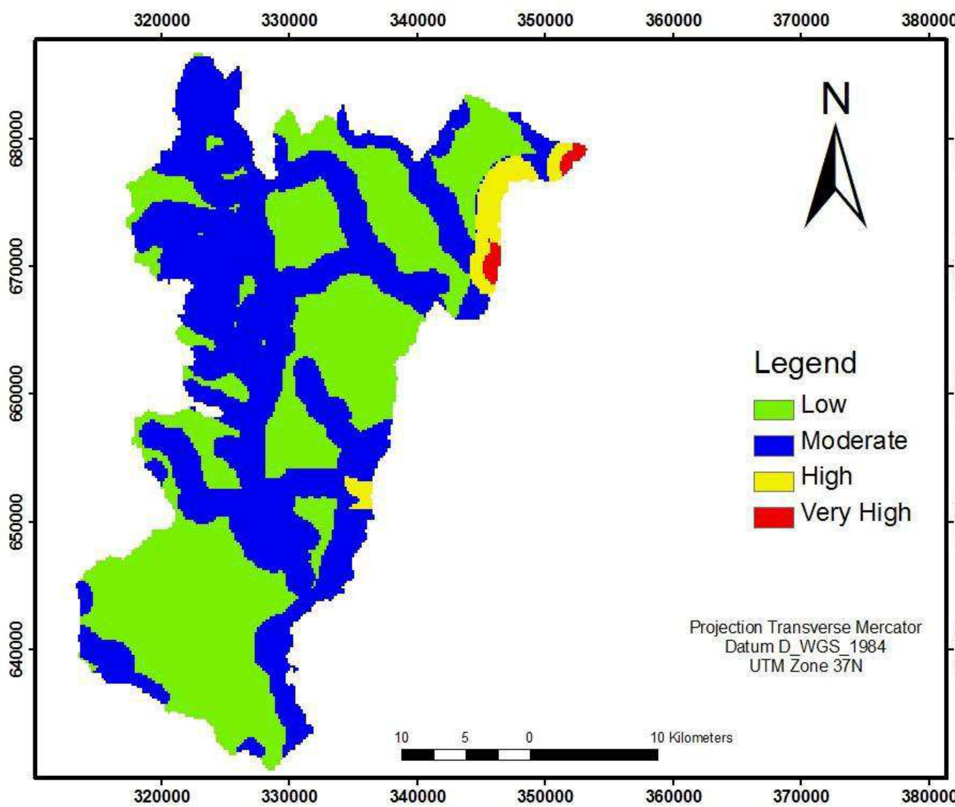


Figure 20. Reclassified map of water bodies (Source: researcher)

4.3.1. Proximity to Rivers

This is based on flight range of mosquito. Since mosquito can fly 2 km from its breeding site, areas mapped as very high, high and low malaria risk located < 1 km, 1 - 2 km and > 2 52 km distance, respectively.

4.3.2. Proximity to Lakes

The study area comprises Lake Abaya. During rainy seasons, these lakes get over flooded and create suitable environment for mosquito breeding. Since mosquito can fly 2 km from its breeding site, people living closer to lakes are under high malaria risk. Since the boundary of the

study area is restricted, it doesn't include the whole portion of the lakes. It includes very small portion of the lakes. So, few villages are bordered by the lakes.

4.3.3. Proximity to Swamps

In the study area, swamps are located along Lake Abaya. Swampy areas are suitable for mosquito breeding because they promote reproduction and maintenance of stable mosquito population. Based on proximity to swamps, the majority of study area is in high risk of malaria.

4.4. Land use land cover

Based on the supervised classification done for the satellite image, the study area has six major land use land cover types. Such as settlement, farmland, water body, bare land, forest and bush land. Based on accuracy assessment done for land use land cover map, the overall classification accuracy is 78.82% and an overall kappa statistics is 0.736. The kappa coefficient shows that 73.6% errors were avoided that could be generated by simple random classification. According to Landis and Koch (as cited in Cunningham, 2009), the values of kappa can ranges from +1 to -1.The agreement between the remotely sensed classification and the reference data is poor when the kappa value is < 0, slight between 0 – 0.2, fair 0.21 – 0.4, moderate between 0.41 – 0.6, substantial 0.61 – 0.8 and almost perfect from 0.81 to 1.Thus, the kappa coefficient of 0.736 is in substantial agreement range. The producers and users accuracy of the classification ranges between 62.5% - 95.12% and 60.71% - 94.44% respectively.

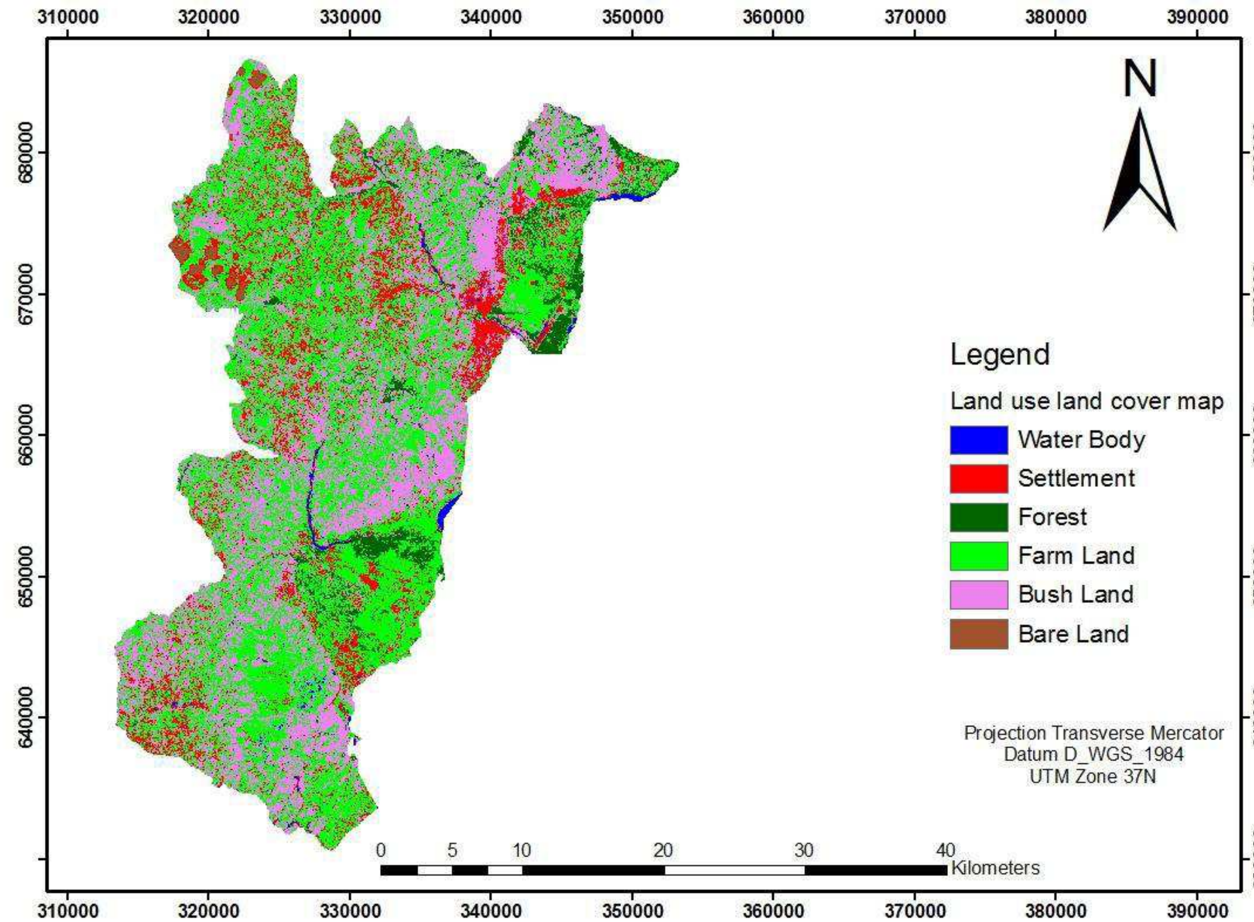


Figure 21. Land use land cover map of the study area

Table 7. Shows the classification accuracy assessment of land use land cover map

Classified Data	Water Body	Farm Land	Forest	Bare Land	Settlement	Bush Land	Row Total	Producere Accuracy	Users Accuracy	a Coefficient
Water Body	17	0	0	0	1	0	18	80.9 %	94.44 %	0.9380
Farm Land	1	39	2	1	5	0	48	76.4 %	81.25 %	0.7496
Forest	3	8	17	0	0	0	28	77.2 %	60.71 %	0.5594
Bare Land	0	0	0	10	1	0	11	62.5 %	90.91 %	0.9013
Settlement	0	2	1	2	38	2	45	73.0 %	84.44 %	0.7909
Bush Land	0	2	2	3	7	39	53	95.1 %	73.58 %	0.6690
Column Total	21	51	22	16	52	41	203			

Source: Researcher

The overall classification accuracy is78.82%
The overall kappa statistics is 0.736
From the total area, 461 km_2 leveled as very high risk of malaria, 65.5 km_2 as high, 466 km_2 as moderate and 8.5 km_2 as low risk of malaria incidence based on the suitability of land use land cover types for mosquito breeding. The area reclassified as very high and high malaria risk level covered by farmlands, water bodies and forests. A similar result with a study conducted in highland community of Africa, which discussed that the highest proportions of *anopheline* positive habitats occurred in pastures and farmlands followed by swamps(Munga et al.,2009). Thus areas covered by farmlands leveled as very high risk level followed by water bodies and forests as high risk level. Bare land which lacks moisture content and food source for larva leveled as low malaria risk level.

4.5. Soil type and malaria risk level

The reclassified soil map shows that 358.6 km_2 area mapped have very high, 80 km_2 high, 85 km_2 moderate and 477.4 km_2 areas have low risk of malaria. The reclassification was based on water storage capacity of soils, which determines their suitability for mosquito breeding. Vertisols and Fluvisols, those are poorly drained soils leveled as very high risk cover 358.6 km2. Nit sols cover 80 km2 have good water storage capacity and mapped as high malaria risk level followed by as moderate and Xerosols,& Leptosols as low malaria risk level.

4.6. Malaria risk map

The final malaria risk map produced by overlaying all environmental factors mentioned above displays that from the total area coverage of the study area 580 km2 in high, 357 km2 moderate and 64 km2 low level of malaria incidence. This shows that the majority of study area fell in high risk level (58 %) and followed by moderate risk level (35.7%). Low malaria risk level is found in very small area, which occupies only 6.3 % of the total area coverage.

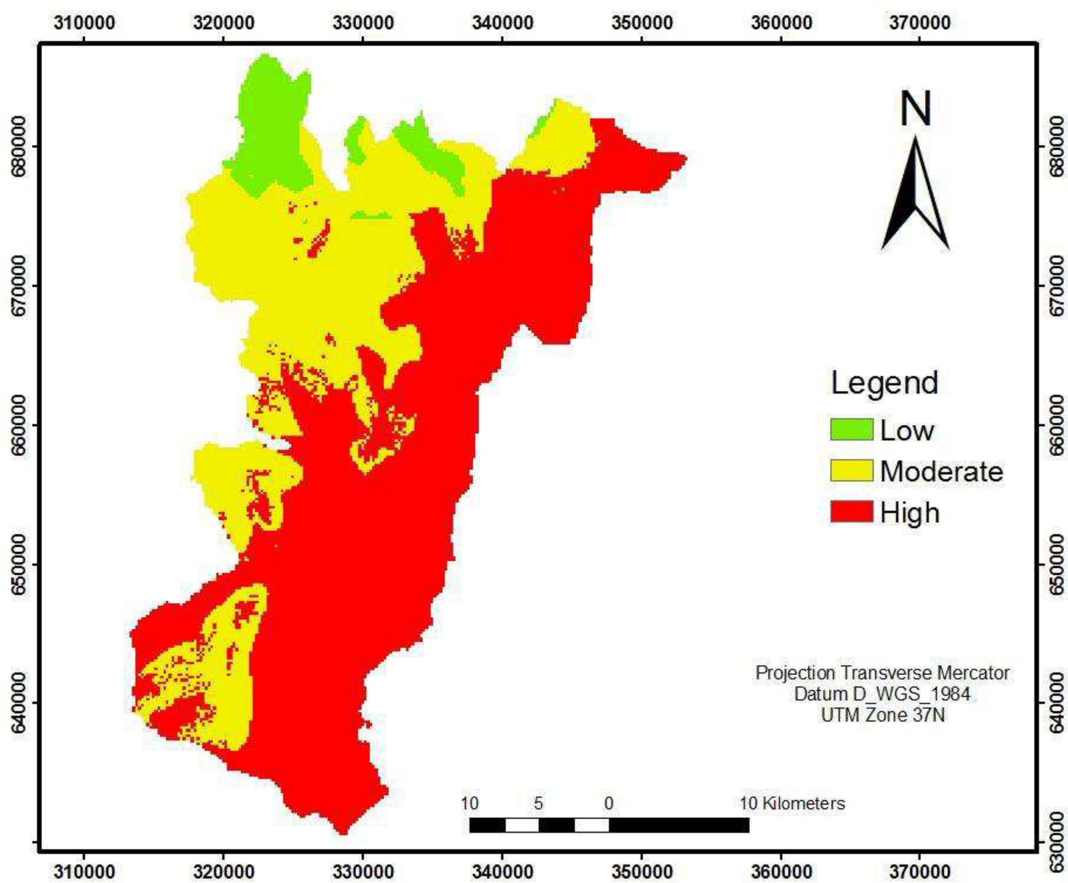


Figure22. Final Malaria Risk Map

Table 8. Summary of factors risk level and their area coverage

No	Factors	Area (km^2)	Percentage (%)	Risk Level	Assigned Value
1.	Temperature	62.2 746.8 192	6.2 74.8 19.2	Low High Very High	2 4 5
2.	Rainfall	118 883	11.8 88.2	High Very High	4 5
3.	Elevation	207.5 289.5 504	20.7 29 50.3	Low High Very High	2 4 5
4.	Slope	93 278 221 107 302	9.3 27.8 22 10.7 30.2	Very Low Low Moderate High Very High	1 2 3 4 5
5.	Land use land cover	8.5 466 65.5 461	0.85 46.55 6.54 46.06	Low Moderate High Very High	2 3 4 5
6.	Soil	477.4 85 80 3 58.6	47.7 8.5 8	Low Moderate High Very	2 3 4

			35.8	High	5
7.	Proximity to water bodies	477 488 29 7	47.65 48.76 2.9 0.69	Low Moderate High Very High	2 3 4 5
8.	Final Malaria Risk Map	64 357 580	6.3 35.7 58	Low Moderate High	2 3

4.7. Malaria risk level in Chewkera kebeles

The malaria risk level of Chewkare Kebele was observed by overlaying the malaria risk level analysis map and Kebele boundary map. Accordingly, among all Humbo woreda Chewkare Kebele which located in the Abaya cluster are malaria proved, therefore, it is critical one in the woreda. Because of its location and factors which are mentioned chapter three.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The main objective of this study was to generate malaria risk map of HumboWoreda particularly Chewkare kebele by using environmental factors. Environmental factors used to generate malaria risk map of the study area include temperature, rainfall, elevation, slope, land use/land cover, soil and proximity to rivers, lakes and swamps, then reclassified based on their suitability for mosquito breeding and malaria incidence.

Depending on the influence of factors, weight was computed by using pairwise comparison 9 point continuous rating scale.

For the presence of malaria risk, the existence of suitable climatic condition and topography particularly elevation for mosquito breeding play major role. The role of proximity to water bodies is negligible since the location of lakes and swamps is restricted to Kebele. Low malaria risk level is confined to areas with high elevation above 2000 m.a.s.l. and cold climatic condition, which is not favorable for mosquito breeding.

Finally, this project work confirmed that GIS and remote sensing technology is very important for analysis of spatial data. In this study GIS played great role in the generation of maps for environmental factors, reclassification, overlaying and identification of risk level. Remote sensing also played an important role by providing environmental information. Therefore, GIS and remote sensing technology is vital tool for health sector, particularly to facilitate vector born disease control and prevention program.

5.2. Recommendations

This project is classified the study area in to three malaria risk level, high, moderate and low based on environmental factors those create conducive environment for mosquito breeding and malaria incidence. Hence the followings are recommended by the researcher.

- The Woreda health office could make malaria prevention and control program like, anti – malaria drug provision, bed net distribution and house spraying by prioritizing based on the risk level of areas.

- GIS and Remote Sensing technology makes vector born diseases prevention and control program easy by enabling to map the breeding habitat, risk level and to make prediction to establish early warning system for impending epidemics. So, if possible the Woreda health office could use GIS and Remote Sensing technology for vector born disease prevention and control programs.

- Even though the role of swamps and other water bodies in the study area is insignificant, as compared to the climatic and topographic factors, to reduce the level of exposure to malaria in areas closer to swamps, the community and other concerned bodies should design appropriate facilities to drain swamps and stagnant water.

- In connection with the newly developing canals for irrigation based agriculture purpose, there should be health packages to be served to the local community as part of the main project to prevent mosquito breeding and malaria prevalence. This could be through service delivery for the malaria victims, awareness creation on malaria prevention and control, and insecticide treated net delivery.

- Further studies could made by using the already identified environmental factors in this project and by integrating additional parameters beyond environmental factors those may contribute for malaria incidence and transmission like population migration, housing style, health facilities and so on for more accuracy.

References

Abose, T., Garrit, J. V., Bosboom, G., Sakr, J. and Habbema, J.D. (2003). Spatial and temporal variation of malaria epidemic risk in Ethiopia: factor involved an implication. Acta Trop. **87**: 331-340.

Afrane,Y.A., Githeko, A.K., and Yan, G. (2011). Malaria transmission in the African highlands in a changing climate situation: Perspective from Kenyan highlands, global warming impacts:- case studies on the economy, human health, and on urban and natural environments, Stefano Casalegno (Ed.), ISBN: 978-953-307-785-7.

Agarwal,S.A., Sikarwar, S.S., and Sukumaran, D. (2012). Application of RS & GIS in risk area assessment for mosquito borne diseases:- A case study in a part of Gwalior City (M.P.) *International Journal of Advanced Technology & Engineering Research,* **2 (1),** 2250-3536.

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

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

Beck, R., Lobitz, M., and Wood, L. (1997). Remote Sensing and Human Health: *New Sensors and New Opportunities*. **6:**217-226.

Bian L, Mushinzimana, E., Munga S., Minakawa N. and Feng C. (2003). Landscape determinants and remote sensing of anopheline mosquito larval habitats in the western Kenya highlands. Malaria journal **5:**13-24.

Boelaert,M., Arbyn,M., and Van der Stuyft,P.(1998). Geographical Information Systems (GIS), gimmick or tool for health district management? *Tropical Medicine and International Health***, 3 (3),** 163–165.

Boelee, E., Konradsen, F. and Wim Vander Hek. (2002). Malaria in irrigated agriculture, papers and abstracts for the SIMA special seminar at the ICID 18th International congress on irrigation and Drainage, Montreal, 23 July 2002. IWMI, working paper 47. SIMA Document 2.Colombo, Sri Lanka.

Broker S, Hay SI, Tchuem Tchuenté LA, Ratard R (2002). Using NOAA AVHRR data to model human helminth distributions in planning disease control in Cameroon, West Africa. Photogram Eng Rem S68 **(2):** 175-179.

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

CDC. (2006). Centers for Disease Control and Prevention. Department of Health and Human Services. Schema of the Life Cycle of Malaria. [http://www.cdc.gov/malaria/biology/life_cycle.htm. On 16 May 2006 **20**:30:24.

Clarke,K.C.,McLafferty, S.L., and Tempalski, B.J. (1996). On epidemiology and geographic information systems: a review and discussion of future directions. *Emerging Infectious Diseases*, **2 (2),** 85-92

CSA. (2007). Central statistical agency of Ethiopia population and housing census report. Addis Ababa, Ethiopia Cunningham.(2009).More than just the Kappa coefficient: A program to fully characterize inter-rater reliability between two raters.SAS Global Forum, paper 242.University of Pittsburgh, Pittsburgh, PA.

Daniel, E. (1999). Malaria: Failure, Puzzle, &Challenge. Perspectives in health. Media center press release megazine.No.**1**.74.

EMA. (1980).1:50,000 scale topographic map of Arba Minch area .Addis Ababa

ESRI. (1990). Understanding GIS:-The Arc/Info method. Environmental systems research institute, Redlands, CA, USA

FAO. (1984). Ethiopian geomorphology and soils (1:1,000,000 scales). Assistance to land use planning,

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

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

FMoH. (2009). Ethiopian national malaria indicator survey 2007: Technical summary. Addis Ababa, Ethiopia.

Getachew Alemu (2006). Prevalence of Malaria and its Influencing Factors in Awassa District, Southern Ethiopia. AAU, Addis Ababa, M. Sc. Thesis.

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

Gilles, H.M. and Warrell, D.A. (1993). Bruce- Chewatt's Essential malariology. 3rd edition. Arnold. London.

Githeko, K., Nbongo, C.M. and Atieli, K. (2000). Climate change and vector-borne diseases: a regional analysis. WHO Bulletin, **78(9):** 1136-1146.

Hay, S.I., Omumbo, J.A., Craig, M.H. and Snow, R.W. (2000). Earth observation, geographic information systems and Plasmodium falciparum malaria in sub-saharan Africa. Book chapter: Remote Sensing and GIS in Public Health. Advances in Parasitology. Eds. Hay, Randolph, Rogers, D. Academic Press, **47:** 173-215.

Jackman,J.A., and Olson,J.K. (1914). Mosquitoes and the diseases they transmit. Texas Cooperative Extension, the Texas A & M University System.

Joshi, V., Sharma, R.C., Singhi, M., Singh, H., Sharma, K., Sharma, Y. and Adha, S. (2005). Entomological studies on malaria in irrigated and non-irrigated areas of Thar Desert, Rajasthan, India. J. Vect. Borne Dis. **4:** 25–29.

Kebede, A., McCann, C. J., Kiszewski, E. A. and Ye Beiyo, Y. (2005). New evidence of the effect of agro-ecologic change on malaria transmission. Am. J. Trop. Med. Hyg.**73**:676-680.

Kaya,S., Pultz, T.J., Mbogo, C.M., Beier, J.C., and Mushinzimana, E. (2001). The use of radar remote sensing for identifying environmental factors associated with malaria risk in Coastal Kenya. A research submitted to the international Geoscience and Remote Sensing Symposium (IGARSS '02).Toronto.

Kimbi,H.K., Sumbele,I.U., Nweboh,M., Anchang,J.K., Lum,E., Nana,Y., Ndip,L.M., Njom,H., and Lehman,L.G.(2013). Malaria and haematologic parameters of pupils at different altitudes along the slope of Mount Cameroon: - A cross-sectional study. *Malaria Journal***,** **12:** 193-199.

Kumar, R, P., Nathawat, M.S., and Onagh, M. (2012). Application of multiple linear regression model through GIS and remote sensing for malaria mapping in Varanasi District, INDIA *Health science Journal,* **6 (4),** 731-749.

Mendis, K. (2009). Spatial technology & malaria control. *Indian Journal of Medical Research* **130**: 498-500.

MFI. (1997). Embracing Humanity Worldwide. Malaria foundation international. Fact Pact. 12 August 1997.

MOA. (1998).National livestock development project working paper 1 – 4.Addis Ababa,Ethiopia

Munga, S.,Minakawa, N., Zhou, G., Mushinzimana, E., Barrack, J., Githeko, K., and Yan, G. (2006). Association between land cover and habitat productivity of malaria vectors in Western Kenyan highlands. *American Journal of Tropical Medicine &* Hygiene**74,** 69-75.

Munga,S.,Yakob,L.,Mushinzimana,E.,Zhou,G.,Ouna,T.,Minakawa,N.,Githeko,A.,andYan,G. (2009). Land use and land cover changes and spatiotemporal dynamics of *Anopheline* larval habitats during a four year period in a highland community of Africa. *American Journal of Tropical Medicine and Hygiene***,** **81(6),** 1079–1084.

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 Arf. Med. J. **82**: 186-192.

Negatu, W., Abebe, M. and Dejene, A. (1992). *Plasmodium vivax* and *P. falciparum* epidemiology in Gambela, South-West Ethiopia. Trop. Med.Parasitol.**43** : 181- 185. *Hygiene,* **81(6),** 1079–1084.

NIAID. (2007). Understanding Malaria: Fighting an ancient scourge. National Institute of Health U.S.A.

Omumbo,J.,Ouma,J.,Rapuoda,B.,Craig,M.H.,LeSueur,D.,andSnow,R.W.(1998).Mapping malaria transmission intensity using geographical information systems (GIS): an example from Kenya. *Annals of Tropical Medicine & Parasitology***, 92(1),** 7- 21

Omumbo,J.A., Hay, S.I., Goetz, S.J., Snow, R.W., and Rogers, D.J. (2002).Malaria transmission intensity in East Africa using Remote Sensing. *Photogrammetric Engineering & Remote Sensing,* **68(2),** 161-166.

Petrocelli,L.D.,Camardiel,A.,Aguilar,V.H.,Martinez,N.,Córdova,K.and Ramos,S.(2011). Geospatial tools for the identification of a malaria corridor in Estado Sucre, a Venezuelan north-eastern state. *Geospatial Health*, **5(2),** 169-176.

Pope, K.O., Sheffner, E.J. and Linthicum, K.J. (1992). Identification of central Kenyan Rift Valley fever virus vector habitats with Landsat TM and evaluation of their flooding status with airborne imaging radar. Remote Sens Environ; **40:** 185-96.

President's Malaria Initiative. (2012).Malaria operational plan (MOP) of Ethiopia FY 2012.

Reiter, P. (2001). Global warming and malaria: knowing the horse before hitching the cart. *Malaria Journal* **7:** 1-9.

Rincón-Romero,M.E.,andLondoño,J.E.(2009). Mapping malaria risk using environmental and anthropic variables in Buenaventura, Colombia. *Rev Bras Epidemiol***, 12(3),** 338 – 354.

Robert, V., Macintyre, K., Keating, J., Trape, J. F., Duchemin, J.B., Warren, M. (2003) Malaria transmission in urban sub-Saharan Africa. Am. J. Trop. Med. Hyg.**68**:169–176.

Saxena,R., Nagpal, B.N., Srivastava, A., Gupta, S.K., and Dash, A.P. (2009). Application of spatial technology in malaria research & control: some new insights, *Indian J Med Res,* **130**,125- 132

Shumbullo, E.L. (2013). Variation in malaria transmission in Southern Ethiopia. The impact of prevention strategies and a need for targeted intervention. (Unpublished doctoral dissertation). University of Bergen,

Norway Simoonga, C., Utzinger, J., Brooker, S., Vounatsou, P., Appleton, C.C., Stensgaard, A.S.,Olesen, A., and Kristensen, T.K. (2009). Remote sensing, geographical information system and spatial analysis for schistosomiasis epidemiology and ecology in Africa. *Parasitology,* **136,** 1683–1693

Tulu, A. (1993). Malaria In: Kloos, H and Zein, Z.A (Eds).The Ecology of Health and Disease in Ethiopia, pp 341-352, .West view Press, Boulder.

Teklehaimanot,H.D., Lipsitch,M., Teklehaimanot,A., and Schwartz,J. (2004).Weather based prediction of *Plasmodium falciparum* malaria in epidemic-prone regions of Ethiopia I. Patterns of lagged weather effects reflect biological mechanisms. *Malaria Journal,* **3,** 41-72 .

Van der Hoek, W., Konradsen, F., Amerasinghe, P.H., Perera, D., Piyaratne, M.K., and Amerasinghe, F.P. (2003). Towards a risk map of malaria for Sri Lanka: The importance of house location relative to vector breeding sites. *International Journal of Epidemiology,* **32,**280 –285

Whelan,P., and Warchot,A.(2009). Mosquito breeding and sewage pond treatment in the Northern Territory. Medical entomology center for disease control department of health and families Northern Territory government.

Whittle, H., and Bole van Hemsbroek, M. (1994). Malaria, In: Lankinen, K. S., Bergström,S. Mäkelä, P. H. and Peltomaa, M. eds. Health and disease in developing countries, The Macmillan Press limited, London, pp. 147-162 .

WHO. (2000). WHO Expert Committee on Malaria. WHO. *Tech. Rep. Ser.* No. **892.** 74 pp.

WHO. (2003).The burden of malaria in Africa. The Africa malaria report, Geneva, Switzerland.

WHO (2005) Roll Back rt. Ethiopia, Country Profile.WHO.

WHO, (2009). World Malaria Report. Geneva, Swizerland.

Wilder, J. (2007). Modeling malaria transmission risk using satellite based remote sensing imagery: fife year data analysis in Democratic People's Republic of Korea. (Unpublished master's thesis).Northwest Norway Missouri State University Maryville, Missouri.

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

World Malaria Report. (2005). Global malaria situation. In: World Malaria Report /WMR/. [http://rbm.wmr 2005/htm/1-1.htm].

World Malaria Report. (2009). Global malaria situation. In: World Malaria Report /WMR/.

Wyatt, P., and Ralphs, M. (2003). Geographic Information System in Land and Property Management. Spon Press, London.

Zacarias,O.P., and Andersson,M.(2010). Mapping malaria incidence distribution that accounts for environmental factors in Maputo Province, Mozambique. *Malaria Journal*, 9, 79-87.

Zhou,G., Munga,S., Minakawa,N., Githeko,A.K., and Yan,G.(2007). Spatial relationship between adult malaria vector abundance and environmental factors in western Kenya highlands. *American Journal of Tropical Medicine and Hygiene,* **77(1)**, 29 –35.

Appendices I

1. Factors weight calculated by AHP in IDRISI

1.1. Weights for proximity to water bodies

Factors	Rivers	Lakes	Swamps	Eigenvector of Weights	Weights in %
Rivers	1			0.1958	19.58
Lakes	1	1		0.3108	31.08
Swamps	2		2	0.4934	49.34
Total					100

1.2. Weights for all environmental factors

Factors	**Soil**	**Land use land cover**	**Slope**	**Proximity to water bodies**	**Rainfall**	**Elevation**	**Temperature**	**Eigenvector of Weights**	**Weights in %**
Soil	1							0.0253	2.53
Land use land cover	3	1						0.0349	3.49

Slope	3	3	1					0.0546	5.46
Proximity to water bodies	3	3	3	1				0.0752	7.52
Rainfall	7	7	5	5	1			0.1895	18.95
Elevation	7	7	5	5	3	1		0.2610	26.10
Temperature	7	7	5	5	3	3	1	0.3595	35.95
Total								1	100

Appendix II

Questioners

Q1 which area malaria proved in woreda?

Q2 How many peoples are affected by malaria?

Q3 In which month the malaria manifestation appeared?

Q4 The trend of malaria in each years?

Q5 How many people's affect of malaria per year each family?

Q6 what are the environmental factories which affect malaria prove?

Q7 The human factories to affect malarias are: --------------------, ------------------------

Q8 what are causes to increment of malaria incident?

Q9 what is the impact of malaria in study area?

Q10 what is the role of government?

Q11 How many cost spend of incase of malaria?

Q12 which kebeles are infect malaria incidence?

Q13 which kebeles is hot spot of malaria infection?

Q14 what is the problem of selected kebele ?

Q15 How about the awareness of malaria in Chewkare kebele ?

DECLARETION

I, the undersigned declare that this project is my original work and has not been presented for a degree in any other university and that all sources of material used for this project have been correctly acknowledged.

ENDRIAS TEGA Signature_________________________ Date ___________________