



SEEK WISDOM, ELEVATE YOUR INTELLECT AND SERVE HUMANITY !

Addis Ababa University
አዲስ አበባ ዩኒቨርሲቲ



**ADDIS ABABA UNIVERSITY COLLEGE OF SOCIAL
SCIENCES AND HUMANITIES DEPARTMENT OF
GEOGRAPHY AND ENVIRONMENTAL STUDIES**

**Geographic Information System and Remote Sensing Based Malaria Risk
Mapping: A Case of shone town administration, Southern Nations
Nationalities and Peoples' Regional State**

By: Tensaye Worku

Advisor: Muluneh W/tsadik(Dr.)

**ADDIS ABABA, ETHIOPIA
June, 2016**

ADDIS ABABA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

This is to certify that a project prepared by Tensaye Worku entitled: *GIS and Remote sensing integrated application for malaria risk zone in Shone town administration , SNNPRs'*, is submitted in partial fulfillment of the requirements for the degree of 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

Table of Contents

Acknowledgements.....	iv
list Of Acronyms.....	v
List of Tables.....	vii
<i>Abstract</i>	ix
CHAPTER ONE.....	1
1. INTRODUCTION.....	1
1.1 Back ground of the study.....	1
1.5. Objectives of the Study.....	6
1.5.1 General objective.....	6
1.5.2 Specific objective.....	6
1.6. Significance of the Project.....	6
1.7. Scope of the study.....	7
1.8. Limitations of the study.....	7
1.9. Definition of Terms.....	7
1.10. Organization of the Project.....	8
CHAPTER TWO.....	10
2. LITERATURE REVIEW.....	10
2.1. Global.....	11
2.2.1 Malaria control measures in Ethiopia.....	14
2.3. Anopheles mosquito habitat suitability (Ecology of Malaria).....	16
2.3.1. Rainfall.....	18
2.3.2. Seasonality in Climate.....	18
2.3.3. Surface Water.....	19
2.3.4. Vegetation.....	20
2.3.5. Elevation.....	21
2.3.6. Slope.....	21
2.3.7. Soil.....	21
2.3.8. Mosquito abundance and distance from breeding sites.....	21
2.4. Vulnerability (Accessibility index) factor.....	22
2.5. Malaria Hazard.....	21
2.6. Malaria risk.....	22

2.7. GIS and Remote sensing Application in malaria risk mapping research and control.	23
2.7.1. GIS Application	23
2.7.2. Remote Sensing and LULC and/or Change	25
CHAPTER THREE.....	27
3. MATERIALS AND METHODOLOGY.....	27
3. 1.The Sphere of Influence and Physical Characteristics.....	27
3.1.1 Relative Location.....	27
3.1.2. Location of the study area.....	27
3.1.3. Population	27
3.1.4. Topography	28
3.1.5. Drainage.....	29
3.1.6. Climate.....	29
3.1.7. Rain fall distribution.....	30
3.1.8. Soil of the study Area.....	30
3.1.9. Geology of the study area	31
3.2 Demographic Feature Of The Study Area.....	31
3.2.1. Population Characteristics.....	31
3.2.2 Age and Sex Composition.....	31
3.3. Social Services.....	32
3.3.1. Education	32
3.3.2. Health service	32
3.3.3. Malaria trend of the study area.....	33
3.4. Sources and Types of Data used.....	34
3.5. Software and materials used in the project.....	35
3.6. Methods of Data Collection and Analytical flow chart	35
3.6.1. Data Processing Analysis.....	38
3.6.1.1 Elevation facto.....	39
3.6.1.2 Slope factor.....	40
3.6.1.3. Irrigation dam factor.....	41
3.6.1.4. Swampy area factor.....	42
3.6.1.5. Stream factor.....	42
3.6.1.6. Breeding site factor.....	43
3.6.1.7. soil factor.....	44

3.6.1.8. LULC factor.....	45
3.6.1.9. Malaria vulnerability map.....	48
3.6.2. Malaria hazard analysis	49
4. RESULTS AND DISCUSSION.....	54
4.2.2. Relation of Elevation and malaria incidence.....	54
4.2.2. Relation of Slope and malaria incidence	56
4.2.3. Proximity to stream.....	57
4.3.4. Proximity to Dam.....	59
4.2.5. Proximity to Swamps	60
4.2.6. Distance to breeding site factor	62
4.2.7 Soil type and malaria risk level	63
4.2.8. Vulnerability Map.....	65
4.2.9. Land use land cover.....	66
4.3. Identified Areas of Malaria Hazard.....	70
4.3.1 Identified Areas of Malaria Risk	72
5. CONCLUSION AND RECOMMENDATION	74
5.1 CONCLUSION.....	74
5.2 RECOMMENDATION	76
References	77
Appendices	

Acknowledgements

My first sincere gratitude goes to the 'Almighty *God*' who gave me life and strength during my stay and who made it possible for me, to start and finish my study successfully. Thank you Lord!

I would like to extend my heartfelt thanks and appreciation to my thesis advisor, Dr. Muluneh Woldetsadik for his valuable, wholehearted and constructive remarks and guidance throughout of this study. His professional experience and practical comments, critique, and advice inspired me to complete my study. My sincere thanks are addressed to my father Worku Dolasso, to my mother Almaz Chalamo, to my brothers and sisters for their kind love, and moral support starting from my childhood, during this study and even more.

I would also like to thank those people who are working at National Meteorological Services Agency, Ethiopia Mapping Agency, shone town administration health office and shone primary hospital for their cooperation and provision of the required data

Last but not least thanks to my classmates and Christian Fellowship with whom we shared a good and hard moments of school life

LIST OF ACRONYMS

BoFED	Bureau of Finance and Economic Development
CSA:	Central Statistics Agency
DEM:	Digital Elevation Model
EMA:	Ethiopian Mapping Agency
EOSAT:	Earth Observing Satellite
ERDAS:	Earth Resources Data Analysis System
ESRI:	Environmental Science Research Institute
ESDI:	Earth Science Data Interface.
ETM ⁺ :	Enhanced Thematic Mapper
FMoH:	Federal Ministry of Health
FDRE:	Federal Democratic Republic of Ethiopia
GFATM:	Global Fund to Fight AIDS, Tuberculosis and Malaria
GIS:	Geographic Information System
GLCF:	Global Land Cover Facility
GPS:	Global Positioning System
LULC:	Land Use Land Cover
MAGI:	Maryland Geographic Information
MDGs:	Millennium Development Goals
MCE:	multi criteria evaluation

MSS: Multispectral Scanner

Km Kilometer

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

MOA Ministry of Agriculture

Mm Millimeter

NMSA National Meteorological Services Agency

RS: Remote Sensing

SNNPRS: Southern Nation Nationality and Peoples Regional State

SRTM: Shuttle Radar Topographic Mission

SWIRShort Wave Infrared

TM: Thematic Mapper

USGS U.S. Geological Survey

UTM: Universal Transverse Mercator

WGS: World Geodetic System

WHO: World Health Organization

List of Tables

Table 3.2: The Existing health service Institution by type, Ownership and location.	38
Table 3.3: Data category (type) applied all the way through the study.	40
Table 3.4: Software types and their application areas.....	41
Table 3.5 Land Use Land cover risk ranking.....	55
Table 3.6: Weighted malaria hazard ranking for study area.....	58
Table 3.7 Malaria risk factors rankings for shone area (Risk Analysis)	60
Table 4.1 Malaria hazard, elevation rating area coverage and percentage.....	63
Table 4.2 Malaria hazard, slope Rating Area Coverage and Percentage.....	64
Table 4.3 Distance to stream Rating, Area Coverage and Percentage.....	66
Table 4. 4 proximity to Dam Rating, Area Coverage and Percentage.....	67
Table 4.5 Distance to swampy Rating, Area Coverage and Percentage.....	69
Table 4.6 Distance to Breeding sites of malara Rating, Area Coverage and Percentage....	70
Table 4.7 reclassified soil Rating, Area Coverage and Percentage.....	72
Table 4.8 Distance to vulnerability Rating, Area Coverage and Percentage.....	73
Table 4.9. Validation of the results from land use land cover as element of the risk.....	77
Table 4.10 Confusion matrix accuracy assessment	77
Table 4.11 LU/LC, Area Coverage and Percentage.....	79
Table 4.12 Distance to hazard map, Area Coverage and Percentage.....	81
Table 4.13 reclassified risk map, Area Coverage and Percentage.....	83

List of figure

Figure 3.1: Map of the study area, Shone town administration.....	31
Figure 3.2: Contour map of the study area.....	32
Figure 3.3: Drainage map of the study area.....	33
Figure 3.6: Malaria trend of the area.....	39
Figure 3.5: Graphical representation of working and dependent age group of the town....	36
Figure 3.6: Malaria Trend of Shone Town Administration from 2005 - 2007	38
Figure 3.7: Analytical Flow chart	43
Figure 3.8: Elevation map	46
Figure 3.9: Slope map	47
Figure 3.10: Irrigation dam digitized map	48
Figure 3.11: Swampy area digitized map.....	49

Figure 3.12: Stream map	50
Figure 3.13: Breeding map	51
Figure 3.14 soil map.....	52
Figure 3.15: LU/LC map	54
Figure 3.16: Vulnerability map.....	56
Figure 3.17: Hazard map.....	59
Figure 3.18: Risk map.....	61
Figure 4.1: Reclassified elevation based malaria hazard map.....	62
Figure 4.2: Reclassified slope based malaria hazard map.....	64
Figure 4.3: Reclassified proximity to stream based hazard map.....	65
Figure 4.4: Reclassified proximity to irrigation dam based hazard map.....	67
Figure 4.5: Reclassified proximity to swampy.....	68
Figure 4.6: Reclassified proximity to breeding sites.....	70
Figure 4.7: Reclassified soil hazard.....	72
Figure 4.8: Reclassified vulnerability risk map.....	74
Figure 4.9: Reclassified LU/LC, element of risk	75
Figure 4.19: Reclassified malaria hazard.....	80
Figure 4.21: Reclassified malaria risk map	82

ABSTRACT

Malaria is a vector born disease that is arisk in sub Saharan Africa and particularly in the East African valley. Billions of dollars has been invested in the development if its control measures, but it is still killing hundreds of thousands of people per year in developing countries.

Malaria control requires the analysis of habitat of its vector (Anopheles sp). However, unknown spatial distribution of mosquito identified to cause malaria, eradication of parasite remains a difficult situation besides high resolution satellite imagery, fieldwork, malaria habitat was identification considering different factors. As a result, increased efforts and resources have been channeled towards finding ways of minimizing the disease.

The purpose of this project was generating malaria risk map of Shone town administration of the Hadiya Zone, Southern Nations Nationalities and Peoples' Regional State, by using GIS & RS techniques. The study also aimed at mapping malaria hazard areas, vulnerability map and at a risk map (considering LULU classification) to generate an output, malaria risk map. The hazard, malaria prevalence is mapped based on some of the environmental factors, computed using Multi Criteria Evaluation technique(MCE) .The final malaria hazard map of the study area shows that from the total area, it was estimated that(19.3%),(27.58%);(16.6%),(16.9%)and(12.86%) of the study area were subjected to very high, high, moderate, low and very low malaria hazard area respectively. Thus, Hazard, vulnerability (health facilities location) and for risk element (LU/LC supervised classification) were overlaid using ArcGIS 10.1 desktop to develop malaria risk zone mapping.

The final output based on this approach is malaria risk map, produced from overlay analysis showed that (35.12%) in high, (21.11%) moderate; and (16.23%) low level of malaria risk;(18.53%),in very high and (7.43%) very low malaria risk area coverage.In other words, according to the result of the findings large area of the town is located in high risk area of malaria.

Geographic Information System and Remote Sensing technology as a tool can provide information timely, with the intention that, decision makers get a hold ready to make better and faster assessments in resource efficient and cost effective way giving a consideration in the risky areas in Shone town Administration.

Key Words: GIS,Remote Sensing, Malaria, MCE , Remote Sensing, Risk map, weighted overla

CHAPTER ONE

1. INTRODUCTION

1.1 Back ground of the study

Malaria is a disease that hounding most tropical countries especially in Sub-Saharan Africa (Mouchet et al., 1993).

Globally malaria clinical cases are reported as 300-500 million and 1.5-2.7 million deaths annually. The increasing trend of environmental change is dramatically changing malaria pattern at the local as well as gbbal scales (Hay et al., 2000). Malaria situation is worsening with large-scale epidemics and increasing mortality. There have been immense efforts to correlate malaria and the environment as the latter influences development of both parasite and the vector (Drake et al., 1989). Many parameters associated with environmental change can now be remotely sensed using remote sensing technologies and combined with geographic information system (GIS) to describe local and landscape-level features influencing disease and disease vector distribution(Hightower, et al., 1998).

The introduction of powerful, inexpensive personal computers and the development of easy to use, menu-driven GIS software made it possible for persons with little or no expertise to design and conduct spatial studies and the acquisition of spatial data has become easier.

The functionalities of GIS can help in developing malaria information system. At the micro level, in village malaria cases thatcan be identified to a specific coordinate and control measures can be easily determined by overlying topological map (Hightower et al., 1998). He recommendedmaps showing risk zone map can be used to select sites for control programs that could also help in therestructureof parasite control component by defining the catchment area of clinical facility;as well this information is useful for planning projected resource needs and the distribution/ requirement of protectorate clinical facilities.

Thus, capability of GIS is especially useful for planning, logistics and operations of malaria control programme (Mouchet et al., 1993).In the context of forecasting and control by integrationof GIS with remote sensing technology it is possible to develop real-time information system depicting potential flows in disease transmission, enabling the initiation of rapid response strategies.

On a smaller scale, GIS has several applications to the study of mosquito biology and ecology (Eskinder et al., 2010), suggesting that GIS is the best or available method to answer questions regarding mosquito ecology as well as studies of risk as a function of distance from known breeding sites and others are one common application of GIS.

However, this is particularly useful in areas with a small number of discrete breeding sites around urban or highland areas where mosquitoes exhibit strong spatial patterns over short distances. Using knowledge of the distribution of adult mosquitoes and the distribution of larval breeding sites, average flight distances of malaria vectors may be inferred using GIS.

GIS in combination with remote-sensing (RS) technology, has also been employed to predict areas of high productivity of mosquitoes and potential malaria epidemics based on the detection of proxy ecological variables (Hay et al., 2000).

GIS allows spatial data handling, manipulation, and analysis with a new dimension and supreme flexibility (Craig et al., 1999). In the current day circumstances, GIS is finding application in diverse fields including health (Tomlinson, 1996), and he put forward that in any disease control programme, there are several factors involved, namely estimation of disease burden, monitoring of disease trend, identification of risk factors, planning, allocation of resources, implementation etc. and a common line involved in all these activities is 'Geography'. Geographic information system owing to its inherent ability to manage both spatial and non-spatial information provides an excellent framework for disease monitoring and control (Tomlinson, 1996).

1.2 Statement of the Problem

Malaria epidemic have had a notable impact on the economic, social, and political sphere of the society. The impact of Malaria derives from the natural environment that is favorable to its transmission and also from the lack of implementation the systematic approach of preventive plans (Ashenafi,2003). As a result, the cost of preventive plan and medical treatment becomes enormous burden on GDP and individual economy. At the same time economic productivity of the individual is declined due to Malaria infection.

According to World Health Organization, 2012 report, it has been estimated that the economic burden due to malaria accounting for 1.3% reduction in the annual economic growth rate of countries. Based on this circumstance, timely and precise information of Malaria outbreak, transmission, and infection is desired in order to effectively implement a Malaria control plan.

Even today, convincing that in some parts of the countries, prevalence and incidence of malaria is increasing with ultimate cause of socio-economic obstacle. An estimated 2.4 billion people are at risk of infection and 3000 to 5000 million suffer in a short period with the disease each year perhaps 90 percent of these occur in tropic of Africa (WHO, 2012)

Malaria kills between 1.1 and 2.7 Million people per year. Of these deaths, approximately one million are children in the tropic of Africa between the ages of 18 months and 5 years (Webb, 2009).

Malaria risk becomes higher developing countries (Donnelly, 2005). A large number of malaria causing factors including proximity to vector breeding site, inadequate use of control measures and land use play a big role (Stratton, 2008). Stratton, (2008) mentioned the multiplicity of malaria causing factors in semi urban areas as the main cause of its prevalence as they are difficult to control at the same time.

WHO (2013), suggest that malaria occurrences is high in the areas characterized by low access of health care facilities and to those people in low income for they lack financial means to pay for vector control technologies such as ITN and IRS and anti-malarial drugs.

Nevertheless, even after more than a century of intense bioscience research on its causes and possible remedies, the disease remains mysterious and ever –hard to pin down rather than the reality of eradication via vaccine, the distribution of venders, or other cure perhaps the answer lies in a return to malaria's ecological roots (Abdulahakim,2010).

Malaria is also a major public health problem in Ethiopia(FMoH, 2009). Accordingly its occurrence in most parts of the country is unstable mainly due to the country's topographical and climatic features. As malaria is a complex disease related to the interaction among parasites, vectors, human hosts and environment, it is fundamental to study these factors together in order to be able to control it (FMoH, 2004).

Thus, the combination between human factors and relevant environmental information to might help in the action of health services easier. One of the measures to be considered as preventive is to work on the main factors contributing for the development and expansion of the problem. In this regard Geographic Information System and Remote Sensing can best fit to investigate the root problem both spatially and temporally. As a result, using Geographic Information System and Remote Sensing as a tool that can grant information within shortest period of time, so that, decision makers get prepared to make better and faster decisions which can reduce the damage and minimize the loss.

Geospatial technologies have been used extensively in malaria risk mapping and malaria control throughout the world (Rainer,2008). Providing accurate malaria risk maps can effectively guide the allocation of malaria resources and interventions in developing countries. The ecological approach to understand malaria transmission views the disease as one of complexity of disturbance of ecological possibility, and of locality (Spuelman et al., 2011). During the last decade, few researches have been made in a relation to malaria to map malaria risk (color shading) area using different technique. For instance research carried out by Biruk .P (2010) was on Space-time clustering of childhood malaria at the household level, and Tefera, A. (2010) was on malaria risk which is an unpublished Msc thesis, Jimma University focused on malaria prevention mechanisms.

A review of those papers suggests that the methodology is still at an explanatory stage and malaria risk topographic factors not examined undoubtedly. Despite the fact that exploratory

analytic techniques are generally used to identify clusters and determine whether these occur by chance, many of these methods do not account for underlying distribution of populations but are a quick way to assess 'hot spots' that may deserve further investigation.

What's more exploratory techniques results can easily be presented in the form of surface maps employing color shading to indicate areas of high or low risk. Overlaying these interpolated maps on other geographic features is an informal approach to identifying potential risk factors. However more formal data analysis can also be done by modeling, integrating GIS data with standard statistical models. Unfortunately, many entry-level GIS software packages do not allow for advanced analytic techniques but these may usually be done in existing statistical packages.

More over due to GIS are subject to the more typical constraints of high technology, including relatively high costs, and need stable power supplies and considerable human skills, resources and it requires a more powerful and sophisticated system such as GIS, differential GPS and Remote Sensing.

Nonetheless, conclusion and a decision using and depending on merely socio-economical data and hardly utilizing GIS and remote sensing application may provide spurious alarms or be unreliable.

For that reason, understanding malaria epidemics using GIS and Remote Sensing data believed to be essential by the researcher.

Accordingly, this paper therefore will set out to bridge the gap using integrated application of GIS and Remote sensing via easily and appropriately accessible data linked like hand held GPS and other freely available satellite imagery data sources and/or DEM (freely available at <http://nasa.gov/gde.m.asp>) to explore appropriate methods for investigating and carrying out relatively simple analysis of these data using personal computer (Desktop), cost effective software, landsat data that is free and can be downloaded through the library development ILO (images of land archives) sensor.

As a result, the information gathered through the combination of GIS tools and remotely sensed satellite image analysis, could allow the spatial analysis malaria risk factors and show their relationship with malaria prevalence at small scale within shone town administration.

Therefore, the goal of this study is to produce map of malaria risk zones and to identify the most important natural factors that facilitate mosquito breeding. Thus, this study is an

integrated concept and methods of the innovative development and application of GIS and RS technology; however, this paper further assessed the importance of integrating GIS, RS and recommends an integrated malaria monitoring system as at this time and future model for malaria research in the study area. Overall, the recommended system would support the malaria prevention and control for the study area cost effectively.

1.3. Objectives of the Study

1.3.1 General objective

The general objective of the study is to show GIS and Remote sensing techniques application used for malaria risk zone mapping in and around Shone town administration, Hadiya Zone, SNNPRs', Ethiopia.

1.3.2 Specific objective

The specific objectives of the study area are:

- ✚ To identify and integrate environmental (topographic) factors which make condition suitable for breeding and outbreak of malaria epidemics.
- ✚ To develop Landuse/ Landcover, using GIS and RS techniques and different factor map in a relation to potential malaria habitats for risk map
- ✚ To analyze and develop different factor and hazard mapping using ArcGIS environment; to compute AHP (Eigen vector) and perform weighted overlay analysis.
- ✚ To develop a malaria risk map.

1.6. Significance of the thesis

This study has the ability of identifying risk areas using GIS and remote sensing application that greatly enhance the effectiveness of prevention efforts and will contribute to cost-effective prevention method by providing mechanism of efficiently targeting high risk areas, which help national and international organizations, medical geographers and any stake holders working in the health and the shone town health sectors in organizing their efforts towards the fight against malaria efficiently and cost effectively.

1.7. Scope of the study

The scope of this study is delimited both in geographical area and issue of concern. Geographically, it is delimited to shone town administration, which is one of the town in Hadiya 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 town administration via integrated application of GIS and Remote sensing tools and technology using many-sided factors to develop malaria risk zone map.

1.8. Limitations of the study

The major limitations of this study include climatic factor like temperature and rain fall also not given serious consideration as a malaria hazard factor but to reimburse this drawback from environmental factor elevation and surface hydrology of the study area intensively examined and discussed. There was also lack of well documented malaria case data for the town administration.

1.9. Definition of Terms

(i) Remote sensing:

Can be defined as any process whereby information is gathered about an object, area or phenomenon without being in contact with it. Given this rather general definition, the term has come to be associated more specifically with the gauging of interactions between earth surface materials and electromagnetic energy. (Idrisi 32, guide to GIS and Image processing, volume 1).

(ii) Geographic Information system:

A computer assisted system for the acquisition, storage, analysis and display of geographic data GIS is defined as an organized collection of computer hardware and software, and geographic data to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information (Idrisi 32 guide to GIS and Image processing, volume 1). With GIS it is possible to analyze differences in multiple spatial data layers related to the geographic position of a phenomenon, its attributes, and spatial relationships and to create new spatial information not available by studying the data layers separately.

(iii) GPS:

Provides users with navigation, position and timing services captured through satellite transmission (Idrisi 32 guide to GIS and Image processing, volume 1).

(iv) Land use:

A definition from the INSPIRE Directive, the land use represents the present and future planned human activities on a territory characterized as residential, industrial, commercial, agricultural, forestry and leisure. It is the expression of the human activity developed for social, economic, cultural and political purposes.

(v) Land cover:

A definition from the INSPIRE Directive explains that land cover represents the physical and biological cover of the Earth's surface including classes as build-up areas, forests, agricultural areas, wetlands, (semi-)natural areas, water bodies.

(vi) Kebele

Is the smallest administration classification in Ethiopia next lower to Woreda.

(vii) Anopheles mosquito habitat:

A species habitat in the location or environment where that organism is most likely to be naturally found (WHO, 2012).

(viii) Malaria infection:

The invasion of host organism's bodily tissues by disease causing organisms, their multiplication, and the reaction of host tissues to these organisms and the toxins they produce. Therefore, malaria infection is the invasions of host organism by its causing pathogens (*plasmodium sp.*) and their multiplication in the blood cells (Malaria journal, 2010)

1.10. Organization of the thesis.

This study is organized in five chapters. Chapter one provides introduction, problem statement, objectives, significance, scope of the study, limitation of the project, Definitions of the terms. 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.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1. Malaria Concept

Protozoan parasites of the genus *Plasmodium* are responsible for human malaria, of which four species are primarily involved, *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae*, and *Plasmodium ovale*. Recent reports have suggested the possibility of a fifth species, *Plasmodium knowlesi*, as an important and common emerging zoonotic pathogen responsible for human infections in Southeast Asia (Cox-Singh et al., 2008). Globally, *P. falciparum* is the most common cause of malarial infection, responsible for approximately 80% of all cases and 90% of the deaths. *Plasmodium* transmission from *Anopheles* vector to human is accomplished through direct injection of the parasite contained in salivary gland fluid during blood feeding. Of the 484 recognized species of *Anopheles* (Harbach, 2004), only about 20% or less are generally involved in malaria transmission (Bruce-Chwatt, 1980). In the life cycle, the *Anopheles* mosquito is the definitive host for the parasite, where sexual reproduction between male and female gametes occurs, whereas the human technically serves as the intermediate host where only asexual multiplication takes place.

Anopheles females become infected by imbibing sexually mature gametocytes present in the peripheral blood of the host. In the mosquito midgut fertilization produces the ookinete which traverses the mosquito gut and forms an oocyst under the outer most layer of the gut wall. After repeated multiplication, each oocyst eventually ruptures releasing hundreds of sporozoites into the mosquito body cavity, a proportion of which will invade the salivary glands awaiting the opportunity to infect another human upon the next blood feeding by the mosquito. This sporogonic cycle (ookinete–oocyst–sporozoite) within the mosquito takes on average 10–14 days depending on the ambient temperature and *Plasmodium* species. Infective female mosquitoes will generally remain infectious during their entire life which is spent repeating a cycle of blood feeding, developing and laying eggs every two to three days per gonotrophic cycle.

2.1. Globalrescue of malaria

Malaria is a major global health problem. Worldwide malaria affects 3.5-5.0 billion people and has devastating effects on health and development with at least one million deaths taking place annually(NIAID, 2015).

According World Malaria Report of 2012, about 70-90 per cent of the risk of malaria is considered due to environmental factors which in turn influence the abundance and survival of the vectors. This has motivated the World Health Organization to pursue the development of new techniques and models in which the role of environmental is fundamental. Spatial technology helps systematic and regular monitoring of the earth's environmental conditionsfurnishing large amounts of spatial and temporal data. Such information together with appropriate field studies can prove very fruitful for early de tection and timely respo nse to disease management.

About 90% of all malaria deaths in the world today occur in Sub Sahara Africa countries. This is because the majority of infections in Africa are caused by *Plasmodium falciparum*, the most dangerous malaria species of the four types. It is the most widespread in Africa and the most difficult to control. About one million people in Africa die from malaria each year, where most of them are children under 5 years old (WHO, 2011).

According to World Malaria Report of WHO, 2012, the global malaria distribution has progressively been reduced since the mid 19th century, especially from 1945 to 1977, when 37 countries were freed of malaria thanks to the efforts of the global eradication programme. Success in malaria elimination occurred mainly in countries in Europe and North America, where malaria transmission was lower. Even today, the 11 countries which are aiming at malaria elimination have low malaria transmission and are placed at the limits of the global map of malaria distribution(NIAID, 2015).

In 2015, WHO convened a technical review on global malaria control and elimination to review the feasibility of malaria elimination, in relation to the intensity of malaria transmission and outline the directions that countries should take over the next few years, at the end of an intensified phase of malaria control.

The feasibility of malaria eradication with the available tools and the gaps in knowledge and research priorities for the next phase of malaria control was identified.

According to WHO Malaria Report of 2015, the recent impact of malaria control interventions, showing in multiple countries over a few years over 75% reduction in malaria cases with high coverage of effective treatment and vector control, has renewed global interest in malaria elimination and eradication.

Although successful eradication of malaria has been achieved in many countries, in Europe and the USA, where it was still endemic not so long ago (last century), the situation is still problematic in many regions of the globe (Najera, 1989). Several initiatives have been launched to reduce malaria on the various continents where the disease still prevails or is re-emerging. The African situation is by far the worst where the number of deaths is actually increasing (Magaylen, 2006), suggesting that the reasons for the persistence and re-emergence of malaria are many and varied like environmental changes, economic reasons, declining control programs and mosquito/parasite adaptation to pesticides/drugs, all contribute to the development of the disease.

2.2. Distribution of malaria in Ethiopia

In Ethiopia, the estimated incidence rate for malaria (i.e., the estimated probability of contracting the disease in a year) is 15%, which is low relative to the rest of sub-Saharan Africa (where the average incidence rate is 0.33), but higher than any other country outside of sub-Saharan Africa, Panama, Laos, Myanmar, and the Solomon Islands (WHO, 2012). Despite the somewhat low incidence rate, this country is an appealing place to do a study on malaria for at least two reasons. First, malaria is still a very important public health problem: Ethiopia is thought to experience some 10 million cases per year, the fourth highest case number in sub-Saharan Africa (behind Nigeria, the DRC, Tanzania, and Uganda (WHO, 2012)). The second reason for considering malaria in Ethiopia is that, unlike most other African countries, there is extensive local variation in malaria incidence.

Clinical malaria accounts for 10 - 40% of all outpatient consultations, 13 - 26% of inpatient admissions at various health facilities, and is responsible for 15-17% of case fatalities in health facilities (FMoH 2009).

The dominant species are *P.falciparum* and *P.vivax*, which are 60% and 40% respectively. 75% of the land mass and 68% of the population in Ethiopia is affected by malaria. Malaria transmission is seasonal and unstable. The main vectors are *An. arabiensis* and *An. pharoensis*.

In Ethiopia, malaria has a personality, geographic character, and impact quite different from other parts of Africa and global malaria (Getachew et al., 2010) they put forward, Ethiopia's malaria is unstable-the high seasonal fluctuations in temperature and moisture result in malaria appearing in epidemic form and with great variation across landscapes. The instability of Ethiopia's malaria means that populations in most areas have never attained a significant level of protective immunity (as has been the case in endemic areas of West Africa) and thus a higher rate of death and morbidity among adults.

In each of those early to mid twentieth-century analyses medical field observations confirmed Ethiopians' own folk epidemiology about malaria as an endemic disease of the moist lowlands and river valleys and its highly seasonal character that followed closely the annual life cycle of its mosquito vectors (FMoH 2009). The malaria landscape followed closely elevation, slope and the seasonal cycle of temperature and moisture (Getachew et al., 2010).

Ethiopia's malaria is also distinctive in the dominance of the parasite *P. falciparum*, a particularly deadly form, and particularly the prevalence of the mosquito vector *A.arabiensis*, a species of anopheline mosquito that has over time and changing ecologies adapted its behavior and habitat preference for the high seasonal variation of East Africa and Sahelian zones where unstable malaria is the dominant form (Asnakew, 2002).

2.2.1 Malaria control measures in Ethiopia

The exposure that the *Anopheles Gambiae*, Africa's most potent malaria vector, was actually five different mating types (showing hybrid sterility) was first made in 1964 by G. Davidson at the London School of Tropical Medicine and Hygiene and only percolated slowly to field workers in areas like Ethiopia. The first reference to *A. Gambiae B* (the original name for *A. Arabiensis*) in Ethiopia came in a WHO document dating from July 1969. Davidson, in fact, noted from the beginning that each of the *Anopheles* species showed hybrid male sterility and could coexist without losing their individual characteristics. Davidson especially recognized that the behavioral differences of each type meant "it may be necessary for the field worker to identify the exact species with which he is dealing before the most efficient means of controlling it can be found (Trape, 1992).

Moreover, the fact that mosquito behavior can, in fact, adapt in a matter of months to new conditions (such as bednets and spraying) has appeared recently in studies in at least two places in Ethiopia (Getachew et al., 2010). In other words, factors like preference for certain breeding habitats, time of biting, preference for human versus livestock blood, indoor versus outdoor biting, etc. could all differ among the genotypes.

Before 2005, malaria was the leading cause of outpatient consultations, admissions and death, but in 2006 and 2007 mortality and morbidity due to malaria decreased dramatically. The decrease could be attributed to interventions such as use of ACT (Coartem®), mass distribution and utilization of ITNs (20 million nets in three years time for 10 million households at a rate of 2 nets per household) and relatively better indoor residual spraying coverage. The management of the diseases has been decentralized down to the household level using 24 753 health extension workers.

Some of the challenges are sustaining the distribution and coverage of the ITNs, low shelf life and high cost of Coartem® and rapid diagnostic tests (RDT), difficulties in stock management and unpredictability of malaria epidemics in space and time and lack of adequate preparedness and response.

The goal of malaria prevention and control in Ethiopia was to reduce malaria morbidity and malaria related mortality by 75% by the end of 2013. To achieve the aforementioned goal the government has taking different intervention strategies. Vector control is essentially based on (i) in-house spraying with insecticides (ii) personal protection through the use of mosquito nets/repellants and (iii) larviciding of breeding sites. A good control strategy is to use the best combination of control methods available where and when they can be most effective. In endemic malaria areas where the intensity of transmission varies little from year to year it is possible to organize control programs according to the calendar of the transmission season and RS may be used to help stratify different levels of endemicity, and the local seasonality of transmission (Thomson *et al.*, 1999).

However, in areas where there is considerable inter-year variation in transmission and the potential for epidemics, a control program can benefit from more cost effective early warning systems supported by the use of satellite data for environmental monitoring which can be used to predict unusually high malaria 1-2 months in advance as well as satellite data for the location of breeding sites; and where necessary, satellite data for monitoring dispersed populations or population on the move. In recent years the use of GIS within the health services in many malaria affected countries has increased and although this process remains problem-atic in some areas (Snipe and Dale, 2003) the routine mapping of health surveillance data, distribution of clinics, breeding sites, etc. means that spatial information, derived from satellite data, can now be directly compared with health data.

Malaria prevention and control program in Ethiopia is guided by a five-year National Malaria Prevention and Control Strategic Plan developed in line with the goals of the Health Sector Development Program (HSDP).

Ethiopia is in the control phase of malaria (WHO, 2012) and according to the Ethiopian National Malaria Strategic Plan (2010-2015), it is expected to achieve malaria elimination within specific geographical areas with historically low malaria transmission and a near zero malaria transmission in the remaining malarious areas of the country by 2015. Consequently, there is a plan to embark on malaria elimination in 2020 with an integrated community health approach (FMoH, 2009).

However, these challenges can be effectively addressed if all partners put their efforts towards assisting the Ministry of Health in health system strengthening providing information as well all the way through a campaign for training a large number of different health workers at national and state levels and strengthening monitoring and evaluation and integrated health information systems using GIS; developing an early warning system for malaria outbreaks based on a thorough understanding of malaria epidemiology, information on topographic features, climate and elimination of residual malaria foci through strong, time-limited attack measures.

2.3. Anopheles mosquito habitat suitability (Ecology of Malaria)

A good understanding of Anophelid mosquito requires understanding of its ecology (Wielgoz 2012), as a factor depending on their ecological preferences, about 20 different species are locally the most active *Plasmodium sp.* vectors around the world and all of these species are operational during the night (WHO, 2012).

Anophelid species are vectors of four parasite species that cause malaria in humans: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae* and *Plasmodium ovale*. *Plasmodium vivax*, and *Plasmodium ovale* are the most common while *Plasmodium falciparum* is the most deadly (NIAID, 2007).

Plasmodium falciparum: is responsible for most malaria deaths, especially in Africa. The infection can develop suddenly and produce several life threatening complications. With prompt, effective treatment, however, it is almost always curable (NIAID, 2007).

Plasmodium vivax: the most geographically widespread of the species, produces less severe symptoms. Relapses, however, can occur for up to 3 years, and chronic disease is debilitating. Once common in temperate climates, *Plasmodium vivax* is now found mostly in the tropics, especially throughout Asia (NIAID, 2007).

Plasmodium malariae: infections not only produce typical malaria symptoms, but also can persist in the blood for very long periods, possibly decades, without ever producing symptoms. A person asymptomatic (no symptoms) *Plasmodium malariae*, however, can infect other either through blood donation or mosquito bites. *Plasmodium malariae* has been wiped out from temperate climates, but it persists in Africa (NIAID, 2007).

Plasmodium ovale: is rare, can cause relapses, and generally occurs in West Africa (NIAID, 2007).

The severity of malaria is a function of the interaction between the parasite, the *Anopheles* mosquito vector, the human host and the environment (Hackett, 1988), as a 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.

The biophysical (topographic and climatic) variables that can determine the region with high endemicity have been object of different researches (Sipe and Dale, 2013). *Anopheles* mosquito proliferation depends on environmental and climatic factors like elevation, slope, temperature, rainfall and humidity in association with vegetation cover and hydrology specially water bodies (Sipe and Dale, 2013), as a factor altitude also an important factor and *Anopheles* mosquito prefers low altitude areas not only because they are characterized by high temperature and humidity in tropics but also because of their ability to retain water during and after rainy seasons.

Certain man-induced environmental changes like deforestation, marshland conversion and vegetation clearance for crop plantations favour ecological conditions that have a positive influence on the number and survival of *Anopheles* mosquito (Ahmed, 2011). These human activities have favoured *Anopheles* mosquito either in creating breeding and resting sites or in favouring their contacts with human (Verdonschot, 2013). This has resulted in the predominance of three *Anopheles* species (*Anopheles funestus*, *Anopheles gambia*, *Anopheles arabiensis*) in the East African region where Ethiopia is located (Mwangangi, 2013).

Anopheles mosquito proliferation requires the abundance of blood meals and therefore, a travel distance is required from breeding site to households where the vector host contact becomes possible (Stoler, 1998).

Verdonschot, 2013 reviewed article about *Anopheles* mosquito flight distance and found average flight distance for *Anopheles sp.* was around 2000m (2km). However the flight distance depends on the habitats of the species and some species have a stronger dispersal capacity than others.

People near breeding sites (less than the average mosquito flight distance) are assumed to be a high risk of malaria while those beyond the average anopheles mosquito flight distance are less likely to be attacked by malaria (Liu, 2011).

During his study in Accra, Stoler (2009) found that malaria risk was higher within 2000 m from the vector breeding sites.

However, the dispersal capacity of the mosquito also depends on the atmospheric conditions especially wind direction and Land use (Verdonschot, 2013).

2.3.1. 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 (Trape, 1992)

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 (Verdonschot, 2013) or by decreasing the temperature, which in regions of higher altitude can stop malaria transmission.

In tropical Africa rain is largely produced from deep convective storms and the clouds with the coldest top surface temperature produce the heaviest rainfall. It is possible to derive estimates of rainfall by measuring cloud top temperatures using thermal infrared images from Meteosat. At a certain threshold temperature (-40 to -70°C depending on latitude and season) clouds will precipitate into rainfall (Trape, 1992).

2.3.2. Seasonality in Climate

The combined influence of rainfall, temperature and humidity, re-grouped under weather (short-term) and climate (long-term) on malaria is very complex, especially for extreme weather conditions (Lindsay, 1998), as an outcome 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 (Gimniet *et al.*, 2003).

In recent years, there have been significant scientific advances in our ability to predict climate on the seasonal timescale (Trape, 2012). The skill associated with these predictions varies from region to region, but is generally higher within the tropics and forecasts may be relevant to malaria early warning.

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 (Verdonschot, 2013).

However, the importance of the factors influencing malaria is not only limited to climatic factors but also anthropogenic changes in the environment, in land use, deforestation; in hydraulic network induce continuous changes in the intensity of malaria transmission.

2.3.3. Surface Water

Anopheles mosquito breeds in water and each species has its own breeding preferences. For example, some prefer shallow collections of fresh water, such as puddles and maize fields (Wielgosz 2012).

Surface water provides the habitat for the juvenile stages (egg, larvae, pupae) of malaria vectors. Irrigated farming increases nutrients and temperature which are favourable for the mosquito breeding and larvae survival (Munga, 2006).

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 (Ceccato *et al.*, 2001).

The SWIR is available on sensors such as LANDSAT-TM, SPOT-VEGETATION and TERRA-MODIS. Recently, research has been developed to use the SWIR to retrieve vegetation water content (Ceccato *et al.*, 2002). TERRA-MODIS with aspatial resolution

of 250 m) and LANDSAT-TM (30 m) provide improved quality of images and can be used as shown later in section 3 for monitoring water bodies. In addition to the potential of the SWIR, further research was also carried out using RADARSAT Synthetic Aperture Radar (SAR) images to monitor wetland ecosystem and flooded areas.

The use of radar systems provides the possibilities to monitor earth features during night or when covered heavily by clouds. The signal amplitude wavelengths emitted and received by the sensors are not influenced by atmospheric conditions and allow the detection of area flooded even during cloudy days. Radar RS programs, like ENVISAT, RADARSAT 2, have been developed and a panel of products made available, increasing the possibility for using operationally radar images to monitor water bodies. RADARSAT was successfully used in different ecosystems and combined with SPOT-VEGETATION data to enhance the accuracy of mapping the surface area of flooded wetland areas (Toyra *et al.*, 2002).

2.3.4. Vegetation

Vegetation type and growth stage may play an important role in determining vector abundance irrespective of their association with rainfall. Irrigation schemes may provide excellent breeding sites for *An. gambiae* s.l. early in the growth cycle of the plants – this change mature and form a dense canopy over the water (Lindsay *et al.*, 1991).

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.

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.

2.3.5. Elevation

In Ethiopia, air temperature is largely determined by elevation. According to old national atlas map of 1988, elevation below 2000 m.a.s.l considered as malaria affected area and above 2,500 meters of elevation, temperatures are consistently below the normal malaria threshold, making villages located there malaria-free.

2.3.6. Slope

Malaria transmission is affected by land slope and temperature. Mosquito larvae need stagnant water pools to survive, and these pools are less likely to form in sloped areas (Lemessa, 2011). Moreover, larvae developing in water pools in sloped areas are more likely to be washed away during downpours. Thus, sloped areas make for poor mosquito breeding ground, reducing the threat of malaria transmission (Burlando, 2012).

2.3.7. Soil

Poorly drained soils facilitate water stagnation and create conducive conditions for mosquito breeding and thus, favor malaria outbreak. Well drained soil doesn't allow water stagnation, so it creates unfavorable condition for *anopheline* breeding (Burlando, 2012).

2.3.8. Mosquito abundance and distance from breeding sites

The distribution of adults is largely dependent upon the distribution of these larval habitats and the flight range of the adults. Using this information it is possible to estimate and even predict the risk of exposure (i.e. infectious bites) based upon the distance to known breeding sites Smith et al. (1995).

The studies that has been made in Dakar, Senegal by Trape in 1992 clearly demonstrate the strong effect of distance to breeding sites on adult mosquito populations and the risk of malaria infection, the dispersion of adult mosquitoes (*An. arabiensis*) from a permanent swamp and the prevalence of antibodies to *Plasmodium falciparum* in children residing near the swamp were investigated.

Clarke, (2002) studied the relationship between distance from mosquito breeding-sites and entomological and clinical malaria indices in 48 villages along the River Gambia in West Africa.

Distances from villages to the nearest edge of the alluvial plain of River Gambia were estimated from 1:50,000 maps. Mosquitoes were collected every 2 weeks throughout the transmission season from 2 houses in each of the 48 villages, the prevalence of parasitaemia and the prevalence of enlarged spleens were all lower in villages >3 km away from the main breeding sites along the river.

However, among infected population, rates of high-density parasitaemia, fever and anaemia were all higher in villages >3 km from the breeding sites.

In a similar study in the same area, Lindsay (2000) correlated exposure to adult mosquitoes in 10 villages with distance to breeding sites. Using multispectral SPOT satellite imagery with 20 m resolution to detect larval breeding sites within 2 km of a village, they were able to estimate the exposure to adult mosquitoes in 26 villages where clinical surveys had been conducted but entomological data were unavailable. Similar to the study of Clarke (2002), the estimated exposure rates for each village were positively correlated with parasite prevalence and negatively correlated with high density parasitaemia and splenomegaly.

2.4. Vulnerability (Accessibility index) factor

Vulnerability is the susceptibility or weakness often associated with a particular situation such as illness, economy; gender (Stephenson, 2014). Malaria vulnerability is the susceptibility to be affected by its causal agent (*plasmodium sp.*).

According to stratton (2008), malaria vulnerability is influenced by demographic characteristics, access to health facilities and socioeconomic condition. However, Malaria vulnerability can be reduced by the advancement of vector control mechanisms. The people that live far from health care facilities were identified the most vulnerable to malaria in most sub-Saharan African countries (Stratton, 2008).

2.5. Malaria Hazard

Hazard is the probability of occurrence of damaging natural phenomenon within specified period of time (Shook, 1997). As a hazard, malaria incidence is mapped by depending on some of the environmental factors which contribute for the survival of Anopheles mosquitoes. For the purpose of identifying areas of malaria hazard, this study focused on elevation, slope, distance to streams, distance to breeding site and proximity to dams and swamps as the factors of malaria incidence in the study area. The malaria incidence and

transmission requires the environment with lower elevation (higher temperature), abundance of wet lands, occurrence of gentle slopes, availability of still waters around rivers, and areas of lower drainage density (Negasi, 2008).

2.6. Malaria risk

In disease modeling risk is defined as the chance or likelihood that an undesirable event or effect will occur as a result of use or nonuse, incidence, or influence of chemical, physical or biological agent, especially during a stated period of time; in other words, it is the probability of developing a given disease over a specified period of time (WHO, 2013). Thus Malaria risk is the probability that an individual will be attacked by malaria in a given interval of time and in a known area. Malaria risk increases with the number of people (Stratton, 2008).

Malaria is one of dangerous vector borne disease in the world (Stratton, 2008). For example, an estimated 3.3 billion people were at a risk of malaria in 2006 and the 1.2 billion at a high risk (1 case per 1000 population) were living in sub Saharan Africa (WHO, 2013). During the same year, estimated 881,000 malaria deaths were reported, of which 91% were in Africa and 85% were children under 5 years of age (WHO, 2013).

The rate of malaria transmission is higher in areas of mosquito lifespan is longer and where it prefers to feed on humans rather than other animals. The long lifespan and human blood meal preference the African anopheles species especially anopheles arabiences more than 90% of the world's malaria death occur in Africa (WHO, 2013).

In addition, to naturally occurring ecological factors, Donnelly (2005) identified poverty, urban farming, deteriorating infrastructure and overcrowding in sub Saharan African urban areas as contributing factors to the development of conditions that modify anopheline mosquito habitats.

The habitat style where people live near wetlands and water bodies, urban agriculture and the poor living conditions in the regions favor not only the breeding of vector but also vector host contact (Smith, 2013).

Malaria risk becomes higher in developing countries (Donnelly, 2005). A large number of malaria causing factors including proximity to vector breeding site, inadequate use of control measures and land use play a big role (Stratton, 2008). Stratton, (2008) mentioned

the multiplicity of malaria causing factors in semi urban areas as the main cause of its prevalence as they are difficult to control at the same time.

WHO (2013), suggest that malaria occurrences is high in the areas characterized by low access of health care facilities and to those people in low income for they lack financial means to pay for vector control technologies such as ITN and IRS and ant-malarial drugs.

In malaria endemic areas, partial immunity is developed over years of exposure, and even if it never provides complete protection, it reduces the risk that malaria infection will cause severe disease to adults.

Therefore, the level of vulnerability is negatively associated with most malaria deaths in Africa; all age groups are equally vulnerable (WHO, 2013).

2.7. GIS and Remote sensing technology application in malaria risk mapping research and control.

2.7.1. GIS Application

GIS has many applications to the study of vector-borne diseases, as many of the underlying processes influencing the distribution of insect vectors of disease are spatially heterogeneous. Mosquitoes require pools of water in which to breed and the short flight range of many species limits the adult populations to areas surrounding their breeding sites. Recently, there has been interest in applying GIS to study the continental and global distribution of malaria and the mosquitoes that transmit malaria (Coetzee, et al., 1998). These continent-scale studies have also been used to estimate the impact of global warming on the distribution of mosquitoes and malaria.

On a smaller scale, GIS has several applications to the study of mosquito biology and ecology. In many cases, GIS is the best or the only available method to answer questions regarding mosquito ecology (Thomson et al. 1996), as a function of distance from known breeding sites studies of risk are one common application of GIS. This is particularly useful in areas with a small number of discrete breeding sites around urban or highland areas where mosquitoes exhibit strong spatial patterns over short distances.

Using knowledge of the distribution of adult mosquitoes and the distribution of larval breeding sites, average flight distances of malaria vectors may be inferred using GIS. GIS, in combination with remote-sensing (RS) technology, used to predict areas of high productivity of mosquitoes and potential malaria epidemics based on the detection of proxy ecological variables (Hay et al. 2000).

GIS has many applications to the study of mosquitoes and mosquito-borne diseases. The distribution and abundance of mosquitoes and other vectors of human disease are often determined by factors that exhibit clear spatial heterogeneity. The most obvious factor influencing the distribution of mosquitoes is the distribution of breeding sites.

The distribution of available hosts and the distribution of vector control interventions may also affect mosquito abundance and distribution. Below, we view some of the applications of GIS technology to the study of malaria risk mapping, with an emphasis on the vectors in the study area.

I). Mapping and geoprocessing; many maps of global malaria risk distribution in space and time have been prepared using GIS and Remote sensing. Mapping the global distribution of malaria risk is motivated by a need to define population at a malaria risk to combat the disease. Snow et al (1998) defined the global extent of the clinical episodes caused by *Plasmodium falciparum* Worldwide by combining epidemiological, geographical and demographic data. Hay et al (2002) used GIS to overlay historical maps of malaria risk to create a single global distribution map of malaria risk which illustrated range changing from 1900 to 2002, and overlaying of contemporaneous population surfaces helped quantify changes in the numbers of people living in areas of malaria risk.

II). Distance Calculation; measuring distance is one of the fundamental functionalities of the GIS Euclidean/straight line or linear distance function measures distance from one point to another. Loha and Lindtjorn,(2010), tried to associate between malaria incidence and distance from settlement to breeding sites which has been documented from different parts of the world where different vectors play role in malaria transmission. This parameter will be quantified and suggesting the use of a distance of 2000m as a cut-off point for developing a risk map of malaria. The concept of distance as a primary influence on a malaria related hospital admissions, prevalence and mortality has been well established by various studies

that has been done showing that the greater distance from the health facility is one of significant risk factors for higher prevalence of plasmodium falciparum and anemia among children(WHO, 2011).

According to Schellenberg et al (1998), investigated in the rate of patients with severe malaria was strongly associated with the distance from the health center and to the distance from a road.

III). Digital Elevation Model (DEM); can be represented as a raster (a grid of square) or as a vector triangular irregular network (TIN). DEM is used to calculate derivative such as slope, aspect, and wetness index which have been applied in many studies relating malaria to topography.

Slope is a measurement of how steep, gentle/plain the ground surface is terrain orientation which is derived from slope and wetness index is considered an approximate measure of predicted water accumulation provides a meaningful description of how topography may affect malaria risk via suitability for potential mosquito breeding.

IV). Buffer zone analysis; Buffering (proximity), the most commonly defined neighborhoods function involves the ability to create distance buffers around selected feature. Buffer zone has been used to identify disease risk areas where control activities need to be strengthened. According to World Health Organization, 2012; World Malaria Report, qualification of a risk areas size or distance helps in qualification and selecting control activities of a risk area. In Natroun lakes in Egypt, GIS was used to create 2 km buffer zone around breeding habitats to delineate risk area mosquito nuisance and disease transmission.

2.7.2. Remote Sensing and LULC and/or Change

RS, an earth-observing instrument on satellite platforms, provides information on landscape features and climatic factors, and can be used to associate these factors with the risk of vector-borne diseases(Marina et. al 2015).

Ever since the launch of the first remote sensing satellite (Landsat-1) in 1972, land use land cover studies were carried out on different scales for different users. For instance, waste land mapping of India was carried out on 1:1 million scales by NRSA using 1980 – 82 Landsat multi spectral scanner data(Moshen, 1999).

In 1985, the U.S Geological Survey carried out a research program to produce 1:250,000 scale land cover maps for Alaska using Landsat MSS data (U.S. Geological Survey, 1999). The State of Maryland Health Resources Planning Commission also used Landsat TM data to create a land cover data set for inclusion in their Maryland Geographic Information (MAGI) database. All seven TM bands were used to produce a 21 – class land cover map (EOSAT 1992). Also, in 1992, the Georgia Department of Natural Resources completed mapping the entire State of Georgia to identify and quantify wetlands and other land cover types using Landsat Thematic Mapper™ data (ERDAS, 1992). The State of southern

Carolina Lands Resources Conservation Commission developed a detailed land cover map composed of 19 classes from TM data (EOSAT, 1994). This mapping effort employed multi-temporal imagery as well as multi-spectral data during classification.

However, prior to earning out such a geospatial analysis, land use/cover maps depicting various types of land surface features and their extent (e.g., agricultural fields, villages, roads, and surface disturbances) need to be generated (Moshen, 1999). A very efficient and effective way of obtaining such land surface information is by using high resolution images as a mapping tool to extract the required information (Shoshany et al., 1994).

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1. THE SPHERE OF INFLUENCE AND PHYSICAL CHARACTERASTICS

3.1.1 Location of the Study Area

The study area is one of the town administrations in Hadiya zone. It is located at a distance of 345 kilometers south of the Federal capital city of Addis Ababa, 121 kilometers North West of its SNNPR Capital, Hawassa. The study area is relatively bounded in the North by Adilo town, East by Amburse kebele, South by Bodit town and in the West by Gere Buligita kebele. The study location is found in Hadiya zone; SNNPR, Ethiopia. The study area is roughly located between $06^{\circ} 7' N$ --- $07^{\circ} 16' N$ latitude and $37^{\circ} 57' E$ --- $38^{\circ} 06' E$ longitude.

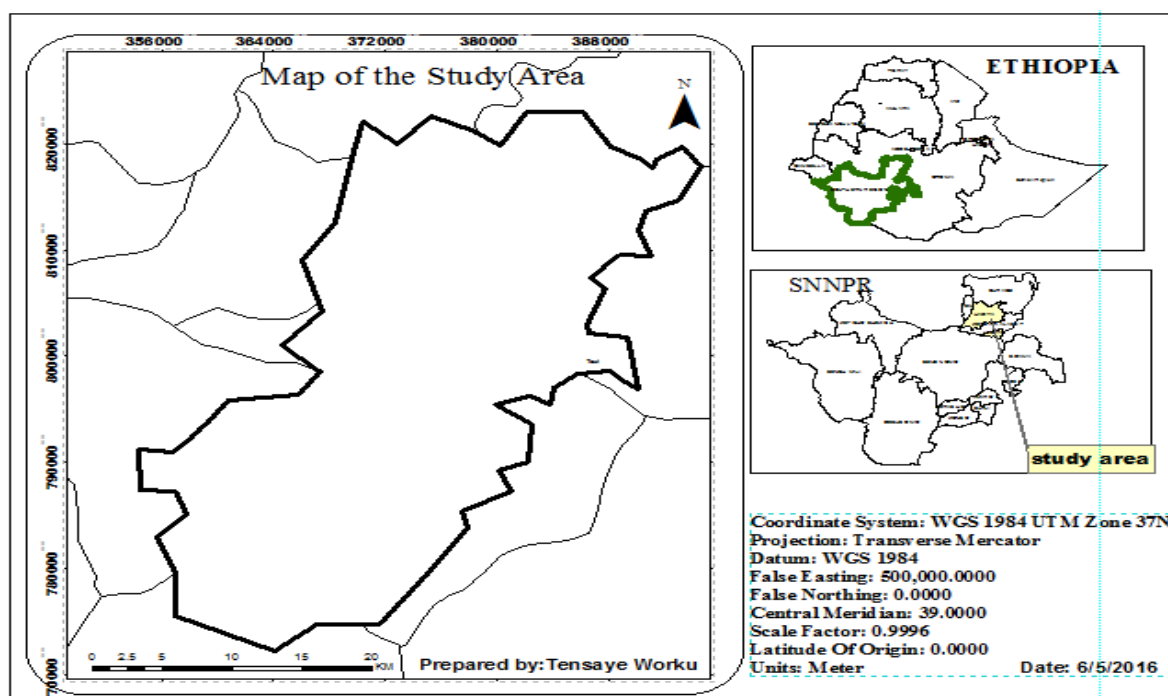


Figure 3.1: Map of the study area, Shone Town administration, Hadiya zone, SNNPR, Ethiopia. Source: ethioGis 1997; CSA 1994 shape files and satellite imagery.

3.1.2. Population

Based on 2007 population census. Shone town administration has a total population of 54,843 of whom 29,192 are men and 25,651 are women (CSA, 2008). The population density of the study area varies from 172 person/km² to 2268 person/km²

3.1.4. Topography

Relief of the town is classified in to plain and undulating surface and hilly. As one moves from the center towards the south west altitude slightly decreases. On the contrary, altitude increases as one moves away from the central part of the town towards the north and east directions where Shone mountain is found.

According to the data obtained from the Regional Statistical Abstract(1996) and Misrak Badewacho woreda Agriculture and Development Office(2015), almost all part of the town is characterized by plain topography. The altitude of the town ranges from 1230 meters above sea level in the south western part to about 1670 meter above sea level in the eastern part where Shone mountain is found. The average altitude of the town is 1450 meter above sea level. Generally, from the topographic point of view the town seems best suited for settlement.

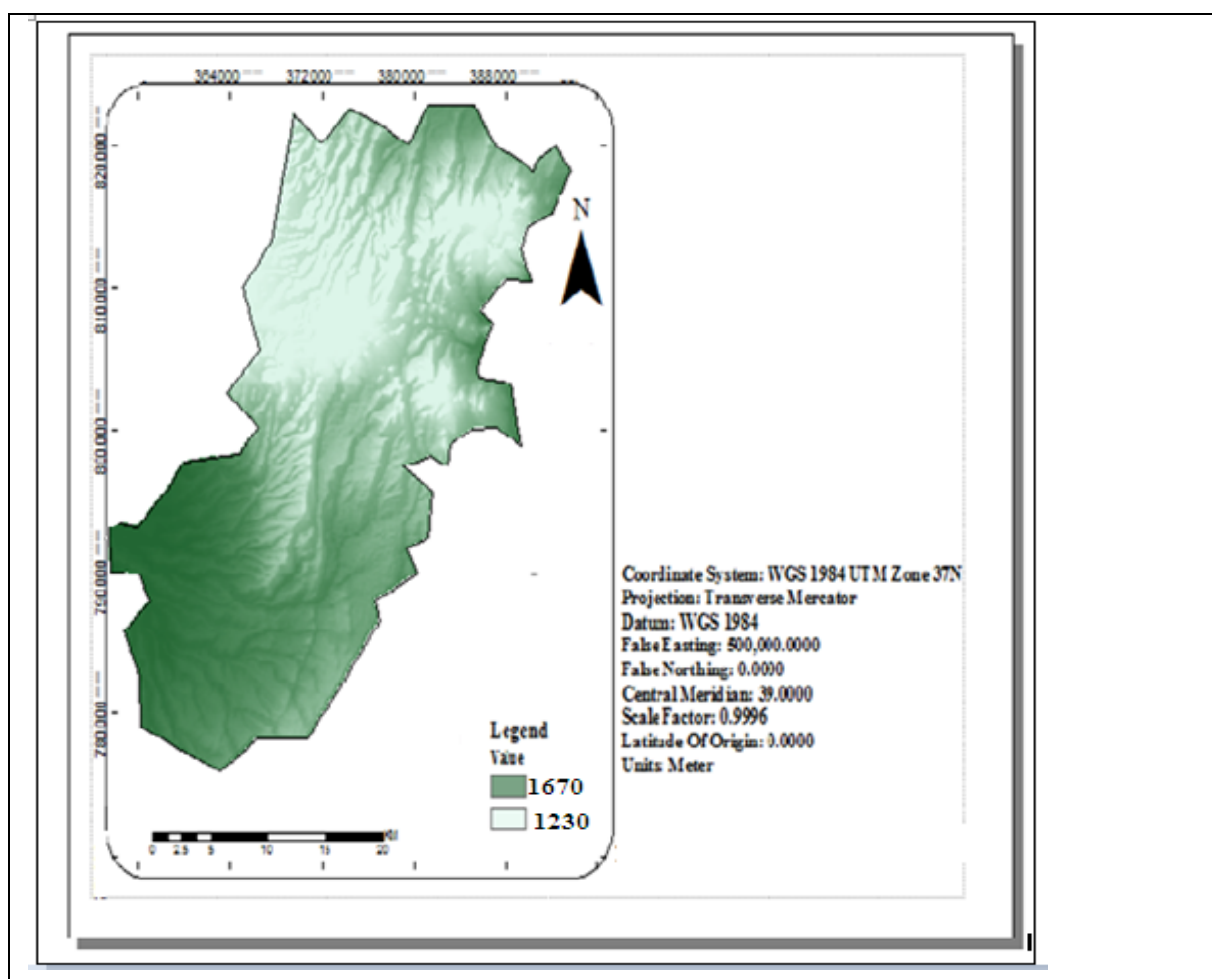


Figure 3.2: Elevation map of the study are

3.1.5. Drainage

There is river, but there are also irrigation dam and swampy areas in and around the town. According to Southern Nation Nationalities People Regional State Water and Mining construction Service Beraue (2014), there are two main source of water system for community: surface water and ground water system for numerous houses hold used for domestic purpose. Surface water is found around the town in the form of reservoir and ground water also be pumped from the aquifer to the earth surface for use. Thus, inhabitants receive water from those two sources: a private well, or a community water system.

3.1.6. Climate

According to the eleven years climatic data, particularly temperature which was obtained from National Meteorological Services Agency (NMSA), the climate of the study region is classified in to Kolla category and some portion as wet/moist woina dega on the western side of the study area. Mean annual temperature of the study area varies from 15.1 to 22.5⁰c, and the annual average, however is about 18⁰c, which is comparatively moderate. (Figure 3.4).

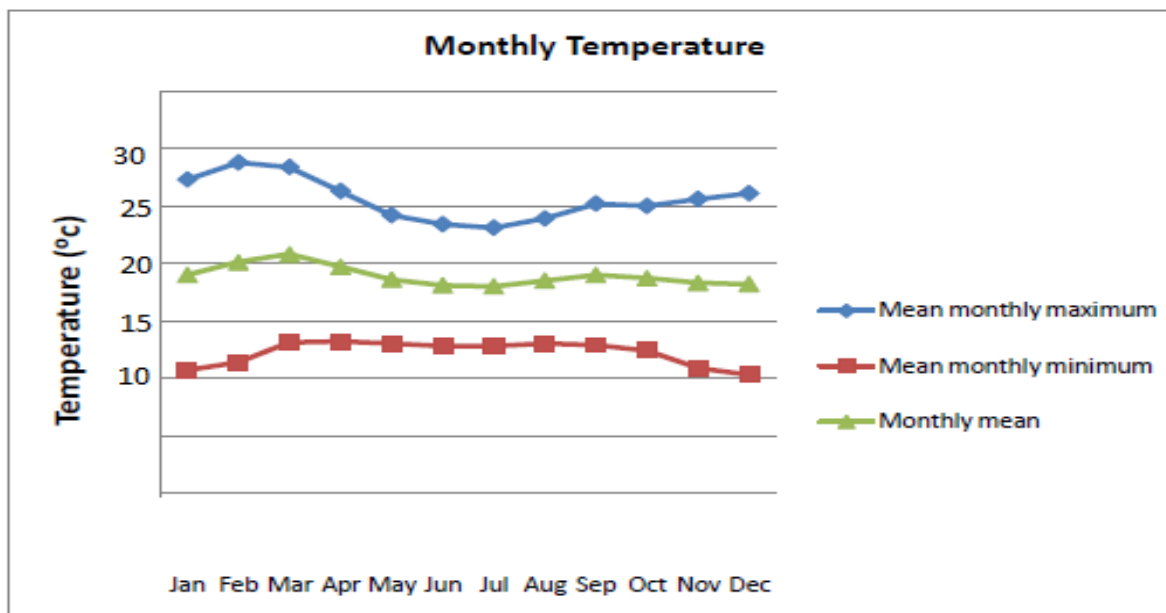


Figure 3.4: Mean monthly: maximum, minimum and mean temperature at shone town administration station (2005 to 2015). Source: National Meteorological Services Agency

3.1.7. Rain fall distribution

According to the regional Finance and Economy Bureau (2015/6), the mean annual total rain fall of the study area ranges from 1100mm to 1300mm and the average mean annual rainfall of the town is 1150mm. The distribution is such that, the amount decreases as one move from western to periphery of north east of the Shone town administration, to the south east.

3.1.8. Soil of the study Area

Soil is loose materials overlaying on the surface of the earth crust. It is very essential for plant to grow, animal and human get their food from these plants. Examining the type of soil helps for agricultural activities while observed from pollen carrying crops in aggravating malaria risk. The soil description for the study area is adapted from the SNNP regional atlas and FAO (1990), Shapefile. The types of soil distribution of the study area is dominated by Andosols, Eutric, Dystric nitosols, Pellic Vertisols/ Black Basaltic Soil and Acrisols. (see Fig.3.5)

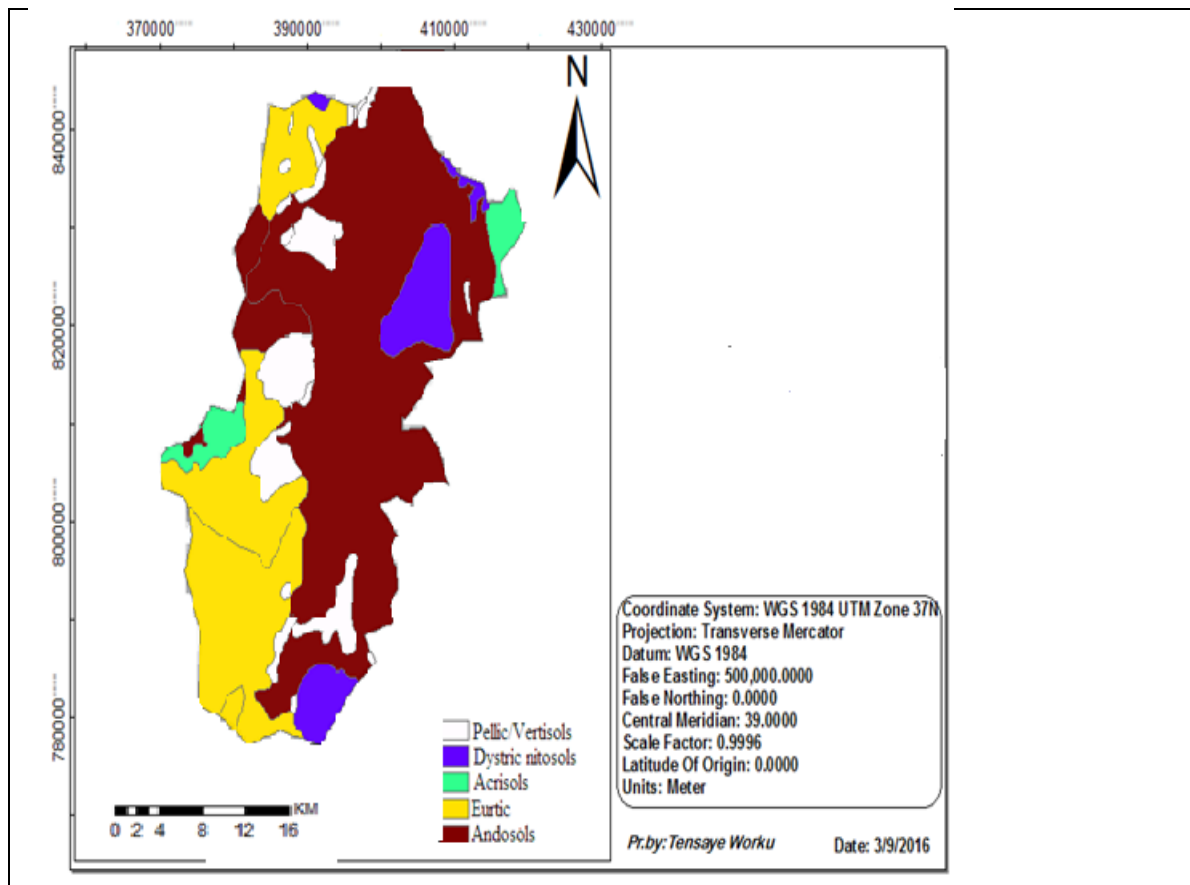


Figure 3.5: Soil map of study area. Sources: Ministry of Agriculture (FAO, 1999); shape file.

3.1.9. Geology of the study area

3.1.9.1 Rock Formation

The geological history of the study region is part of the geological history of Ethiopia. According to Southern Nation Nationalities and Peoples Regional state Mines and Energy Report and from Geological map of southern region, the geological unit of the study area falls in to Cenozoic Volcanic rocks. The highland volcanic terrain of the study region is the result of eruption of basaltic magma that erupted from fissures during the early and middle tertiary period of Cenozoic era.

- a) The Tertiary volcanic rock group covers 75% of the land area of the study region. This volcanic rock type which is found in the study area Magdala volcanic Groups of the Tertiary volcanic in Cenozoic era.
1. Magdala Groups: - erupted during Miocene to Pleistocene periods and covered most of the study area.
 2. Ashange formation:-It is the earliest flood basalt. Ashange formation consists of alkaline basalts interbedded proclastics and rare rehyolities. Ashange group covers about 5% of the total land area of the study area.
 3. Silicious domes and flows:-Although great in amount, silicious domes and flows, comprise of pantellerites and obsidian formation is found in the northern part of the study area. Silicious domes and flows cover about 15% of the land area of the study area.

3.2 Demographic Feature of the Study Area

3.2.1. Population Characteristics

In the report of national census conducted in 2007 by the central statistics Authority (CSA), the population size of the study area was indicated to be 54,843. Population is expected growing at a rate of 2.9% per annum.

3.2.2 Age and Sex Composition

As to Shone town administration, according to the 2007 national census report, out of the total population 54,843 population, the number of male and female population was 29,192 and 25,651 respectively. This gives an overall sex ratio of about 108 males for every 100 females.

Similarly, population grouping showed 29.3% of the total population is with ageenclosure of below 15 years.The age group between 15-64 accounts for the major portion (69.2%) and the above 65 years constitute 1.5%. Therefore, this age structure profile of the town depicts that, the shape of the age structure pyramid of the town is similar to that of the age pyramid known for developing countries.

Table 3.1: Working and dependent age group distribution of the town

Age group	Number	Percent (%)	Depe ndency Ratio
0-14	4575	29	42.3
15-64	10800	62.2	Active
65+	236	1.5	2.2
Total	15611	100	44.5

Source:-2007 CSA report

3.3.Social Services

3.3.1. Education

One of the parameters to evaluate the level of socio-economic development status of a given society is the accessibility that society has to education service. In this regard, the education service distribution level of the study area according to the shone town administration Education Office shows that there are 8 kindergarten, 20 primary schools, 2 secondary schools (one with preparatory school (9-12) and ot her without (9-10)) and one primary school for hearing disabled in the study area.

3.3.2. Health service

Although there are 15 medium and junior level private clinics,the health services provision of the study area is mainly dependent on governmentowned health center and 6 health extension po sts.

Table 3.2:The Existing health service Institution by type, Ownership and location.

No	Type of health Institution	Owner	Location			Total
			Shone 01	Weyra Mazoria	Kenchera	
1	Health Center	Governmental	3	1	1	5
2	Health Extension/post/	>>	2	2	2	6
3	Medium Clinic	Private	3	1	2	6
4	Junior Clinic	>>	6	3	-	9
Total			14	7	5	27

Source: - Own survey in 2015/16

3.3.3. Malaria trend of the study area

Based on 3 years data obtained from Shone Town Administration Health office, the number of malaria cases in the town is very high but the prevalence is decreasing. The trend of malaria in Shone Town is decreasing irregularly between 2005 and 2006 and increased between 2006 and 2007. But since 2007, it showed decreasing trend due to several preventive actions taken by the town administration health office and other concerned bodies. Even though, these actions have been undertaken, malaria is still a major health problem in the area. The following graph shows the malaria trend of the town in the most recent 3 years, i.e., between 2005 and 2007 (Figure 3.6).

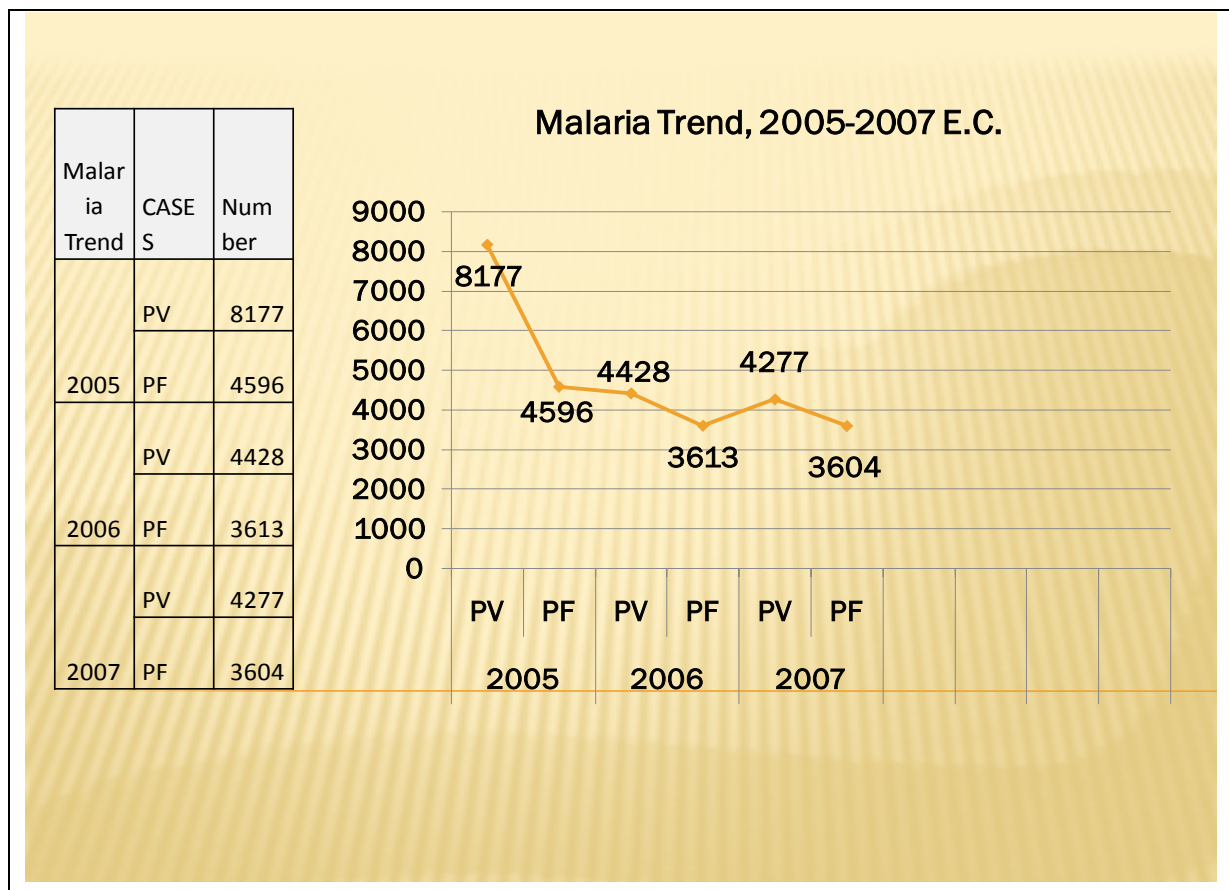


Figure 3.6: Malaria Trend of Shone Town Administration from 2005 – 2007 E.C

Source: Shone Town Administration health office.

3.4. Sources and Types of Data used

The data for this study obtained from both primary and secondary sources. The primary sources include GPS, and topographic information (SRTM data), topographic map (1:50,000 scale), Remote sensing satellite images, soil map and clinical data (malaria cases) of the study area. In the study multi parameter analyzer, hardware and software's were applied. In the study, the landscape features of the study area identified using remote sensing data for future identification of high risk areas with the help of distribution data for vector mosquito. Different sites are recognized as mosquito breeding sites and the location of the sites captured by using GPS instrument for further ground truthing.

The image used in this analysis was acquired on February 16, 2016 by Landsat 8 Libra sensor and it was downloaded using [www.http:libra.developmentseed.org](http://libra.developmentseed.org). (Landsat Imagery Archive).

It has a solar elevation angle of 123.87 degrees and a cloud cover lower than 3.96%. Satellite images at higher spatial resolution such as Landsat, SPOT-HRVIR and TERRA-MODIS have been used to map changes in vegetation in particular deforestation, a process widely thought to be associated with changing levels of malaria transmission (Lindsay *et al.*, 1991).

It is also important to state that the study area and its environs were impressed out using the local government boundary map and Ethiopian Administrative map were obtained from Ethio_gis.

A 30m resolution digital elevation model (DEM) was preprocessed to derive elevation, slope and other factors. Closed depression or sinks in DEM often occur as work of arts due to generalization process. Therefore, even very accurate, DEM usually have artificial closed depression, also called pits or sinks. Typically such pits occur either in generally flat areas or in areas where the slope of channel lines is quite low. By using filling mechanism the DEM fill/cut processing has been applied and used for further derivative of slope, flow direction, flow accumulation and other topographic factor.

Table 3.3: Data types used for the study.

No	Types of data	Source of data	Spatial resolution/scale	Year of Acquisitions	Format
1	Land Sat 8 satellite image	www.http:libra.developmentseed.org .	30m	2016/02/16	Raster
2	Digital Elevation Model	(SRTM) (Lab.exc.)	30m	2014	Raster
3	Study area boundary shape file	Central Statistical Agency	-		Vector
4	GPS data points	Field survey	-		Raster
5	Clinical data (malaria cases)	Woreda health office	-	2016	Excel
6	Soil map	Ministry of Agriculture	-		Vector

		(FAO, 1994)			
7	Topographic Map	Ethiopian Mapping Authority	1:50,000		Vector

3.5. Software and materials used in the project

The software types used for different types of activities in the process of generating malaria risk zone map include: Arc Map 10.1 ERDAS IMAGINE 2013, IDRISI 32 and ENVI+4.7. Global Positioning System was used for collection ground points to prepare accuracy assessment for land use land cover map.

Methods of Data Collection and Analytical flow chart

The main objective of this project work is to produce malaria risk zone map of Shone Town Administration based on environmental factors responsible for malaria incidence. These environmental factors were selected based on Shook model (1997) and depending on previous research works and by collecting information from malaria experts of the Town. According to this elevation, slope, soil, swamps, streams, and irrigation dam were selected as major environmental factors for malaria Hazard incidence. For each environmental factors mentioned above maps were generated and then reclassified depending on their suitability for mosquito breeding. In the process of reclassification, new values 1, 2, 3, 4 and 5 were assigned and they represent Very high, High, Moderate, Low and Very Low malaria hazard level, respectively and the influence of each factor, weight computation was done by pair wise comparison matrix. Land use land cover type selected as one risk element for malaria risk mapping besides malaria Hazard and Vulnerability. This LULC were then reclassified depending on their suitability for mosquito breeding. In the process of reclassification, new values 1, 2, 3, 4 and 5 were assigned and they represent Very high, High, Moderate, Low and Very Low malaria risk element level, respectively. Vulnerability map also generated as another element of risk mapping based on population distance from Health centers.

This vulnerability for malaria risk element as usual reclassified given, new values 1, 2, 3, 4 and 5 were assigned and they represent Very high, High, Moderate, Low and Very Low malaria risk element level, respectively. Finally, weighted overlay carried out using Arc Map 10.1 to generate the final malaria risk zonemap of the study area.

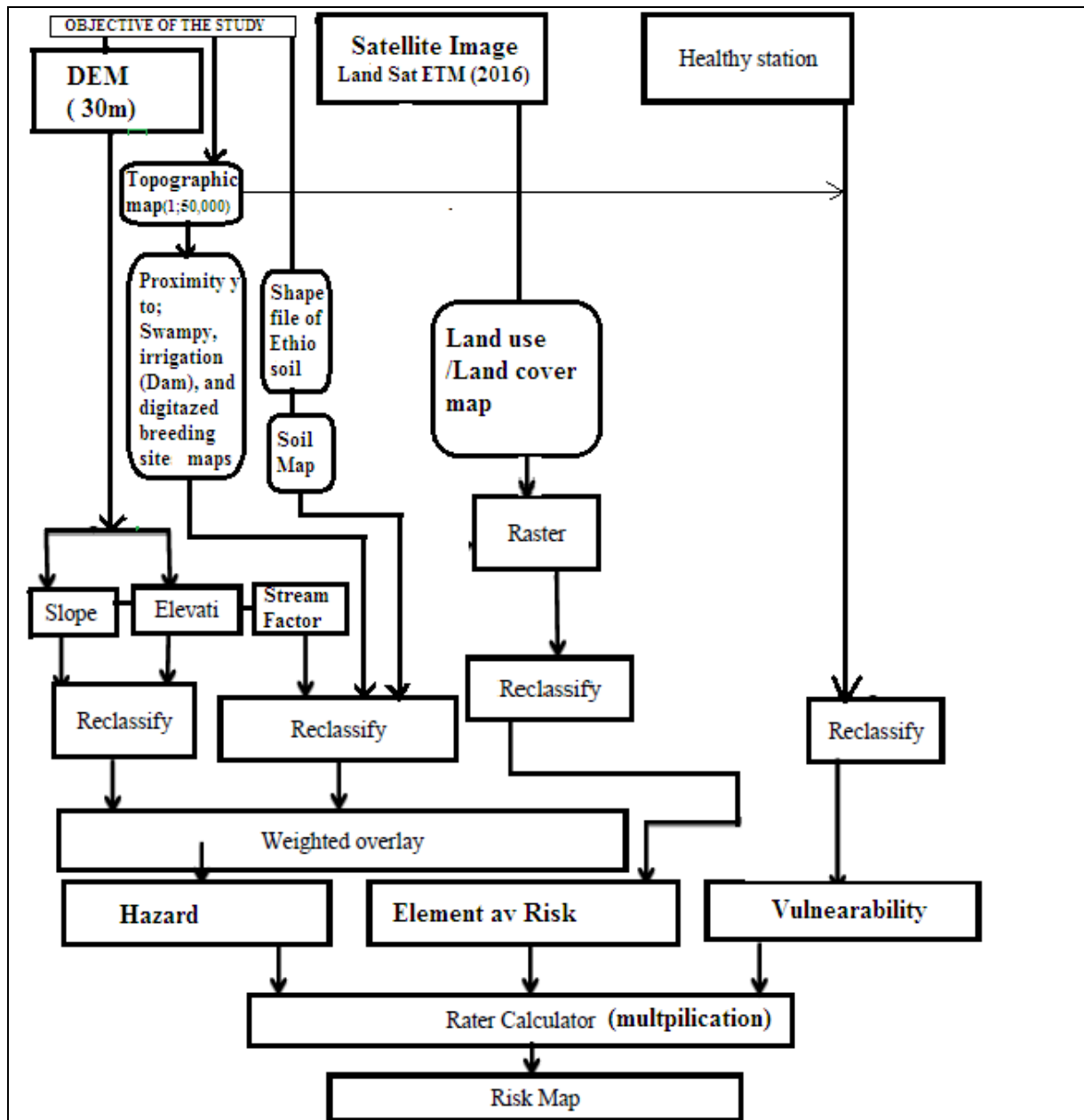


Figure 3.7:Analytical Flow chart showing the general methodology of the objective of the study in malaria risk mapping,adapted from Shook (1997).

As far as discussed above, a risk computation equation was developed based on Shook(1997),which was used to estimate the development of malaria risk in the study area.

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

“Hazard (H)” is the probability of occurrence of a potential damaging natural phenomenon within a specified period of time and within a given area. Element at risk includes the population, public services and vulnerability is the exposure of a given element or set of elements at risk resulting from the occurrence of a damaging phenomenon of a given magnitude where as risk is the expected degree of loss due to a particular natural and/or physical phenomenon. It may be expressed as the product of Hazard, Vulnerability, and Element at risk.

The malaria hazard analyses will be computed using multi criteria evaluation (MCE). To run MCE, the selected environmental factors such as topographic factors (elevation, slope and flow distance to stream), Swampy area, irrigation dam and breeding sites was developed and weighted. Then, weighted overlay technique was used, in ArcGIS 10.1 environment to generate malaria hazard map. For vulnerability analysis, digitized population settlement in Spatial Analyst/ module was used to generate distance to settlers (vulnerable groups) factor maps. Land use land cover map was used to generate element at risk factor map. Finally, malaria risk map of the town will be generated in ArcGIS 10.1 environment using spatial analyst/ raster calculator tool. This specific tool helps to multiply malaria risk factors as element of the risk (LULC), vulnerability and hazard map.

3.6.1. Data Processing Analysis

Malaria transmission is strongly associated with environmental conditions, which control mosquito maturity and parasite development. Accordingly breeding sites, elevation, slope, and distance to stream are listed in order of importance.

To assess malaria risk of the study area using GIS and Remote Sensing, Multi-Criteria Evaluation was used. MCE is a procedure which needs several criteria to be evaluated to meet a specific objective.

The standardized raster layers were weighted using Eigen vector that is important to show the importance of each factor as compared to other in the contribution of malaria hazard.

Accordingly, the Eigen vector of the weight of the factors was computed in ArcGIS 10.1 /AHP extension software.

3.6.1.1.Elevation factor

Elevation is a prominent factor for malaria transmission, this is because of elevation highly determines the amount of Temperature, and temperature in turn affect mosquito breeding as the length of immature stage in life cycle. In high temperature, the egg, larval and pupil stages will be shortened so that the turnover will be increased and also affect the length of the saprogenic cycle of the parasite within the mosquito host i.e. when Temperature increase, the period of the saprogenic cycle of mosquito will be shorted (ministry of health, Ethiopia.1999). Elevation map was generated from SRTM 30 meter resolution Digital Elevation Model (DEM). The elevation of study area classified in to five classes as 1200-1300, 1301-1400m,1401-1500, 1501-1600and 1601-1700m.a.s.l. and new values were assigned for each class as 1, 2, 3, 4 and 5, respectively supported on prior research works and literature. Finally elevation based malaria risk level is leveled as very high, high ,moderate, low and very low respectively.

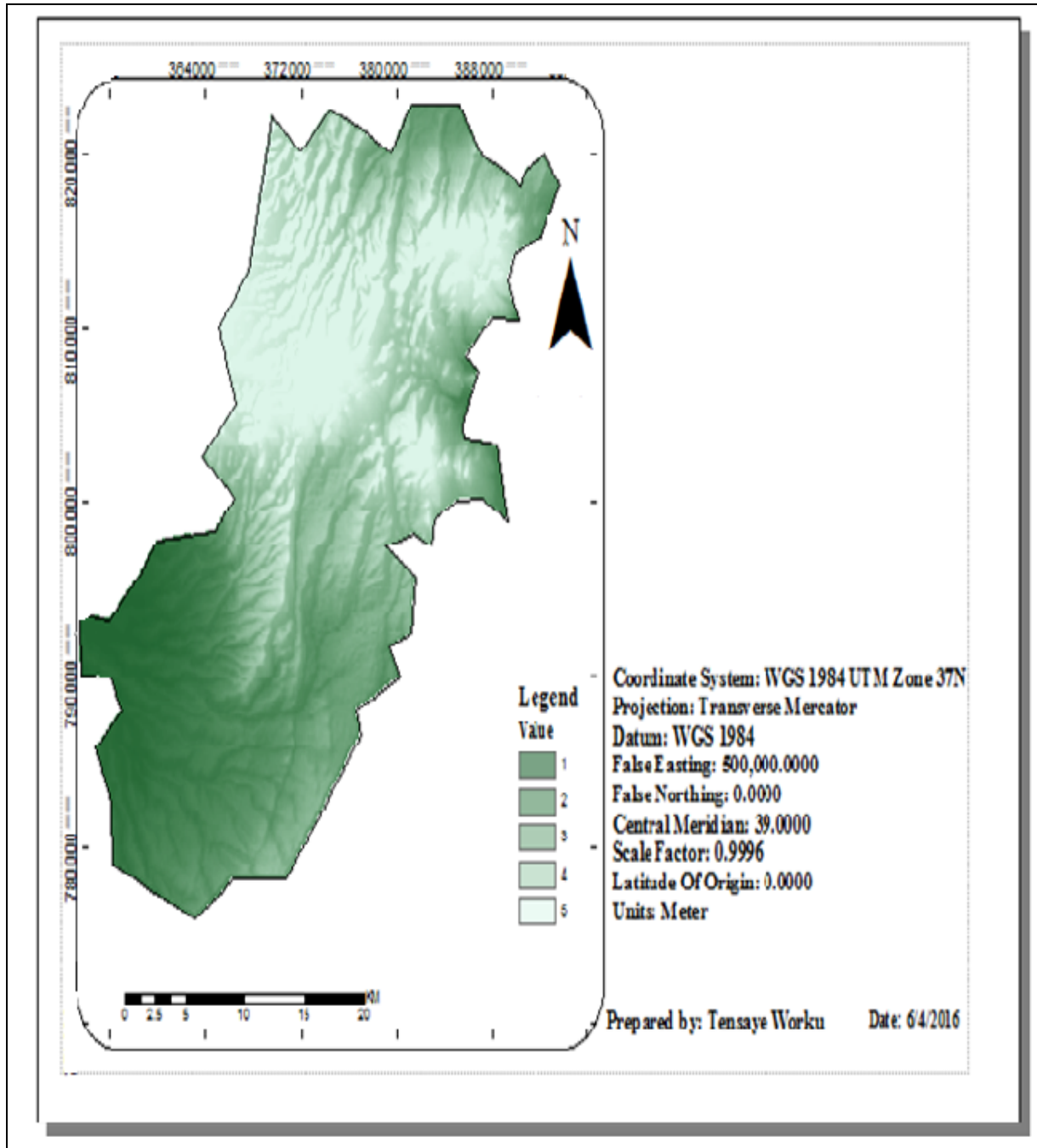


Figure 3.8: Elevation map

3.6.1.2. Slope

Slope is another topographic parameter that may be associated with mosquito larval habitat formation, is the measurement of the rate-change of the land per unit distance which may affect the stability of the aquatic habitat (Stephen, 2000). Slope map of the study area was generated from SRTM 30 meter resolution Digital Elevation Model.

Then, the slope map was reclassified in to five sub groups based on suitability of the slope for mosquito breeding by using spatial analyst tools in Arc GIS. The reclassified slope raster layer sub groups were ranked accordingly to the degree of suitability for malaria incidence in the locality as: 0.03- 0.47, 0.47 – 0.73, 0.73 – 0.95, and 0.95 – 1.32 and 1.32 – 2.33 and Assigned new values as 1, 2, 3, 4, and 5 respectively. Slope based malaria risk level is described as very high, high, moderate, low and very low, respectively. To elaborate, the steeper slope values are related to lesser malaria hazard and the gentler slope have high susceptible for malaria incidences. And new values re-assigned in order of Malaria hazard rating.

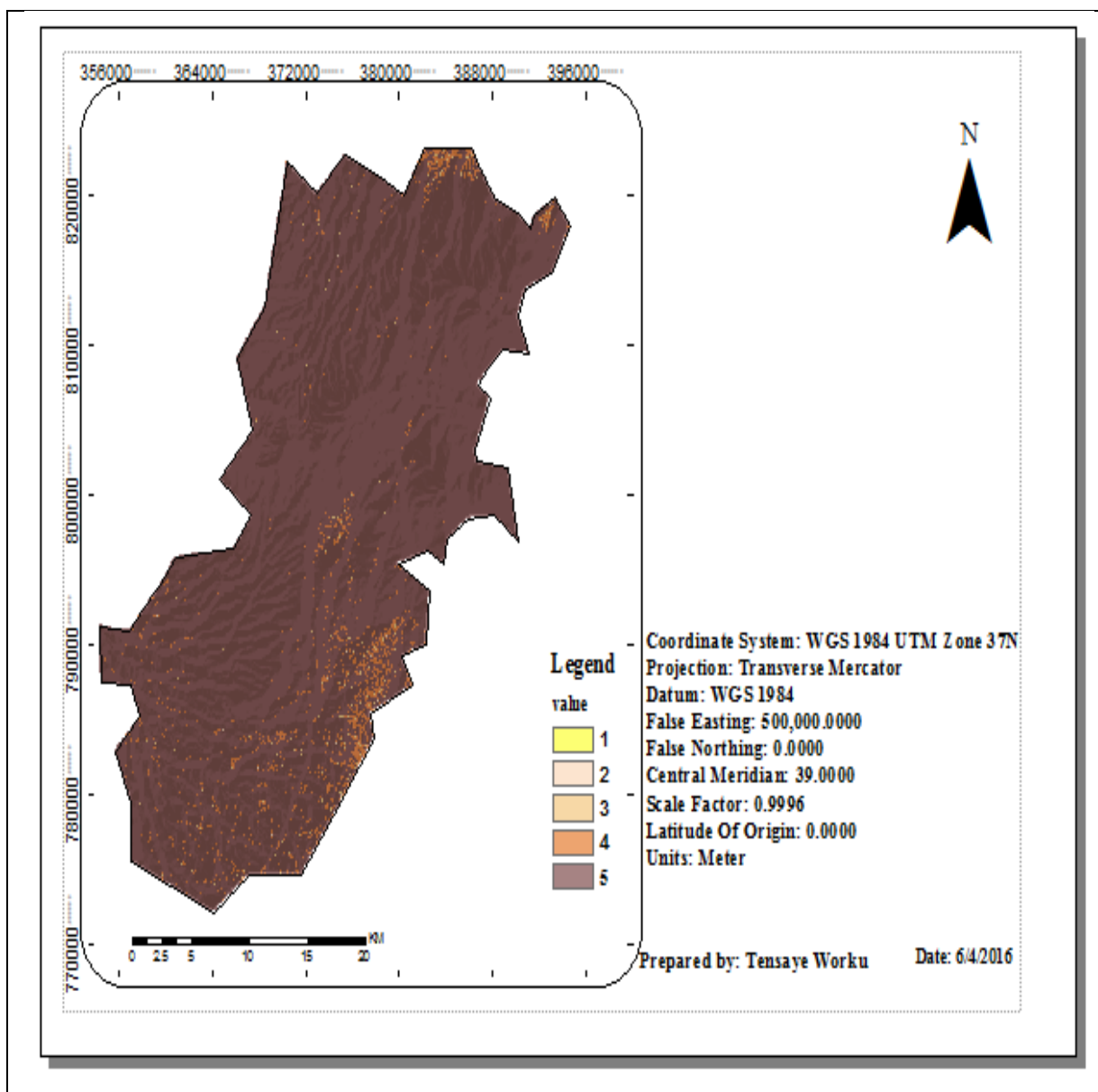


Figure 3.9: Slope map

3.6.1.3. Proximity to Irrigation/Dam

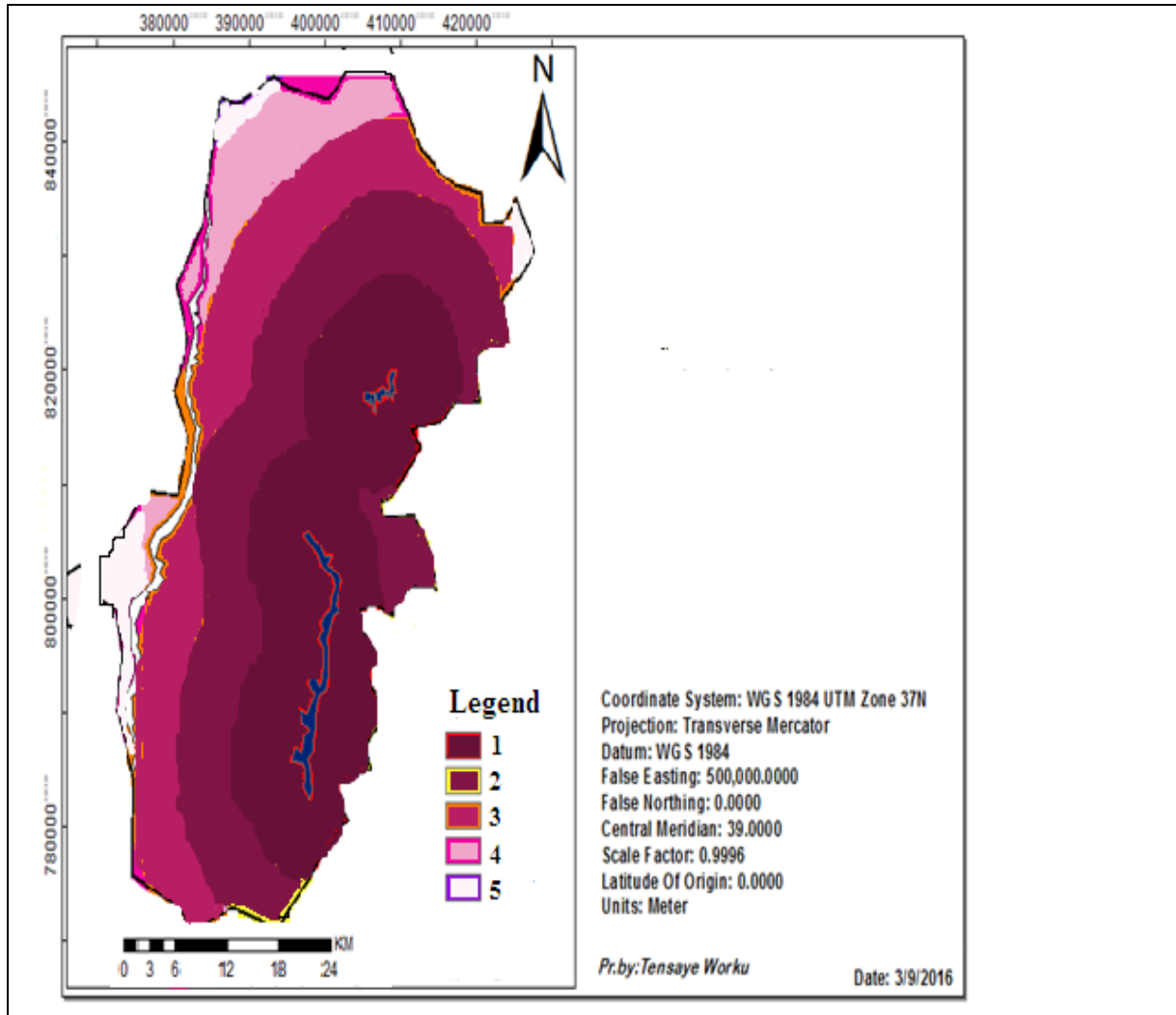


Figure 3.10: Irrigation dam digitized map

Proximity to Irrigation dam is generated and by using euclidean distance calculation in spatial analyst tools, and new values was assigned as 1, 2, 3, 4 and 5. Then reclassified as very high, high, moderate, low and very low malaria risk level, respectively.

3.6.1.4. Proximity to swamps

As it was mentioned above, swamps are digitized from 1:50,000 scale topographic maps obtained from Ethiopia Mapping Agency (EMA) and the map was generated in Arc GIS environment using Euclidean distance calculation. The reclassification was done on the basis of mosquito flight range. New values were assigned as 1, 2, 3, 4 and 5. Then reclassified as very high, high, moderate, low and very low malaria risk level, respectively.

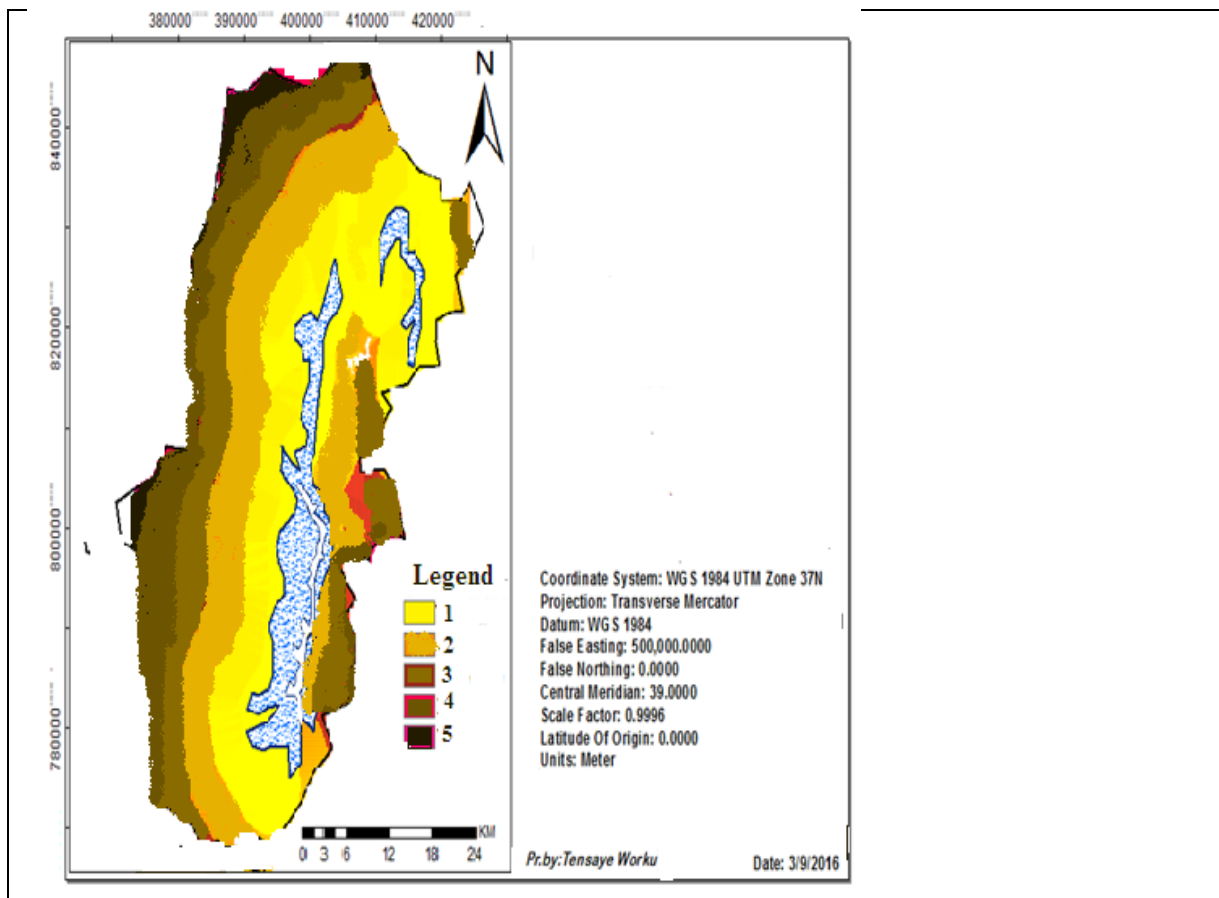


Figure 3.11: Swampy area digitized map

3.6.1.5. Distance to stream factor

The flow distance to stream raster layer was generated from the DEM using DEM hydrology tool (terrain analysis using Digital Elevation Model). Taking heed of the maximum flying distance of anopheles mosquito from the distance to stream is 2 km as a basis for reclassification distance to the stream layer.

Then stream distance raster layer was further reclassified using natural break standard reclassification method in ARC GIS software in to five subgroups as: 1, 2, 3, 4, 5 and the reclassified subgroups of stream distance raster layer were ranked as: Very high, high, moderate, low, very low according to mosquitoes flying distance threshold value, respectively which means areas out of the flying distance threshold were considered as less malaria risk level and new values re-assigned in order of Malaria hazard rating.

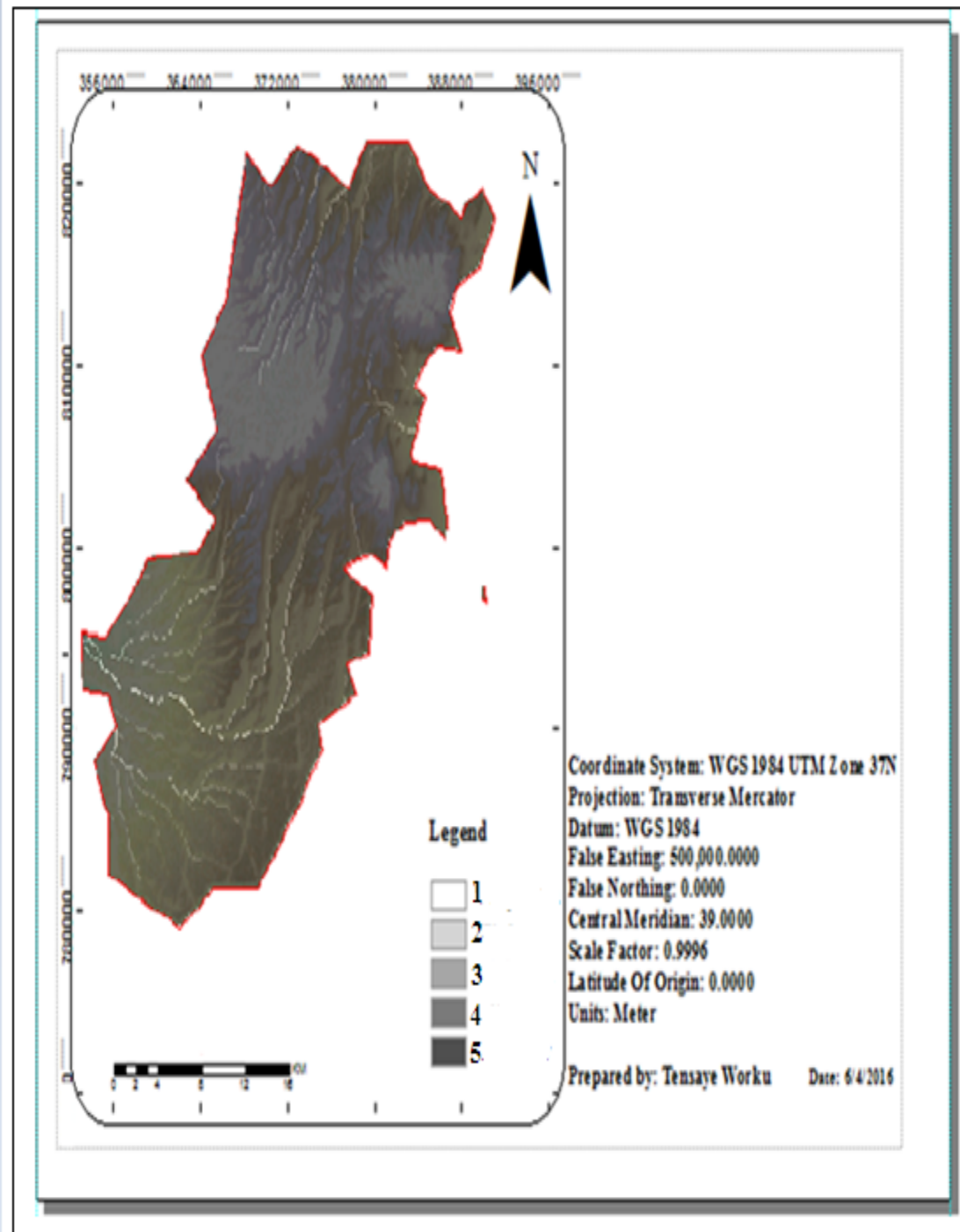


Figure 3.12: Stream map

3.6.1.6 Distance to breeding site factor

One of environmental covariate significantly related to transmission intensity was distance from the water and wet land, indicating high transmission in the areas within 2 km of the water source (malaria journal of 2002). Taking heed of the maximum flying distance of anopheles mosquito from the breeding site, which is 2 km as a basis for reclassification of a quadric bodies distance layers (malaria journal of 2002). Euclidean distance of spatial analysis tool was used to calculate the distance from the breeding site. Then the breeding site distance raster layer was further reclassified using natural breaks standard reclassification method in ArcGIS as: 1, 2, 3, 4, and 5 and the reclassified sub groups of breeding site distance raster were ranked as: very high, high, moderate, low, and very low respectively, according to mosquitoes flying distance threshold value which means areas out of the flying distance are considered as less malaria hazard area and new values re-assigned in order of Malaria hazard rating

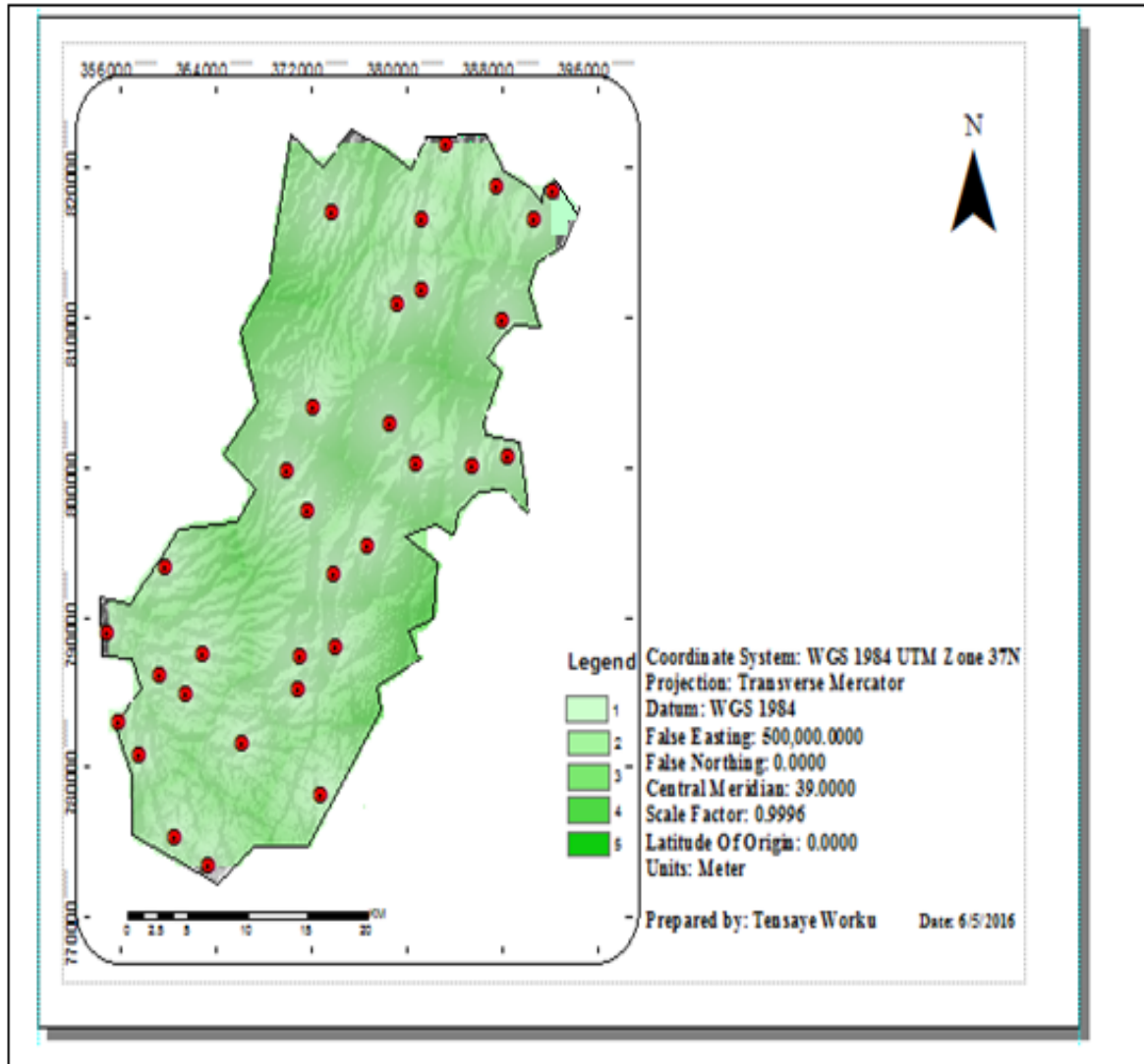


Figure 3.13: Breeding map

3.6.1.7 Soil

Soil types of the study area reclassified based on their ability to hold moisture and/ or being permeable or impermeable. The soils were classified according to color and moisture content into red soils (dry upland soils, mainly found on hills and representing plowed fields), and two types of gray soils (dry and wet lowland soils, mainly found in stream cuts, depressions, and floodplains/wetlands). As it was mentioned above in description part, Vertisols are very sticky poorly drained soils and reclassified as very high malaria risk level. Eutric and Dystric Nitisols, those have also high moisture storage capacity and reclassified as high and moderate malaria risk level respectively. Andosols poorly drained soils and classified as low risk level.

Acrisols those have good drainage leveled as very low malaria risk level. Thus, reclassified as very low risk area and assigned new value 1, 2,3,4,5 respectively.

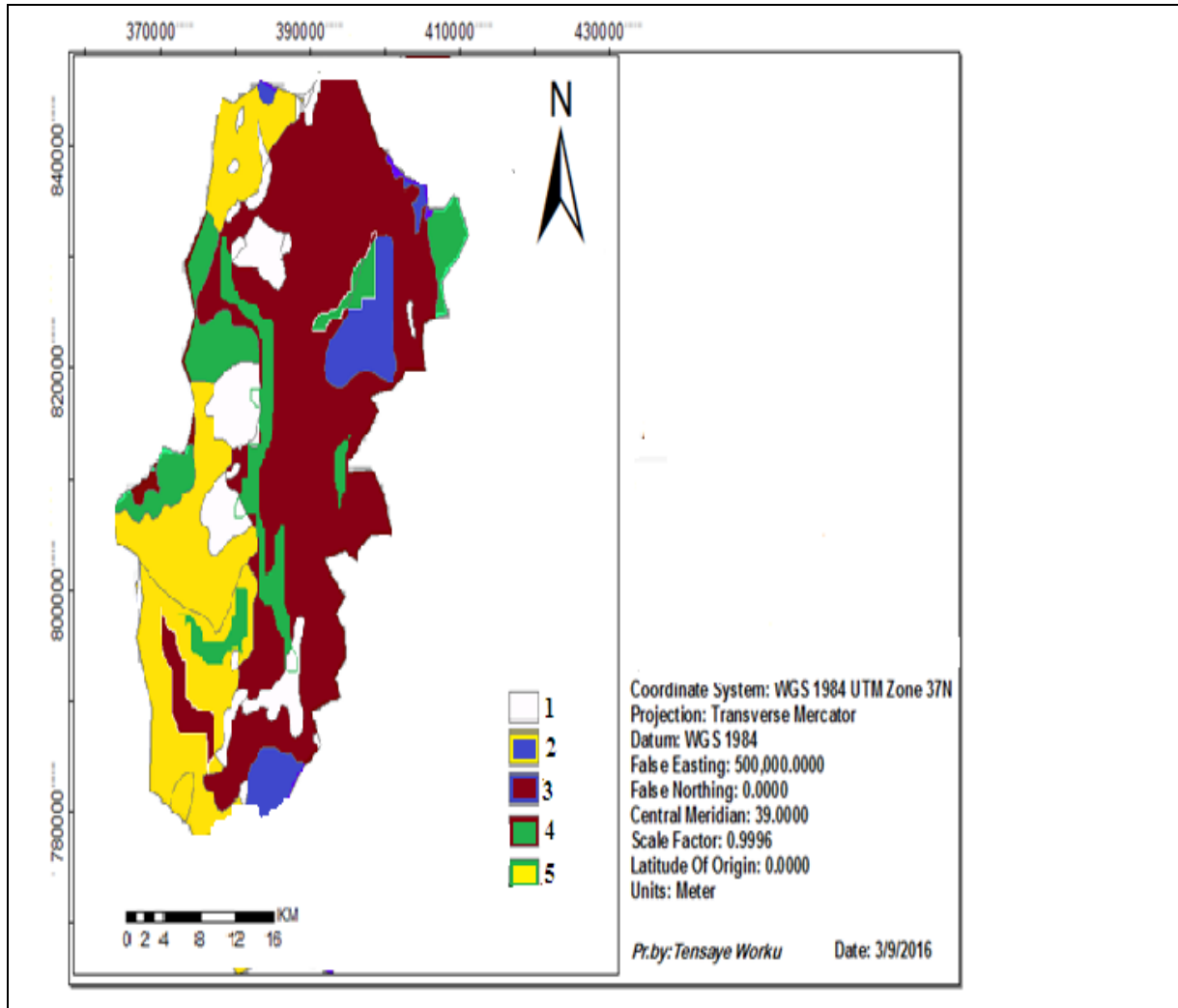


Figure 3.14 soil map

3.6.1.8 Land use land cover factor

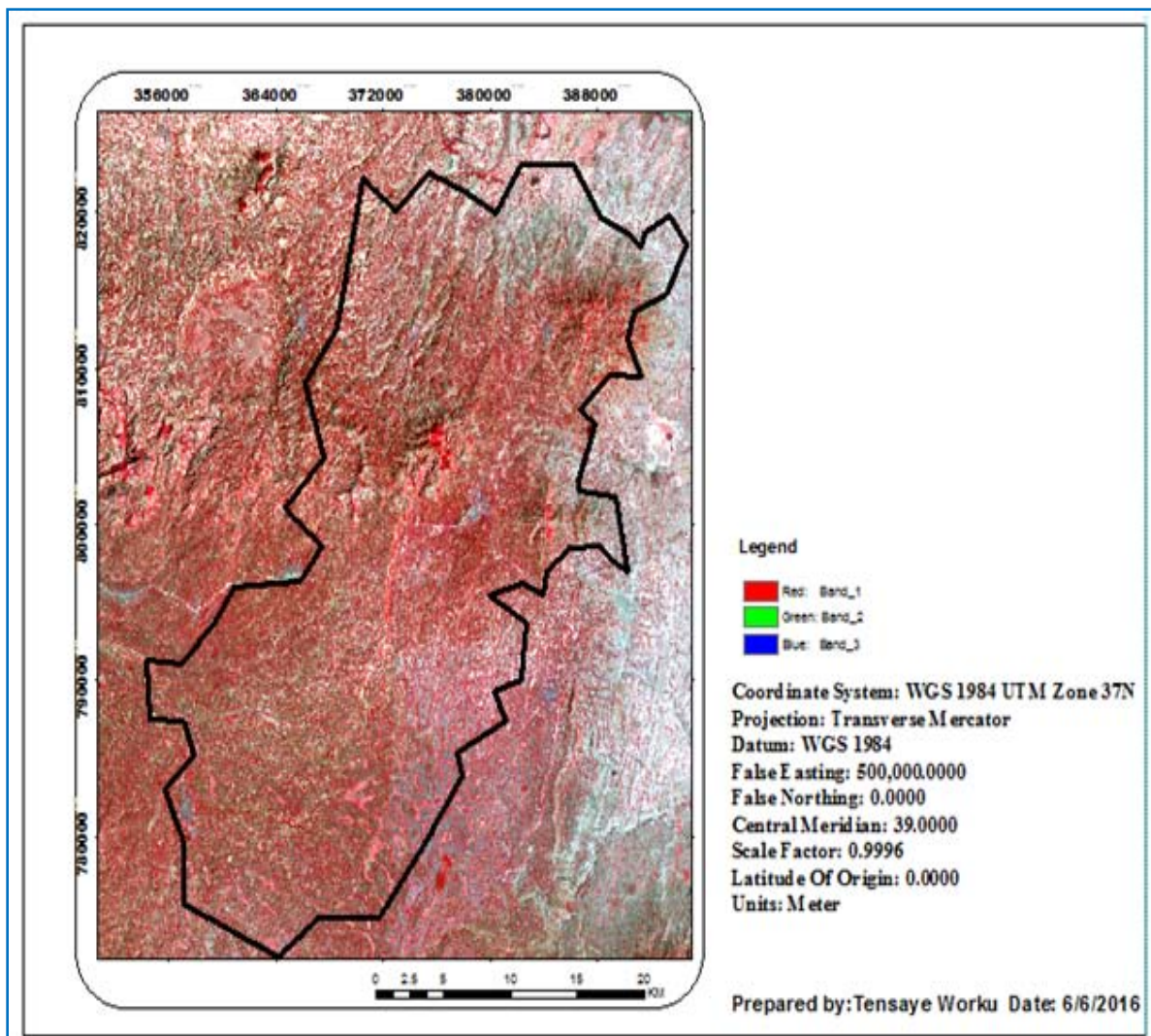
The land use land cover map was produced from Land Sat 8 scene of the year 2016. Supervised classification technique was used to classify the image in ERDAS IMAGINE 2014.

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.

Land cover affects the temperature of larval habitats directly and food conditions and other factors indirectly, but the combined effects of these factors may be more significant to larval survivorship (Munga et al., 2006). A study on Western Kenya highlands indicates the influence of land use and land cover on larval survivorship and adult productivity by affecting the amounts of temperature reaching the place of breeding and their source of food. According to this study, water body followed by wet and farm lands are more suitable for larval survivorship than forested areas (Zhou et al., 2007). Forest areas or areas with tree canopy reduces the water temperature of larval habitats, as tree canopy cover reduces the amount of solar radiation reaching the larval habitats, the algal contents, one major food source of *Anopheles gambiae* larvae, was considerably lower in forest than in the farmland and the larvae from forested habitats took a much longer time to develop into adults than those from farmland habitats (Munga et al., 2006). The land use land cover map was reclassified depending on its suitability to mosquito breeding. According to literatures and previous works water body, and wet land are most suitable for mosquito breeding so, they classified as very high, farm land as high; bare and shrub lands as Moderate; settlement as low; and forest as very low that assigned new values assigned 1, 2, 3, 4, and 5 respectively.

3.6.1.8.1. Satellite data pre-processing

The study area is covered by Landsat 8 scene 183/29 (path/row). The image used in this analysis was acquired on Feb. 16, 2016 by Landsat 8 OLI (Operational Land Imager) sensor and it was downloaded [www.http// libra.developmentseed.org](http://libra.developmentseed.org) (Landsat Imagery Archive). It has a solar elevation angle of 123.87 degrees and a cloud cover lower than 3.96 %. ENVI 4.7 software has been used for this classification to enhance spectral response using false color composite before classifying.



Figurexxxx: False color composite

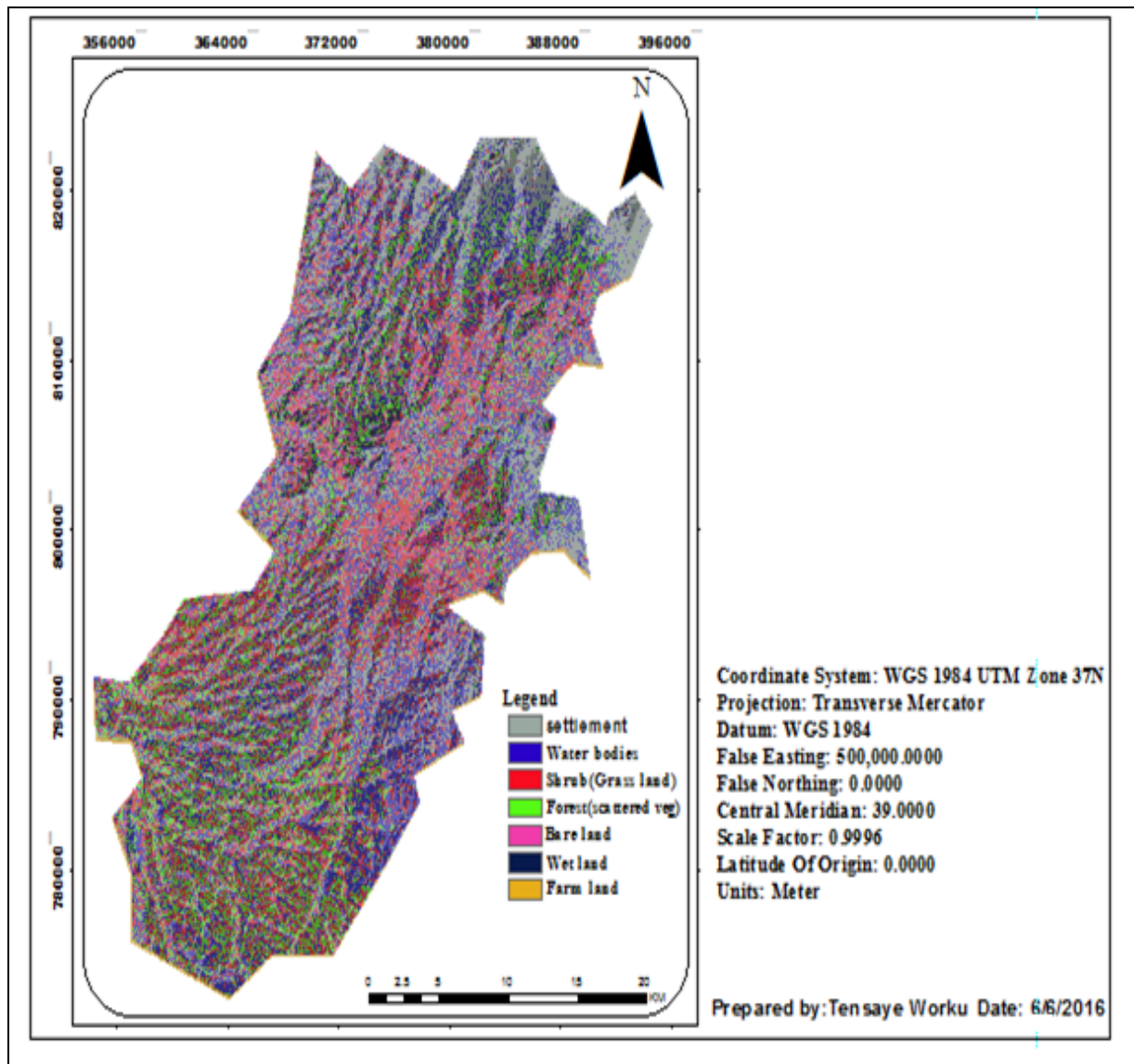


Figure 3.15: LU/LC map

Table 3.5 Land Use Land cover risk ranking

Rank	Class	Risk
1	Water body and wet land	Very High
2	Farm land	High
3	Bare and shrub land	Moderate
4	settlement	Moderately High
5	forest	Moderate

3.6.1.9 Malaria Vulnerability

Vulnerability is the susceptibility or weakness often associated with a particular situation such as illness, economy; gender (Stephenson, 2014). Malaria vulnerability is the susceptibility to be affected by its causal agent (*plasmodium sp.*). According to stratton (2008), Malaria vulnerability is influenced by demographic characteristics, access to health facilities and socioeconomic condition. However, Malaria vulnerability can be reduced by the advancement of vector control mechanisms. The people that live far from health care facilities were identified the most vulnerable to malaria in most sub_ Saharan African countries (Stratton, 2008).

Vulnerability (Accessibility index) is prominent factor to malaria vulnerability. It was generated from digitized after georeferencing GPS field collected data in ArcGIS environment. The vulnerability was further reclassified in to 5 sub class as: 1, 2, 3, 4, and 5. And the reclassified sub groups of vulnerability (accessibility index) raster layer were ranked as: very high, high, moderate, low and very low respectively, and new values re-assigned in order of Malaria vulnerability rating.

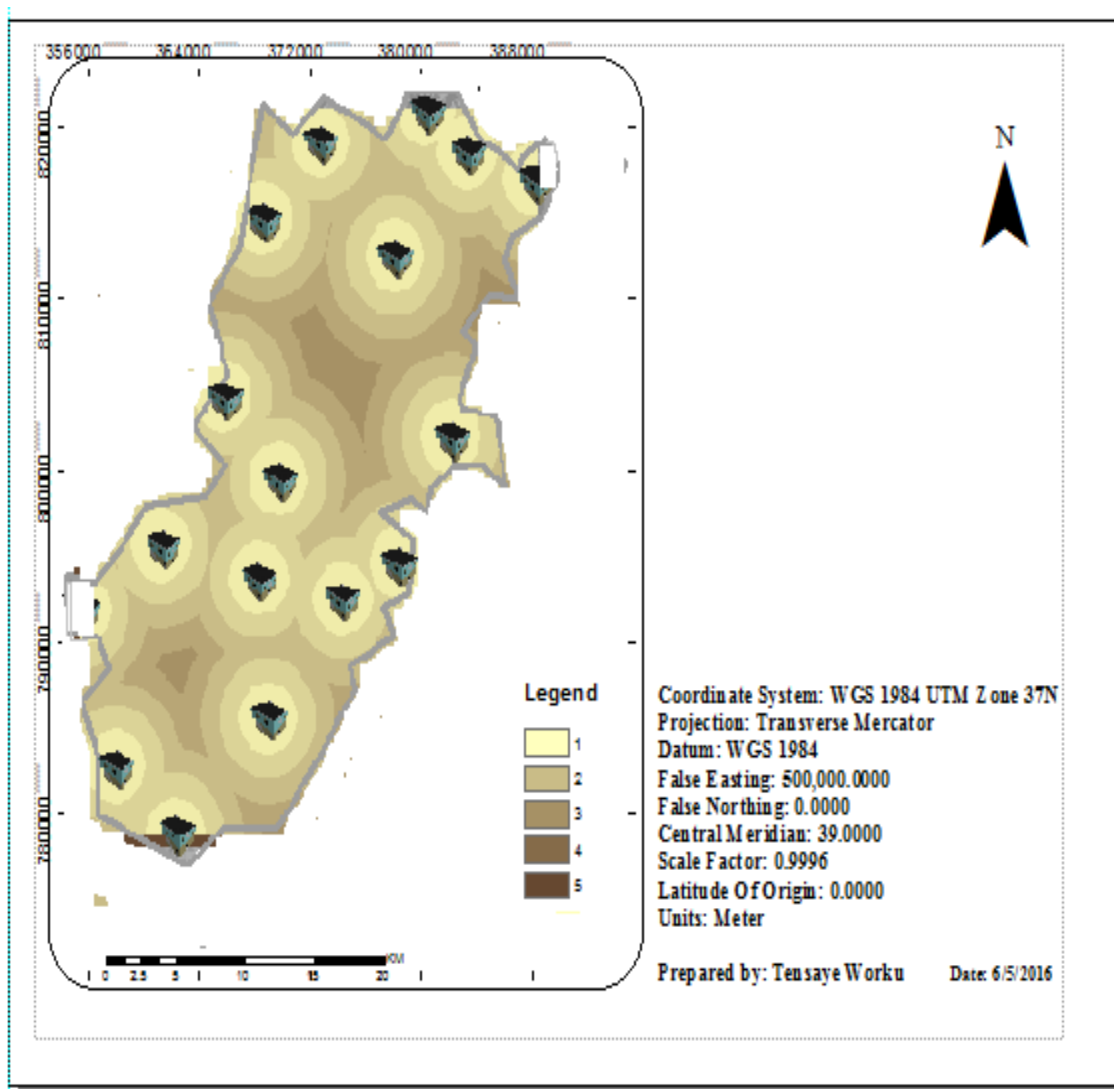


Figure 3.16: Vulnerability map

3.6.2 Malaria hazard analysis

Hazard is the probability of occurrence of damaging natural phenomenon within specified period of time. As a hazard, malaria incidence is mapped by depending on some of the environmental factors which contribute for the survival of *Anopheles* mosquitoes. For the purpose of identifying areas of malaria hazard, this study focused on distance to breeding factor, elevation factor, slope factor, soil factor, distance to stream factor and, distance to swampy, and irrigation dam, as the factors of malaria incidence in the study area. The malaria incidence and transmission requires the environment with lower elevation (higher temperature), abundance of wet lands, occurrence of gentle slopes, availability of still waters around rivers, and areas of lower drainage density (Negasi, 2008).

Hazard is the probability of the incidence of mosquitoes infective with malaria in a certain area. It was approached by assessing the suitability of environmental condition for malaria transmission based on environmental and physical factors.

After preparing all the factor parameters compatible to hazard analysis, estimating weights for hazard parameters was what comes next. Running hazard map requires estimating weight for each individual hazard parameters. The following sections demonstrate the procedure of MCDM as a means of calculating weight for hazard parameters. To illustrate, the following actions were carried out to estimate weight during the Hazard mapping by the ranking method. This method had been taken in to consideration to find Hazard location of malaria, under this study; five evaluation criteria had been considered namely distance to breeding factor, elevation factor, slope factor, soil factor, Distance to stream factor and , distance to swampy, and irrigation dam. The criteria were first ranked according to what seemed appraisable value for their importance. After assigning weight according to their importance for each parameter, the hazard layer was computed by over laying the five selected hazard parameter factors using AHP extension in GIS environment

The Hazard map was further reclassified in to 5 sub classes as: 1, 2, 3, 4, 5, and the reclassified sub groups were ranked as: very high, high, moderate, low and very low respectively, and new values re-assigned in order of Malaria hazard rating.

The computed Eigen vector, which is an output of the pair wise comparison matrix to produce a best fit set of weight, of Weight Module was: Distance to breeding site 0.1155, Elevation 0.1710, Slope 0.3253, Distance to stream 0.0344, soil 0.1616, distance to swampy 0.0439, and distance to irrigation 0.1082

The consistency ratio (CR) of the calculated Eigen vector was 0.0401 which is acceptable. The computed Eigen vector was used as a coefficient for the respective factor maps to be combined in Weighted Overlay in Arc GIS environment.

Table 3.6: Weighted malaria hazard ranking for shone area District (Hazard Analysis)

Factor	Weight	Value(sub factor)	Ranking	Hazard
Distance to breeding site	0.1155	0-1.4	1	Very High
		1.4000001-1.8	2	High
		1.8000001-2.2	3	Moderate
		2.2000001-2.6	4	Low
		2.6000001-3	5	Very Low
Elevation:	0.1710	1200-1300	1	Very High
		1301-1400	2	High
		1401-1500	3	Moderate
		1501-1600	4	Low
		1601-1700	5	Very Low
Slope	0.3253	0.03-0.47	1	Very High
		0.48-0.73	2	High
		0.74-0.95	3	Moderate
		0.96-1.32	4	Low
		1.33-2.33	5	Very Low
Distance to stream	0.0344	0-71.3	1	Very High
		71.4-285	2	High
		286-723	3	Moderate
		724-1273	4	Low
		1273-2597	5	Very Low
Soil	0.1616	-	1	Very Low
			2	Low
			3	Moderate
			4	High
			5	Very High
Distance to swampy (Marshy land)	0.0439	0-53.7	1	Very Low
		53.8-1007.7	2	Low
		1007.8-1613.4	3	Moderate
		1613.5-2150.8	4	High
		2150.9-2688.4	5	Very High
Distance to Irrigation (Dam)	0.1082	0-79.7	1	Very Low
		79.7-1037.21	2	Low
		1037.21-1316.29	3	Moderate
		1316.30-1795.36	4	High
		1795.37-2586.05	5	Very High

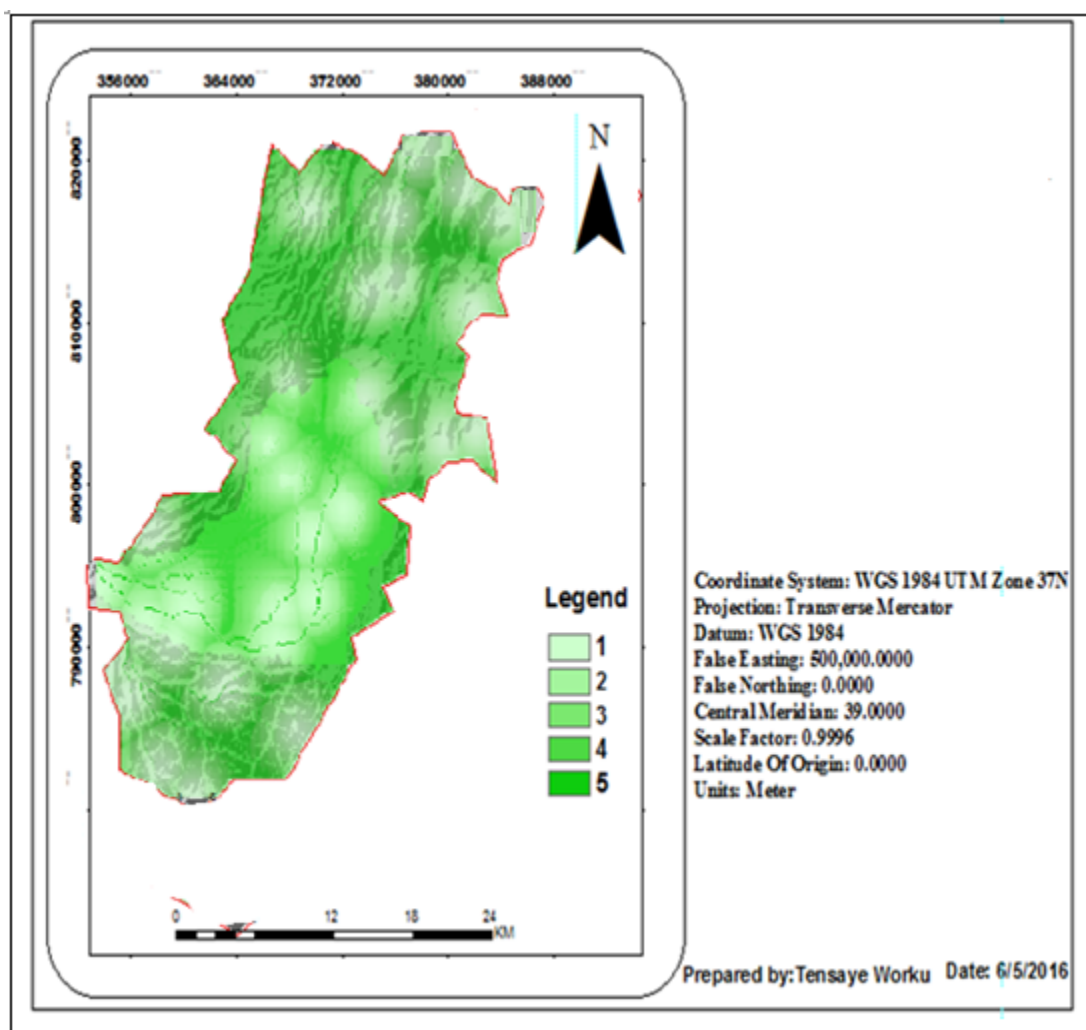


Figure 3.17 hazard map

3.6.2.1 Malaria risk analysis

In disease modeling risk is defined as the chance or likelihood that an undesirable event or effect will occur as a result of use or nonuse, incidence, or influence of chemical, physical or biological agent, especially during a stated period of time. In other words, it is the probability of developing a given disease over a specified period of time (WHO, 2013). Thus Malaria risk is the probability that an individual will be attacked by malaria in a given interval of time and in a known area.

The development of malaria risk map of the study area was done on the basis of risk computation model (shook, 1997).

$$\text{Risk} = \text{Element at risk} * \text{Hazard} * \text{vulnerability}$$

The three components of malaria risk analysis are hazard, element at risk and vulnerability layers.

The malaria hazard layers was computed by overlaying the five selected causative factors like distance to breeding site, elevation, slope, and distance to streams and wetness index raster layer, in weighted over lay module in the ArcGIS 10.1 software. The element at risk layer was developed by rasterizing and reclassifying land use/ land cover image file on the basis of malaria susceptibility of each land use/ land cover image file on the basis of malaria susceptibility of each land use/ land cover classes. Moreover, vulnerability layer was developed by computing distance module on the layer that was developed by computing health facility per population index density on the existing number of health facilities distribution per population distribution. In continuation, all the three components of risk were taken with equal importance for malaria risk. Finally raster calculator was used to multiply the three components of risk. The final out put raster layer generated by multiplying the risk components was the malaria risk raster layer, and it was reclassified according to the risk level in to five sub groups as very high, high, moderate, low and very low risk areas.

Table 3.7 Malaria risk factors rankings for shone area (Risk Analysis)

Factors	Sub-factors	Ranking	level
Malaria hazard	1.19-2.21	1	Very High
	2.21-2.59	2	High
	2.59-2.99	3	Moderate
	2.99-3.45	4	Low
	3.45-4.61	5	Very Low
vulnerability	0.05-0.0702	5	Very Low
	0.0702-0.099	4	Low
	0.099-0.1496	3	Moderate
	0.1496-0.2	2	High
	0.2-0.35	1	Very High
Element at risk	Water body & wetland	1	Very High
	Farm Land	2	High
	Bare and shrub land	3	Moderate
	settlement	4	Low
	forest	5	Low

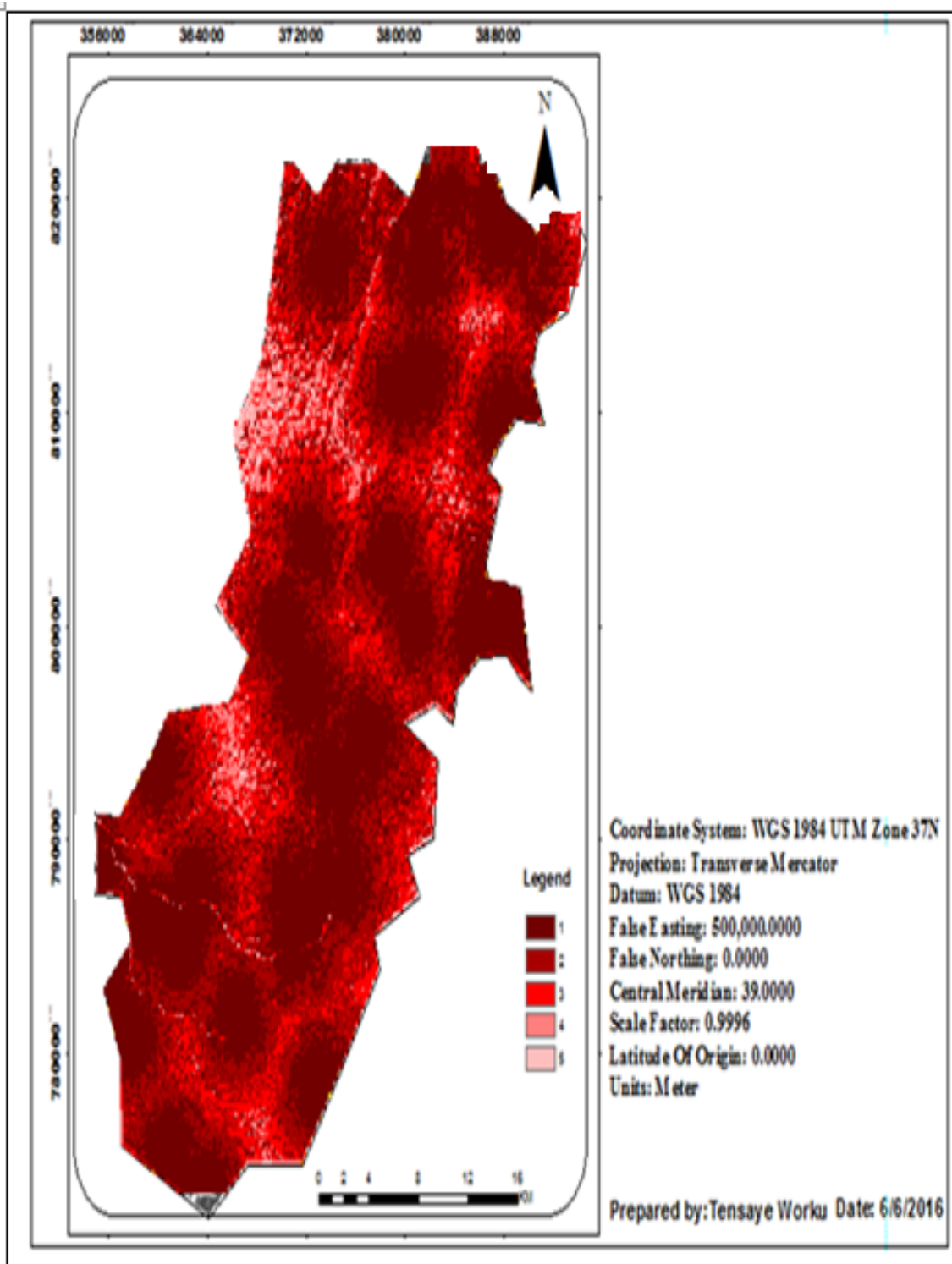


Figure 3.18 Risk map

CHAPTER FOUR

RESULTS AND DISCUSSIONS

In this chapter, the result are presented, interpreted and discussed in line with the research objectives, conceptual frame work and the methodology of the study. Potential anopheles mosquito habitats detected through satellite imagery and data acquired from the field. Malaria prevalence is spatially analyzed with in administrative boundaries are detected. Malaria causing environmental factors is identified.

Finally, malaria risk area mapping and its causing factors is analyzed through the integrated application of GIS and Remote Sensing environment.

4.2. Relationship between topographic factors and malaria incidence level

4.2.1. Elevation and malaria risk level

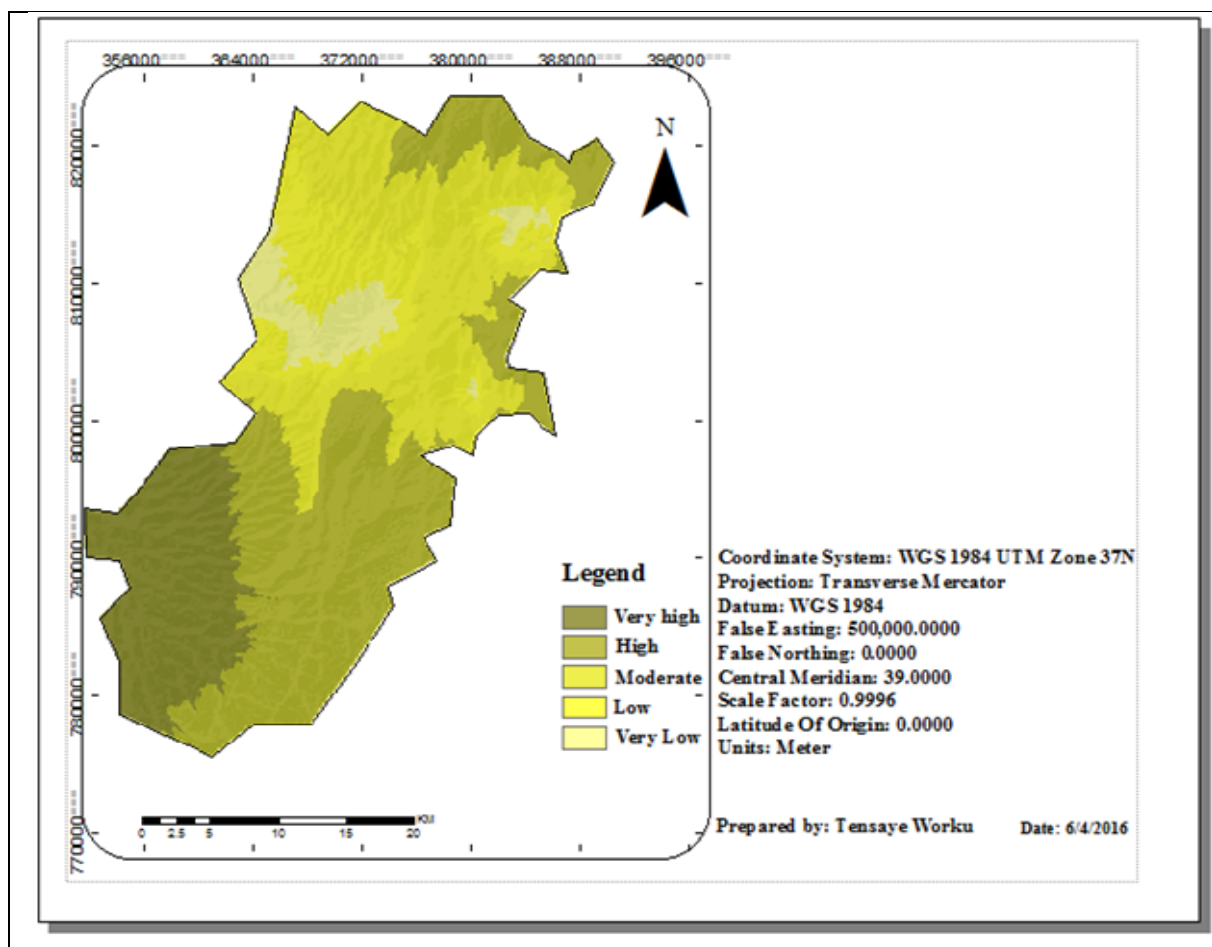


Figure 4.1: Reclassified elevation based malaria hazard map

Table 4.1 Malaria hazard, elevation rating area coverage and percentage

No	Rating	Elevation range	Pixel count	Area in m ²	Area in km ²	Percent (%)
1	Very High	1200-1300	123478	111130200	111.13	21.93
2	High	1301-1400	168724	151851600	151.85	29.97
3	Moderate	1401-1500	106969	96272100	96.27	19.00
4	Low	1501-1600	87421	78678900	78.67	15.53
5	Very Low	1601-1700	76314	68682600	68.68	13.55
	Total		562906			100

Figure 4.1, the reclassified elevation map covering 21.93%, 29.97%, 19%, 15.53%, and 13.55% were mapped as areas of very high, high and moderate, low, and very low malaria hazard level, respectively. From this figure, it is possible to deduce that about

52 % of the study area is in high and very high and moderate malaria hazard zone and 29.1% of the area is in low malaria hazard zone while about 29.1% of the area is in low to very low malaria hazard zone. The remaining 19% is in the modern situation. Thus, according to old national Atlas map of Ethiopia (1988) in Ethiopia malaria frequently occurs in areas with elevation below 2000 m above sea level and its transmission is very severe in areas below 1500 m. Hence, as about 71% of the area is below 1500 meter above sea level is likely under risk of malaria prevalence.

4.2.2. Relation of Slope and malaria incidence

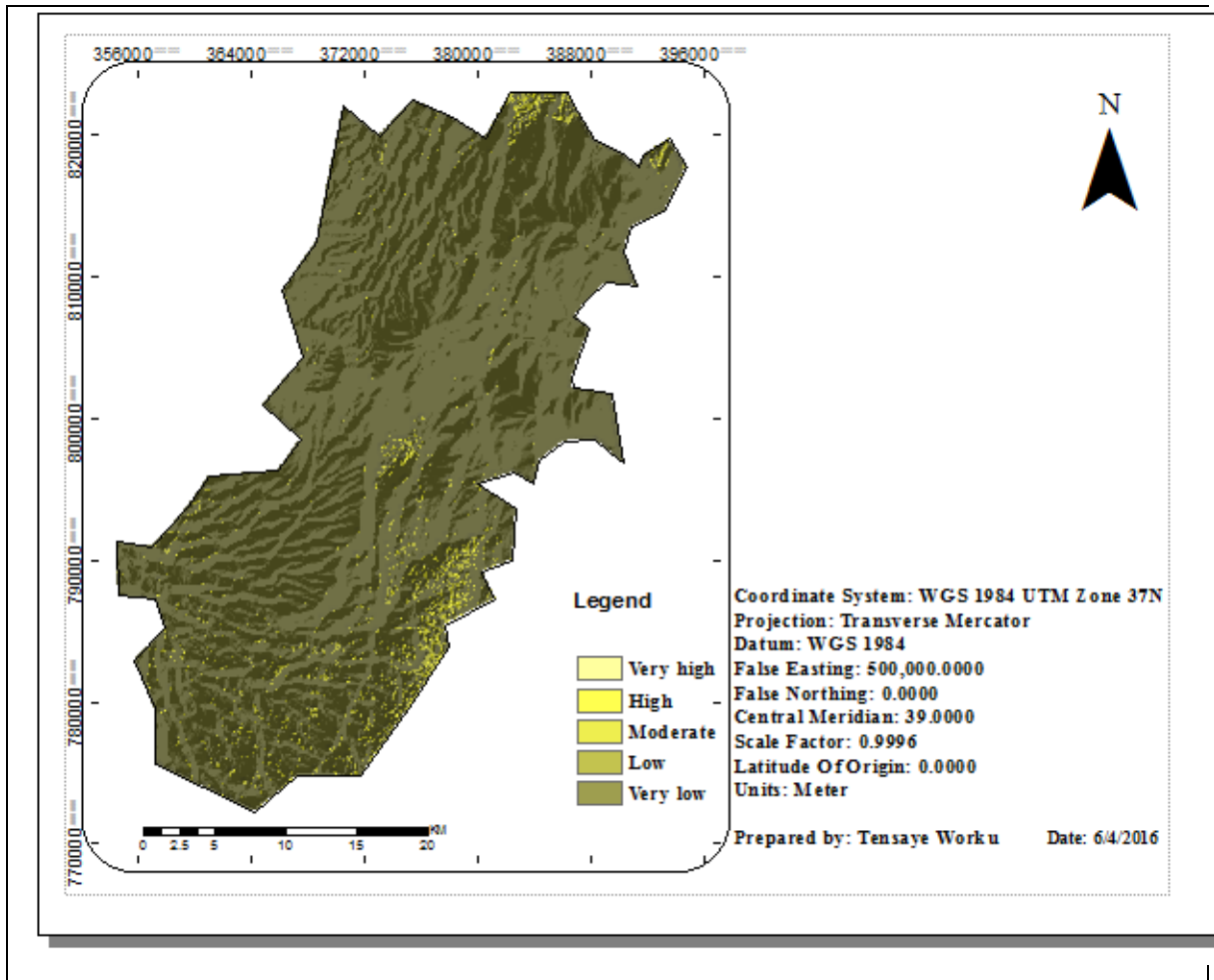


Figure 4.2: Reclassified slope based malaria hazard map

Table 4.2 Malaria hazard, slope Rating Area Coverage and Percentage

No	Rating	Slope range	Pixel count	Area in m ²	Area in km ²	Percent (%)
1	Very High	0.03-0.47	83870.8	75483360	75.5	15.34
2	High	0.48-0.73	191074	171966600	172	32.73
3	Moderate	0.74-0.95	159195.5	143275950	143.3	27.56
4	Low	0.96-1.32	127536.6	114782760	114.80	22.42
5	Very Low	1.33-2.33	1229.1	1106190	11.06	1.9
	Total		562906			100

Based on the suitability of the slope for mosquito breeding, the reclassified slope map shows of the area about 15.34%, is in a very high; 32.73%, in high; 27.56%, in moderate; 22.42%, low; and 1.9%, very low hazard of malaria incidence. Of the total area, 48.7% is in high and very high malaria risk level, while the rest 51.3% area is in moderate, low and very low risk level. Areas leveled as high and very high malaria hazard levels have, slope less than 0.95 – 1.32 and 1.32 – 2.33 that allow water stagnation and create suitable conditions for mosquito breeding. Hence, about half of the area (48%) is at risk, which closely equal to the area at malaria hazard risk zone in terms of elevation range (52%).

4.2.3. Proximity to stream

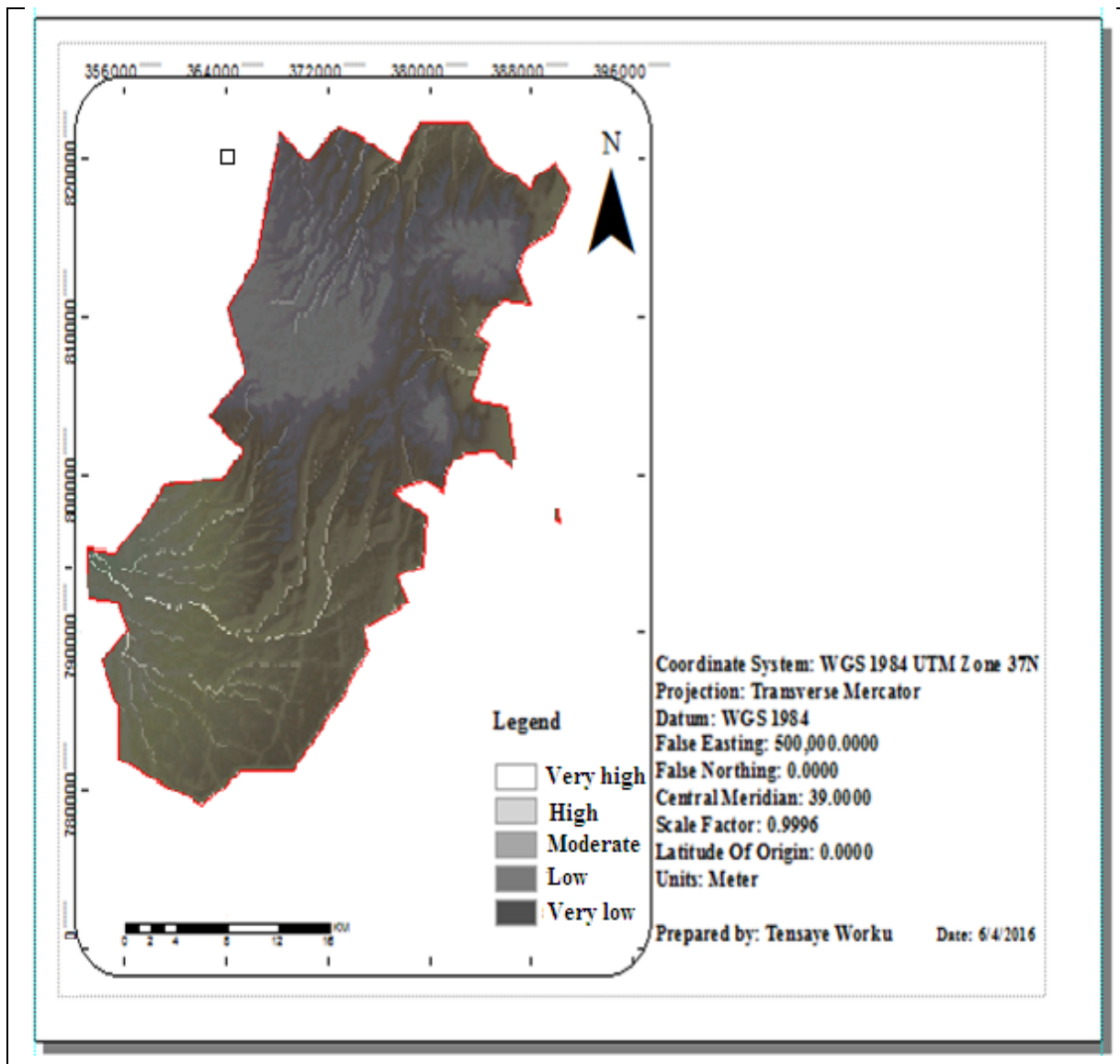


Figure 4.3: Reclassified proximity to stream based hazard map

Table 4.3 Distance to stream Rating, Area Coverage and Percentage

No	Rating	Stream distance range	Pixel count	Area in(m²)	Area in (km²)	Percent (%)
1	Very High	0-71.3	109424	98481600	98.5	19.50
2	High	71.4-285	182415	164173500	164.18	31.31
3	Moderate	286-724	136721	123048900	123.05	23.80
4	Low	724-1272	134297	120867300	120.87	23.42
5	Very Low	1273-2597	49	44100	0.44	1.9
	Total		562906			100

The reclassified map of distance to streams indicates that very high malaria risk covers 19.50%; high malaria risk covers 31.31%, moderate hazard covers 23.80%; low malaria risk covers 23.42%; very low malaria hazard incidence covers an area of 1.9%. This is based on flight range of mosquito. Since mosquito can fly 2 km from its origin, areas mapped as very high, high and low malaria risk located 0-0.071 km, 0.071-0.258km and 0.259-0.723km respectively which accounts 74.60%; and low and very low hazard located km 0.724-1.27km, and 1.28km-2.59km respectively accounts 25.40% of the study area.

Verdoschot(2013) reviewed article about anopheles mosquito flight distance and found average flight distance for *anopheles sp.* was around 2000m (2km). However the flight distance depends on the habitats of the species and some species have a stronger dispersal capacity than others.

4.3.4. Proximity to Dam

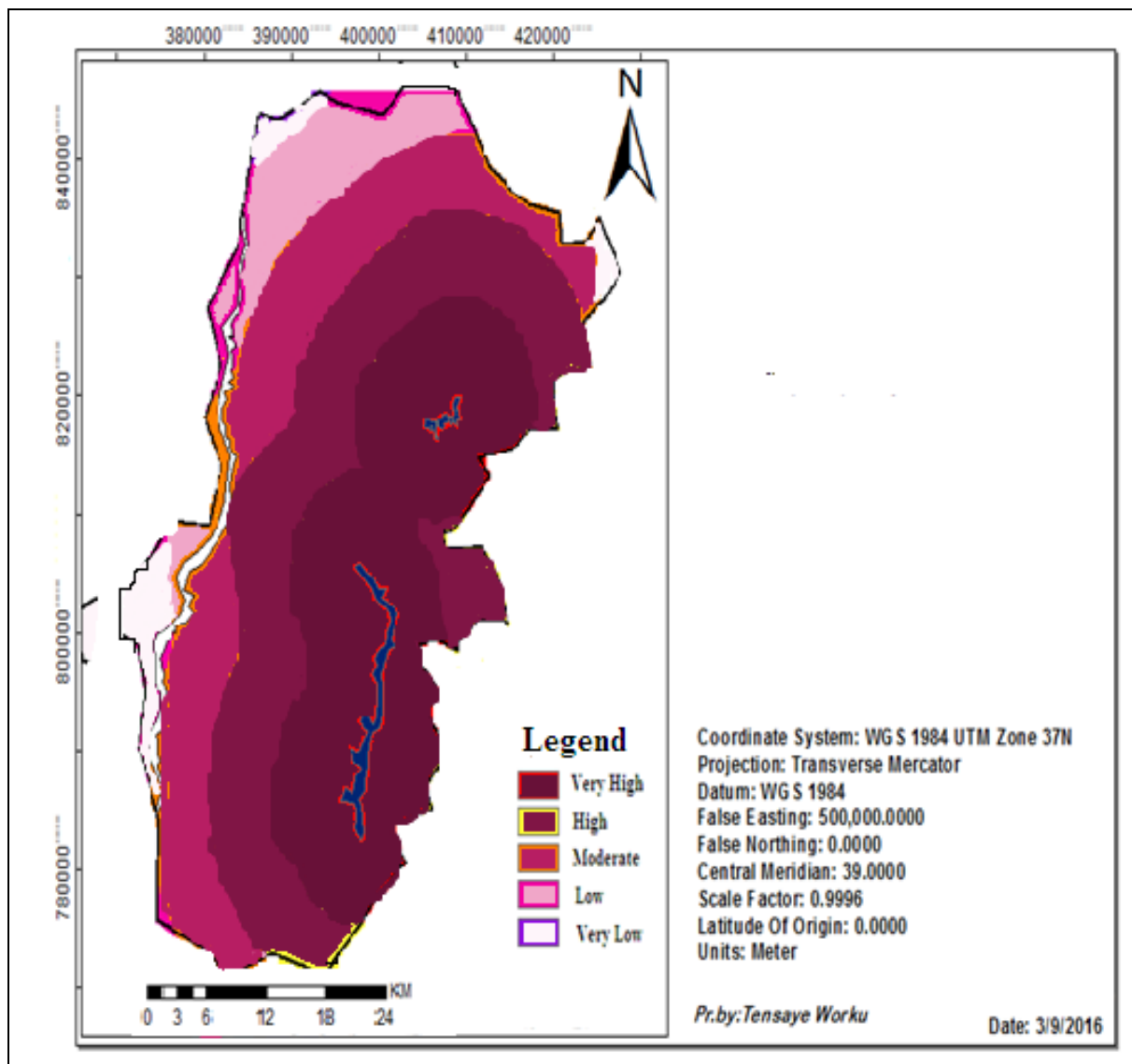


Figure 4.4: Reclassified proximity to irrigation dam based hazard map

Table 4. 4proximity to Dam Rating, Area Coverage and Percentage

No	Rating	Distance range Proximity dam	Pixel count	Area in m ²	Area in(km ²)	Percent (%)
1	VeryHigh	0-79.6	77983	70184700	70.18	14.42
2	High	79.7-1037.20	139833	125849700	125.85	24.39
3	Moderate	1037.21-1316.29	210200	189180000	189.18	35.73
4	Low	1316.30-1795.36	134137	120723300	120.07	23.47

5	Very Low	1795.37-2586.05	753	677700	0.67	1.97
	Total		562906			100

A figure 4.7 above shows that, based on the proximity to the irrigation/dam 14.42% has very high, 24.39% has high and 35.73% has moderate; 23.47%, has low; 1.9%, very low hazard risk of malaria incidence. Hence, 38.0% of the total area falls in high and very high malaria risks level, in view of the fact that mosquito can fly 2 km from its breeding site; people living closer to irrigation dam are considered under high malaria risk (hazard), and majority 62% of an area is within moderate, low, and very low malaria hazard prevalence.

Anopheles mosquito breeds in water and each species has its own breeding preferences. For example, some prefer shallow collections of fresh water, such as puddles and maize fields (Wielgosz 2012). Surface water provides the habitat for the juvenile stages (egg, larvae, pupae) of malaria vectors. Irrigated farming increases nutrients and temperature which are favourable for the mosquito breeding and larvae survival (Munga, 2006).

4.2.5. Proximity to Swamps

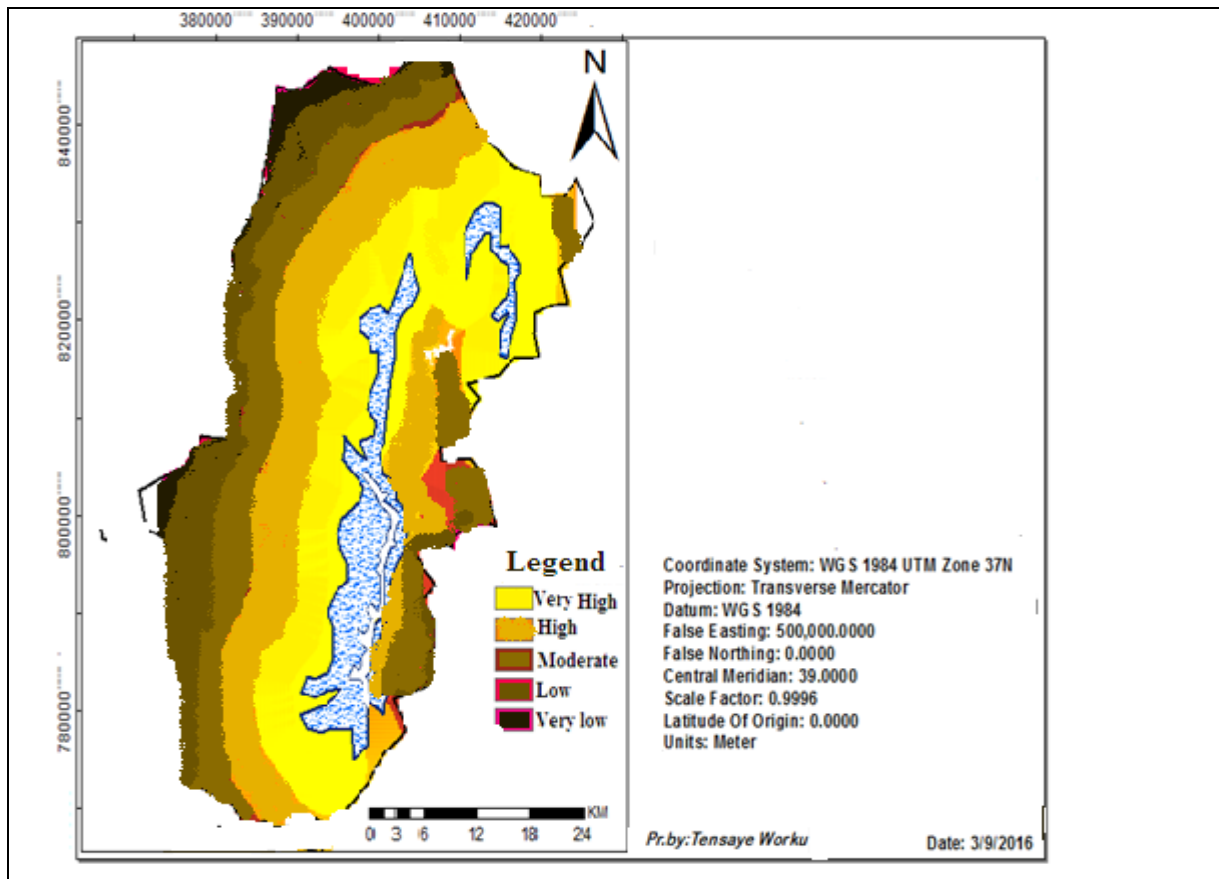


Figure 4.5: Reclassified proximity to swampy

Table 4.5 Distance to swampy Rating, Area Coverage and Percentage

No	Rating	swampy ranges	Pixel count	Area in m ²	Area in km ²	Percent (%)
1	Very High	0-53.7	121083	108974700	108.97	21.40
2	High	53.8-1007.7	173325	155992500	155.99	29.98
3	Moderate	1007.8-1613.4	130830	117747000	117.75	22.99

4	Low	1613.5-2150.8	938443	84458700	84.45	16.91
5	Very Low	2150.9-2688.4	43825	39442500	39.45	8.70
	Total		562906			100

Based on the reclassified proximity to swamps, the majority of study area is in very high risk of malaria that cover 21.40%; High malaria hazard cover and moderate risk level areas account for 29.98% and 22.99%, respectively, as well low and very low malaria hazardous areas accounts for 16.91% and 8.7%, respectively. Thus, the study area fell in 74.61%; high and very high malaria hazard and moderate malaria hazard. Since mosquito can fly 2 km from its origin and/or considered as malaria hot spot, areas mapped as very high, high and moderate malaria risk (hazard) located 0-0.53km, 0.53-1.007km and 1.008-1.61km respectively which accounts 74.5%; and low and very low hazard located 1.62km -2.15km, and 2.16 km-2.68 km respectively accounts about 25.6% of the study area.

4.2.6. Distance to breeding site factor

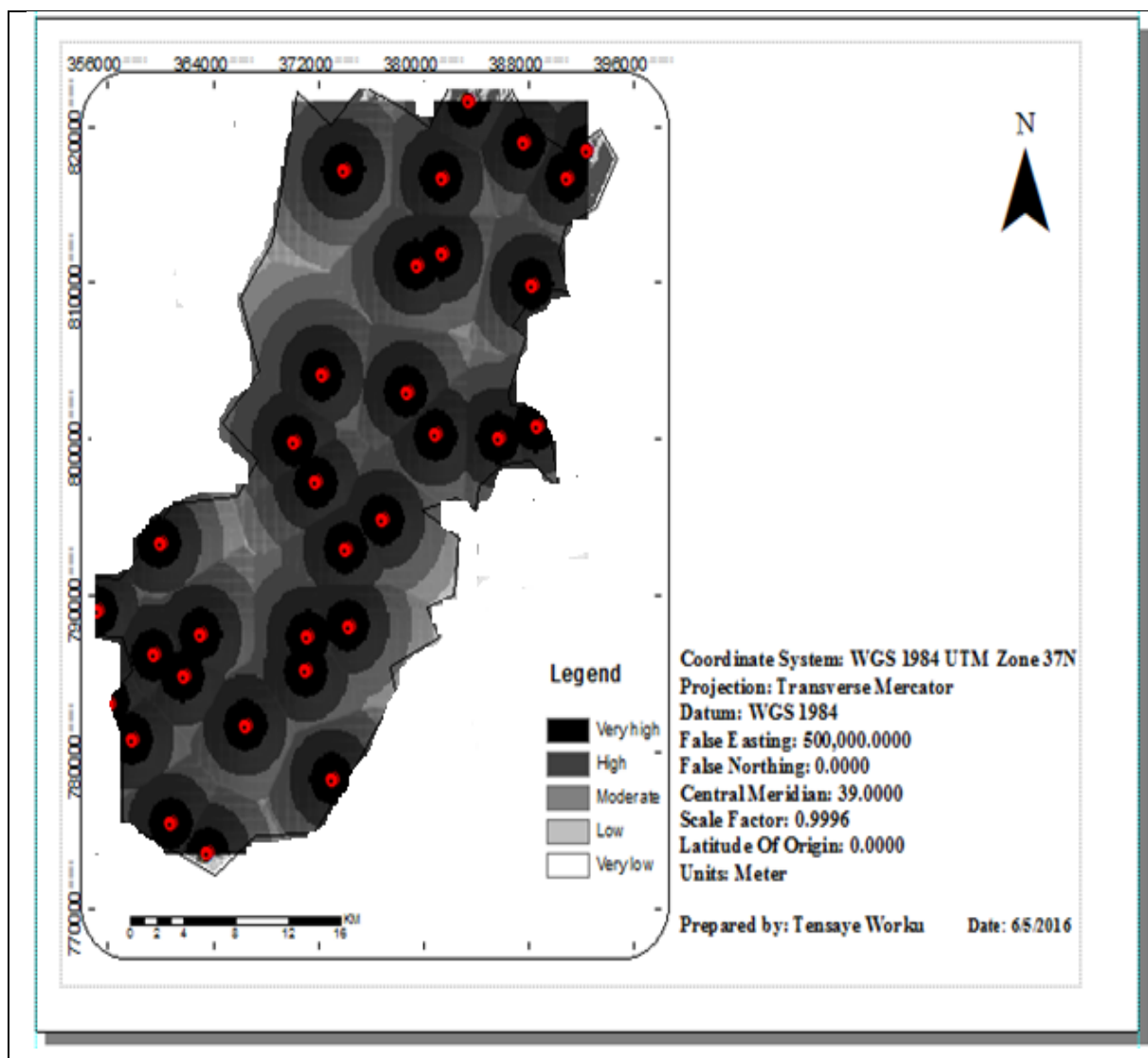


Figure 4.6: Reclassified proximity to breeding sites

Table 4.6 Distance to Breeding sites of malaria Rating, Area Coverage and Percentage

No	Rating	Breeding ranges	Pixel count	Area in m ²	Area in km ²	Percent (%)
1	Very High	0-1.4	57967	52170300	52.17	12.02
2	High	1.4000001-1.8	150094	135084600	135.08	25.47
3	Moderate	1.8000001-2.2	167953	151157700	151.16	28.08
4	Low	2.2000001-2.6	133431	120087900	120.09	23.04
5	Very Low	2.6000001-3	53461	48114900	48.15	11.36
	Total		562906			100

Based on the reclassified distance to breeding sites, the majority of study area is in high risk of malaria that cover **25.47%**; Very High malaria hazard cover **12.02%** malaria hazard level and moderate risk level areas account for and 28.08%), as well low and very low malaria hazardous areas accounts for 23.04% and 11.36%, respectively. Thus, the study area fell in 65.57%; high and very high malaria hazard and moderate malaria hazard and remaining 34.43% of the region fell under low and very low malaria hazard and/or risk. Since mosquito can fly 2 km from its breeding site, areas mapped as very high, high and low malaria risk located 0-1.4 km, 1.41-1.8km and 1.81-2.2km respectively which accounts 65.57%; and low and very low hazard located 2.2km -2.6km, and 2.61km-3km respectively accounts 34.43% of the study area.

People near breeding sites (less than the average mosquito flight distance) are assumed to be a high risk of malaria while those beyond the average anopheles mosquito flight distance are less likely to be attacked by malaria (Liu, 2011). During his study in Accra, Stoler (2009) found that malaria risk was higher within 2000m from the vector breeding sites. However, the dispersal capacity of the mosquito also depends on the atmospheric conditions especially wind direction and Land use (Verdonschot, 2013).

4.2.7 Soil type and malaria risk level

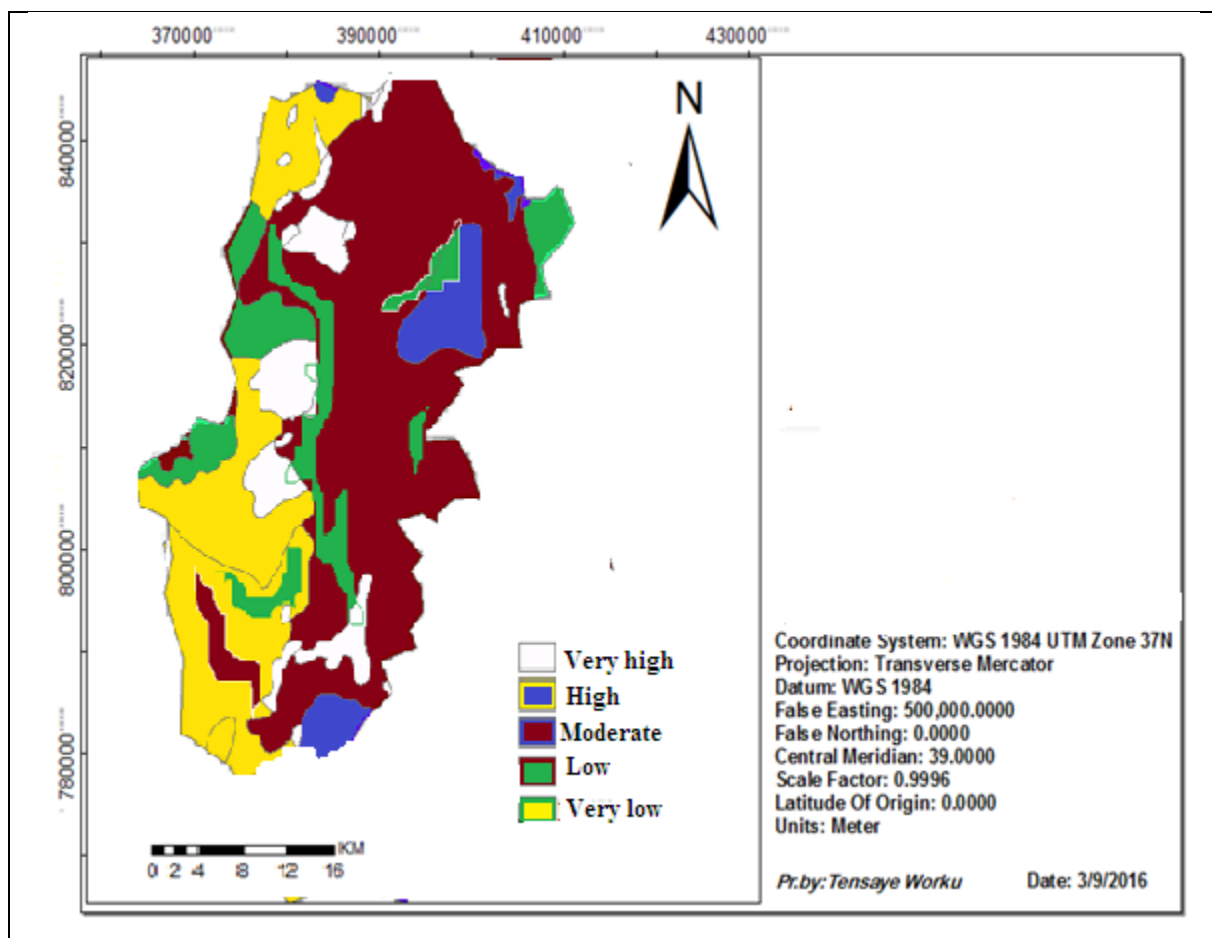


Figure 4.7: Reclassified soil hazard

Table 4.7 reclassified soil Rating, Area Coverage and Percentage

No	Rating	Soil type	Pixel count	Area in m ²	Area in km ²	Percent (%)
1	Very High	Vertisols	111020.1	99918090	99.91	20.06
2	High	Eutric and	151797.7	136617930	136.61	26.30
3	Moderate	Dystric Nitosols	161918.1	145726290	145.72	27.85
4	Low	Andosols	136738.5	123064650	123.07	24.00
5	Very Low	Acrisols	1431.3	1288170	12.90	1.7

	Total		562906			100
--	--------------	--	---------------	--	--	------------

The reclassified soil map shows that 20.06%, area mapped have very high; 26.30% high, 27.85% moderate and 24.00% areas have low, and 1.7% areas have very 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 level, cover 20.6%; Eutric and Dystric Nitosols, those have also high moisture storage capacity and reclassified as high malaria risk level, cover 26.30%; Andosols poorly drained soils and classified as moderate risk level cover 27.85%; Acrisols have good drainage leveled as low malaria risk level, covers 141.15km², and Leptosols, have very good drainage capacity cover leveled as very low malaria hazard, covers 1.7%.

4.2.8. Vulnerability Map

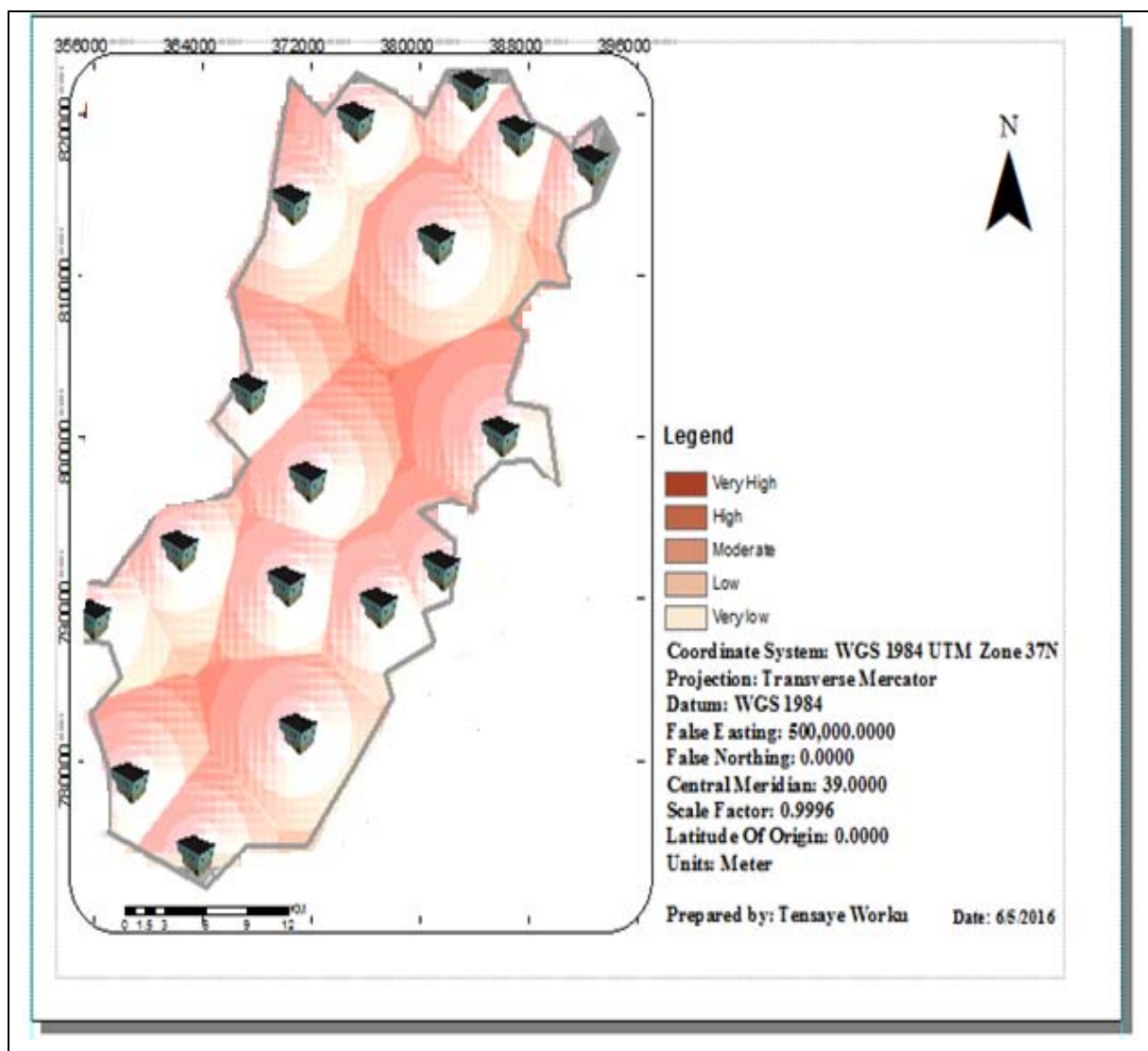


Figure 4.8: Reclassified vulnerability risk map

Table 4.8 Distance to vulnerability Rating, Area Coverage and Percentage

No	Rating	Vulnerability Ranges	Pixel count	Area in m ²	Area in km ²	Percent (%)
1	Very High	0.05-0.0702	145684.1	131130168.4	131.13	25.43
2	High	0.0702-0.099	153890.3	138501270	138.90	26.74
3	Moderate	0.099-0.1496	176250.2	158625180	158.62	30.30
4	Low	0.1496-0.2	86441.0	77796900	77.80	15.99
5	Very Low	0.2-0.35	640.4	576360	5.7	1.52
	Total		562906			100

Based on the reclassified malaria vulnerability map, 30.30% of study area is in moderately vulnerable for malaria; High malaria vulnerable area covers about 26.74% malaria hazard level and moderate vulnerability risk level areas account for and 30.30%, as well low and very low malaria vulnerable areas accounts for 23.04% and 1.52%, respectively. Thus, the study area fell in 42.73%; very high and high malaria vulnerability and moderate, low and very low malaria vulnerable area accounts for 55.27% of the region fell under low and very low malaria hazard and/or risk.

From this, it may be possible to say that more than half of the area is found close to the health centers. Hence, it is only 42.73% of the total area falls in high and very high malaria vulnerability.

4.2.9. Land use land cover

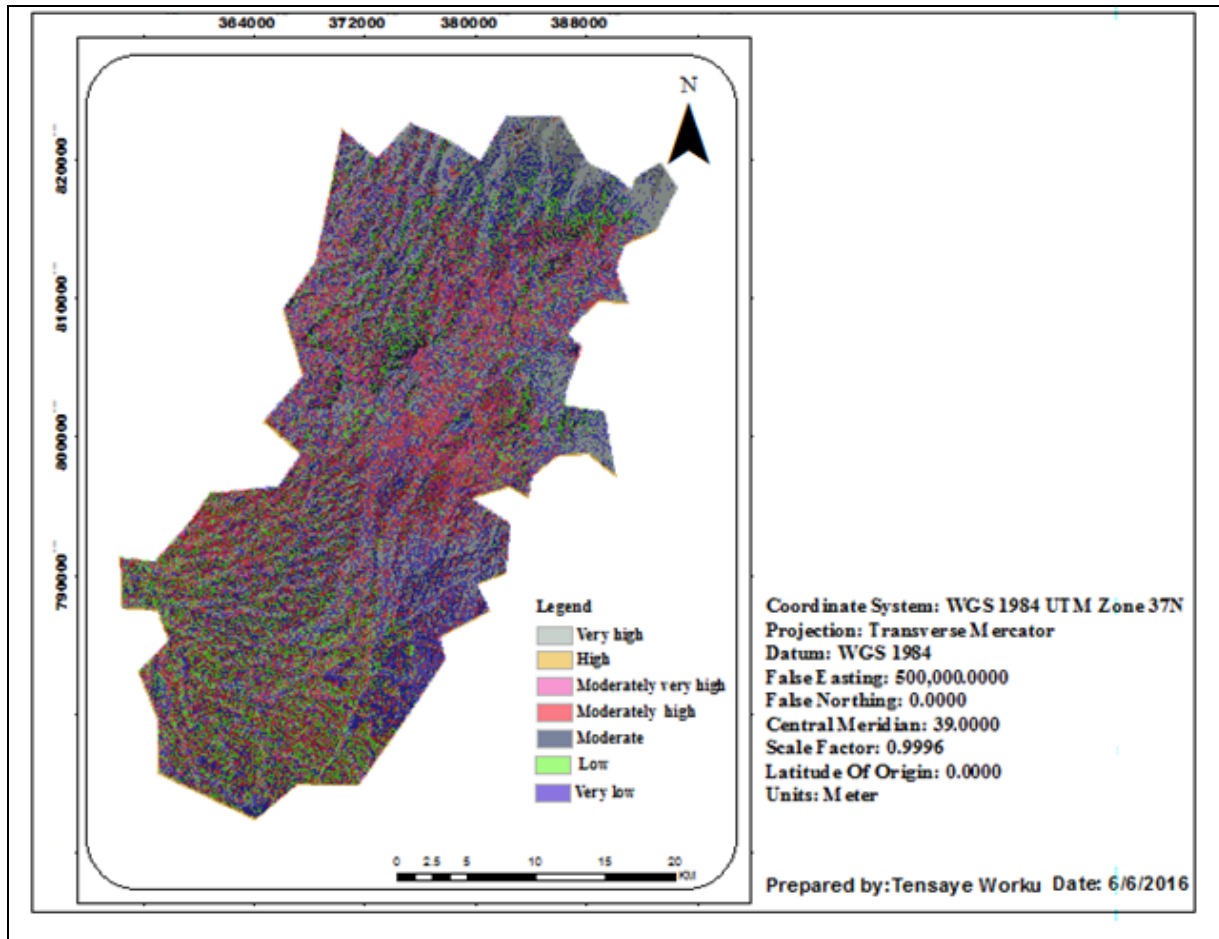


Figure 4.9: Reclassified LU/LC, element of risk

The study area was both urban and surrounding rural kebeles with buildings at the center mixed with crops.

Land use has a big influence on anopheles mosquito life cycle (Munga, 2006); The same author suggested that land use features increases anopheles larvae survival rate and shortens the pupation and due to their influence on the temperature, and water nutrient, irrigated farming has positive effect on the larval survivorship and on the adults breeding.

The identified potential anopheles breeding sites are relevant for malaria transmissions in the study area, which is rural Jensen, proved the association of settlement, irrigated farm lands, Range and bare land, forest and malaria and in rural areas of the western Kenya.

Yamemoto (2010) found the association between malaria and water bodies in semi-urban areas of Burkina Faso. The fact that the study area is characterized by rural and semi-urban places makes the relationship between malaria infection and Anopheles mosquito breeding sites. Thus, potential anopheles mosquito habitats in the study area are made of settlement, mixed land use, farm, range and bare lands, forest and water body. Anopheles mosquito depends on blood meal and accordingly, its habitat combines breeding and resting sites.

Table 4.9. Validation of the results from land use land cover as element of the risk

		Ground Truth Data							
L a n d C o v e r D a t a S e t	Class	Settlement	Farm land	Bush land	Shrub	Wet land	Forest	Water body	
	Settlement	33	0	2	0	1	0	1	37
	Farm land	1	18	0	1	2	0	0	21
	Bush land	0	0	24	0	1	0	0	25
	Shrub	0	2	1	17	0	1	0	21
	Wet land	6	2	0	1	25	0	0	34
	Forest	3	0	0	0	1	40	0	44
	Water body	0	0	2	0	1	0	15	18
		43	22	29	19	31	41	16	201

Table 4.10: Confusion matrix accuracy approach between ground truth data and land cover dataset.

	Commission	Omission	Producer's acc.	User's acc.
Settlement			11.74%	23.25%
Farm land			19.04%	18.18%
Bush land			4.00%	17.24%
Shrub			19.04%	10.52%
Wet land			26.47%	19.35%
Forest			9.09%	2.43%
Water body			16.66%	6.25%
			76.74%	89.18%
			81.81%	85.71%
			82.75%	96.00%
			89.47%	80.95%
			80.64%	73.52%
			97.56%	90.90%
			93.75%	83.33%

Overall Accuracy =81.9% Kappa coefficient= 83%

A measure for the overall classification accuracy can be derived from this table by counting how many pixels were classified the same in the satellite image and on the ground and dividing this by the total number of pixels:

$$\frac{33+18+24+17+25+40+15}{210} = (172/210)=81.9\%$$

201

The drawback of this measure is that it does not tell you anything about how well individual classes were classified.

The user and producer accuracy are two widely used measures of class accuracy. The producer's accuracy refers to the probability that a certain land-cover of an area on the ground is classified as such, while the user's accuracy refers to the probability that a pixel labeled as a certain land-cover class in the map is really this class. The user and producer accuracy for any given class typically are not the same.

Note that all these measures of accuracies are estimates for the true, unknown accuracies.

The probability that a classified pixel from the (LC) map accurately corresponds with the referenced data is determined by the user's accuracy (Jensen, 2005), while the Khat Coefficient (K) or Kappa statistic measures the difference between the true agreement of

classified map and chance agreement of random classifier compared to reference data (Lillesand et al., 2004).

It is stated that Kappa values of more than 0.80 indicate good classification performance. Kappa values between 0.40 and 0.80 indicate moderate classification performance and Kappa values of less than 0.40 indicate poor classification performance (Jensen, 2005, Lillesand et al., 2004)

$$k^{\wedge} = \frac{N \sum_{i=1}^K X_{ii} - \sum_{i=1}^K (X_{it} * X_{ti})}{N^2 - \sum_{i=1}^K (X_{it} * X_{ti})}$$

$$N^2 - \sum_{i=1}^K (X_{it} * X_{ti})$$

$$\sum_{i=1}^K X_{ii} = (33+18+24+17+25+40+15) = \underline{172}$$

$$\sum_{i=1}^K (X_{it} * X_{ti}) = (42 * 37) + (22 * 21) + (29 * 25) + (19 * 21) + (31 * 34) + (16 * 18)$$

$$= 1554+462+725+399+1054+1804+288$$

$$= \underline{6286}$$

$$k^{\wedge} = \frac{201 * 172 - 6286}{201^2 - 6286}$$

$$= \frac{34572 - 6286}{40401 - 6286}$$

$$\frac{28286}{34115}$$

$$= \underline{0.829} = \underline{(83\%)}$$

Based on above different scholarly and review judgment, this LULC element of the risk classification has proved high accuracy assessment has been applied for it is above 0.8 kappa value considered as high accuracy assessment.

The Kappa coefficient estimate the agreement between map and reality and it is ranging from 0 to 1, where 0 represents total disagreement and 1 total agreement (0.9074 for the current land cover mode l).

Table 4.11 LU/LC, Area Coverage and Percentage

No	Rating	Features type	Pixel count	Area in m²	Area in km²	Percent (%)
1	Very High	Water body and wet land	98695.3	88825770	88.82	17.69
2	High	Farm land	193149.9	173834910	173.83	33.53
3	Moderate	Bare land and shrub land	145382.5	130844250	130.84	27.56
4	Low	Settlement	121895.4	109706040	109.70	25.43
5	Very Low	Forest	3783.9	3408104.7	3.40	1.96
	Total		562906			100

Figure 4.17, reclassified land use land cover based malaria risk level. From the total area, 17.69% leveled as very high risk of malaria; 33.53% as high, 27.56% as moderate ;and 25.43% as low risk; and 1.96% leveled as very low malaria incidence as elements of the malaria risk and mosquito breeding. The area reclassified as very high, high and moderate malaria risk level covered by settlement, mixed land use, Farm land, range land and bare land, as well as low and very low malaria risk covered by forest and water body respectively.

4.3. Identified Areas of Malaria Hazard

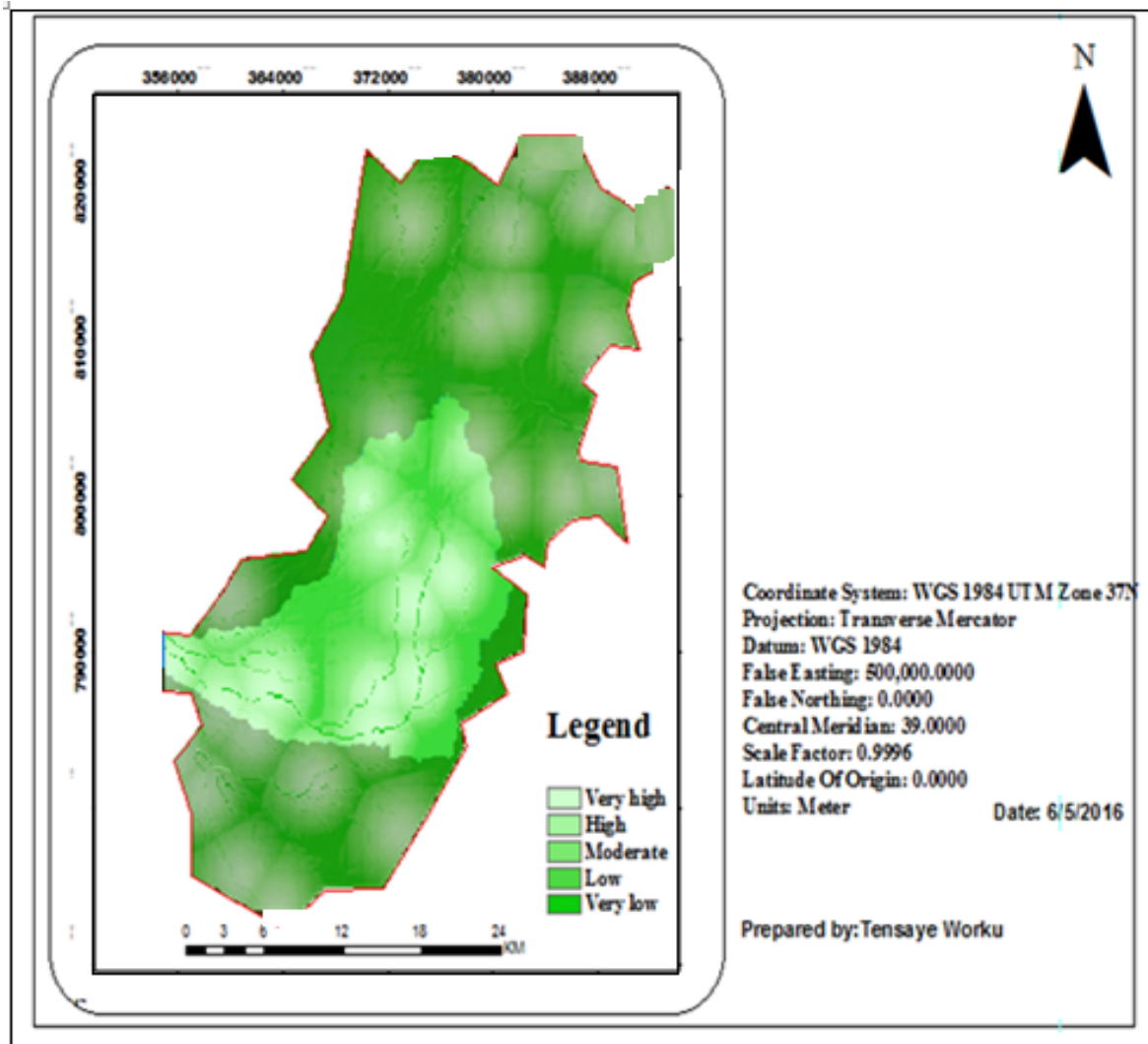


Figure 4.10: Reclassified malaria hazard

Table 4.12 Distance to hazard map, Area Coverage and Percent

No	Rating	pixel count	Area in m ²	Area in Km ²	Percent (%)
1	Very High	114891	103401900	103.40	20.33
2	High	165626.4	149063760	149.06	27.58
3	Moderate	128859.1	115973190	115.97	22.32
4	Low	90861.3	81775170	81.78	16.89
5	Very Low	62668.2	56401380	56.40	12.86
Total		562906			100

Hazard is the probability of occurrence of damaging natural phenomenon within specified period of time. As a hazard, malaria incidence is mapped by depending on some of the environmental factors which contribute for the survival of Anopheles mosquitoes. For the purpose of identifying areas of malaria hazard, this study focused on elevation, slope, distance to streams, distance to breeding site and wetness index as the factors of malaria incidence in the study area.

The malaria incidence and transmission requires the environment with lower elevation (higher temperature), abundance of wet lands, occurrence of gentle slopes, availability of still waters around rivers, and areas of lower drainage density (Negasi, 2008). It is by overlaying these factors that areas vulnerable to malaria were identified. The overlay analysis was done after each factor was given the appropriate weight according to the degree of importance that they have for the incidence of malaria in this research. Pair wise Comparison of the five parameters was carried out to develop the pair wise comparison matrix. After the overlay analysis of the five factors namely; elevation, slope, distance to streams, distance to breeding site and wetness index, the malaria hazard map in was produced.

According to the malaria hazard map it was estimated that 19.2%, 27.58%, 16.6%; 16.9% and 12.86% of the study area were subjected to very high, high, moderate, low and very low malaria hazard area respectively

According to stratton (2008), Malaria vulnerability is influenced by demographic characteristics, access to health facilities and socioeconomic condition. However, Malaria vulnerability can be reduced by the advancement of vector control mechanisms.

The people that live far from health care facilities were identified the most vulnerable to malaria in most sub_ Saharan African countries (Stratton, 2008)

4.3.1 Identified Areas of Malaria Risk

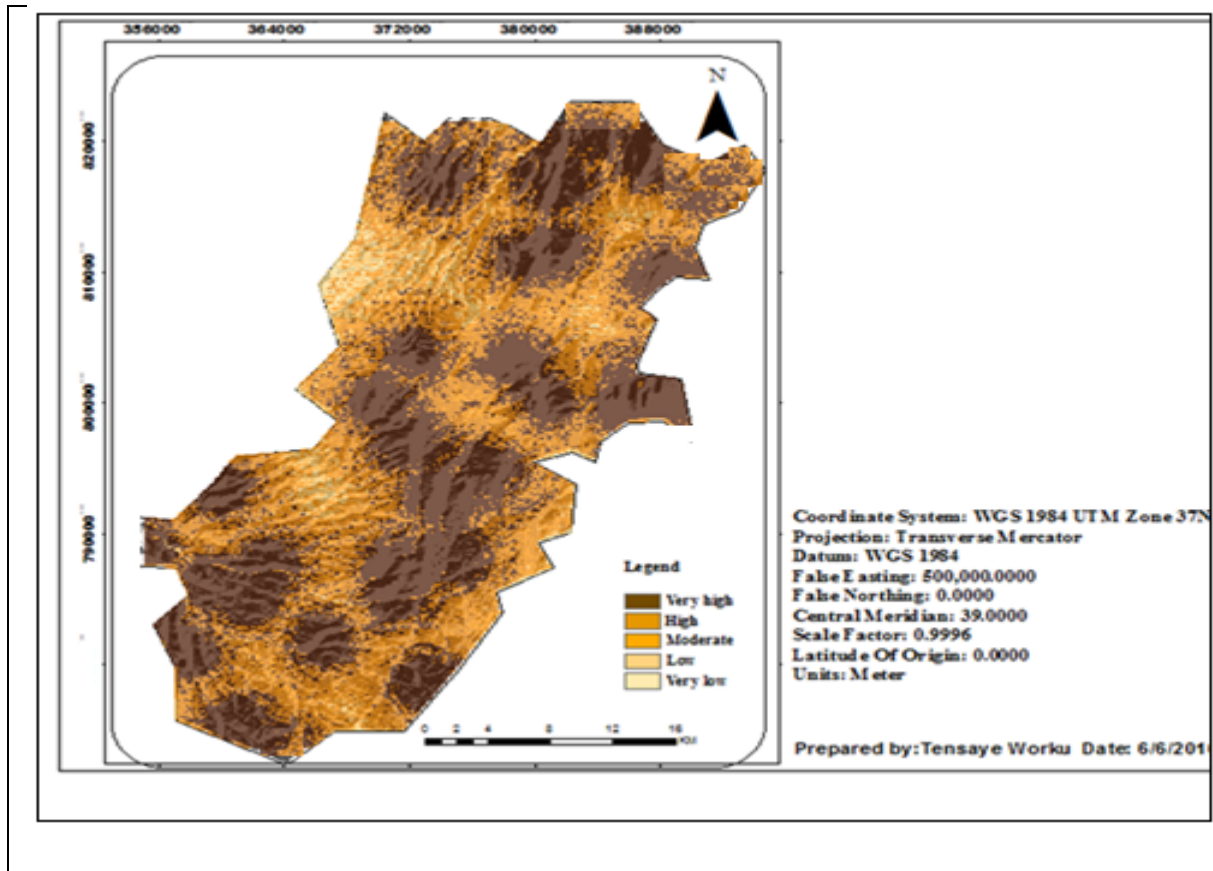


Figure 4.11: Reclassified malaria risk ma

Table 4.13 reclassified risk map, Area Coverage and Percentage

No	rank	pixel count	Area in m2	Area in Km2	Percentage (%)
1	Very High	123976	111578400	111.6	18.93
2	High	202835	182551500	182.6	35.52
3	Moderate	106417	95775300	95.8	21.95
4	Low	93016	83714400	83.70	16.63
5	Very Low	76662	68995800	68.99	13.82
Total		562906			100

The final reclassified malaria risk map produced by overlaying all environmental factors mentioned above displays that from the total area coverage of the study area 35.52% in high, 21.95% moderate risk zone; and 16.63% low level of malaria risk zone; 18.93%, very high risk zone; and 72.33km²(13.82%) very low malaria risk area coverage.

This shows that the majority of study area fell in high risk level (54.5 %) and followed by moderate risk level (21.95%). Low and very low malaria risk zone covers small area, which occupies only 30.4% of the total area (Table 4.13).

CHAPTER FIVE

Conclusion and Recommendation

5.1 Conclusion

The objective of this study was intended at producing malaria and risk map of Shone town administration that it can help to improve the management and control of malaria vector. This study has shown that GIS and remote sensing techniques were used malaria hazard and risk zone maps based on maps for environmental factors, reclassification, overlaying and identification of risk level. Remote sensing also took part in an important role by providing remotely sensed raster data (ecological information). Therefore, GIS and remote sensing technology is vital tool for health related sector and stake holders, which could facilitate vector born disease control and prevention program and assist the vector controlling organizations to identify hazard and risk areas for handling disease.

The hazard, malaria prevalence areas were mapped based on some of the environmental (topographic) factors which provide for the endurance of Anopheles mosquitoes such as:- elevation, slope, distance to streams, distance to breeding site, distance to swampy area and distance from irrigation / dam as the factors of malaria incidence in the study area.

Consequently, this research confirmed the method used was capable to integrate all the malaria hazard causative topographic factors and the components of malaria risk as well in a GIS environment. One of the Multi Criteria Evaluation technique which is known as

Weighted Overlay in GIS environment was used mapping malaria hazard and malaria risk zones.

Moreover, factor weight computation in AHP module, that is developed by providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated, has generated valuable information. This could be useful for disaster control in the future. Therefore, it has been shown that MCE GIS based model combination has potential to provide through lucid approach in making decisions.

The final malaria hazard map of the study area showed that of the total area, about 47% which is about half of the area was identified very high and high malaria hazard prevalence zone while the remaining half of an area was identified as moderate (22.32%) to low and very low hazard risk zone (29.7%).

Risk maps are essential for predicting the scale of the risk, and for this reason the resources needed to fight malaria. The study attempted to develop a risk map of malaria that would support malaria related decision making process in shone town administration.

Findings of the study showed that of the total area, about 54.4% which is about more than half of the area was identified very high and high malaria risk prevalence zone while the remaining 21.95% of an area was identified as moderate to low and very low hazard risk zone covers small areas (30.4%). In other words, according to the result of the findings large area of the town is located high and very high risk area for malaria.

In malaria endemic areas, partial immunity is developed over years of exposure, and even if it never provides complete protection, it reduces the risk that malaria infection will cause severe disease to adults

5.2 Recommendation

This study is small but vital contribution to the decision making and implimantation process of malaria prevention and control programm in Shone town administaration. It shows malaria is the result of many factors from environmental to human behaviour. The following recommendations are proposed by the researcher.

- ✚ The town administration Health officeas well any stakeholders based on the spatial distribution of anopheles mosquito habitats could do with to give more attention to high malaria risk and hazard zone)
- ✚ To implement to further the malaria control and elimination program shone town administration: focus on high-risk malaria zones.
- ✚ providing more GPS, GIS, and RS strategies to characterize spatial heterogeneity with malaria risk at a fine scale and identify high risk areas that have not been studied
- ✚ focusing on interventions to be targeted and timed according to risk profiles of endemic areas

References

Abdulkhakim A , (2013). GIS and Remote Sensing application towards risk map of malaria; the case study of Kersa District, Oromia Region, Ethiopia. *MSc Thesis, Teri University; New Delhi, India.*

Ahmad, R., Ali, W. N., Nor, Z. M., Ismail, Z., Hadi, A. A., Ibrahim, M. N., & Lim, L. H. (2011). Mapping of mosquito breeding sites in malaria endemic areas in Pos Lenjang Kuala Lipis, Pahang, Malaysia. *Malaria journal, 10*(1), 361.

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.*

Najera, J. A. (1989). Malaria and the work of WHO. *Bulletin of the World Health Organization, 67*(3), 229.

Bian, L. Mushinzimana, E., Munga, S., Minakawa, N., Li, L., Feng, C. C.,... & Githeko, A. K. (2006). Landscape determinants and remote sensing of anopheline mosquito larval habitats in the western Kenya highlands. *Malaria journal, 5*(1), 13.

Bogdan-Andrei Mihai University of Bucharest, Faculty of Geography, Nicolae Bălcescu Blvd., No. 1, Bucharest, 010041, Romania

Bruce-Chwatt, L. J. (1980). *Essential malariology*. William Heinemann Medical Books Ltd., London, 354 p.

Central Statistical Authority. The 2007 population and housing census results of Oromia, Ethiopia. Addis Ababa. Central Statistical Authority. Ethiopia Demographic and health survey 2005, Addis Ababa, September, 2006.

China.

- Clarke, S. E., Bøgh, C., Brown, R. C., Walraven, G. E., Thomas, C. J., & Lindsay, S. W. (2002). Risk of malaria attacks in Gambian children is greater away from malaria vector breeding sites. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 96(5), 499-506.
- Coetzee, C., & Nuttall, S. (1998). *Negotiating the past: The making of memory in South Africa*. Oxford University Press.
- Cox-Singh, J., Davis, T. M., Lee, K. S., Shamsul, S. S., Matusop, A., Ratnam, S., ... & Singh, B. (2008). Plasmodium knowlesi malaria in humans is widely distributed and potentially life threatening. *Clinical infectious diseases*, 46(2), 165-171.
- Craig, M. H., Snow, R. W., & Le Sueur, D. (1999). A climate-based distribution model of malaria transmission in sub-Saharan Africa. *Parasitology today*, 15(3), 105-111.
- CSA, (Central Statistics Authority), 1996, Statistical Abstract of Ethiopia; Statistical bulletin Vol. II, Central Statistics Authority; Addis Ababa, Ethiopia.
- Donnelly, M. J., McCall, P. J., Lengeler, C., Bates, I., D'Alessandro, U., Barnish, G. & Hastings, I. M. (2005). Malaria and urbanization in sub-Saharan Africa. *Malar J*, 4(1), 12.
- Drake J, Mooney H, Williason M(1989). The occurrence of invasive prosopis species in the north-western cape,south Africa.*South African J.of science*,7(5),pp.188
- EMA. (1980).1:50,000 scale topographic map of shone town area .Addis Ababa
- EOSAT 1994. EOSAT,s Statewide Purchase Plan Keeps South Carolina Residents in the know, in EOSAT Notes, Vol. 9, No 1, EOSAT Company Lanham, MD.
- ERDAS, Inc. 1992. ERDAS Production Services Map State for Georgia DNR in the Monitor, Vol. 4, No 1, ERDAS, Inc, Atlanta, GA.
- Eskinder Loha , Lindtjørn B, 2010. Model variations in predicting incidence of Plasmodium falciparum malaria using 1998–2007 morbidity and meteorological data from South Ethiopia. *Malaria J* 9:166.
- FAO-unesco.1999.*The FAO-unesco Soil Map of the world.revised legend.World soil resources report 60, Rome.*
- Fitzpatrick-Lins, K., Doughty, E. F., Shasby, M., Loveland, T. R., & Benjamin, S. (1987). Producing Alaska interim land cover maps from Landsat digital and ancillary data. In *Pecora XI Symposium* (pp. 339-348).
- FMoH (2009) National Strategic Plan for Malaria Prevention, Control and Elimination in Ethiopia 2010 – 2015. Federal Ministry of Health, Addis Ababa, Ethiopia

Foreman, W. T., Connor, B. F., & Maloney, T. J. (1999). *New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the US Geological Survey National Water Quality Laboratory* (p. 19). US Department of the Interior, US Geological Survey.

Gimmig, J. E., Kolczak, M. S., Hightower, A. W., Vulule, J. M., Schoute, E., Kamau, L., & Hawley, W. A. (2003). Effect of permethrin-treated bed nets on the spatial distribution of malaria vectors in western Kenya. *The American Journal of Tropical Medicine and Hygiene*, 68(4 suppl), 115-120.

Hadiya Zone Health Administration (HZHA), 2015, general fourth quarterly health (2015) report, Hadiya Zone, SNNPR, Ethiopia

Harbach, R. E. (2004). The classification of genus *Anopheles* (Diptera: Culicidae): a working hypothesis of phylogenetic relationships. *Bulletin of entomological research*, 94(06), 537-553.

Hay, S. I., Omumbo, J. A., Craig, M. H., & Snow, R. W. (2000). Earth observation, geographic information systems and *Plasmodium falciparum* malaria in sub-Saharan Africa. *Advances in Parasitology*, 47, 173-215.

Hightower, A. W., Ombok, M., Otieno, R., Odhiambo, R., Oloo, A. J., Lal, A. A., & Hawley, W. A. (1998). A geographic information system applied to a malaria field study in western Kenya. *The American journal of tropical medicine and hygiene*, 58(3), 266-272.

Hill, A. G., Vather, R., Sammour, T., Kahokehr, & A., Connolly, A. B. (2009). Lymph node evaluation and long-term survival in Stage II and Stage III colon cancer: a national study. *Annals of surgical oncology*, 16(3), 585-593.

Idrisi 32 guide to GIS and Image processing, volume 1, Release 2. Pp. 17

INSPIRE, T. (2013). INSPIRE data specification on buildings version 3, release candidate 3—draft technical guidelines, identifier D2. 8. III. 2_v3. 0rc3, INSPIRE thematic working group buildings.

Jensen, J. R. (1986). *Introductory digital image processing: a remote sensing perspective*. Univ. of South Carolina, Columbus.

Jima, D., Getachew, A., Bilak, H., Steketee, R. W., Emerson, P. M., Graves, P. M., ... & Hwang, J. (2010). Malaria indicator survey 2007, Ethiopia: coverage and use of major malaria prevention and control interventions. *Malar J*, 9(58), 10-1186.

Lillesand TM, Kiefer RW, Chipman JW, (2004): Remote Sensing and Image Interpretation (5th edn.), John Wiley and sons, Inc.: Hoboken, New Jersey.
Detection. http://www.isprs.org/proceedings/XXXVII/congress/7_pdf/10_ThS-18/22.pdf.

Lindsay, D. S. Dubey, J. P., & Speer, C. A. (1998). Isolation of a third species of *Sarcocystis* in immunodeficient mice fed feces from opossums (*Didelphis virginiana*) and its

differentiation from *Sarcocystis falcatula* and *Sarcocystis neuona*. *The Journal of parasitology*, 1158-1164.

Liu, X. B., Liu, Q. Y., Guo, Y. H., Jiang, J. Y., Ren, D. S., Zhou, G. C., ... & Chen, Y. (2011). The abundance and host-seeking behavior of culicine species (Diptera: Culicidae) and *Anopheles sinensis* in Yongcheng city, People's Republic of China. *Parasit Vectors*, 4, 221.

Magaylen W, (2006).Landscape determinants and remote sensing of mosquito larval habitats in the Low land of Ethiopia. *Malaria journal*.

Meyer, W. B. (1995). Past and Present Land Use and Land Cover in the U. S. A. *Consequences: The Nature and Implications of Environmental Change*, 1(1).

Ministry of Health of Federal Democratic Republic of Ethiopia,2004. Malaria Diagnosis and Treatment Guidelines for Health Workers in Ethiopia. Second edition. Addis Ababa: Ministry of Health.

Misrak Badewacho Woreda Agriculture and Development Office (MBWAO), (2014), Agro ecological Abstract of Misrak Badewacho Woreda, Hadiya Zone,SNNPR,Ethiopia.

MOH. National Strategic Plan for Malaria Prevention, Control and Elimination in Ethiopia, 2010-2015 Federal Ministry of Health of Ethiopia, Addis Ababa2009.

Moshen, A. (1999). Environmental Land Use Change Detection and Assessment Using with Multi-temporal Satellite Imagery. *Zanjan University*.

Mouchet J, Carneval P, Coosemans M, Fontenille D, Ravaonjanahary C (1993). Linking field-based ecological data with remotely sensed data using geographic information system in two malaria endemic urban areas of Kenya. *Malaria journal*.2(44):1-7

Mwanganga et.al ,(2013). The role of *Anopheles arabien* and *Anopheles coustani* in indoor and outdoor malaria transmission in tevate district, Kenya.*parasites and vector* 6,114.

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

Olorunfemi, J. F. (1983). Monitoring urban land use in developing countries—an aerial photographic approach. *Environment International*, 9(1), 27-32.

Rainer. S. Dong, H., Gbangou, A., De Allegri, M., & Pokhrel, S. (2008). The differences in characteristics between health-care users and non-users: implication for introducing community-based health insurance in Burkina Faso. *The European Journal of Health Economics*, 9(1), 41-50.

Regional Health Bureau, 2010. Medical Service Annual Report of 2009/10 Fiscal Year. Hawassa: Southern Nations and Nationalities Peoples' Regional Health Bureau, Ethiopia.

Regional Health Bureau, SNNP Region overview. 2013; Available at:http://www.snnprhb.gov.et/index.php?option=com_content&view=article&id=9&Itemid=39

Riebsame, W. E., Meyer, W. B., & Turner II, B. L. (1994). Modeling land use and cover as part of global environmental change. *Climatic change*, 28(1-2), 45-64.

Saxena, R., Nagpal, B. N., Srivastava, A., Gupta, S. K., & Dash, A. P. (2009). Application of spatial technology in malaria research & control: some new insights. *Indian Journal of Medical Research*, 130(2), 125.

Schellenberg JA, Saxena, R., Nagpal, B. N., Srivastava, A., Gupta, S. K., & Dash, A. P. (1998). Application of spatial technology in malaria research & control: some new insights. *Indian Journal of Medical Research*, 130(2), 125.

Shook, G. (1997). An assessment of disaster risk and its management in Thailand. *Disasters*, 21(1), 77-88.

Shoshany, M., Kutiel, P., Lavee, H., & Eichler, M. (1994). Remote sensing of vegetation cover along a climatological gradient. *ISPRS journal of photogrammetry and remote sensing*, 49(4), 2-10.

Sipe, N. G., & Dale, P. (2003). Challenges in using geographic information systems (GIS) to understand and control malaria in Indonesia. *Malaria journal*, 2(1), 36.

Smith, W. H. (1998) & Wessel, P.,. New, improved version of Generic Mapping Tools released. *Eos, Transactions American Geophysical Union*, 79(47), 579-579.

Southern Nation Nationalities People Regional State Water and Mining construction Service Beraue, (2014). Potable and ground water sample survey (2013/2014) report.SNNRS, Ethiopia.

Spuelman Jr, Zhou, G., Afrane, Y. A., Vardo-Zalik, A. M., Atieli, H., Zhong, D., Wamae, P., ... & Yan, G. (2011). Changing patterns of malaria epidemiology between 2002 and 2010 in Western Kenya: the fall and rise of malaria. *PloS one*, 6(5), e20318.

Stephenson, T., Li, Z., Olsen, B., & Mitlin, D. (2014). Lithium ion battery applications of molybdenum disulfide (MoS₂) nanocomposites. *Energy & Environmental Science*, 7(1), 209-231.

Stoler, J. M., Huntington, K. S., Peterson, C. M., Peterson, K. P., Daniel, P., Aboagye, K. K., & Holmes, L. B. (1998). The prenatal detection of significant alcohol exposure with maternal blood markers. *The Journal of pediatrics*, 133(3), 346-352.

Tomlinson R. F., & Harrington, J. L. (1996). *Field computation by moment methods*. Oxford University Press.

Trape, J. F., Lefebvre-Zante, E., Legros, F., Ndiaye, G., Bouganali, H., Druilhe, P., & Salem, G. (1992). Vector density gradients and the epidemiology of urban malaria in Dakar, Senegal. *American Journal of Tropical Medicine and Hygiene*, 47(2), 181-189.

U.S. Geological Survey, 1999. The Landsat Satellite System Link, USGS on the World Wide Web. URL: http://landsat7.usgs.gov/landsat_sat.html. 11/10/99.

Verdonschot, P. F. M., Spears, B. M., Feld, C. K., Brucet, S., Keizer-Vlek, H., Borja, A., ... & Johnson, R. K. (2013). A comparative review of recovery processes in rivers, lakes, estuarine and coastal waters. *Hydrobiologia*, 704(1), 453-474.

WHO. *World Malaria Report*. Geneva: WHO; 2012.

Wielgosz, B., Mangheni, M., Tsegai, D. W., & Ringler, C. (2012). Malaria and agriculture: A global review of the literature with a focus on the application of integrated pest and vector management in East Africa and Uganda.

World Health Organization, 2011. *World Malaria Report*. Geneva: World Health Organization.

World Health Organization, 2012. *WHO Recommended Insecticides for Indoor Residual Spraying against Malaria Vectors*. Geneva: World Health Organization.

Xiaomei, Y., & Ronqing, L. Q. Y. (1999). *Change Detection Based on Remote Sensing Information Model and its Application to Coastal Line of Yellow River Delta—Earth Observation Center, NASDA, China*.

Yamamoto, S., Louis, V. R., Sié, A., & Sauerborn, R. (2010). Household risk factors for clinical malaria in a semi-urban area of Burkina Faso: a case-control study. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 104(1), 61-65.

Yeates, M., & Garner, B. J. (1976). *The North American City*. HarperCollins Publishers, 88(4), 622-639.

Appendices

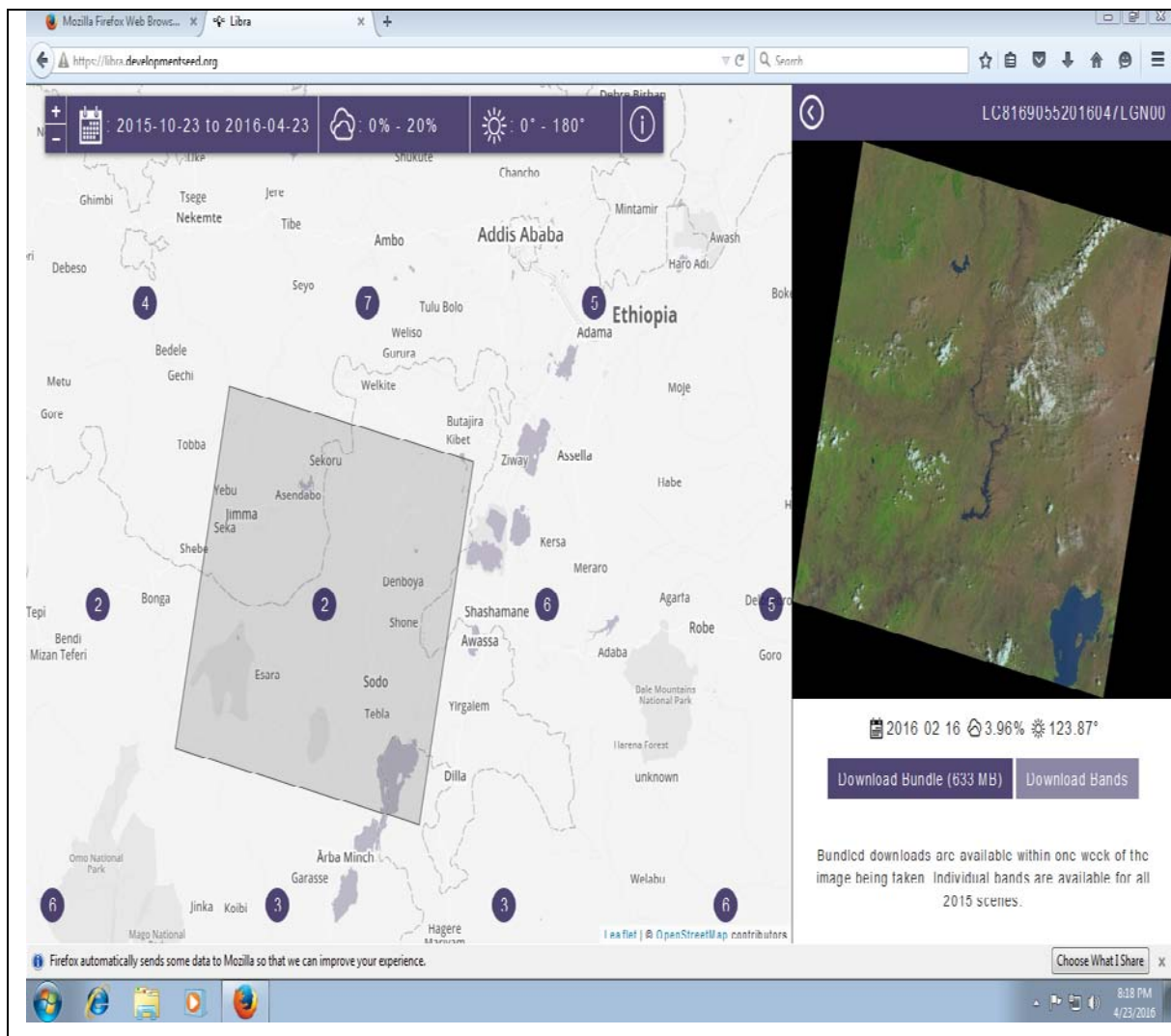
1. GPS Readings used for land use land cover map for accuracy assessment and validating results

No	Longitude	Latitude	Land use/land cover
1	384500	788400	Settlement
2	384945	788700	Settlement
3	3 84800	788630	Settlement
4	384089	788723	Settlement
5	384545	788644	Settlement
6	384023	788469	Settlement
7	384634	788539	Settlement
8	384781	788613	Settlement
9	384848	788596	Settlement
10	384916	788637	Settlement
11	384048	788682	Settlement
12	384027	788668	Settlement
13	384139	788593	Settlement
14	384178	788571	Water Body
15	384194	788891	Water Body
16	384242	789518	Water Body
17	384340	789536	Water Body
18	385396	789544	Water Body
19	385464	789570	Water Body
20	385524	789586	Water Body
21	385653	789557	Water Body
22	385704	789529	Water Body

23	384758	789417	Water Body
24	384752	789346	Water Body
25	384781	788276	Water Body
26	384790	788186	Water Body
27	384809	7890087	Shrub (Grass land)
28	386842	789021	Shrub (Grass land)
29	386836	789931	Shrub (Grass land)
30	384833	789881	Shrub (Grass land)
31	394818	789753	Shrub (Grass land)
32	394356	789551	Shrub (Grass land)
33	394399	7896545	Shrub (Grass land)
34	394459	788517	Shrub (Grass land)
35	394515	790442	Shrub (Grass land)
36	389567	790374	Shrub (Grass land)
37	390640	779276	Shrub (Grass land)
38	390745	778311	Shrub (Grass land)
39	388778	778662	Shrub (Grass land)
40	389797	789590	Forest (Dense veg ⁿ .)
41	389776	789465	Forest (Dense veg ⁿ .)
42	399991	789312	Forest (Dense veg ⁿ .)
43	399411	798300	Forest (Dense veg ⁿ .)
44	399540	799222	Forest (Dense veg ⁿ .)
45	399758	777140	Forest (Dense veg ⁿ .)
46	388944	777112	Forest (Dense veg ⁿ .)
47	399142	777038	Forest (Dense veg ⁿ .)
48	383002	777920	Forest (Dense veg ⁿ .)
49	399589	777505	Forest (Dense veg ⁿ .)
50	399268	777315	Forest (Dense veg ⁿ .)
51	383188	778233	Forest (Dense veg ⁿ .)
52	383401	778185	Forest (Dense veg ⁿ .)
53	399872	778917	Farm Land'
54	399264	778861	Farm Land
55	395444	778907	Farm Land
56	395433	779866	Farm Land
57	383348	799554	Farm Land
58	383397	799581	Farm Land
59	395356	778621	Farm Land
60	395326	778721	Farm Land
61	395290	779826	Farm Land
62	395265	779948	Farm Land
63	387320	778099	Farm Land
64	387156	778086	Farm Land
65	387961	777071	Farm Land
66	387816	777022	Wet Land
67	385549	777869	Wet Land
68	385615	777838	Wet Land
69	385519	779169	Wet Land
70	384491	779231	Wet Land
71	384483	779339	Wet Land
72	384474	779442	Wet Land
73	384462	787572	Wet Land
74	384097	787439	Wet Land

75	383395	787937	Wet Land
76	383378	787974	Wet Land
77	383274	787976	Wet Land
78	384805	787389	Bare Land
79	384003	787715	Bare Land
80	383057	787503	Bare Land
81	383127	789760	Bare Land
82	384831	787222	Bare Land
83	384004	787335	Bare Land
84	383872	786331	Bare Land
85	383974	786330	Bare Land
86	383064	786357	Bare Land
87	385235	786820	Bare Land
88	385310	786776	Bare Land
89	385349	789853	Bare Land
90	385122	788909	Bare Land
91	385548	788542	Bare Land

2. Satellite imagery downloading free web site for further malaria risk element map.



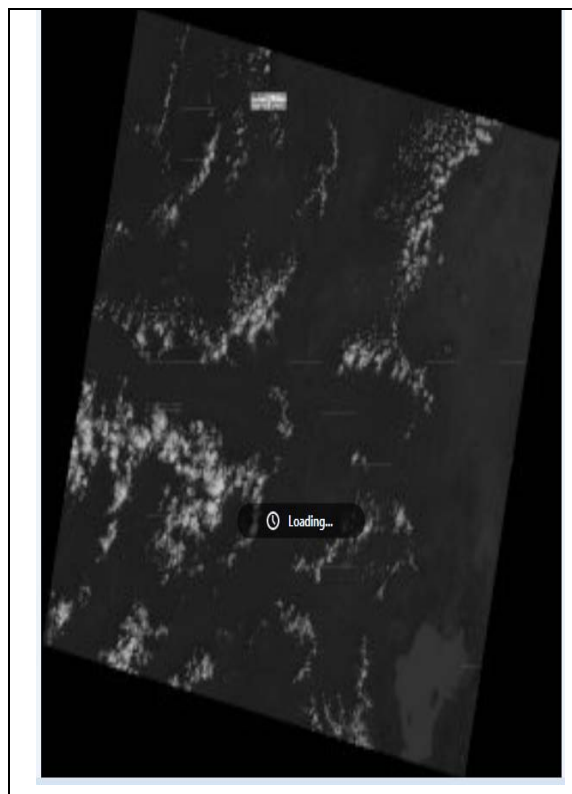


Figure 2: Image while seen at Band _4, with cloud cover needs correction (atmospheric)

Figure 1: shows time, cloud cover percentage and sun angle

1.2. Weights environmental factors for malaria hazard mapping

	soil	Stream distance	slope	Proximty to swamp	Breeding site	Elev ^a	Prox.Dam	Eigenvector	Weights
Soil	1	3	1/7	5	3	1/3	3	0.1301	
Stream distance		1	1/3	3	1/5	1/7	1/3	0.1040	
Slope			1	7	3	1/3	3	0.2300	
Proximty to swamp				1	5	1/7	1/3		
Breeding site					1	3	3	0.1201	
Elev ^a						1	5	0.1492	
Prox.Dam							1	0.1112	
Total								1	

Monthly Average Min.Temp.(°C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	12.7	13.6	15.1	14.8	15.1	14.7	14	14.6	13.9	12	10.5	10.2
2006	13	14	14.7	14.4	13.9	13.9	14.8	14.5	14	14	11.8	14.3
2007	14.3	14.8	12.9	13.6	14.4	14.6	14.1	14.5	14	11	11.5	10.9
2008	12.7	13.2	12.1	13.9	14.5	14	14.1	14.2	13.9	12.1	11.3	10.9
2009	12.2	13	13.9	14.3	13.8	13.8	14.3	14.3	14	12.6	11.2	15
2010	13.2	15.6	14.2	15.3	16.1	14.7	15	14.8	14.4	12.1	11.2	12.2
2011	12.9	13.4	14.9	14.7	15.2	14.9	14.3	14.6	14.3	12.3	13.4	11.3
2012	12.2	12.3	14	15.3	14.7	14.7	14.7	14.4	14.1	11.8	12	12.5
2013	13.2	13.8	15.5	15.1	14.6	15.4	16.6	17.6	17.4	16.7	16.3	14.6
2014	16.6	18.2	17.3	17	18.3	18	19.2	19.3	19.6	16.2	16.4	16.6
2015	17.9	18.3	18.3	18.1	19.5	20.1	20.2	20.9	21.1	20.4	19.8	20.6

Monthly Average Max.Temp.(°C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	29.6	32	30.3	29.5	26.4	25.9	24.3	25.3	25.9	28.6	29.2	29.7
2006	30.7	31.4	29.1	27.3	27.9	26.3	23.7	24.2	26.8	28.7	30	29.5
2007	30.3	29.9	31.5	29.2	28.6	24.7	24.9	24.8	26.3	28.4	30	29.9
2008	31.7	31.4	33.2	31.1	28.3	25.9	24.1	25.4	27.4	29.1	28.5	30.3
2009	30.6	31.7	33.4	30.5	30.4	29.2	25.7	26.7	28.9	29.1	31.1	29.3
2010	30	29.2	29.8	29.3	28	27.1	25.1	25.6	26.9	30.6	31.5	30.7
2011	31	31.9	31.4	32	28.4	26	25.6	25.5	27.3	30.3	29.6	29.7
2012	31.4	32.3	32.9	28.4	30.8	27.2	24.7	25.3	27.1	30.3	31.7	31
2013	31.6	33	31.7	29.9	28	26.1	24.6	24.9	28.2	29	30	30.3
2014	31.7	30.4	32.1	30.8	28.6	27.9	25.7	26.2	27.1	27.1	29.3	28.6
2015	31.5	33.7	34.1	33.4	30.3	28.1	28.2	28.7	29.6	32.6	31.8	31.1