JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

GIS-based Malaria Risk Assessment in Makuey *Woreda,* South Western Ethiopia

Bisirat Tesfay

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GIS-based Malaria Risk Assessment in Makuey *Woreda,* South Western Ethiopia

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I, the undersigned, declare that this thesis is my original work and has not been presented for any degree in any University before and that all sources of data and materials were used for this thesis have been accordingly acknowledged.

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Acronyms

AHP	Analytical Hierarchy Process
ARRA	Administration for Refugees and Returnee Affairs
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CSA	Central Statistical Agency
DDT	Dicholoro –Dephenyl -Trichloroethane
DEM	Digital Elevation Model
EMA	Ethiopian map Agency
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental System Research Institute
ETM^+	Enhanced Thematic Mapper
FAO	Food and Agricultural Organization
FMoH	Federal Ministry of Health
GDP	Gross Domestic Product
GIS	Geographic Information system
GPS	Global Positioning System
HEWs	Health Extension Workers
HH	House Holds
IDW	Inverse Distance Weight
IOM	International Organization of Migration
ITNs	Insecticide Treated Nets
JU	Jimma University
LLIsN	Long Lasting Insecticidal Nets
LULC	Land Use Land Cover
m.a.s.l	Mean above Sea Level
MCE	Multi Criteria Evaluation
MOA	Ministry of Agriculture
MOH	Ministry of Health
MSF	Medicine San Frontier for France
MWHB	Makuey Woreda health Buroue
NMA	National Meteorological Agency

P	Plasmodium
RCS	Red Cross Societies
RS	Remote Sensing
SNNPRS	Southern Nations, Nationalities and Peoples Regional State
SPSS	Statistical Package for Social Science
SRTM	Shuttle Radar Topography Mission
T°	Temperature
TM	Thematic Mapper
UNHCR	United Nation Higher Commissioner for Refugees
UNICEF	United Nations Children' Fund
USIAD	United tate. Agency for International Development
USGS	United State Geological Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WHO	World Health Organization

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Abstract

Malaria is still the famous virulence diseases to human beings especially in developing countries. The unremitting worldwide campaign to control malaria have been started predate decades and yearlong activities were done in diverse countries of the world. However, the unknown distribution of malaria parasite detection leads hindrance to malaria controlling strategies. As a result to minimize such challenges, GIS and Rs discipline with large data sets has good potential to analyze easily the environmental factors of malaria. The purpose of this study was the new GIS-approach that better visualizes malaria risks in Makuey Woreda, South Western Ethiopia. Malaria risk map was generated from three main factors namely hazard map, risk at element and vulnerability group. Hazard map was created based on five environmental factors namely temperature, rainfall, distance to water body, elevation and soil were computed using Multi Criteria Evaluation technique. Hazard map was produced by overlay weight analysis processed in ArcGIS 10.4.1 desktop. The product of hazard, vulnerability and element at risk were said to be final malaria risk map of the study area. Socio-economic factors was analyzed a data collected from households through questionnaires surveying. The sever malaria risk area were visualized so, majority of the study area fell at very high risk level 61% and followed 31% of the area subjected to high risk level, and 7.5% low malaria risk level. Large household size and ineffective using ITN was more associated with the prevalence of malaria. Generally if all the study area could be supported by the output of malaria risk map, the result of prevention and control over malaria would be better than today's situation.

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

CHAPTER ONE

Introduction

1.1 Background

The sever diseases for human health is caused by vector borne diseases, like mosquito born is dengue, elephantiasis, malaria, etc. The protozoan parasites are called plasmodium and the type of plasmodium species are Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale and Plasmodium malaria. Still carry on to be a global problem (Agarwal et al., 2012). Globally malaria affects about 3.5 to 5.0 billion people and overwhelming its effects on health and development of human beings besides about one million deaths reported every year (Saxena et al., 2009).

Sub-Saharan Africa is the leading zone in malaria transmission in the world approximately it accounts 90% of the total population (Kitaw Y., 1998). There are about 1-2 million pediatric malaria deaths in Africa per annum (Waller et al., 1995). Where the transmission rates utmost and where it is considered to be a major obstacle to economic development (Robert et al., 2003).

Malaria is one of the main health problems in Ethiopia in which its cases are one of the highest and it is increasing at alarming rate. Malaria incidence in Ethiopia is different apparently by topographic structure and season throughout the year. Altitude of Ethiopia extends rang from; -100 m.a.s.l to 4420 m.a.s.l. and geographically areas are considered suitable for mosquito reproduction life cycle. Thus below 2000 m above sea level about 50 million (68%) population are existed assumed to be at risk of malaria with a variation of temperature annually. In general, the main reasons given for the increment are environmental and climatic changes. The rainfall season during July August, September, October and November, it is the peak point of malaria occurrence each year (Negassi, 2008).

Gambella is one of the areas of Ethiopia with high malarial endemics. Hospital records indicate that in 2014/15 year about 36% of deaths in this region were due to malaria. Most of malarial morbidity and mortality occur in children and pregnant women. Children, particularly under-fives, are at risk of developing severe malaria due to their relatively less developed immunity to malaria and the decline of passively acquired immunity (Alamerew, 1998).

In Makuey *Woreda*, malaria transmission varies over season implies it increases from May to July at highest rate. It depends up on environmental and socio-economic factors throughout the year. Since 97% of the population live in rural areas the accessibility of health service were very low. Societies live in villages which produce little immunity in the community; hence malaria epidemics are common and lead to high mortality and morbidity (MoH, 1999). Most of the communities are lacks the health service to prevent malaria at *Woreda* level.

Therefore combination of environmental variables and socio-economic characteristics producing of hot spot malaria risk map through GIS based can investigate the major causes of problem that occurs spatially and temporally also might help in the action of health services easier to access along the host community.

1.2 Statement of the problem

Malaria epidemic had a remarkable impact on the economic and social aspects of the communities. 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 so the cost incurring on preventing malaria and medical treatment become burden on national GDP as well as in individual economic productivity begins to decline due to the malaria infection of human capital (Ashenafi, 2003).

The local and regional government has taking different intervention strategies. Such as Insecticide Treated Net (ITNs) provisions, free anti-malarial drugs, free indoor residual spraying of houses, community health education. Even though, the above-mentioned intervention strategies were implementing, malaria is still the major health problem of the study area, affecting adults, especially children and pregnant women and the society as a whole (MoH, 1999). Makuey *Woreda* hospital records about 36% peoples died by malaria in 2014/15 due to the high mobility of illegal migrants from south Sudan.

Most of malarial morbidity and mortality occur among children and pregnant women. Children, particularly under-fives are at risk of developing severe malaria due to their relatively less developed immunity to malaria and the decline of passively acquired immunity (Alamerew, 1998). Seasonal rainfall, presence of pastures and water loading along the flat areas land feature create conducive environment for emergence of mosquito breeding sites. Severity of malaria increases at the rainy seasons putting challenging on the activity of the local people whose livelihood is dependent on crop farming. It reduces labor, time for farm follow up, and children's' school attendance that in turn result in the decline of agricultural production, economic dependency of vulnerable individuals on others, high school dropouts and social crisis (Tensaye, 2016).

Makuey *Woreda* boarders lie with South Sudan along in western direction (Abraham, 2002). The gap of this study found, Nongovernmental organization has been trying to control malaria prevention in this study area. But those organizations like UNHCR, ARRA and MSF their prioritization giving for refugees which migrate from south Sudan. The intervention on host community is very low; by observing this problem all communities should acquire the malaria prevention system either from government or nongovernmental organization. .

The difficulty is gets more due to weak road network, unavailable transportation system consequently time consuming malaria control and prevention system. Currently malaria prevention and control system in the study area based on larvae assessment and number of malaria cases report from different *Kebels* within the study area. So it interrupted to the quickly response of malaria prevention.

In the study area different researches were conducted in relation to malaria. However, they didn't consider the importance and application of GIS and remote sensing technology in malaria risk mapping and risk level identification. For instance a research conducted by UNICEF (2012), was on par check test versus microscopy in the diagnosis of *falciparum* malaria. It was focused on diagnostic tests in detecting *falciparum malaria.*

Accordingly, 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, this methodology can help malaria control and prevention system which can alleviate this problem.

1.3 Objective

1.3.1 General objective

The main aim of this study was the new GIS-approach that better visualizes malaria risks in Makuey *Woreda,* South Western Ethiopia.

1.3.2 Specific Objectives

In line with the general objective, the specific objectives of this study include the following:

- To identify the spatial distribution and severity of malaria in Makuey *Woreda*
- To assess the relationship between environmental and socio-economic factors on the one hand and spatial distribution in malaria risk on the other hand.
- To model and map malaria risk hotspot areas for better surveillance and decision-making efforts in the fight against the disease;

1.4 Research questions

Basic questions answered by this project work are:

- ➢ What are the major environmental and socio-economic factors facilitating mosquito breeding conditions?
- ➢ Which parts of the study area have very high, high, and low malaria risk levels?

1.5 Significance of the study

This study is significant in identifying malaria risk level of the study area by producing the risk map. This will enable the *Woreda* health office to prioritize malaria prevention and controlling actions based on the risk level such as insecticide house spraying, anti-malaria drugs distribution, and bed net distribution. In other words, the findings from this study will make malaria prevention and controlling program time and cost efficient. The campaign program to control malaria made by Regional and Federal government makes time and cost efficient. Besides, it will help NGOs that works in emergency response in this area as a guide line and an input to other researchers who study a risk assessment with related objectives.

1.6 Scope of the study

Spatially this study is enclosed both in geographical area and issue of concern. Geographically, it is delimited to Makuey *Woreda*, in Gambella Region. Regarding the area of concern, the main focus of the study were develop malaria risk map at *Woreda* level. Moreover it is limited to GIS-based malaria risk map integrating both environmental and socio economic factors.

1.7 Limitation of the study

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

1.8 Organization of the study

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

1.9. Definition of terms

Potential Risk: vulnerability is defined as the possibility of being exposed to illness, harm either physically or emotionally (oxford dictionary, 2015). Includes risk, illness, uncommon situations happened than before and cannot be fully verified at present so further investigation is required to determined whether risk is present or not.

Risk Map: the outcome model of potential disease risk level; based on spatial environment and socio-economic data of the malaria infection in a specified tertiary area.

High malaria areas: May describe areas for full year (endemic) or seasons (rainy seasons) classifying all children with fever as "malaria" is considered an acceptable.

High risk areas: all children with febrile diseases assumed to have malaria

Low malaria areas: No simple method for detecting malaria in low-risk area

Low risk areas: only children with no other diagnoses should be considered to have malaria

No risk areas: anti-malarias' should not be used (WHO, 2014)

Risk: the Consequence of a specified hazardous event.

Hazard: a situation with a potential for harm.

Elements at Risk: Human population living in geographical area where locally acquired malaria cases occur.

Vulnerability: is the exposure of a given element.

Malarias: the area affected by malaria

Risk assessment: Over all process of risk analysis in a given area

GIS: a set of tools for collecting, storing, retrieving, transforming, and displaying spatial data from the real world for a particular set of purposes.

CHAPTER TWO

Literature review

2.1 Malaria parasite

Vectors are living organisms that can transmit infectious diseases between humans or from animals to humans. Many of these vectors are bloodsucking insects that ingest disease-producing micro-organisms during a blood meal from an infected host (human or animal) and later inject them into a new host during their next blood meal. Mosquitoes are the best known disease vector (Kimbi H. et al., 2013).

Malaria is distributed in every tropical and subtropical landscape across the globe, sometimes making seasonal digressions into temperate areas as well. The protozoan parasites that cause it have more complex genomes, metabolisms and life cycles than almost any other vector-borne threat. This complexity makes them a difficult target for interventions such as drugs and vaccines because the parasite's shape-shifting ways allow it to evade chemical and immunological defenses. They front a moving target as well, intentionally changing their outer coating during each phase of their life cycle, and creating a diverse antigenic and metabolic wardrobe through sexual recombination, an engine of diversity creation unavailable to simpler microbes such as viruses and bacteria (WHO, 2014).

Four species of parasites affect humans, but two of them, Plasmodium falciparum and P. vivax account for more than 95% of cases. P. falciparum, the most dangerous of the pair, ranges throughout the deep tropics from Africa to Asia and South America. P. vivax, which can develop in mosquitoes at cooler temperatures, has a wider range, extending beyond the fringes of P. falciparum distribution and often coexisting with P. falciparum in many areas (Mestewat, 2014).

P. falciparum malaria poses the greatest danger to industry of any vector-borne disease, as it can kill a defenseless individual very quickly and repeatedly hinder even those who develop semi-protective immunity. In local populations most deaths occur in children between 6 months and 2 years old. Their vulnerability derives from a lack of immunological protection. The immune evasiveness of malaria parasites prevents complete immunity from developing, but older children and adults, who have experienced multiple infections, enjoy some level of protection from the most severe manifestations of the illness (Paul et al, 2003).

2.2 Global distribution of malaria

Over two hundred million cases of malaria occur every year. According to WMR (2009), the global numbers of malaria cases in 2008 were an estimated 243 million. The vast majority of cases 85% were in the African Region followed by the South-East Asia 10% and Eastern Mediterranean Regions 4%. And it accounted for an estimated 863,000 deaths, of which 85% were in the African Region, followed by the Eastern Mediterranean 6% and the South-East Asia Regions 5%. At global level malaria has been recorded from 64º North latitude to 32º South latitude and in altitude ranges of 400m below sea level up to 2,800m.a.s.l. But within these limits of altitude and latitude, there are large areas free of malaria. There for the malaria transmission depends by local environmental aspects (Gilles and Warrell, 1993).

2.3 Malaria disease burden in Ethiopia

High malaria transmit season begins from September to December and April to May coinciding with major harvesting season is with serious consequences for the subsistence; Economy of Ethiopia's countryside, and for the nation in general. In addition, major epidemics occur every five to eight years with focal epidemics as the commonest form. The yearly report shows just surrogates for overall infection levels estimated at about 5 million a year and show that the incidence of malaria in Ethiopia is not only high but rising. The overall trend is one of a gradual progression from around four-fifths of a million confirmed cases a year in 1990 to almost a million and a half in the year 2005-06 reporting period (UNICEF, 2012).

Ethiopia has experienced overwhelming effects of malaria epidemics. The most notable epidemic of malaria occurred in 1958. That was a devastating epidemic as there were an estimated three million cases out of which 150,000 people died. The epidemic covered about 100,000 square miles of highland areas between June and December 1958. Since 1958, major epidemics of malaria occurred at intervals of approximately 5-8 years, but recently there is a trend of more frequent small- or large-scale epidemics occurring in the same or different parts of the country (FMoH, 2009).

Based on this altitudinal variation and coupled climatic characteristics, areas of the country are categorized into climatic zones, locally named as, “Dega” represent the cold zone; “Kolla” the hot zone; and “Weyna Dega” areas of average climatic conditions. The cold zone, which covers areas more than 2,500 m.a.s.l has a mean annual temperature of 10–15°C. This highlands area is considered free of local malaria transmission. The midland area, ranging in altitude from 1,500–2,500m with a mean annual temperature between 15–20°C, has different malaria transmission patterns. In the hot lowland zone, located in areas below 1,500m.a.s.l, where the mean annual temperature varies from 20–25°C, malaria transmission is endemic, and its intensity and duration are mainly dictated by the amount and duration of rainfall. In the midland zone, where temperature is a determining factor, malaria transmission often occurs in areas below 2,000m, while areas between 2,000 and 2,500m may become affected during epidemics (FMoH, 2009).

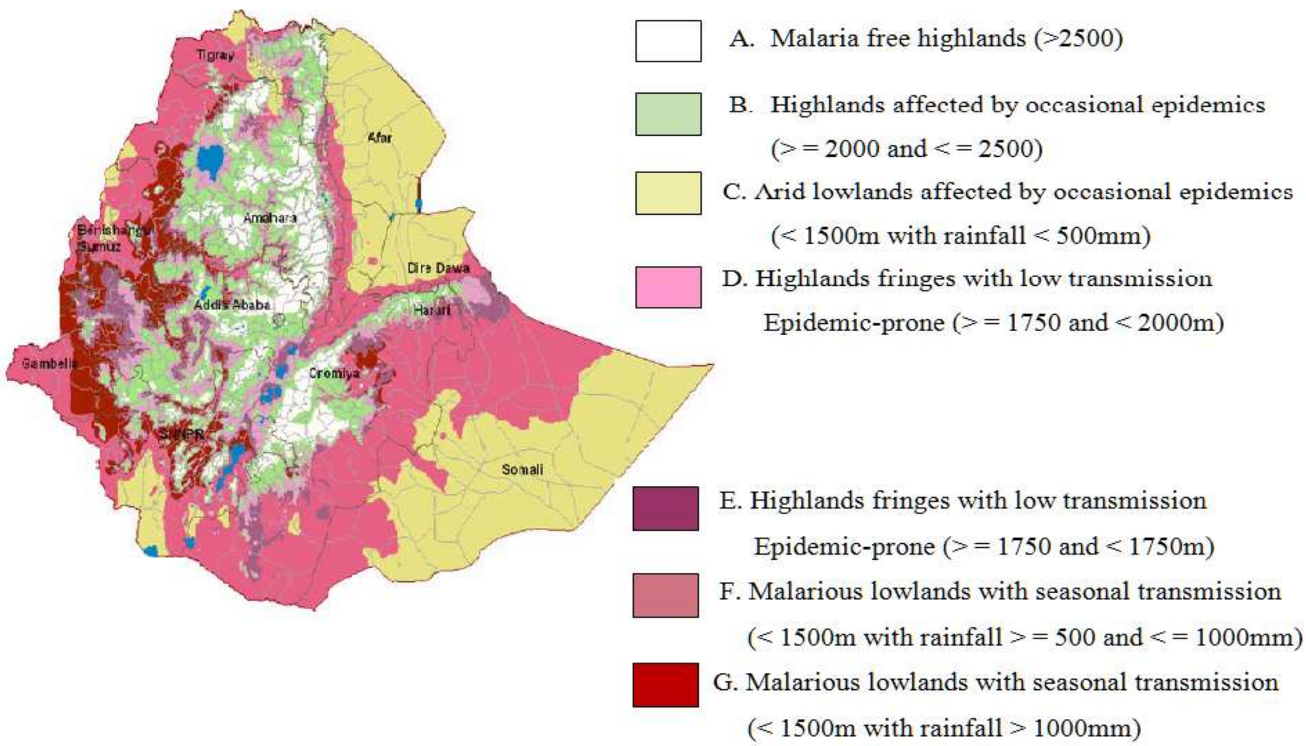

Figure 1. The malaria epidemiological strata in Ethiopia

Source: WHO country office for Ethiopia (2005)

2.4 Application of Geographic Information System and Remote Sensing in malaria risk mapping

In modern times there has been devoted interest in mapping malaria distribution and risk. Such maps would make it likely to target control actions at high-risk areas and greatly increase the cost effectiveness of malaria control programs. Most risk maps that have been developed so far have used as key inputs climatic models and information on weather data such as rainfall, temperature, and relative humidity, which are too a large extent determine the survival and reproduction of the mosquito and the development of the parasite in the vector. Other studies have used different indicators of vector presence, reproduction, and survival, such as vegetation patterns, land use, and soil moisture. The environmental variables are then linked with entomological and epidemiological information to identify geographical areas at high risk for malaria. These have covered either vast areas, such as the efforts to map the malaria risk in Africa or a relatively limited number of villages (Wim et al., 2003).

During the last decade, few researches have been made in a relation to malaria to map malaria risk area using different technique. For instance Biruk (2010) was on Space-time clustering of childhood malaria at the household level, and Tefera, (2010) was on malaria risk which is a thesis master of science, it focused on malaria prevention mechanisms. Therefore, a review of those papers suggests that the method is still at an explanatory stage and malaria risk topographic factors not examined certainly. Despite the fact that tentative analytic techniques are generally used to identify clusters and determine whether these occur by chance and 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. Considerate malaria epidemics using GIS and Remote Sensing with socio-economic characteristics data believed to be essential by the researcher (Meme, 2016).

Many governmental and non-governmental studies conducted in different areas and time but, they focused treating directly or indirectly for patients when it is a happened. Environmental factors that make condition suitable for breeding of mosquito were not identified the above study areas. This has resulted in failure of identifying areas severely affected by malaria, and this in turn resulted in improper utilization of scarce financial and human resource for the places which are not given top priority (WHO, 2015).

Makuey *Woreda* is one of among 15 districts of Gambella, and is situated 120 km to the west of the regional capital of Gambella. The district has 18 precinct organizations (*Kebele).* The district's average annual temperature and rainfall are 29°C and 1,000 mm, respectively. District climatic conditions are favorable for the existence of a stable form of malaria throughout the year (Asseged, 2006). According to a 2006 (Ethiopian calendar) fiscal year district health office report, the district has three health centers though 18 *Kebele* were covered by four health-extensions.

The discipline of GIS and Remote Sensing offers powerful tools to present spatial information on malaria risk areas. Such information has important implications for the disease eradication strategy to be employed. GIS allows policy makers to easily understand and visualize the problems in relation to the available resources and target resources to those communities in need. But based on the current available information 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 to explore appropriate methods for investigating and carrying out relatively simple analysis of these data using personal computer (Desktop), cost effective software, land sat data that is free and can be down loaded (Mohamed O. et al., 2011).

GIS is being introduced in tropical disease control programs against sleeping sickness, Chagas disease, leishmaniasis, schistosomiasis, guinea worm and malaria. For national health policy makers, cartographic display can indeed facilitate identification of risk areas, their subsequent targeting and monitoring of interventions to these areas (Boelaert et al., 1998).

Spatial technology has advanced greatly in parallel with progress in information technology to the extent that it is now possible to capture and manipulate an array of complex spatial information with relative ease and in real time. Generally, Integration of GIS with Remote Sensing helps in identification, characterization, monitoring and surveillance of breeding habitats and mapping of malaria risk areas. GPS data in a GIS assists in generating base map, mapping breeding habitats and analysis of areas of high disease prevalence (Saxena et al., 2009).

Geospatial technologies have been used widely in malaria risk mapping and malaria control throughout the world. 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 (Rainer, 2008).

2.5 Attributing factors to prevalence of malaria

2.5.1 Environmental factors

2.5.1.1 Temperature

Hotness and coldness changeability affects the development and progress of cycle system. In cold temperatures the larvae develop very slowly and in many cases they may be eaten by predators and may never live to transmit the disease. Once larvae emerge to become adults, the rate at which they feed on man is dependent upon the ambient temperature. At 17°C the female mosquitoes feed on humans every 4 days while at 25°C they take blood meals from humans every two days (Githeko, 2009). The incidences of malaria will be higher in areas with high temperatures especially in the range of 18°C to 32°C, with high relative humidity (above 60%)/rainfall and dense vegetation providing conducive conditions that favors the survival of the vector and development of the parasites (Bayissa, 2007).

2.5.1.2 Rainfall

It plays an important role in malaria epidemiology because water not only provides the medium for the aquatic stages of the mosquito's life but also increases the relative humidity and thereby the longevity of the adult mosquitoes Rainfall increases the reproduction habitats for mosquitoes leading to increased population sizes and the rate of malaria transmission (Paaijmans et al. 2010). Therefore, breeding increases dramatically in the rainy season when water collects in stagnant bodies and these provide ample breeding ground through wells, ponds, water tanks, paddy fields etc., which act as breeding grounds (Sivani, 2010)..

2.5.1.3 Surface Water

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

2.5.1.4 Altitude

In Ethiopia, malaria frequently occurs in areas below 2000 meters elevation and the transmission is very intense in areas below 1500 meters elevation (Afrane etal 2011). The prevalence of malaria parasites in people varies with altitude. People at low lands have significantly higher prevalence of malaria than those in middle and highlands (Kimbi et al., 2013). Even though, altitude has a significant in determining the distribution of malaria and its seasonal impact on many parts of the World other factors can affect the prevalence of malaria which crate conducive breeding site for mosquitoes.

2.5.1.5 Proximity to rivers

One of important parameter that sometime plays important role to increase malaria parasites and malaria disease is the distance to river. The closeness of the populated area to drainage systems is an important parameter for malaria vector breeding source in malaria risky areas (Kumar et al., 2012).

2.5.2 Socio-economic factors

2.5.2.1 Agriculture and irrigation

The rural population of the study area depends on crop and livestock husbandry. Crop production is mainly rain-fed. However, two harvests per year are possible through rain fed farming in the main season and riverside cultivation at the end of wet season along the river banks of Baro. In general, the type of farming system pertinent to the study area includes riverside cultivation, arable farming and shifting cultivation. In addition livestock raring, poultry farming, bee keeping, fishing and hunting are also peculiar practices of the farmer of the study area. Irrigation creates an ideal habitat for mass-production of mosquitoes. Through the creation of larval habitats, reservoirs can promote enhanced populations of certain vectors (Reiter, 2008).

2.5.2.2 Location of housing and livelihood system

Peoples who live in rural area appear to experience higher rates of transmission. Rural locations can be associated with increased malaria risk for both epidemiological and socioeconomic reasons. Certain types of housing may influence malaria transmission. Greater exposure to the outdoors (lack of windows or screens, for example), may increase contact between an individual and the mosquito vector. Similarly, the presences of particular structural features that limit contact with the mosquito vector are likely to reduce infection (Woldesemayat, 2015).

2.5.2.3 Land use /land cover

Land cover has been associated with malaria transmission, because it provides suitable environment for mosquito breeding. According to the type and distribution of vegetation, grass land and pasture can influence mosquito populations. The presence of these creates microclimatic conditions which are moderate temperature and humidity; it is suitable for mosquitoes (Alen, 2002).

2.5.2.4 Population density

Higher population living in space often leads to an increase in malaria transmission because of poor housing and sanitation, lack of proper drainage of surface water, and use of unprotected water reservoirs that increase human-vector contact and vector breeding (Woldesemayat, 2015).

2.5.2.5 Health center facilities

Existence of health institutions in a particular area is very important for reduction of disease, awareness creation about different diseases and their means of prevention, easily convenience and fair cost of treatment. These in turn influence the prevalence of a particular disease. Absence and distant health institutions result in difficulties in accessibility and high cost of treatment. Therefore, people who are near to health institutions are safer relative to those who are at farther places and takes lower risk level (MoH, 2008).

2.5.3. Malaria incidence and controlling frame work

Modeling of conceptual framework readers can understand easily its direction, work flow and points to be incorporated along the entire study structure. In this study conceptual frame work includes five parts, thus environmental variables, Anopheles cycle, parasite cycle, socio-economic characteristics and malaria control. See figure 2;

2.5.3.1 Environmental factors

Separated in to sub groups are, climatic factors (temperature, humidity and rainfall), topographic factors (slope and altitude), and ecological factors (wet land, soil drainage and hydrology) while, ecological factors are subjective to human activities may vary the malaria risk in a given area (Kenneth, 2016).

2.5.3.2 Anopheles cycle

A favorable breeding site of mosquito increases population on its life cycle and leads to high mortality rate that reduce its population in a given place.

2.5.3.3 Parasite cycle

Spread by successively infected between two of hosts called female Anopheles mosquito and humans.

2.5.3.4 Demographic characteristics

Are all peoples vulnerable to malaria may depend up on socio-economic factors among the population livelihood system (kleinschmidt et al., 2000).

2.5.3.5 Malaria control

All measures take to prevent malaria transmissions. Possible measurement may scientifically diagnosis treatment or transmission prevention as an artificial method.

Since the conceptual frame work broadly categorized in to five groups, but this study focuses the interactions of environmental variables and demographic and socio-economic characteristics were used in the production of risk map in Makuey *Woreda*.

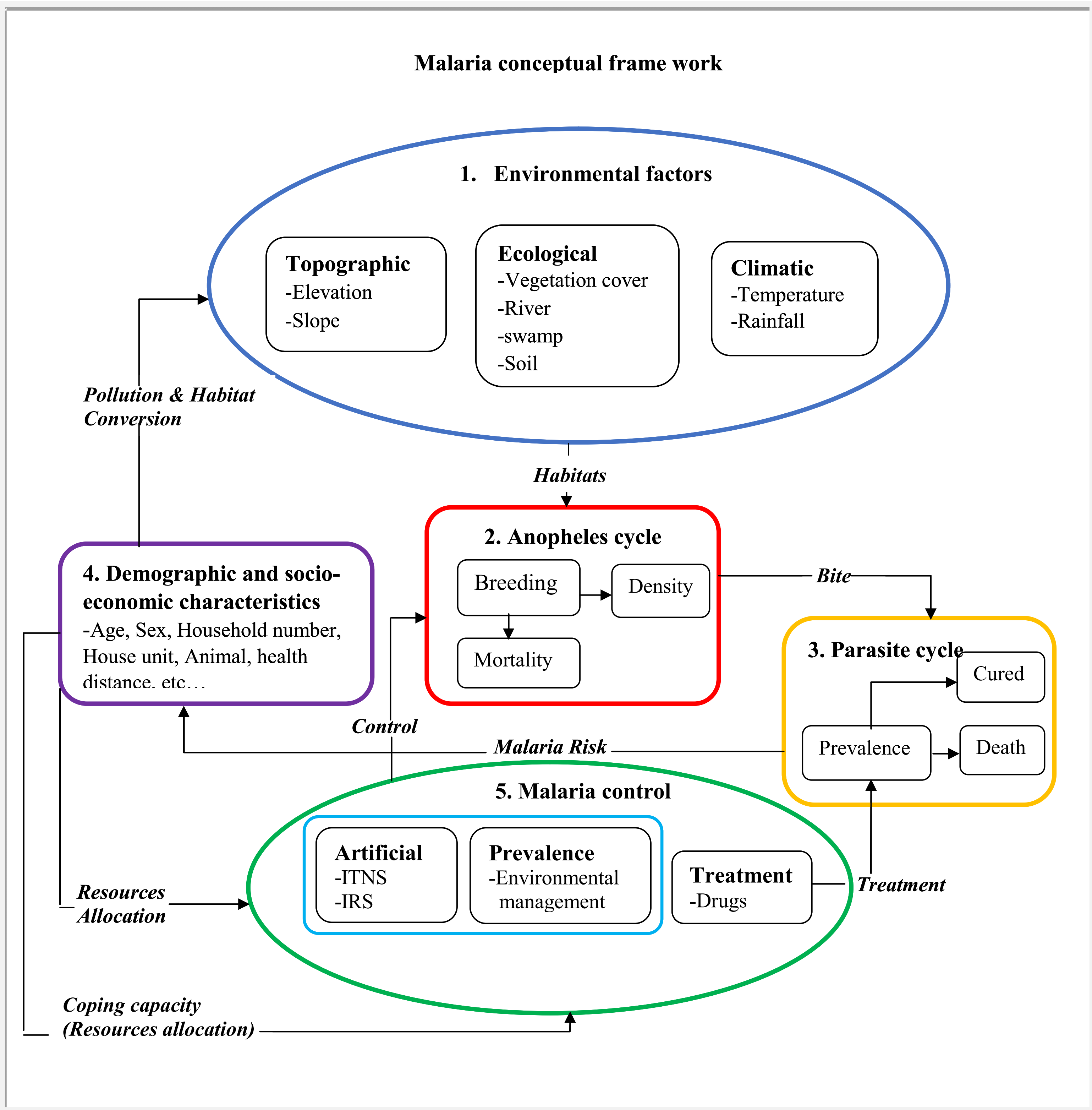

Figure 2. Malaria conceptual frame work (Tuyishimire, 2013)

CHAPTER THREE
Methods and materials

3.1. Description of the Study area

3.1.1. Location

Gambella is one of nine regional states of Ethiopia, located at about 776 km southwest of Addis Ababa. Makuey is one of among 15 districts in Gambella, regional state, and is situated 120 km west of the regional capital city Gambella. Geographically, the *Woreda* located at 7°57' 55" N and 8°32' 52" N, latitude and 33°24' 18" E and 34°15' 23" E longitude.

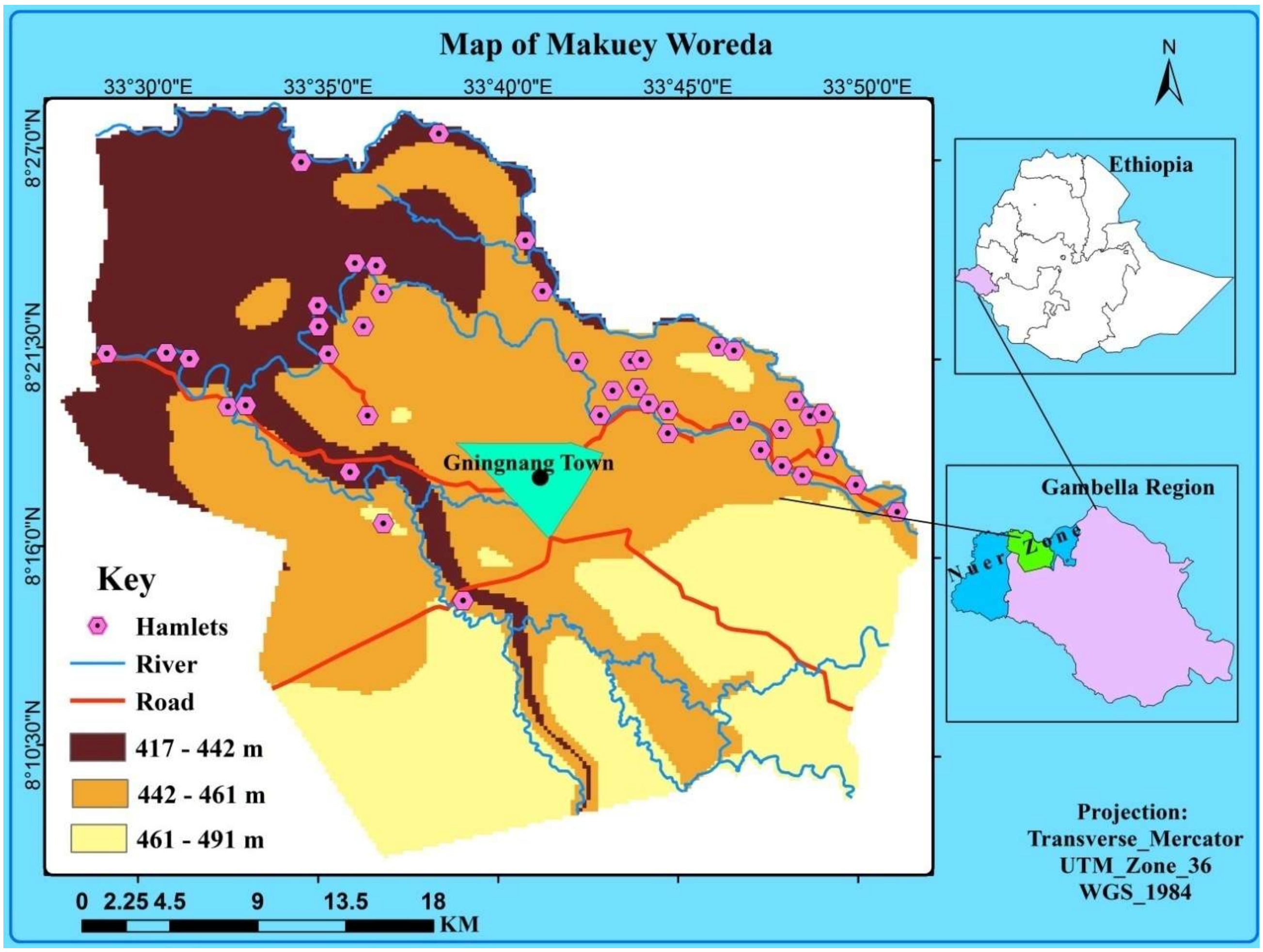

Figure 3. Map of study area

Source: CSA, 2007 and USGS DEM, 2017

3.1.2 Demographics

According to the 2007 national census, the *Woreda's* population was reported to be 22656 in 4925 households; of who 11557 were men and 11099 women; 2588 or 11.4 % **of** the population were urban inhabitants. The two largest ethnic groups in Makuey were the Nuer (97.96%), and the Anuak (1.97%); all other ethnic groups made up 0.07% of the population. Nuer is spoken as a first language by 98.08%, and Anuak by 1.88%; the remaining 0.04% spoke all other primary languages reported. The majority of the inhabitants said they were Protestant, with 56.25% of the population reporting they held that belief, while 19.04% practiced traditional religions and 4.37% professed Ethiopian Orthodox Christianity (CSA, 2007). Based on 2007 population census, the population density relatively the study area is 26.5 person per square km.

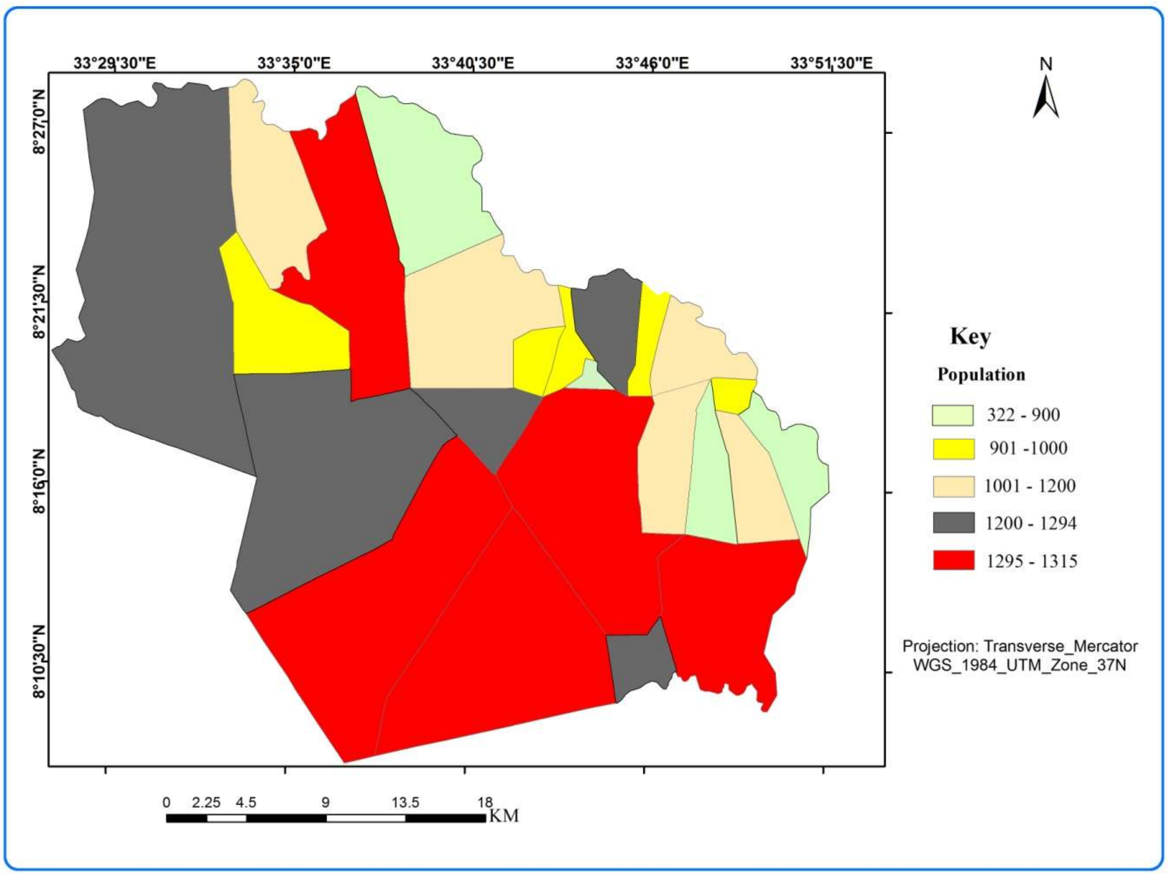

Figure 4. Population density map of the study area

Source: CSA, 2007

3.1.3 Economic Activity

In the region as well as in the study area, agriculture is dominated by subsistence farming systems with no use of modern agriculture inputs and in Gambella region is owned by each farm household head and they have fully controlling right over the use of land including natural vegetation grown in the area. There are no restriction on movement and use of land for cropping as well as grazing except along the river bank (Woldesemayat, 2015).

The rural population of the study area depends on crop (maize) and livestock husbandry. Crop production is mainly rain-fed. However, two harvests per year are possible through rain fed farming in the main season and riverside cultivation at the end of wet season along the river banks of Baro. In general, the type of farming system pertinent to the study area includes riverside cultivation, arable farming and shifting cultivation. In addition livestock raring, poultry farming, bee keeping, fishing and hunting are also peculiar practices of the farmer of the study area (Woldesemayat, 2015).

3.1.4 Climate

3.1.4.1 Temperature

Mean monthly and annual temperature was calculated for the study area. The mean minimum monthly temperature of ten years of study area lies between 17.85^{o}C on December to 20.74^{o}C on Jul and mean maximum ranges from 29.63^{o}C on August to 38.30^{o}C on March. The mean of temperature of study area is 24.82^{o}C to 29.51^{o}C. From the above temperature description it can understand in Makuey *Woreda* is suitable for the development of malaria breeding.

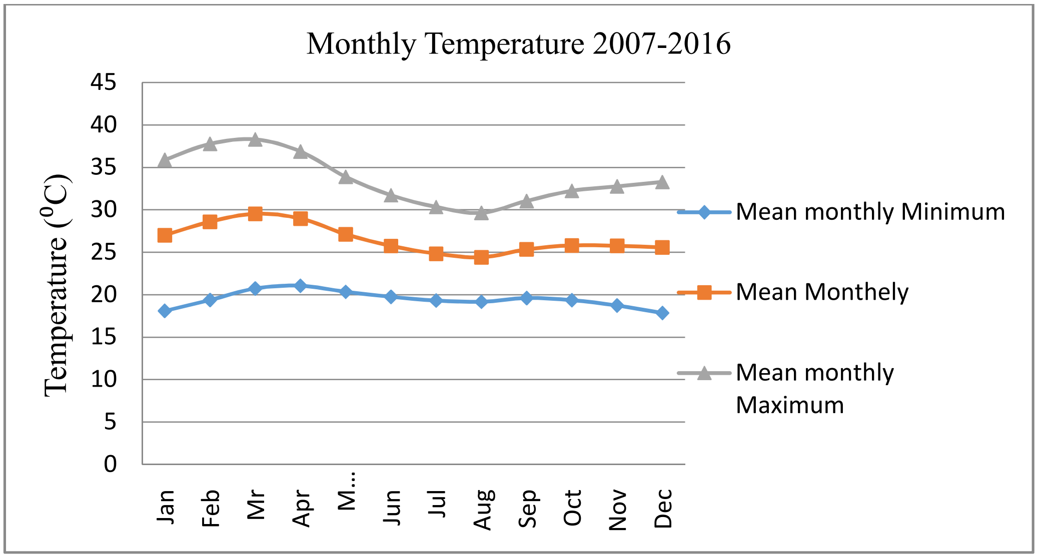

Figure 5. Mean monthly, mean maximum and mean minimum monthly temperature 2007-2016

Source: National meteorological agency.

3.1.4.2 Rainfall

The life of mosquito in environments is determined by the existence of water body on surface. Rainfall plays an important role on malaria epidemiology by increasing the relative humidity and moisture and thereby makes longevity of the adult of mosquitoes and its life cycle (Mabratu, 2010). Especially areas with lower elevation have offers abundance breeding site.

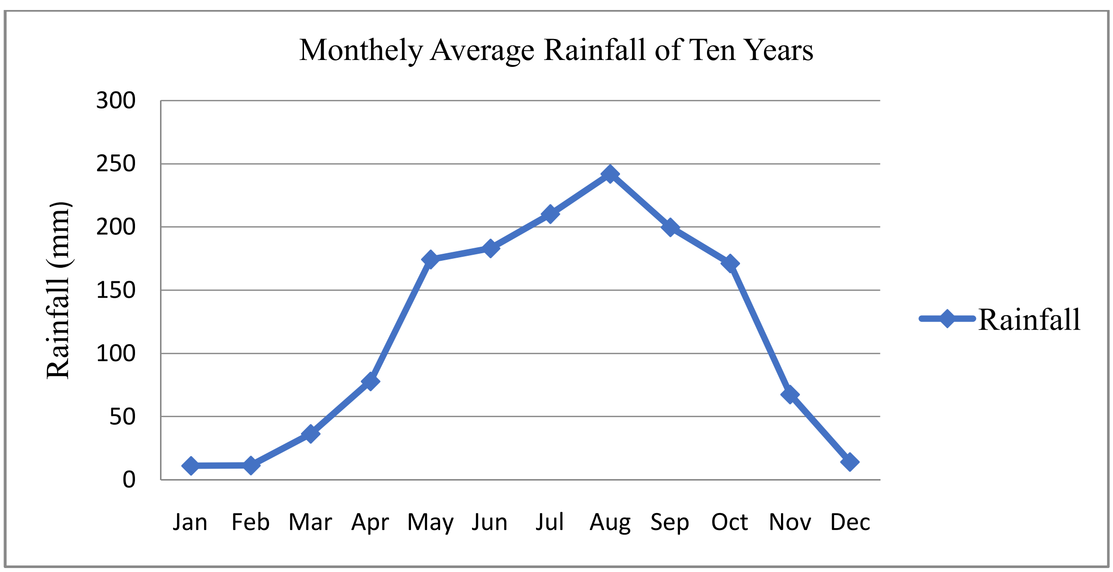

Figure 6. Mean monthly rainfall of Makuey Woreda (2007-2016)

Source: National meteorological agency.

The rainfall pattern of study area evenly distributed throughout the year. This area has one rainy season in a year. The highest rain season which received on Jul to September constitutes 210.2 mm to 199.8mm respectively during the Ethiopian summer season. On the other hand rainfall season from December up to February the area receives very small amount of rainfall which was recorded 14.2mm to 11.4mm respectively (NMA, 2017).

3.1.5 Trend of Malaria in Makuey *Woreda*

The number of malaria case in Makuey *Woreda* is very high. The trend of malaria case in this *Woreda* was showed irregular in different years. According to the Makuey *Woreda* health office that recorded within seven years showed at increasing level up to 2013. From 2013 to 2014 showed decreasing rate at alarming rate. This is due to the use of different preventive action keeping environmental sanitation, distributing insecticide treated mosquito net, spraying DDT throughout the year was taken by *Woreda* health office and collaborating with non-governmental organization such as UNICEF, MSF and USIAD ware try to regulate in this area.

According to the *Woreda* health office in the year of 2015 malaria case dynamically increased. Thus because of the political instability in South Sudan more than 40 thousand migrants ware temporarily settled in this *Woreda* (IOM, 2016). Consequently, when refugees become relocated to their permanent camp the number of malaria case in the area becomes decreased.

As the Makuey *Woreda* health office described that the highest malaria transmission season in the area was from September to December and secondly from June to August also recorded highest amount. Due to the high temperature in March malaria case was recorded low.

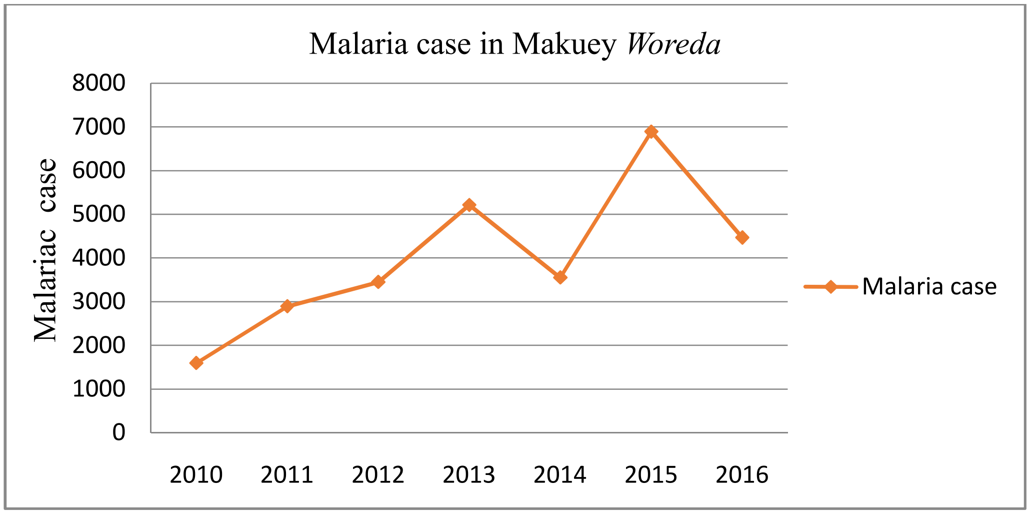

Figure 7. Malaria cases of Makuey *Woreda* from 2010- 2016

Source: MWHB, 15/04/2017

3.1.6 Soil

Based on the *Woreda* agriculture office there are more than five soil types existed in the study area. But the valuable soil type classification listed by Food and Agriculture Organization (1984). Vertisols are characteristics of this soil type are churning, heavy clay soils with a high proportion of swelling and shrinking clays. These soils form deep extensive cracks from the plane downward when they dry out, it occurred in most years. They are almost resistant, when saturated and very plastic and muggy when wet. Fluvisols are characterized a young soils. They are found in alluvial plains, river fans, valleys and tidal marshes on all continents and in all climate zones and Xerosols are arid wasteland soils enclose low organic matter; the top layer is of a light color, and underlying layers having low water storage capacity, thus they have good drainage (FAO, 2006).

3.1.7 Health center facilities

In Makuey *Woreda* there are only two governmental health centers and one non-governmental Red Cross Societies (RCS) that can give service to communities and three health extensions in rural *Kebeles* as to call used for emergencies. Those found at *Woreda* town Gningnang and Adura (RCS) and Nibnib *Kebeles*. But the researcher did not include three of them for malaria risk map of the study area due to their minimal contribution on the medicinal method of malaria in the study area. So to identify the spatial distribution of health centers, the researcher was collected point data using GPS on field survey.

3.1.8 Land use /Land cover of the study area (LULC)

Settlements both houses built from cement and mud with grass in the study area were included. Agriculture of the study area was practiced limited agricultural activities observed following Baro River. This is still based on flooded irrigation or water loading over surface seasonally using the river Baro.

Water body of the study area is composed of small and large rivers laying over an extended land surface throughout the Year like Baro River that crossed up to South Sudan nation.

Forest land an area or region covered with different type of scattered trees and most forests exited at the margin of study area. The type of land use land cover of study area especially the unused and large grasses, agriculture, settlement, forest and water body area occupied 47 % , 29 %, 3.3 % and 0.3% respectively.

3.2 Data type and source

Both primary and secondary data was used for the malaria risk mapping of the study area. A data which were obtained from field survey such as GPS point, field observation to land use land cover and data of socio-economic factors from questioners was primary source of data.

Climatic data (rainfall and temperature) were collected from NMA of ten years with seven station neighboring *Woredas* including the study area. DEM with 30 m spatial resolution data were downloaded from USGS American free web. Topographic map (1:50,000 scale) was received from EMA used to digitized water body. Clinical data was obtained from Makuey *Woreda* health office and local Nongovernmental organizations which provide health services to the communities are considered as a secondary data.

Table 1. Data Sets

No	Types of data	Source of data
1	Satellite image and Topographic Map	USGS (ASTER) Ethiopian Mapping Agency (EMA)
2	Digital Elevation Model	USGS (SRTM)
3	Rainfall and temperature data	National Meteorological Agency (1:50000)
4	Study area boundary shape file	Central Statistical Agency
5	Ground control points	Field survey and Google Earth
6	Clinical data(malaria cases)	*Woreda* health office
7	Soil map	Ministry of Agriculture (FAO, 1984)

3.3 Data processing and analysis

3.3.1 Environmental malaria risk factors

Including the study area Akobo, Itang, Lare, Jikawo, Jore, wantwa and Gningnang were the meteorological station for temperature and rainfall data used. From six neighboring stations the nearest station is Jikawo, 23.8 Km and the farthest Itang, 52.4 Km, about 47 km boundary of study area connected with South Sudan so that station was not used for interpolation.

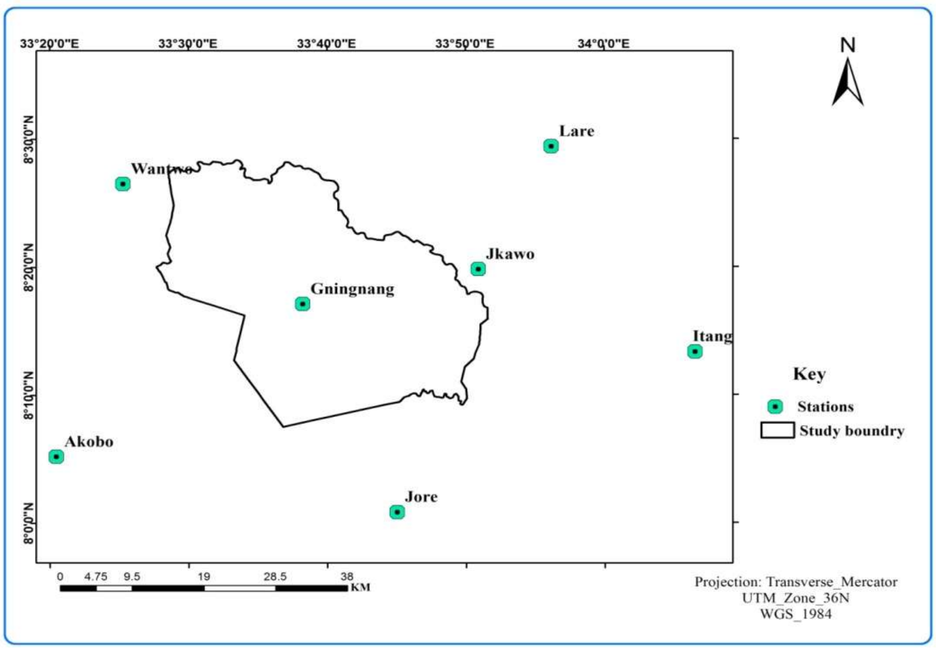

Figure 8. Map of meteorology stations surrounding the study area

Source: National Meteorological Agency, 2007-2016 and field survey

3.3.1.1 Temperature

Temperature related risk map were derived a data available from seven years mean monthly maximum and mean monthly minimum temperature data from seven stations were examined. After computing mean annual temperature that produced a single value each stations. Then spatial temperature data of Makuey *Woreda* were interpolated in ArcGIS environment Spatial Analysis Tool by Inverse Distance Weight (IDW) method.

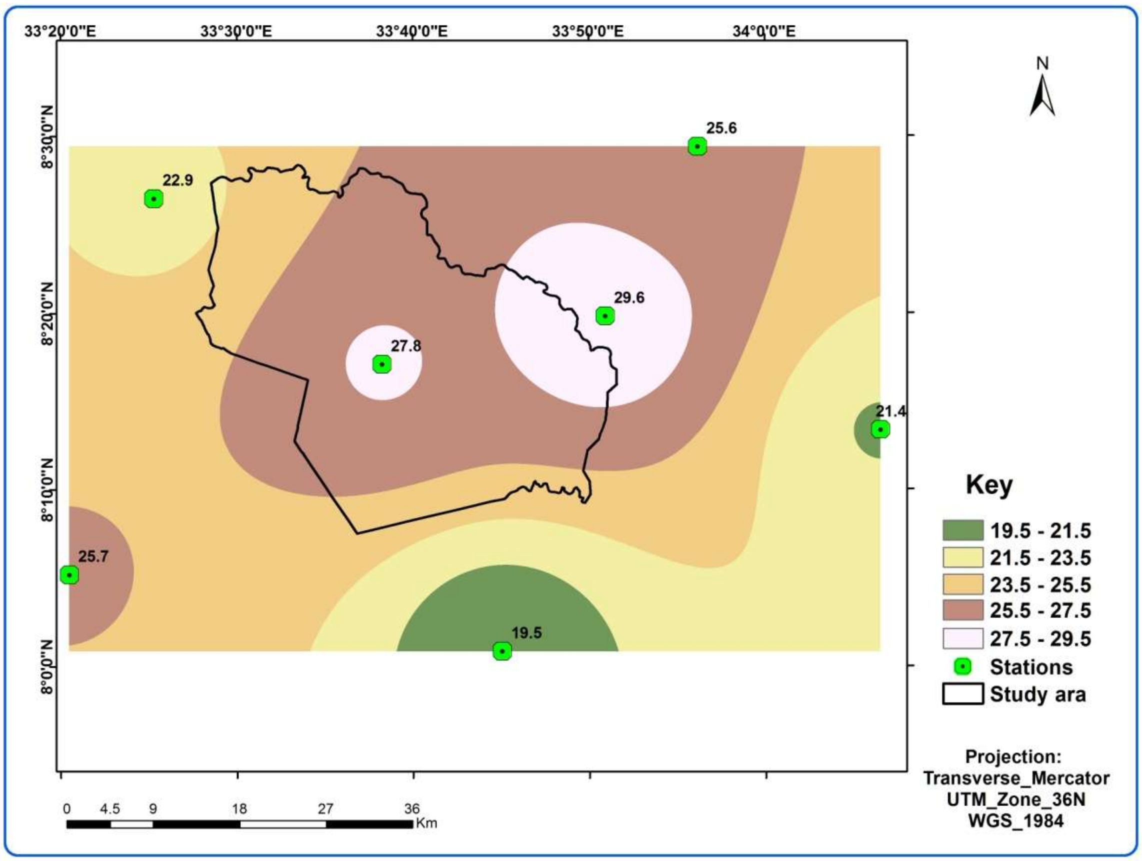

Figure 9. Temperature interpolated data map

Source: National Meteorological Agency, 2007-2016 and field survey

The temperature map was reclassified by spatial analyst stools in ArcGIS. The study area is reclassified in to three classes based on its suitability to mosquito breeding 23.3-26.5ºC, 26.6-29.3ºC and, the new value were assigned 3, 4 and 5 which represents moderate high and very high respectively.

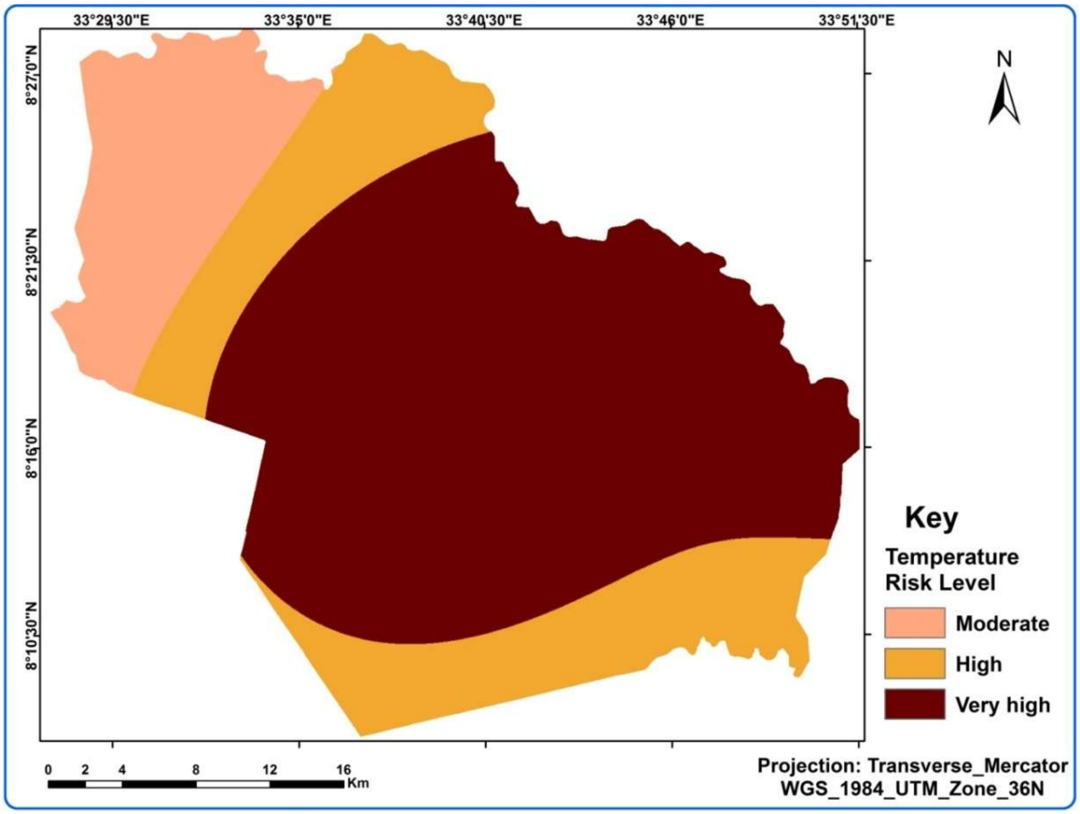

Figure 10. Temperature map

Source: National Meteorological Agency, 2007-2016

3.3.1.2 Rainfall

Mean annual rainfall data of study area were interpolated from seven metrological stations in ArcGIS environment Spatial Analysis Tool using Inverse Distance Weight (IDW) technique continuous surface was created become the range between 880 and 1310mm annually.

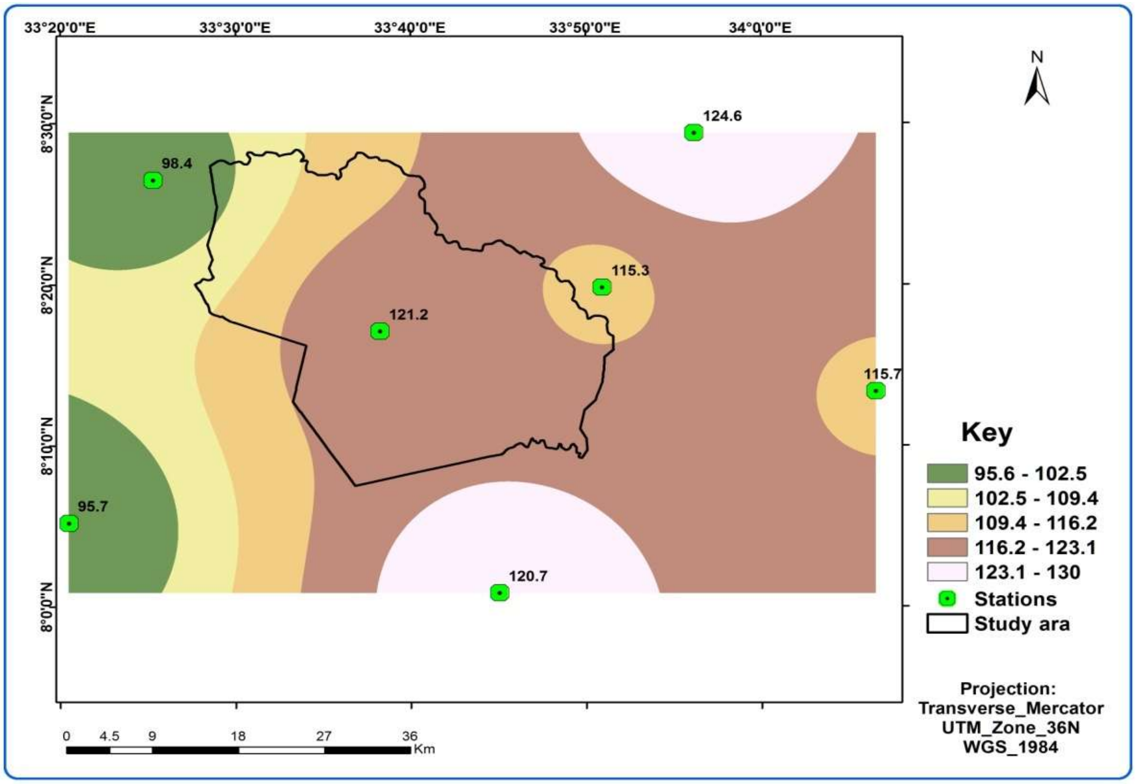

Figure 11. Rainfall interpolated data map

Source: National Meteorological Agency, 2007-2016 and field survey

The rainfall map was then reclassified to five classes based on its suitability to mosquito breeding. New values 3, 4 and 5 were assigned to rainfall class 100.3-110.8mm, 110.8-117.1mm and 117.1-121.4mm, respectively. Then the classes were marked as moderate, high and vey high malaria risk level, respectively.

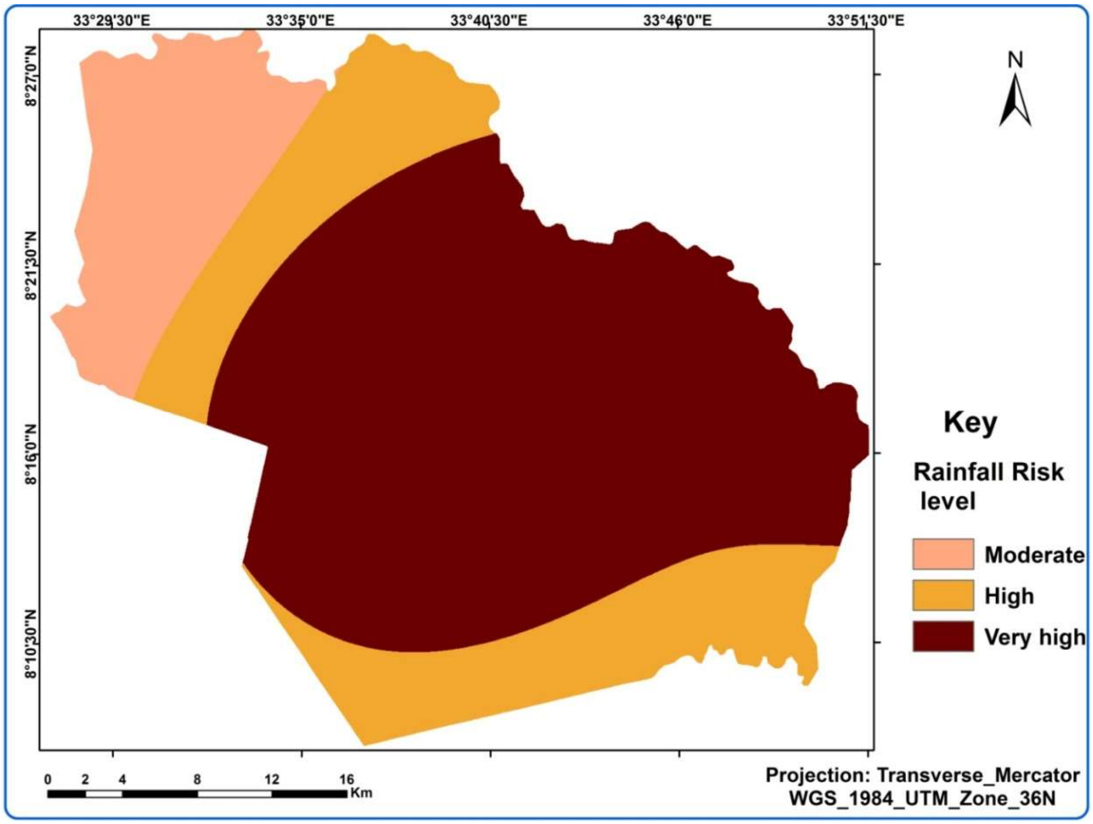

Figure 12. Rainfall map

Source: National Meteorological Agency, 2007-2016

3.3.1.3 Elevation

Elevation of study area was generated from Digital Elevation Model DEM 30 meter resolution with path 172 and row 054 zone of 36 N in south western Ethiopia. The elevation map was reclassified on the basis of the relationship between elevation and malaria incidence with the study area. The elevation of study area classify in to two 362-401 and 401-451m new values were assigned to each as 5 and 4 respectively. Finally elevation based malaria risk level is leveled as very high and high respectively.

3.3.1.4 Proximity to water bodies related factors

Both proximity to river and swamp areas were derived from 1:50,000 scale topographic map of the area that designed in (EMA, 1980). The soft copy of study area topographic map was digitized followed geo-referencing based on the standard coordinate system WGS_84 UTM zone 36 was digitized by Arc GIS. The distance calculation from water bodies and the reclassification processes was also done in ArcGIS Spatial Analysis Tools. It was generated in ArcGIS environment by using Euclidean distance calculation. The reclassification was done on the basis of mosquito flight vary. Region found <500m, 500-1000m, 1000-1500m, 1500-2000m very and >2000m new values given as 5, 4, 3, 2 and 1 and classified as very high, high, Moderate, low and very low malaria risk level, respectively.

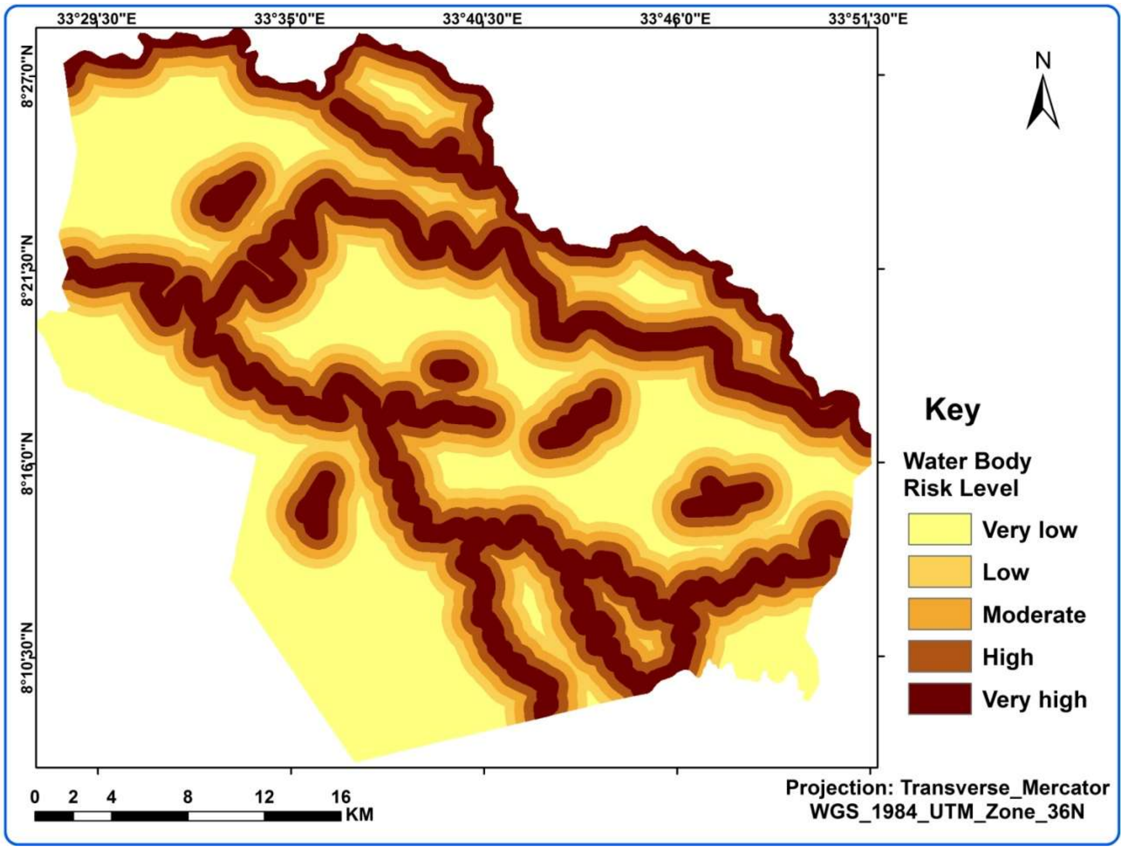

Figure 13. Distance to water body map

Source: USGS DEM, 2017

3.3.1.5 Soil

Soil data was derived from Food and Agricultural Organization (1984), were three soil type exist in the study area called Vertisols Fluvisols and Xerosols. Soil types of the study area reclassified based on their ability to hold moisture or based on being permeable or impermeable. As it was mentioned above in description part, Vertisols are very sticky poorly drained soils and Fluvisols are found along tidal marshes and alluvial plains allow water stagnation. So they were reclassified, Vertisols very high malaria risk level and assigned new value 5, Fluvisols also high moisture storage capacity are given new value 4 and Xerosols have good drainage leveled as low malaria risk level and assigned new value 2.

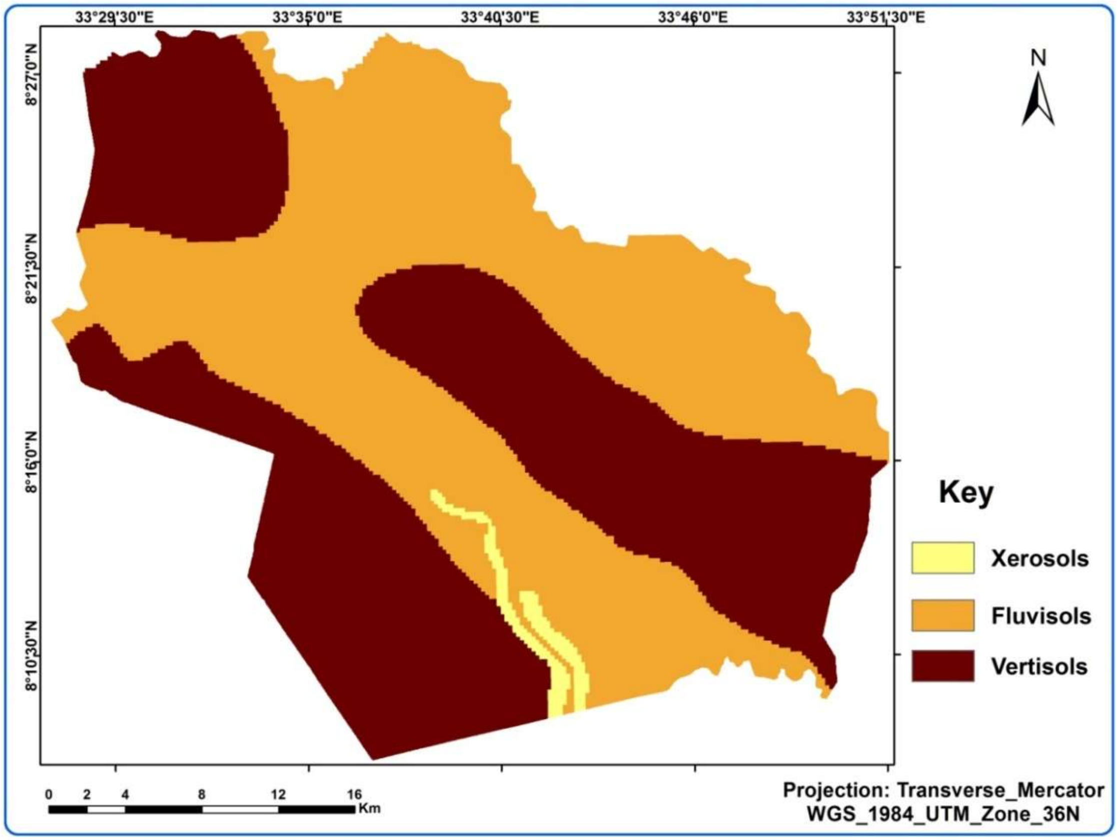

Figure 14. Soil map

Source: FAO, 1684

3.3.2 Socio-economic malaria risk factor

3.3.2.1 Health facilities center

The spatial distribution of health centers of the study area was collected from field as point data using GPS instrument. Based on the spatial distribution of health center in the study area, using Euclidean distance how much far settlement from each health institution were calculated and reclassified in to five class based on minimum requirement accessible distance. The classification were <3000m, 3000-4000m, 4000-5000m, 5000-6000m and >6000m, thus assigned malaria risk level very low, low, moderate, high and very high with anew value, 1, 2, 3, 4 and 5 malaria risk level respectively (WHO, 2013).

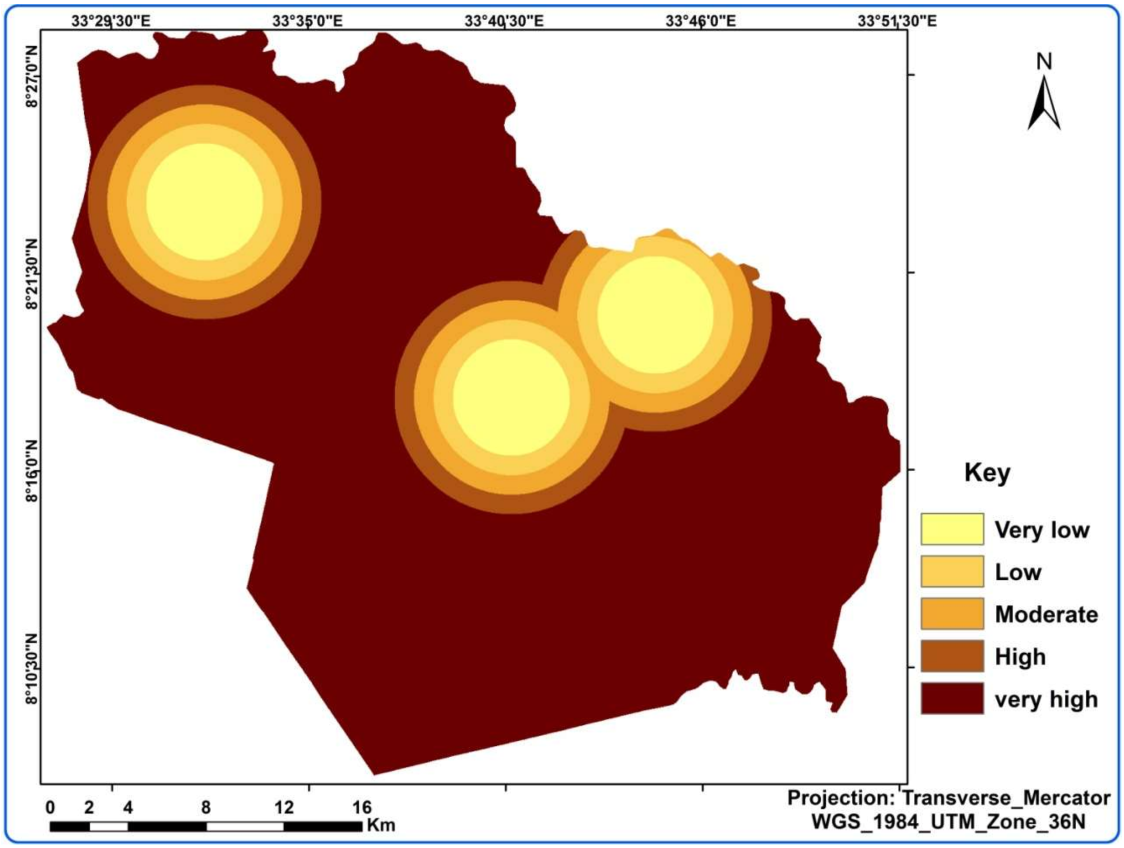

Figure 15. Health facilities distance risk level
Source: MWHB and field survey

3.3.2.2 Population density

Population data was collected from Makuey *Woeda* administration office a point data for each *Kebele*. Point data entering in to excel sheet and converted in to spatial distribution of population at *Wereda* level by interpolation method in ArcGIS software. Distribution of spatial population density layer was reclassified into three classes as low, high, and very high to 322-900, 900-1130 and 1130-1320 respectively. The new value assigned as 2, 3, and 4 respectively.

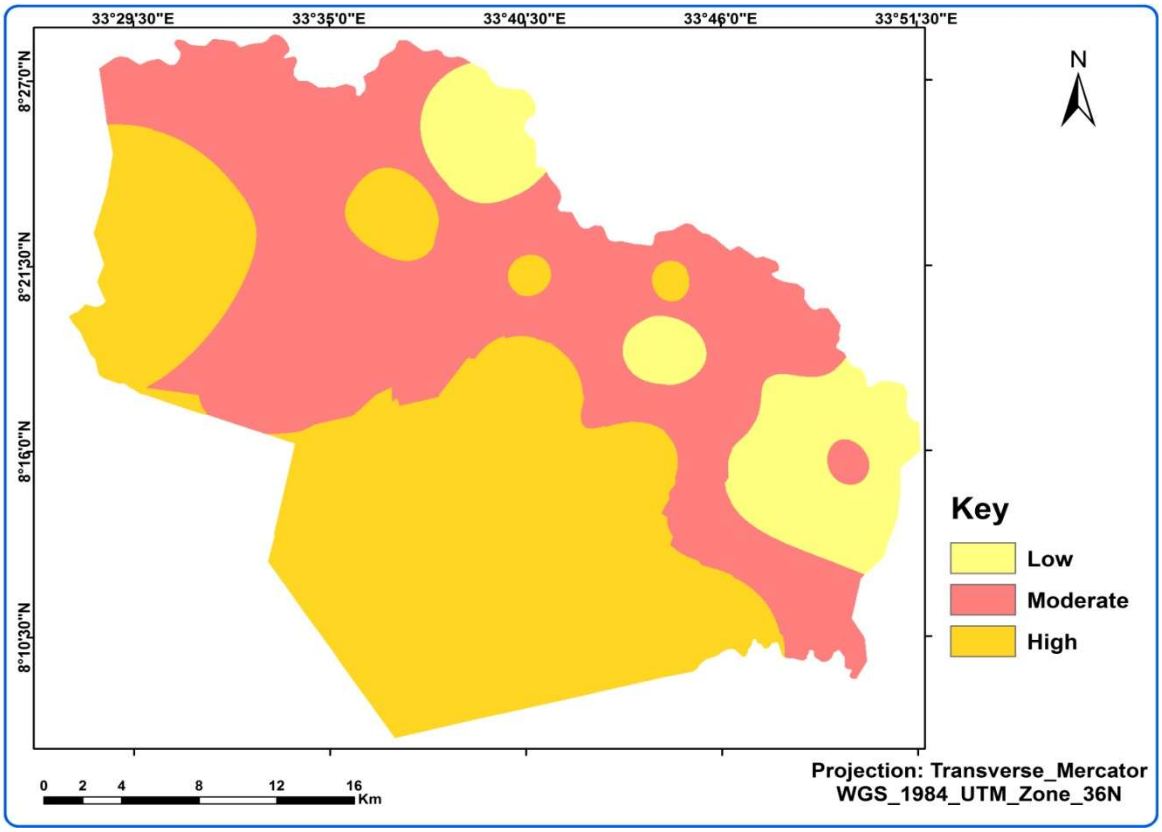

Figure 16. Population density

Source: CSA, 2007

3.3.2.3 Land use/ land cover

The image of study area was derived from ASTER archived landsat ETM$^+$ imagery of path 172 and raw 54 obtained on 02, 23, and 2017 with 30m spatial resolution. The quality of spatial resolution was improved by rescaling in to 15m x15m panchromatic which black and white color. Supervised image classification was taken five representative samples for each land-use/land-cover types were conducted. .

The image was classified in to five major namely water body, settlement, agricultural practice, grass land and forest area types. Based on the study area susceptibility to suitable breading site, source of food and use as a shelter from climatic condition for the vector mosquito were reclassified in to five classes with new values 5 to 1, water bodies were considered as very high risk in terms of malaria breeding and repose sites in the study area and the remaining grass land, settlement, agriculture and forest, forest land assigned as high, moderate, low and very low malaria risk respectively.

Table 2. Land use /land cover risk ranking

New value	Feature name	Rating
5	Water body	Very high
4	Grass land	High
3	Settlement	Moderate
2	Agriculture	Low
1	Forest	Very low

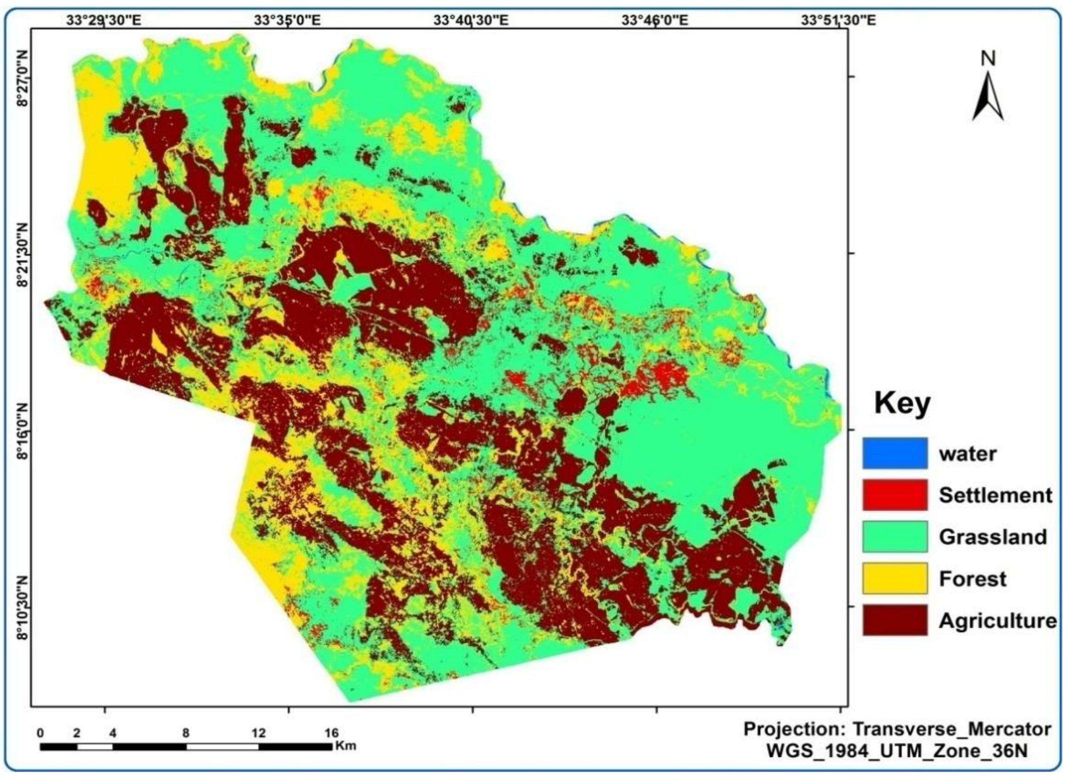

Figure 17. Land use/ land cover map

Source: ASTER, 02/23/2017

Accuracy assessment

Classifying of satellite image and ground truth is always concomitant issues (Lillesand and Kiefer, 1994). During survey questionnaire distributing side by side ground GPS control point was collected. Proportional GPS points convene for each five classification land use land cover map. Integrating all points with the classified image in to ArcGIS environment was extracted to values raster and error matrixes were generated from pivot raster analysis. Accordingly the result overall classification accuracy is 79.52% and overall kappa statistics of 74.3%, less than 0.40 Kappa values indicated low classification performance . From the error matrix of study area Kappa coefficient were calculated using the following formula the Kappa statistic measures the variation between the true agreements of classified satellite image and chance agreement of GPS point random classified compared on error matrix (Lillesand et al., 2004). Complete error matrix, user accuracy and producer accuracy is affixed in appendixes.

$$\hat{K} = \frac{N \sum_{i=1}^{\hat{K}} xii - \sum(Xit * Xti)}{\mathbf{N^2} - \sum_{i=t}^{k} (Xit * Xti)} \quad \textit{Equa} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Table 3. Ground truth point error matrix result

Class Name	Forest	Agriculture	Settlement	Grassland	Water body	Total Row
Forest	21	0	1	3	0	25
Agriculture	0	19	3	1	1	24
Settlements	0	2	16	1	0	27
Grassland	2	4	3	27	0	36
Water body	1	1	1	0	18	21
Total column	**24**	**26**	**24**	**32**	**19**	**137**

Overall classification accuracy = 79.5

Overall kappa statistics = 73.4

3.3.3 Materials and soft wares

By running different software and using materials output of this study were produced. Such ERDAS IMAGINE 2014 were used to classification of land sat image, ArcMap 10.4.1 were used for production of factor maps, Garmin GPS for collection of ground control points to prepare accuracy assessment for distance to swamps, health stations that digitizing from topographic map. Besides IDRISI v.17 software was used for MCE weighted overlay processed. SPSS were used for questionnaires producing the magnitude of frequency and percentage of respondents and digital camera was used for field observation during questionnaire distributions**.**

3.3.4 Data base for malaria risk analysis

There is no universal definition exists for malaria risk; it is essential to choose an approach that is appropriate for the context in which the risk assessments are implanted and considering the hazard that is addressed (e.g., climate change, natural hazards, vector-borne diseases, etc.). Risk is defined as a function of hazard and the vulnerability of exposed population groups. The interrelation of these components (hazard, vulnerability, and element at risk) reflects the vital importance of feedback when dealing with the malaria diffusion and transmissions cycle in a given area and specified period of time.

3.3.4.1 Identifying malaria hazard analysis

Hazard is the probability of occurrence of damaging natural phenomenon within specified time through infective Anopheles mosquitoes to spread malaria in a given area. Hazard analysis was mapped depending and approached environmental factors that suitable for mosquito life cycle on surface in the study area. Identification of malaria hazard in this study were evaluated five variables are temperature, rainfall, distance to river and swamps and elevation were processed in IDRISI software for appropriate weight values. Once organized all the factors which compatible with the study area hazard analysis approximation weights for hazard parameter was become processed in IDRISI software. Operating of hazard parameters in IDRISI software requires estimating weight for each individual factors hazard parameters can produced scientifically (Tensaye, 2016).

Each hazard map factors were changed to IDRIS readable format using the ArcGIS environment which conversion tool from raster to ASCII format. Accordingly weight values for each were assigning comparing each other based on the susceptibility potential to malaria transmission in AHP weight derivation tool. Finally after running the tool with in second new values was produced between 0 and 1, later each value changed in to percentage.

Calculated Eigen vector, which is an output of the pair wise comparison matrix to produce a best fit set of weight, of Weight Module was: temperature 0.4066 (40%), rainfall 0.2546 (25%), distance to water body 0.210 (7%), soil 0.0301 (3%) and elevation 0.987 (10%). The consistency ratio (CR) of the calculated Eigen vector was 0.07 which is acceptable. The computed Eigen vector values was changed in to percentage used as a coefficient for the respective factor maps to be combined in Weighted Overlay in ArcGIS software.

Table 4. AHP weight derivation for hazard map

	Soil	Elevation	Water body	Rainfall	temperature	
Soil	1					
Elevation	3	1				
Water body	5	3	1			
Rainfall	7	5	3	1		
Temperature	7	5	5	3	1	

After completing weight based on their significance for each parameter, the hazard map layer was computed by over laying the six selected hazard parameter factors using AHP extension GIS environment. Further it was reclassified in to 3 sub classes' the new values 5, 4, 2, assign for risk ranking as, very high, high, and low respectively.

Table 5. Weight and ranking of malaria hazard factors analysis

Factors	Weight	Class	Ranking	Degree of vulnerability	Percentage (%)
Temperature	0.4066	23-25ºC 25-27ºC >27 ºC	3 4 5	Moderate High Very high	40
Rainfall	0.2546	100.3-110.8mm 110.8-117.1mm 117.1 -121.4mm	3 4 5	Moderate High Very high	25
Water body	0.21	0-500m 500-1000m 1000-1500m 1500-2000m >2000m	5 4 3 2 1	Very High High Moderate Low Very Low	21
Elevation	0.987	362-401 m 402-501 m	5 4	Very high High	11
Soil	0.0301	Vertisols: Fluvisols Xerosols	5 4 3	Very High High Low	3
Total	**1**				**100 %**

3.3.4.2 Vulnerability map

Vulnerability is the defenselessness regularly associated the occurrence of anomalous condition than before such as illness, economy; gender (Stephenson, 2014). Many researchers were used population density to vulnerability map, but this study due to settlements of the study area sparsely distributed distance to health center were accounts the highest percentage than population density. Thus two factors were weighted overlay computed in ArcGIS environment Spatial Analysis Tool and Vulnerability Map of study area were produced.

Table 6. Vulnerability risk level weight derivation

Feature name	Weight	Class	Ranking	Degree of vulnerability
Population density	50	322-900	3	Low
		900-1130	4	Moderate
		1130-1320	5	High
Distance to health facilities	50	<3000m,	1	Very low
		3000-4000m	2	Low
		4000-5000m	3	Moderate
		5000-6000m	4	High
		>6000m	5	Very high

3.3.4.3 Identification malaria risk map

Malaria transmission is coupled with socio-economic and environmental factors. But environmental factors strongly associated with incidence of malaria which it can shape the potential of mosquito maturity and parasites' life cycle development (WHO, 2013). Even though, the discipline GIS have multi strategies model on producing malaria risk map for this study by integrating three elements of environmental and socio-economic factors data set in to one were produced a hotspot malaria risk map of Makuey *Woreda*. The developments of malaria risk map of the study area were prepared on the basis of risk computation model developed by (shook, 1997).

Risk = Element at risk * Hazard * Vulnerability

Table 7. Malaria risk factors

Factors	Weight	Ranking	Level
Hazard Map	Map Algebra (Raster calculator)	2	Low
		4	High
		5	Very high
Vulnerability		2	Low
		4	High
		5	Very high
Element at risk		1	Very low
		2	Low
		3	Moderate
		4	High
		5	Very high

3.3.4.4 Description of the rating risk analysis

There is no universal definition exists for malaria risk; it is essential to choose an approach that is appropriate for the context in which the risk assessments are implanted and considering the hazard that is addressed (e.g., climate change, natural hazards, vector-borne diseases, etc.). Risk is defined as a function of hazard and the vulnerability of exposed population groups (Wim, 2008).

Table 8. Description of rating risk analysis

Level	Description
Low risk	- No simple method for detecting an area for malaria- Serving health service less than 1 km (WHO, 2013) -ITN distributing one to one -communities out of fishing activities
High risk	children occasional with diseases assumed to have malaria low participation of peoples in working activities
Very high risk	-all children with febrile diseases assumed to have malaria -all household members affected by malaria per year -above three times affected one person per year -describe areas for full year (endemic) or seasons (rainy seasons) classifying all children with fever as “malaria” is considered an acceptable

3.4 Socio-economic data

3.4.1 Study design

It is an analytical cross-sectional survey was conducted with an objective of determining the relationship socio-economic with environmental factors that affected malaria distribution on space by integrating both factor groups environmental with GIS-based analyzed and socio-economic with questionnaires distributed to households in one hand.

3.4.2 Sample size and sampling procedure

The objective of this study was rely on both environmental and socio economic factors. Therefore by integrating both factors it makes accurately that identify the hotspot malaria risk areas. Primarily

Gambella region was selected because of this region owned high temperature and more suitable for mosquito breeding than other regions. And Nuer zone were selected the water lording were challenged along the settlement in this zone. The study area was exposed by flood, water loading the previous five years. Due to the weak road network with other *Woredas* and remotely located than others prioritization was made.

Purposively the researcher was focused on 4 out of 18 *Kebeles,* which have the highest population size that described their homogenous characteristics and to cross check with environmental factors at which area more affected. This selection method helps to identify multi activities in the study area such as population in its socio-cultural, demographic and geographical diversity.

Based on the *Woreda* administration office Lomgjiok 335 HHs, Nyabukliek 291 HHs, Nyinenyang 276 HHs and Adura 254 HHs were purposively selected. Therefore, the sample frame is 1156 of households are part of the study area. The sample size determination formula was developed by (Jeff, 2001) so, to determine the total sample size for this inquiry.

$$S= \frac{X2\ NP(1-P)}{d2(\ N-1)+\ XP(1-P)}$$

Where: S = required sample size.

X2 = the table value of chi-square for 1 degree of freedom at the desired confidence level (3.841).

N = the population size

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

d2= the degree of accuracy expressed as a proportion (0.05).

From the above sample frame the required sample size was calculated as:

$$S= \frac{3.841x1156x0.1\ (1-0.1)}{(0.0\ 5)2(\ 1156-1)+\ 3.841x0.1(1-0.1)}$$

$$= \frac{399.6}{3.2} = 124.875 \approx 125$$

To determine respondents from each sample frame in Makuey *Woreda* Lomgjiok, Nybukliek, Nyinenyang and Adura that represent n_1, n_2, n_3, n_4 respectively and computed by the following

N_1=S(n_1/N), n_1=125(335/1164) = 36

n_2 = 125(291/1164) = 31

n_3 = 125(276/1164) = 29

n_4= 125(254/1164) = 27

Table 9. Sample determination of household in *Kebele*

No	Selected *Kebeles*	No. of HH per *Kebeles*	Sampled HH from *Kebeles*
1	Lomgjiok	335	36
2	Ngabukliek	291	32
3	Nyinenyang	276	29
4	Adura	254	28
Total		1156	125

Sampling design of the study was included both probability and non probability design method. Probability sampling was used for respondents to complete the questionnaire through systematic technique and it gives equal opportunities for all population that selected in to the sample (Kothari, 2004). Besides non probability sampling technique engages the process of selection based on some reasons than mathematical operations. Researchers' believed that; they provides relevant and detail information concerning the issues in the study. Questionnaires were distributed evenly through systematic sapling techniques. Thus first person was started randomly following pick every K^{th} element for each *Kebeles* of households in the sampling frame. Hence, to select K value the researcher used the following method.

K = N/n

Lomgjiok (n_1); K = 1156/335 = 5

Nybukliek (n_1); K = 1156/291 = 3

Nyinenyang (n_1): K = 1156/276 = 4

Adura (n_1): K = 1156/254 =8

The above k values shows that every 5th households from Longjiok *Kebele*, 3rd household from Nybukliek *Kebele,* 4th household from Nyinenyang kebele and 8th household from Adura was selected based on their listed file.

3.4.3 Data collection

Questions were drafted in English language latter translated in to local “Nuerigna” language. The prepared questioner were distributed to sampled households and advised to complete within two weeks after completing each questioners were collected by the help of selected guidance. Primary data was collected using a structured questionnaire from given selected household heads. It focused on household size, education and economic status. Impacts of malaria in family such as age group and frequencies of repetition infected by malaria and way of preventing methods towards malaria were the major components of questioners. Questionnaire and interview the way data collection instruments were part of the study. Secondary data was collected from *Wereda* health center all patients of malaria within seven years and population statistics from local administration office.

3.4.5 Data processing, analysis and presentation

Descriptive statistics was given to the analysis of data that helps describe, show or summarize data in a meaningful way such that, for example, patterns might emerge from the data. Descriptive statistics therefore enables us to present the data in a more meaningful way, which allows simpler interpretation of the data (Creswell, 1988). Using SPSS version 20 statistical software packages, the association and frequency of variables were carried out. Row data were described percentage, graph and tabulation form used. For this study, statistical significance was defined at probability level of 0.05. The magnitude of respondent was presented in tables, bar graph and percentage form.

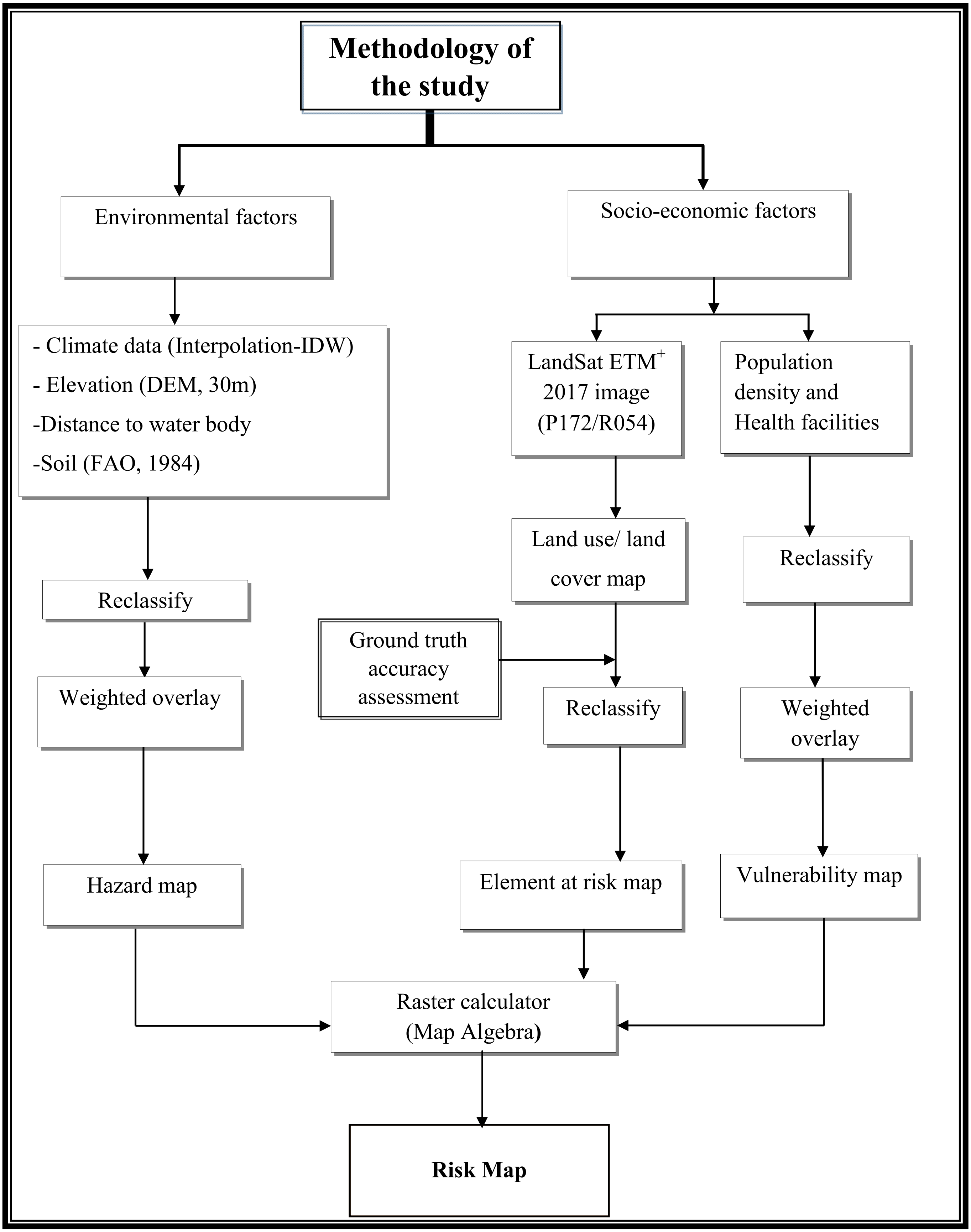

Figure 18. Methodological framework and method of data analysis

CHAPTER FOUR

Results and discussion

4.1. Environmental factors

4.1.1 Temperature

Malaria life cycle not survived under 15ᴼC and if it does, it cannot transmit malaria parasite at this temperature. Hence, areas with such temperature value caked malaria free with respect to temperature related malaria risk. Both the vector and the parasite start to reproduce gradually as temperature boosts above 15ᴼC up to 20ᴼC (WHO, 2014).

Mean annual temperature of ten years of the study area fall in to 23-25ᴼC, 25-27ᴼC, and >27 ᴼC the corresponding temperature related malaria risk level was assigned moderate high and very high respectively were observed. The new values were assigned 3, 4 and 5 for high and very high respectively.

Figure 20 depicts majority of the study area fall with very high malaria risk level. The reclassified temperature map, 478.06 km² and 444.69 km² were mapped as -high and very high malaria risk level, respectively, which is based on suitability of temperature for mosquito breeding. As the figure all the study area is the temperature range between 23°C to 27°C, which is suitable for mosquito breeding. Finding similar with a study conducted by Alemayeh (2013) in east Shewa Fentale *Woreda* the temperature ranges from 21.9°C to 29.2°C and 99.7% of the area at high malaria risk level. Therefore, temperature of this study area is above 23°C highly suitable to mosquito breeding.

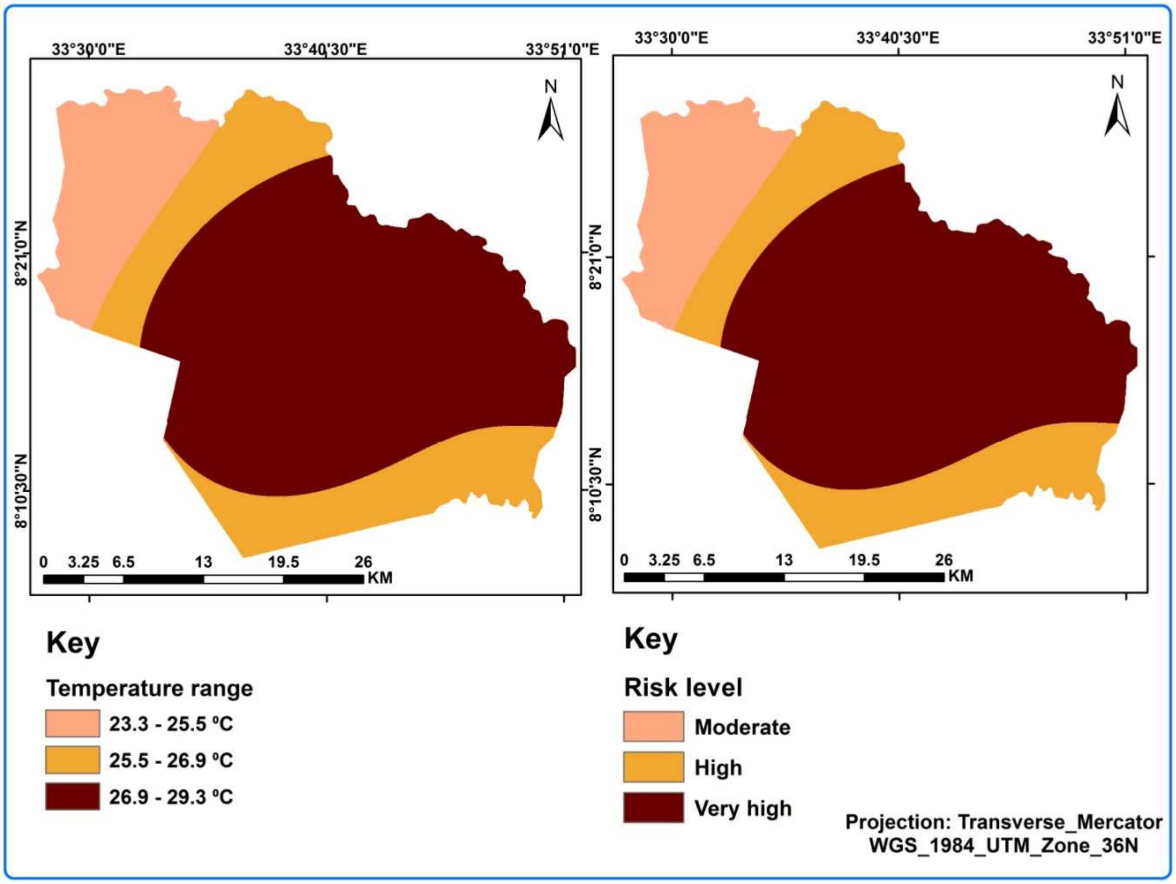

Figure 19. Reclassified temperature related malaria risk map

Source: National Meteorological Agency, 2007-2016

Table 10. Temperature related risk area coverage

New value	Risk level	Temperature range (°C)	Area km^2	Percent (%)
3	Moderate	23.3 – 25.5	215.31	23
4	High	25.5 – 26.9	478.06	42
5	Very high	26.9 – 29.3	444.69	35
	Total			100

4.1.2 Rainfall

The reclassified rainfall map Figure 21 shows that 223 km^2 areas have moderate risk of malaria, 366.54 km^2 and 444.69 km^2 areas have high and very high risk of malaria depending on the amount of rainfall. Based on the amount of rainfall, the whole study area is in very high and high risk of malaria.

Unlike a study conducted in Amhara north Shewa (Mame, 2016) argue that low rainfall associated favorable mosquito life and dropping high rainfall leads to destroy mosquitoes, thus assigned low amount of rainfall very high risk of malaria. While in this study the opposite is true, dropping of low rainfall has uncomfortable for mosquito life cycle. While similar finding observed a research conducted in Fentale *Woreda* (Alemayehu, 2011) showed that high amount of rainfall makes favorable for mosquito larva production site.

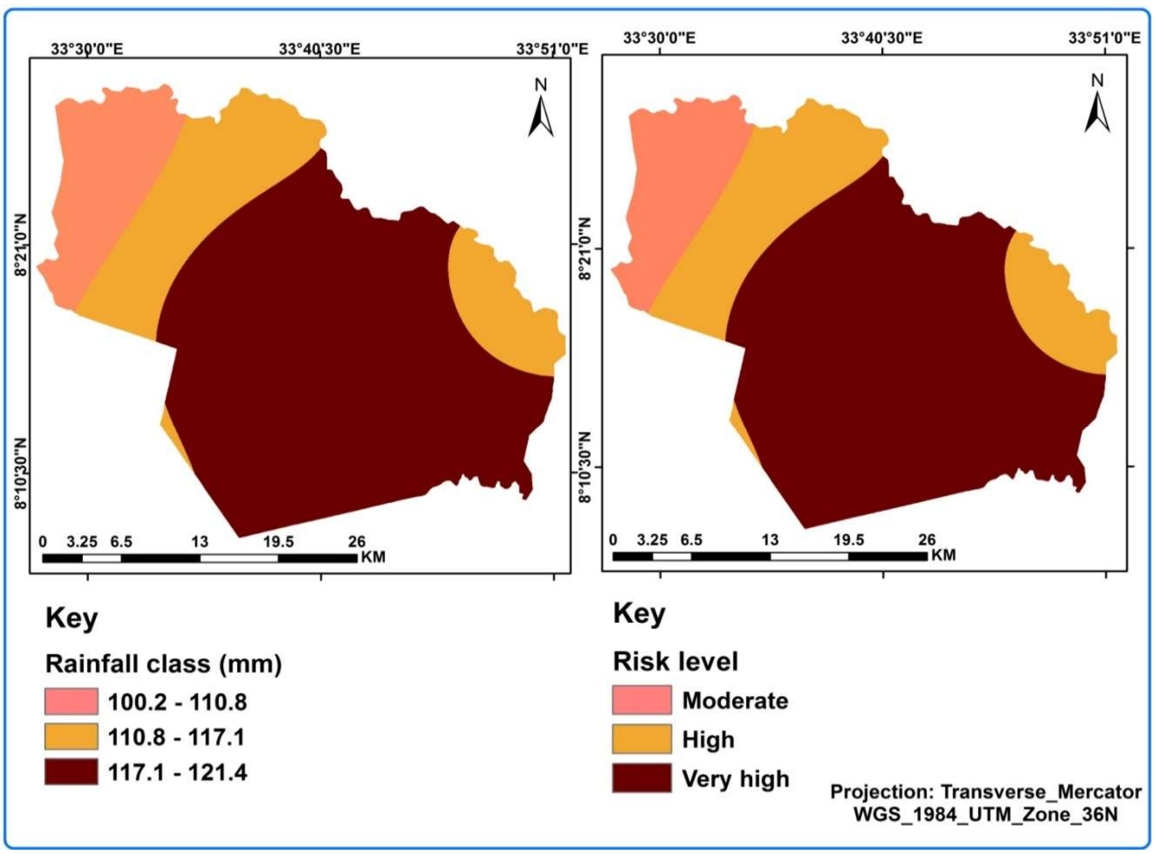

Figure 20. Reclassified rainfall related malaria risk level map

Source: National Meteorological Agency, 2007-201

Table 11. Rainfall related risk area coverage

New value	Risk level	Rainfall range	Area km^2	Percent (%)
3	Moderate	100.3-110.8	223.04	21.56
4	High	110.8-117.1	366.54	35.43
5	Very high	117.1-121.4	444.69	42.99
	Total		1034.27	100

4.1.3 Elevation

Figure 22 the reclassified elevation map covered 60.3% and 39.6%, were indicated high and very high malaria risk level respectively. 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 (WHO, 2013). But other determinant to malaria transmission should underestimate. A research conducted in Island of Timor described below 500 m.a.s.l classified into 0-20, 100-500, and >500 m.a.s.l coastal plain, low land plain and high land plain respectively. Thus classes have different potential to malaria exposure (Robert, *et al.*, 2010).

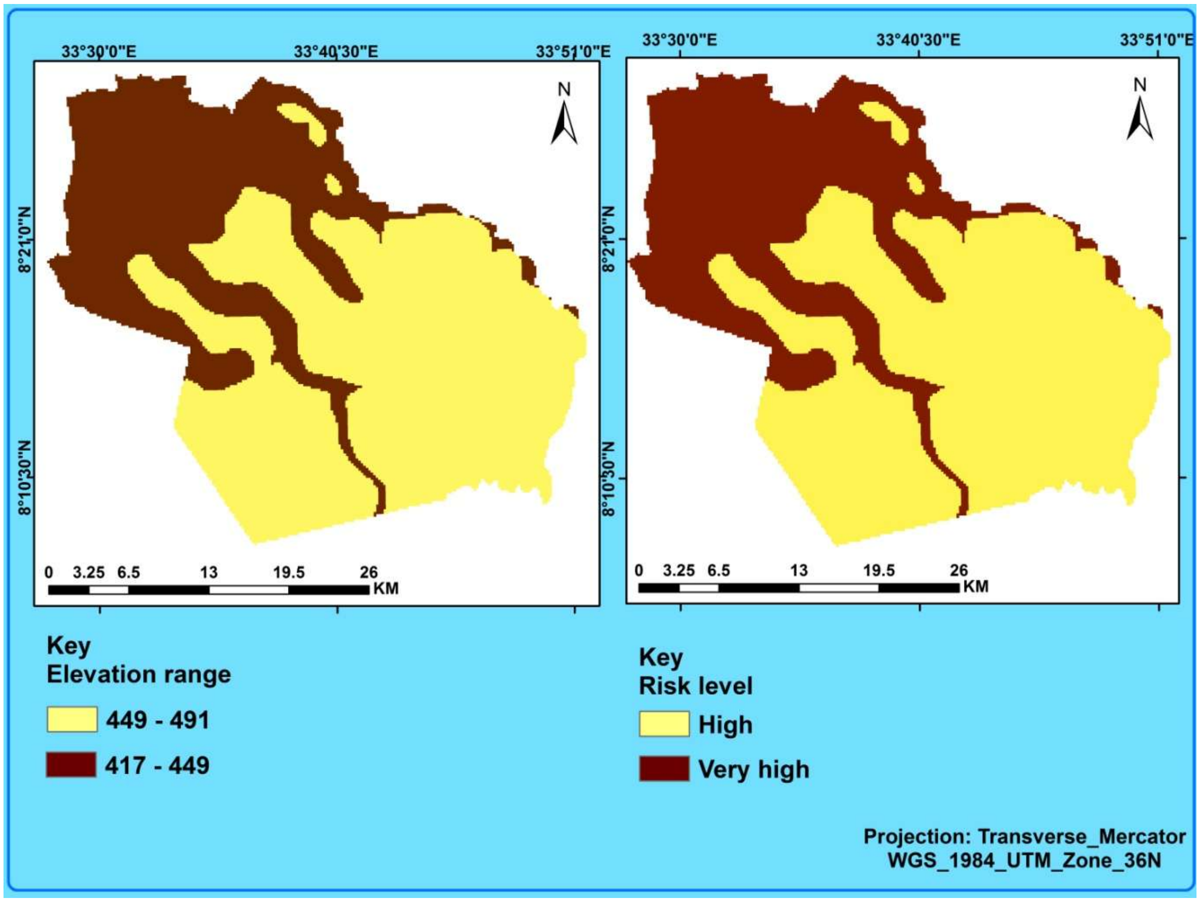

Figure 21. Elevation related malaria risk level map

Source: USGS – DEM, 2017

Table 12. Elevation related malaria risk area coverage

New value	Risk level	Elevation range	Area km^2	Percent
4	High	417-449	624.06	60.33
5	Very high	449-491	410.21	39.66
	Total		1034.27	100

4.1.5 Proximity to water bodies

A figure 23 shows that, based on the reclassified both proximity to water and swamp areas, half of study area 255, in very high risk; 185 and 16% is, high and moderate malaria risk level respectively. About 30% of the area fall in very low malaria risk area. Very high and high malaria risk observed in few areas located within 1 km and 2 km distance from lakes and swamps. So that less weighted value were given on hazard map production when compared with other factors. Settlements which located above 2km distance from any water body termed as low malaria risk level. This result similar with a study conducted in Fentale *Woreda,* summarized that areas located closer to (< 2000 meters) rivers, irrigation canals and lakes are in high risk of malaria than areas further away (Lemessa,2011).

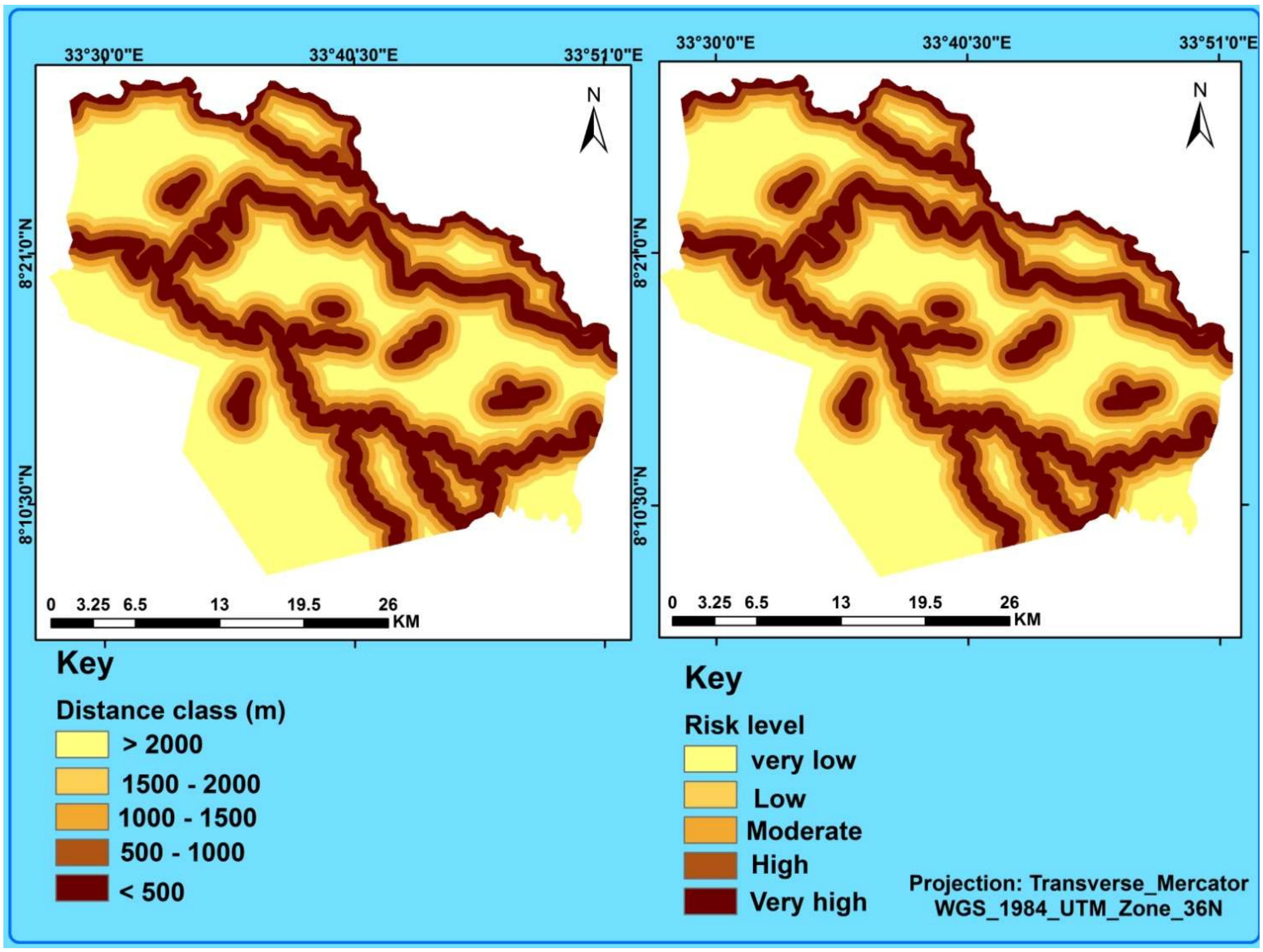

Figure 22. Water body related malaria risk level map

Source: USGS – DEM, 2017

Table 13. Distance to water body malaria risk area coverage

New value	Risk level	Distance range	Area km^2	Percent
1	Very high	< 500m	226.62	25.39
2	High	500m-1000m	190.26	18.39

3	Moderate	100m-1500m	165.23	15.97
4	Low	1500m-2000m	134.65	13.01
5	Very low	> 200m	317.50	30.69
	Total		1034.27	100

4.1.6 Soil

Figure 24 reclassified soil map shows that 48.82%, areas have very high, 36.94% high and 14% areas have low risk of malaria. Reclassification process was done based on water storage capacity of soils, which determines their suitability for mosquito breeding and reproduction of parasites. Vertisols and Fluvisols, those are poorly drained soils leveled as very high and high risk level respectively. Xerosols characterized poor water storage capacity were reclassified low malaria risk level. Study conducted in Arba-Minch (Mestawot, 2014) similar findings was observed. More than half of the study area is with Vertisol which rich water storage makes favorable condition for mosquito breeding.

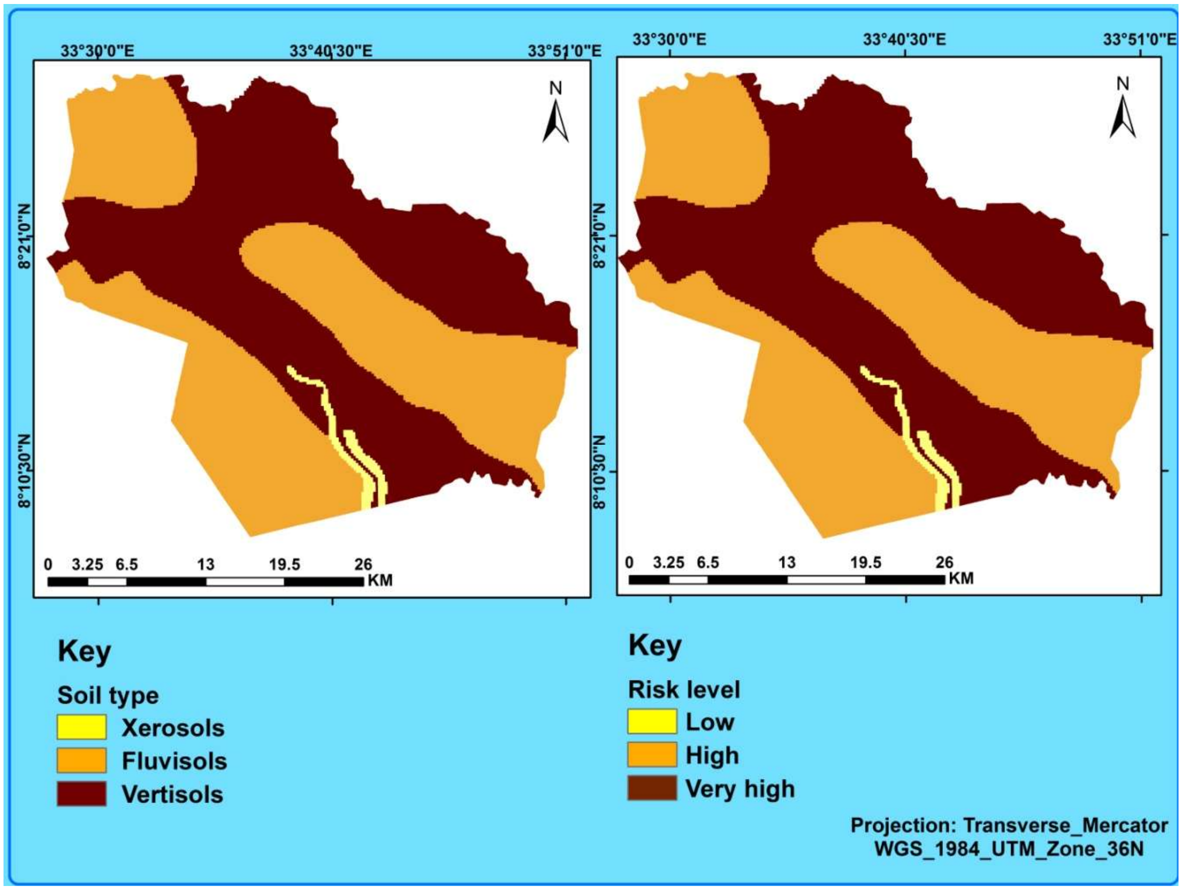

Figure 23 Reclassified risk level soil map

Source: FAO, 1984

Table 14. Soil related malaria risk area coverage

New value	Risk level	Soil type	Area km^2	Percent
2	Low	Xerosols	147.18	14.23
4	High	Fluvisols	382.14	36.94
5	Very high	Vertisols	504.95	48.82
	Total		1034.27	100

4.2 Socio-economic factors

4.2.1 Distribution of health centers

The reclassification health facilities in figure 25 shows that about 78% out of total area characterized high and very high malaria risk level. Only 15% of the study area at low risk which is peoples has access health service. Report made by UNICEF (2015) on South Sudan refugees declared when peoples live more than 3km are highly affected by malaria. These in turn influence the prevalence of a particular disease. Absence and distant health institutions result in difficulties in accessibility and high cost of treatment. Therefore, people who are near to health institutions are safer relative to those who are at farther places and takes lower risk level (MoH, 2008). Therefore, the study area lacks the minimum requirement of health services.

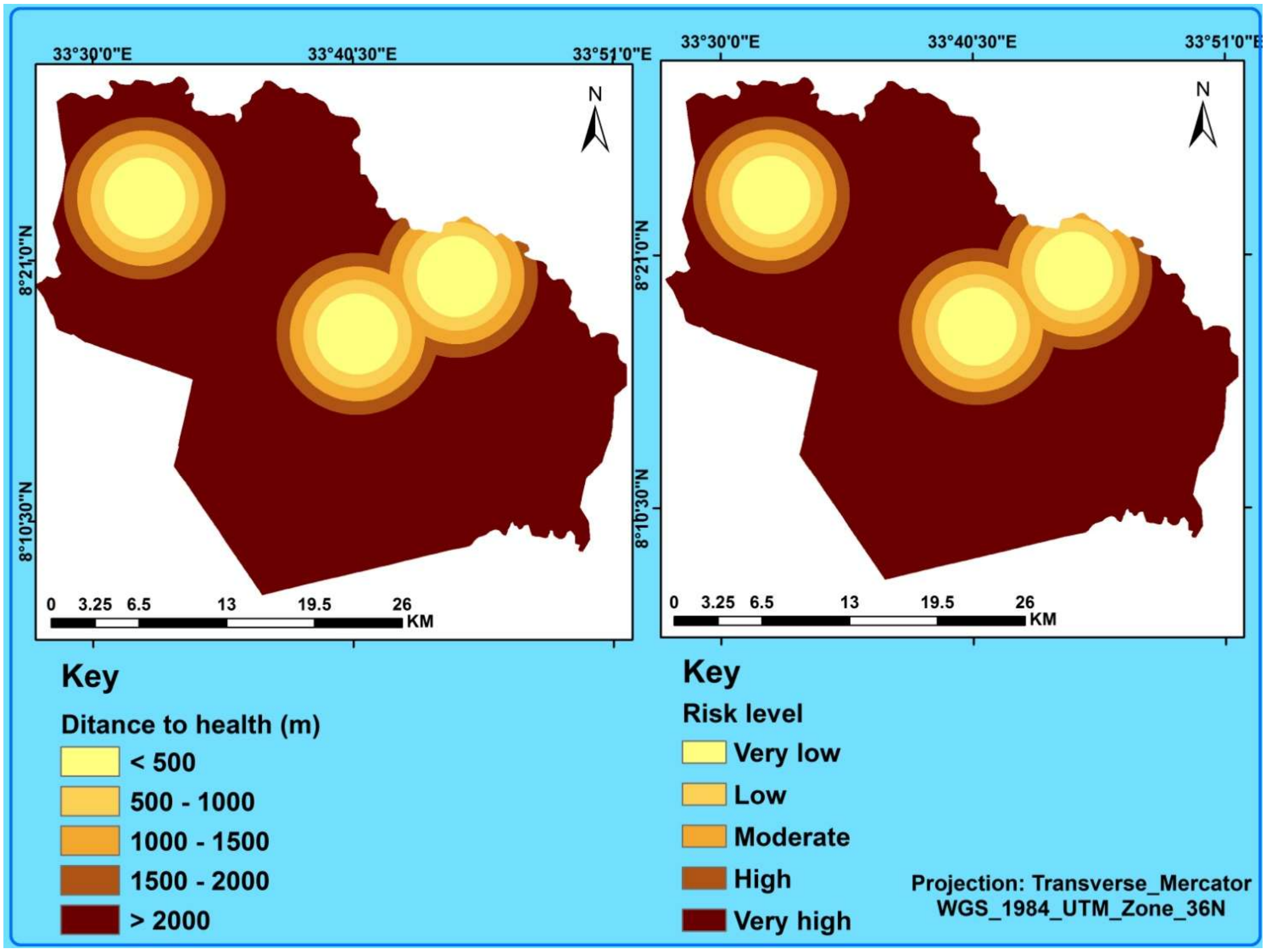

Figure 24 Distance from health centers related malaria risk level map

Source: *Woreda* health office and field survey

Table 15. Health service catchments distance area coverage

New value	Risk level	Health catchment distance range	Area km^2	Percent (%)
1	Very low	500m-1000m	84.74	8.19
2	Low	2000m-25000m	65.95	6.37
3	Moderate	1500m-2000m	72.99	7.05
4	High	1000m-1500m	78.10	7.55
5	Very high	> 2500m	732.48	70.82
	Total		1034.27	100

4.2.2. Population density related malaria risk

When population quickly increases, it becomes high demand to search and find to new habitats for the malaria vectors. Densely population have intensive work activities on environmental as well as in social can lead to more efficient transmission of the disease and thus enlarged exposure to infection over the population continuously (Prakash 2014).

Population distribution of the study area sparsely located. Figure 26 shows that the reclassified population data along the environment contained 45% of the study area lived from 1130 to 1320 populations. About 42% and 11% characterized in high and low malaria risk level. Especially in this zone household size is an important issue rather than population distribution.

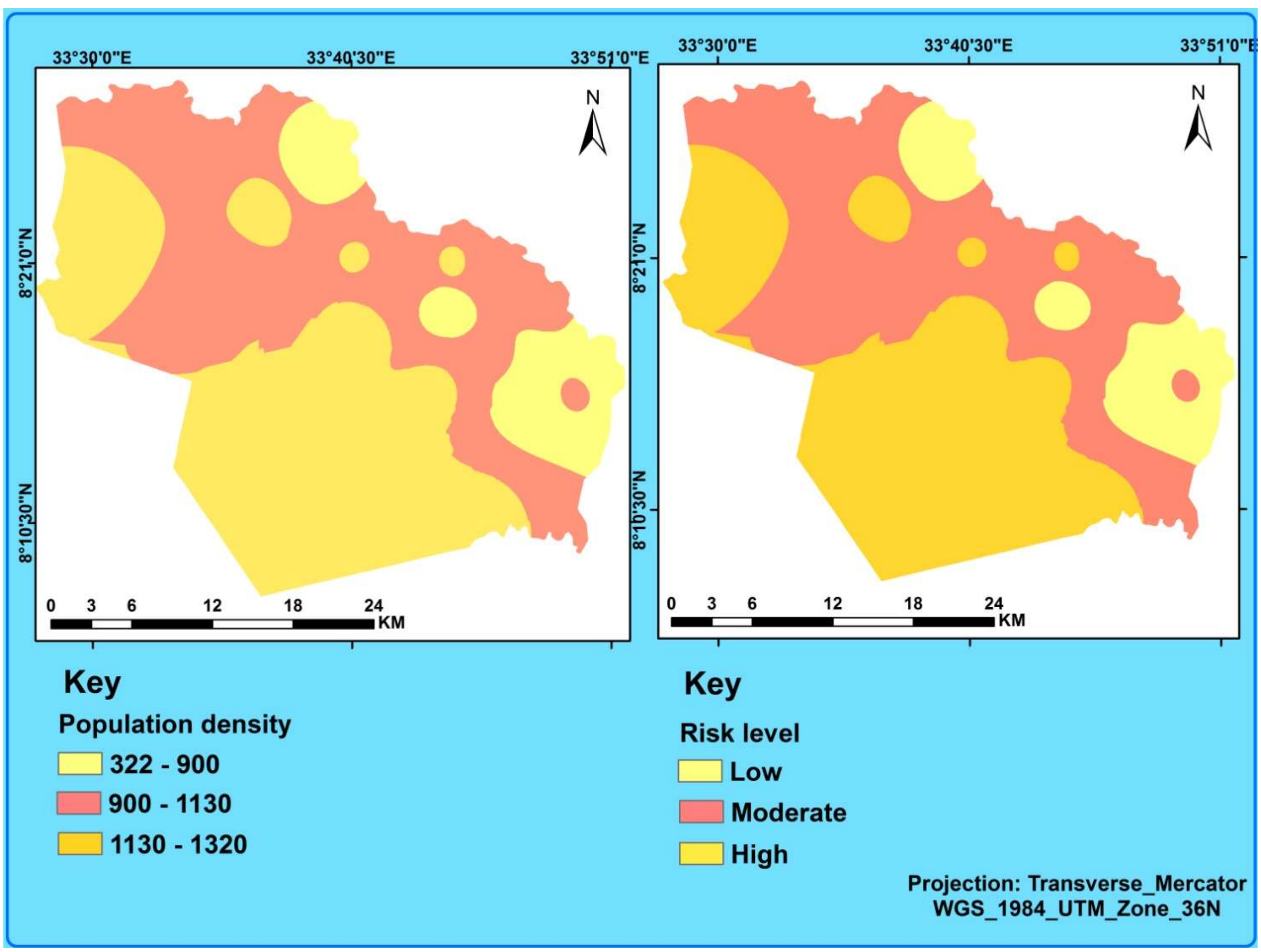

Figure 25. Reclassified population density map

Source: CSA, 2007

Table 16. Population density related malaria risk level

New value	Risk level	Population distribution range	Area km^2	Percent (%)
2	Low	322 - 900	123.58	11.94
4	High	900 – 1130	441.57	42.69
5	Very high	1130 - 1320	469.11	45.35
	Total		1034.27	100

4.2.3 Land use land cover (2017)

Figure 27 the reclassified land use land cover element at risk, based on many researchers finding indicated stable water body is more favorable for mosquito breeding than others and unused grass land covers about 47% at high risk level. Settlement area occupied 3.3% at moderate risk level, water body the smallest area coverage 0.3% very high risk level and 20% forests were very low risk level in the study area.

The type of land use land cover of study area especially large grasses land which surrounds highly suitable till it dry than vegetation and agriculture for breeding sites basically supply feeding for adult mosquitoes, and provided ideal sites for resting this conditions enhancing longevity of the vectors at the environment.

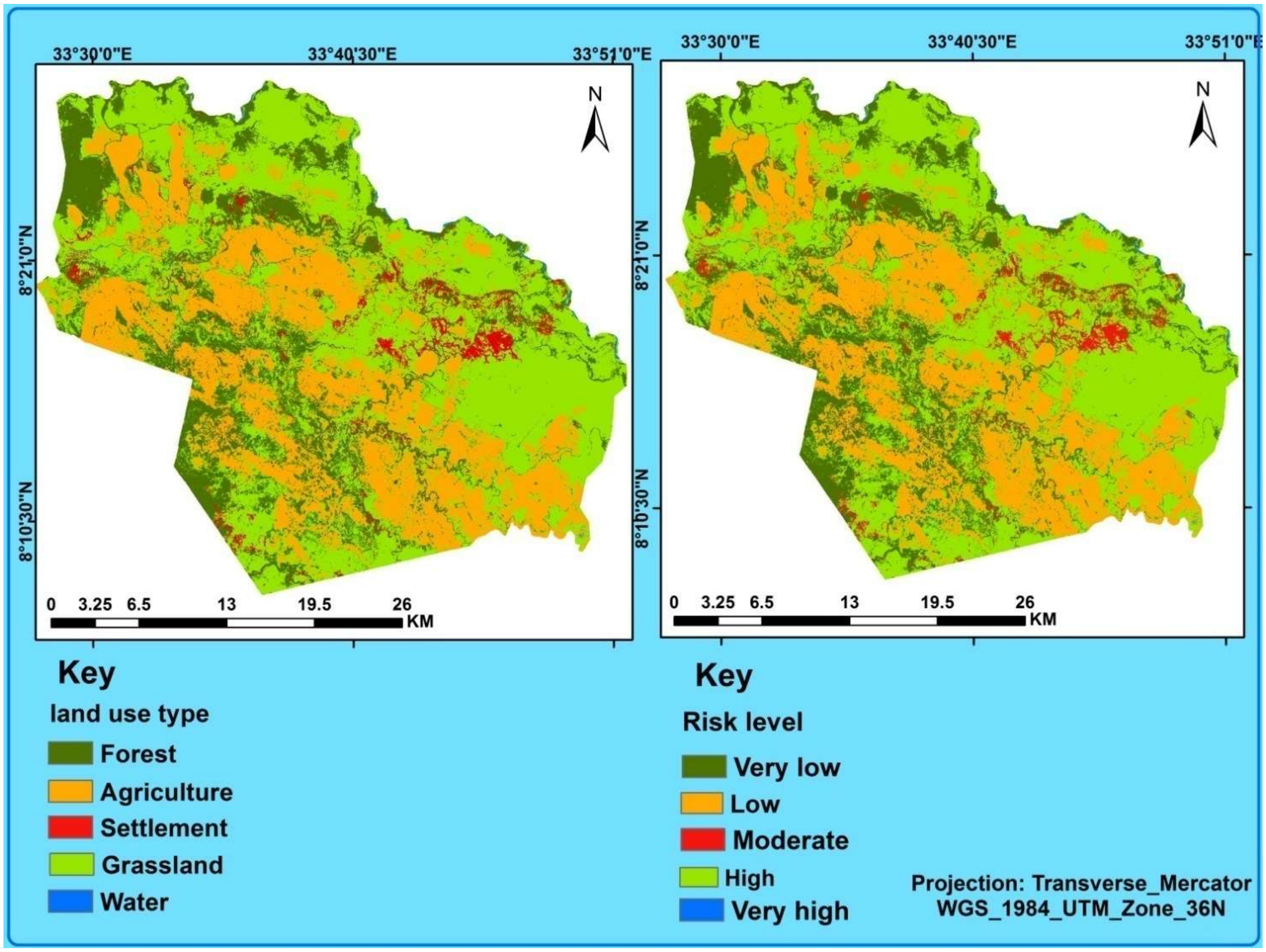

Figure 26. Reclassified land use land cover map and element at risk

Source: USGS – ASTER, 2017

Table 17. Land use land cover, area coverage (2017)

New value	Feature name	Risk level	Km^2	Percent (%)
1	Water body	Very high	2.70	0.3
2	Grass land	High	488.06	47.2
3	Settlement	Moderate	34.15	3.3
4	Agriculture	Low	303.86	29.2
5	Forest	Very low	217.43	20
	Total		1034.27	100

4.3.1 Hazard map

Five parameters were accepted to develop pair wise comparison matrix. After identifying for each weighted values the overlay analysis process comes next. Accordingly the malaria hazard map of the study area was produced. Malaria hazard map predictable that to 39.8%, 39%, and 20.9% were subjected to very high, high, and malaria hazard area respectively. About 80% of the study area exposed to high and very high malaria hazard risk level. Malaria transmission and mosquito life cycle more vantage points which environmental atmospheric with lower elevation and high temperature, water loaded areas, at flat slopes, and areas of lower drainage density (Negasi, 2008).

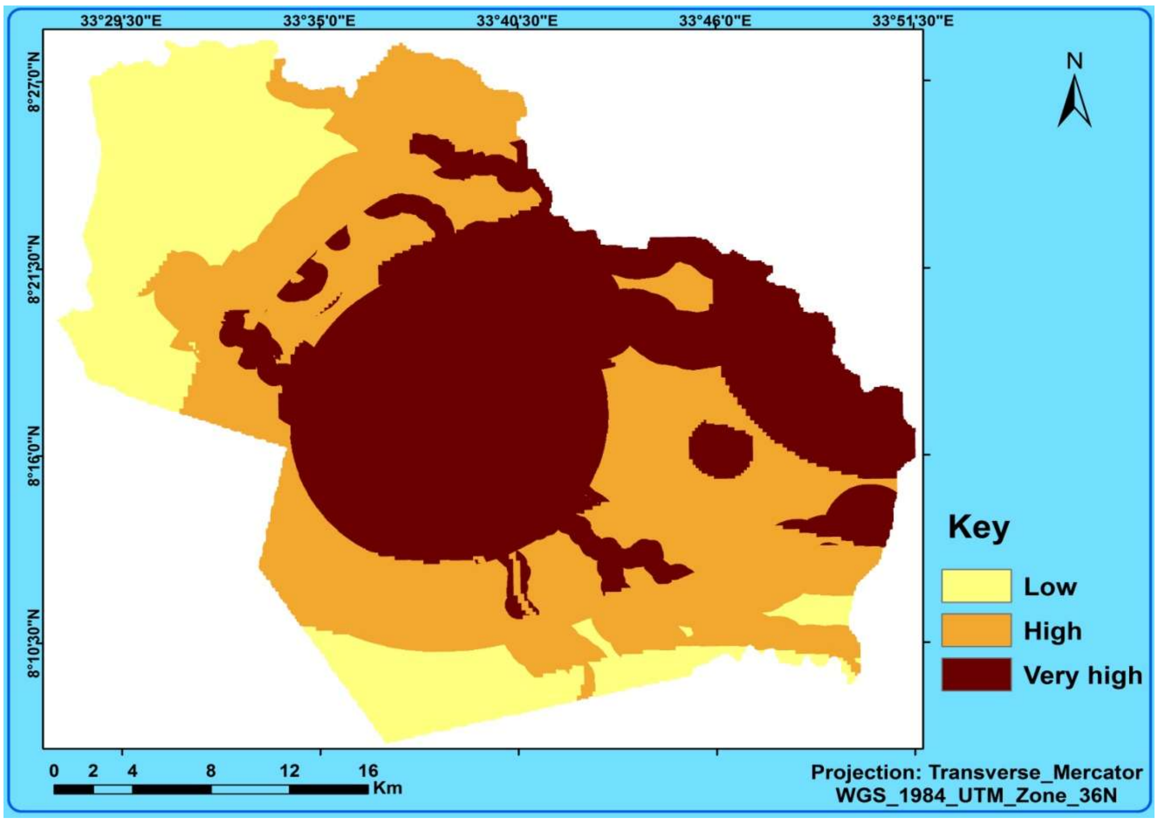

Figure 27. Hazard map risk level

Table 18. Hazard map area coverage

New value	Risk level	Area Km^2	Percentage (%)
2	Low	216.82	20.96
4	High	405.55	39.21
5	Very high	411.89	39.82
Total		**1034.27**	**100**

4.3.2 Vulnerability map

The reclassified vulnerability map indicated the largest area coverage occupied 31.43% very high vulnerable risk level, 56.61% subjected to high and 11.94% low vulnerability malaria risk level. From the result we can understand peoples are under peril situation they need quick follow-up treatment and pre medications activities. A people who live far from heath center and densely population areas were considered to be most vulnerable to malaria (Stratton, 2008).

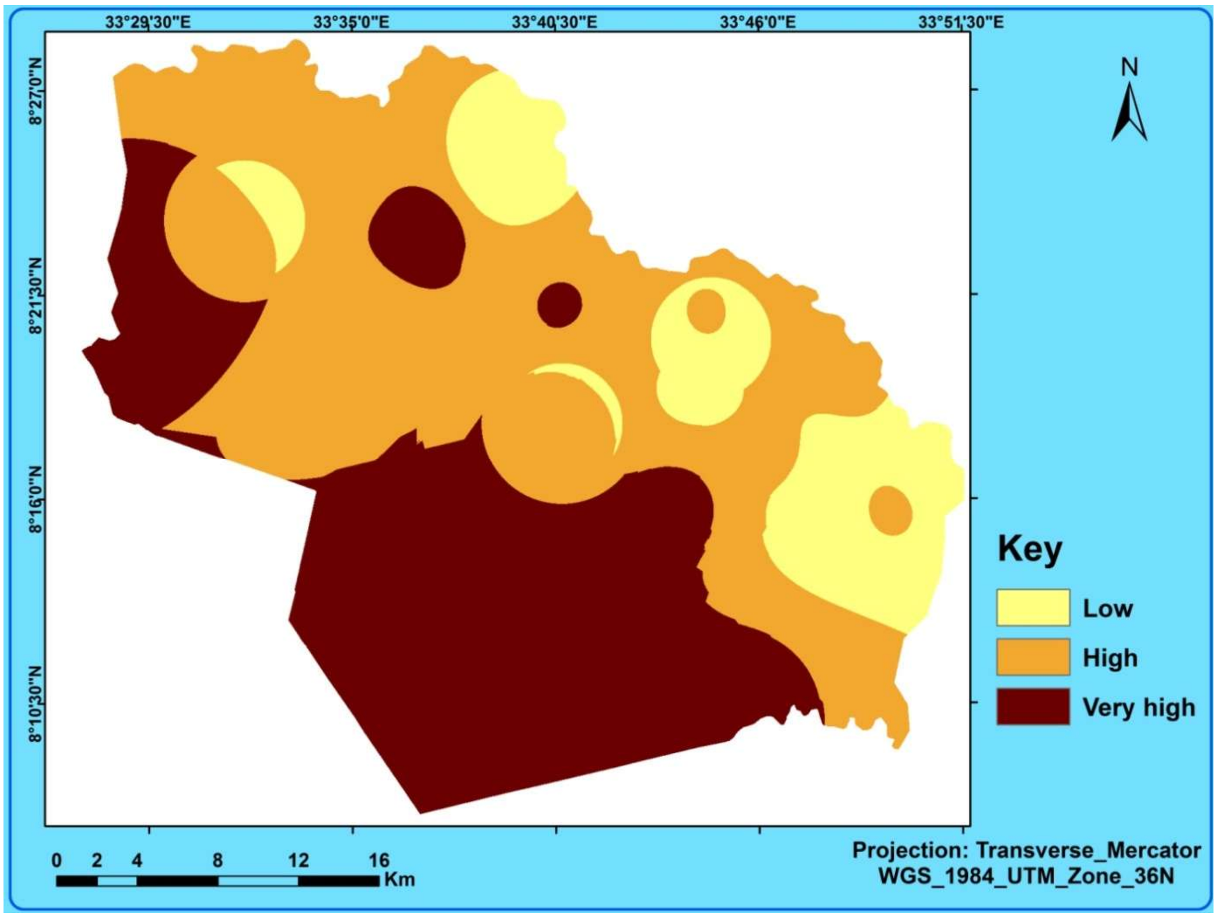

Figure 28. Vulnerability Map

Table 19. Vulnerability risk level and area coverage

New value	Risk level	Area Km^2	Percentage %
2	Low	123.58	11.94
4	High	585.58	56.61
5	Very high	325.11	31.43
Total		1034.27	100

4.3.3 Identifying areas of malaria risk

Based on the three basic element final malaria risk map was produced by using raster calculator in spatial Analysis Tool. As displayed below table the study area covers 1035 Km^2. Out of the total area about, 77.66 Km^2 indicated at low risk, 319.34 km^2 and 637.26 km^2 in high and very high risk level respectively. The risk map shows that majority of the study area fell 61.6% at very high, 30% high risk level and 7.5% of the area subjected to low malaria risk level. Even though malaria prevention strategies in Ethiopia intentionally practiced still malaria is a harmful disease in this study area.

This finding was contradicted with; a study conducted in Fentale *Woreda* east Shewa (Alemayeu, 2011) showed that a temperature range 18°C - 20°C, rainfall 550 – 100mm and elevation 862 – 1997 m.a.s.l were described as 7% , 93% and 0.1% subjected to high, moderate and low risk malaria respectively. A study conducted in west Gojam *Mecha* district with similar temperature 23°C - 27°C and rainfall 1000 – 2000 mm were indicated 0.23% as very high, 46% high, 51% moderate and 1.97% low malaria risk level (Emebet, et al., 2015). Besides, the study done in Jimma zone Kersa *Woreda* (Abdulhakim, 2014) about 4.1%, 11.6% and 26% of the area were very high, high and very low malaria risk area.

Similar study conducted in Kenya (Francis, 2016) showed that, an area temperature range 28°C - 28°C were more than 63% area coverage point out at very high and high malaria risk level. While, 18% and 37% were indicated low and moderate malaria risk area. In accord with this, report made from Sierra Leone showed that an altitude range from 320 – 800 m.a.s.l and temperature 24 °C - 35°C about 69% were subjected in to high and very high malaria risk level (WHO, 2015). Therefore, these studies supported to the present findings.

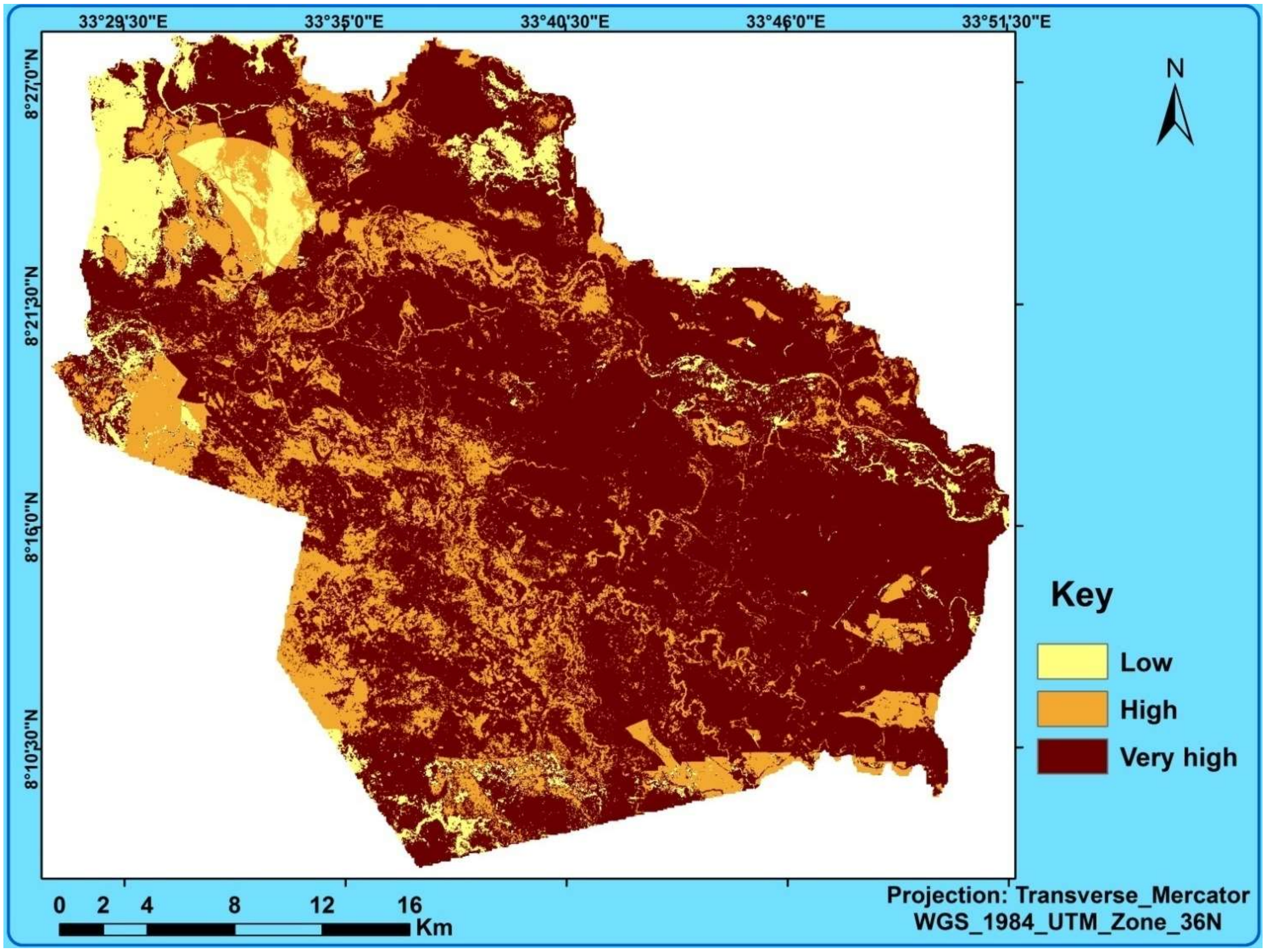

Figure 29 Malaria risk map of the study area

Table 20. Malaria risk level and area coverage

New value	Risk level	Area Km^2	Percentage %
2	Low	77.66	7.50
4	High	319.34	30.87
5	Very high	637.26	61.6
Total		1034.27	100

4.3.5 Socio-economic data analysis and interpretation

Data analysis and interpretation were processed based on the objective stated and nature of the problem that data collected, different statistical methods were used in this study. The percentage and graph was used to analyze the characteristics of respondents such as household size, age, sex, income, status of households. The mean score was also used to identify which of the item is rated above average to be considered among the major factor highly association demographic characteristics of households.

Out of 125 distributed questionnaires three of them were not returned and four of them were not completed. There were 119 questionnaires and with five key informant health officials' interview was conducted. Therefore, the total 124 respondents were involved or about 95% successful.

Table 21. Number of households in *Kebele* and number of selected households

No.	Name of *Kebels*	Total households in Kebele	No. of household Selected	Selected households in (%)	Remark
1	Lomgjiok	335	36	28.8	Village
2	Nybukliek	291	32	25.6	Village
3	Nyinenyang	276	29	23.2	Town
4	Adura	254	28	22.4	Village
Total		1164	125	100 %	

Source: Field survey, March - April, 2017

Table 22. Questionnaire distributed and retrieved from households

No.	No. of household selected	No. of questionnaire distributed	No. of questionnaire retrieved	Questionnaire retrieved (%)	Remark
1	36	36	35	97.2	Village
2	32	32	30	93.7	Village
3	29	29	29	100.0	Town
4	28	28	25	89.3	Village
Total	125	125	119	95.2 %	

Source: Field Survey, March - April, 2017

4.4.1 Socio-economic characteristics of respondents

Respondents' frequency is classifieds in to four groups includes demographic characteristics, socio-economic, impacts of malaria and controlling mechanisms to be taken by government and residents.

A demographic characteristics respondent of the study area was summarized in Table 23 from the total respondent 119 samples were between age 20-30 (7.5%), about 59 the age range, 31-40 (49.6), 37 (31.2) respondents from 41-50 years and the remaining 14 (11.2) respondents ware above 50 years. Therefore the highest percentages of respondents of the study area were under the range of (31-40) years and this age group said to be active participation on working.

Table 23 indicated that, 42.8% respondents owned highest household size constituted from 4–6 members; more than 7 members accounts 31%, while below 3 members were accounts 26.1% respondents were replied. Therefore, we understand this study area shared large household size. According to the study conducted in Arba Minch by Yarcho (2011) results showed that large household size were more affected by malaria than small households' size.

Religion and household size are well interrelated, especially in the developing countries. (Paden, 2008) observed that religion as sacred engagement that is believed to be a spiritual reality. Some cultures recognize polygamy— that is, marriage to more than one wife or husband at a time and culturally polygamy is practiced in this zone as rather than religious; Table 4.10 shows that 43.7% households have two wives, 21% have more than three wives and 35.3% of households have one wife. Therefore, polygamy practices have negative impacts on controlling malaria may causes lapse the strategies and required extra costs.

Table 23. The demographic characteristics of the study population in Makuey *Woreda*

Characteristics	Frequency	Percentage
Age:	-	-
20-30	9	7.5 %
31-40	59	49.6 %
41-50	37	31.2 %
>50	14	11.2 %
Sex:	-	-
Male	95	79.8 %
Female	24	20.2 %
Household Size:	-	-
1-3	31	26.1 %
4-6	51	42.8 %
>7	37	31.1 %
No. of Wife per household	-	-
1	42	35.3%
2	52	43.7%
3	25	21%
Total	119	95.6

Table 24 Illustrates educational status of sampled respondents represent 69 % was illiterate; 13.4 %, 7.5% and 5.8 % respondents were writing and reading, primary school and secondary school respectively. The remaining 4.2 % respondents college and above they are the only educated that involved in governmental and other sectors. Greater part of the study area which the former generations were not educated.

Income of the study area estimated based on which they receive salary from government, other institutions and abroad nations. Table 24 respondents' result shows that 41.2% respondents' 500-1000 ETB income they gate. Followed 31.1% respondents received 1000-2000 ETB and less than 500 ETB, it accounts 12%, besides about 12% and 5% respondents their income receives 2000-3000 and above 3000 ETB respectively. Generally the highest population of study area is under low economic activities.

Table 24 shows the number of livestock 34% respondents shares the highest livestock from one to ten they owned. Secondly from 11-20 numbers of livestock per household replied 32% respondents, Also 21-30, above 30 livestock's answered the question 22.6%, 6.7% respectively. While, 5 respondents said that have not animals. Therefore majority of households of the study area lived with successive number of animals, and they forced to keep them at night time and remote areas very far from their residents. When children sleep outdoor mosquito can inject simply them.

Just the study area is located geographically at low land plain surface most of rural house type was built by mud and grasses. Below table indicated 83.2% of respondents live in conventional type of house. About 12.6% and 4.2% respondents replied made of mixed cement with mud and *Blocket* respectively. Even though those house majorities of respondents indicated in Table 24 is, 47.9 %, 23.5% were sleep in two and one class per house respectively. Besides, it shows that 95% respondents seasonally they sleep outside of house, thus occurs due to the high temperature receive the environment and keeping animals at night 62.2 % and 21 % respectively.

Regarding to the accessibility of health center 47.1 %, respondents were travel 1-3 Km 36.1% grater than3 Km and 16.8 % less than 1 Km. Due to the high temperature area traveling to health center is challenging and no transportation access.

Table 24. The socio- characteristics of the study population in Makuey *Woreda*

Characteristics	Frequency	Percentages
Educational status:	-	-
Illiterate	82	69 %
Reading & Writing	16	13.4 %
Primary School	9	7.5 %
Secondary school	7	5.8 %
College Diploma & Above	5	4.2 %
Income in Ethiopian Birr:	-	-
<500 Birr	15	12.6 %
500-1000 Birr	49	42.2 %
1000-2000 Birr	37	31.1 %
2000-3000 Birr	12	12 %
>3000 Birr	6	5 %
Housing unit:	-	-
Mud & grass	99	83.2 %
Mud with cement	15	12.6 %
Blocket	5	4.2 %
Total	119	95.6 %

4.4.2 Assessment the impact of malaria

Study population survey results on impact of malaria were summarized on table 25. As a result that majority of the respondents 100 % indicated, their families were affected by malaria in the past ten years.

Regarding the age group affected by malaria in each household 37% of respondents replied children under 10 age, thus highly affected with in a household. The age group, 11-20 and above 40 were affected proportional percentage, 20% and 16.8% respectively respondents replied. The productive group were less affected by malaria when compare to the other age group. From the result it concluded that children because of low nutritional feeding system.

Majority of respondents 32.8% replied about one month takes time patients return to their normal condition. 22.7% and 29.4 % respondents' rates within one week and two weeks return to normal condition respectively. Also 15.2% respondents replied more than a month. Thus discussion showed as all age group students, labors and mothers under risk of malaria.

Concerning to the malaria risk level, 45.4% and 39.5% of respondents answered as malaria has very high and high impact on their health status as well as in economy, 15.2% of sampled respondents replied that malaria has moderate impacts, 5.9% indicated low impact of malaria and the remaining 2.5% said no impact on their economy. Therefore, from the above data we can conclude that most of the respondents‟ economy was affected by malaria due to their infection.

Table 25. Malaria severity in the study area

Characteristics	Frequency	Percentage (%)
Age group affected by malaria the past ten years	-	-
<10 years	44	37
11-20 years	24	20
21-30 years	14	11.8
31-40 years	16	13.4
>40 years	20	16.8
Time required to return to normal condition	-	-
One week	27	22.7
Two weeks	35	29.4
Three weeks	39	32.8
> 1 month	18	15.2
Rating level of malaria impact	-	-
Very high	54	45.4
High	47	395
Moderate	18	15.2
low	7	5.9
Total	119	95.6

Respondents replied that, 54.6% more than 3 people, 27.8% three member of household, 13% two people, and 4% one person affected by malaria in a year. From the result we can understand the frequency may vary by other factors but, no one person lives without malaria throughout the year.

The above two paragraph described quantity and age group affected by malaria within household. Besides regarding the repetition of malaria disease for one person in a year; Table 25 shows that, 58% respondents were replied two times in a year, 17.6% one times thorough out the year, 15% and 9.2 % replied 3 and above 3 times respectively malaria disease frequent in one year. Therefore the study area have high risk malaria zone.

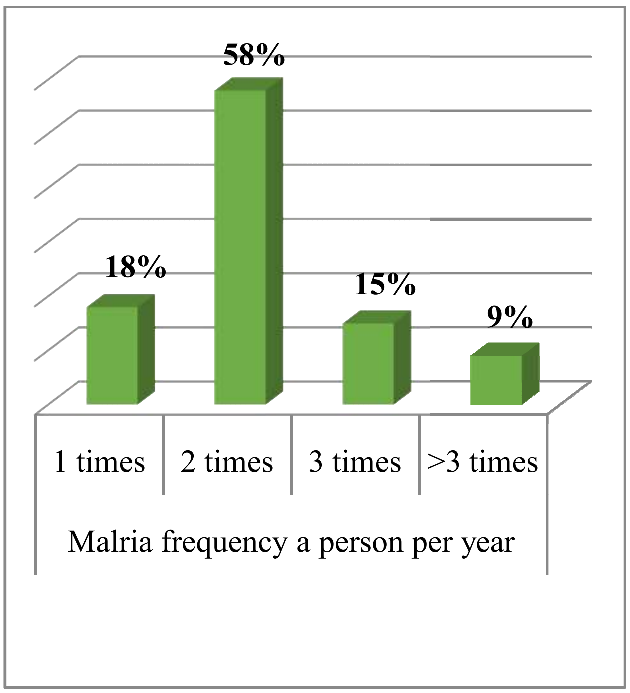

Figure 31. Malaria repetitions over one person

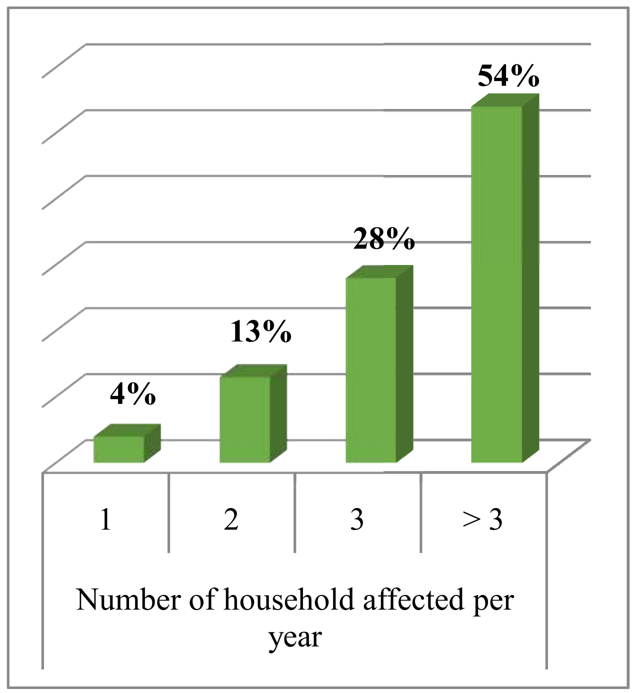

Figure 31. Number of household affected by malaria per year

Source: Field survey, 2017

4.4.3 Intervention mechanisms to control malaria by government and residents

Table 26 of the respondents 42.6% replied that insecticide treated bed net (ITN) is most important mechanism to control malaria; 17.5% replied taking tablets; 15 12.6% shows that they used insecticides spraying; 7.6% indicated environmental sanitation and the remaining 5% and 3.3% replied that using local cotton and smoke from burning leaves respectively. Therefore, from this we can understand that using ITN is the leading prevention method that is used by the residence in the study area.

This result is similar with research conducted in Tanzania also shows ITN as leading means of malaria protection (Mazigo et al., 2010). On the other hand, other findings in central part of Ethiopia reported chemoprophylaxis as the major prevention method (Mengistu and Wakgari, 2009). So, the variation of in different studies its findings could be probably recognized to differences in accessibility, variations in topographic structure and level of awareness in using preventive methods from place to place.

In case of who used ITN in the study area respondents frequency were 27.7% respondents replied the whole family were used; 21% answered father and mother only; about 32.8% participants said children; while 18.5% were not used. Thus result shows as ITN is not distributed to all household size these possibilities were people exposed to high malaria risk.

Because of high incidence of malaria there are many supplier of ITN in Gambella region. Majority of the respondents42.8% got ITBN from government trough local health center; and most of them 29.4% bought from drug vendors. While few of them received from NGOs and religious institutions. From the result we understand government only impossible to access ITN to all household members.

Regarding the treatment of malaria societies have some alternatives rather than going to health center. Majority respondents 51% were treated in health center; 26.9% were bought a tablet from pharmacy themselves without scientific diagnosis; 21.1 % respondents replied they treated traditional method like, drinking excessive alcohols and smoking tobacco (for old persons), were used throughout their life experiences. Why those methods adopted in their life experience, due to the low accessibility of health service for villages.

Even though ITN distributed during high malaria season, respondents described that ITN used for other purpose, 42.8% used for home built, 17 % for fishing activities, 10% for distillation purpose and 26% used for effective purpose.

Table 26. Controlling and prevention mechanisms on malaria

Characteristics	Frequency	Percentage (%)
Malaria prevention methods	-	-
Taking tablets	21	17.5 6%
insecticide treated bed net	50	42 %
insecticide spraying	15	12.6 %
Using local cotton sheet	6	5 %
Environmental sanitation	9	7.6 %
Using smoke from burning leaves	4	3.3%
ITN suppliers	-	-
Health center	51	42.8 %
Drug vendors	35	29.4 %
Religious institution	5	4.2 %
NGOs	14	11.7 %
Extra purpose of ITN	-	-
Fishing activities	21	17.6 %
Home built as lasso	51	42.8 %
Drinking Purification	12	10 %
used for preventing	35	29.4 %
Total	119	95.6

Concerning to the number of ITN distributed per household, 53% of respondents possess one ITN; 23.5% had two ITNs; 16% of respondents had three ITN for each household and the remaining 8% of the respondent indicated they got more than three ITNs per household. According to the respondents about 73% of the study area constitutes 4 and above persons live in one home. But, 28% respondents had above 2 number of ITN used in household. Still there is shortage of ITN in the study area in addition ineffective using ITN observed.

About 80% respondents replied they population were settled far from health center so that, distance vary from place to place according to the result; 57.1% of them had travel more than 3 km; 26.1% respondents traveled about 3 km; while 16% have access the health facilities which they travel less than one km. Therefore, malaria treatments should access to entire study area and in scientific way of ordered by connoisseur person.

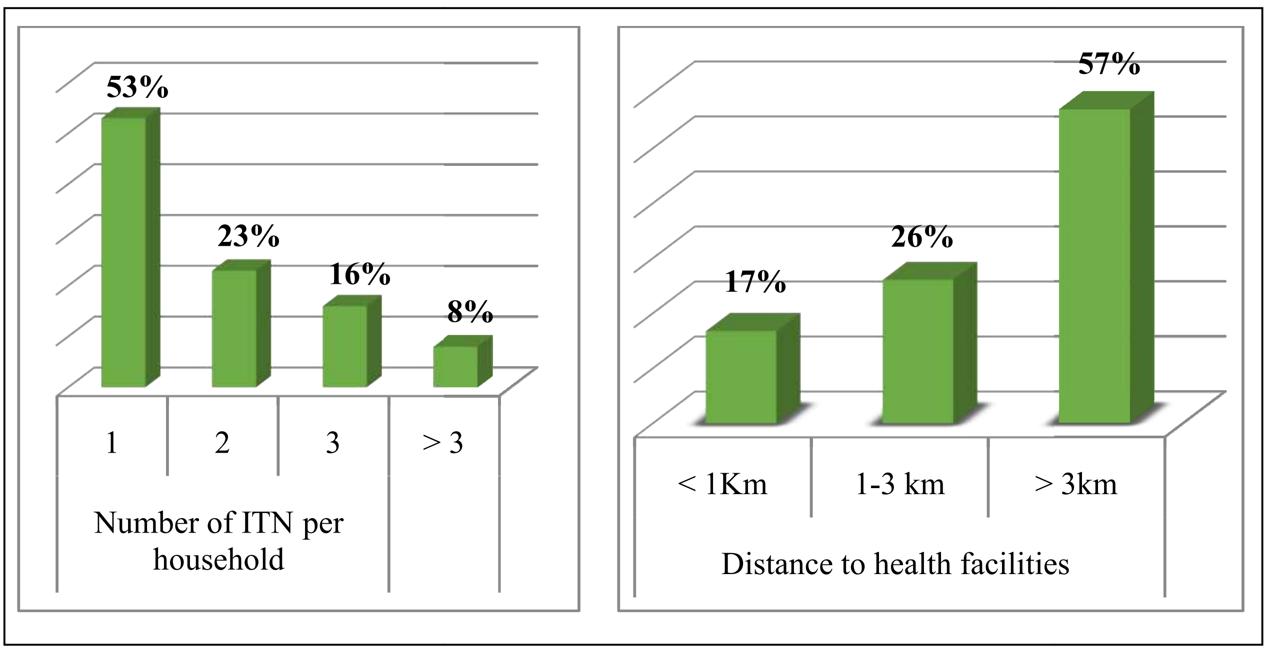

Figure 32. Respondents' frequencies number of ITN in household and distance to health facilities
Source: Field survey, 2017

As stated in the objective this study were try to integrate both environmental variables through GIS-bade and socio-economic characteristics through questionnaire surveying from sampled household in four *Kebeles.* Each data were processed separately based on necessary parameter requirement for environmental and socio-economic factors. To sum up according to the environmental factors' findings shows that, about 7.5% the area coverage exposed to low malaria risk level and 92.5% of the total area subjected to high and very high malaria risk level.

To realize environmental factors whether the finding is satisfied or not the researcher further investigation were conducted through interview and questionnaires distributing from sampled households. Thus an average result of four *kebeles*; about 88% household members were affected by malaria, 69% of sampled HH were illiterate group of societies, 83% respondents owned traditional house unit made up of mud and grass, 71.% one member of HH affected more than two times per year and 63% of respondents married two and above wife. As a result based on different literatures largest percentage of the study area was subjected to high and very high risk of malaria. Both environmental and socio-economic factors similar results and finally by overlaying sampled HH in one malaria risk map were produced. See figure 34:

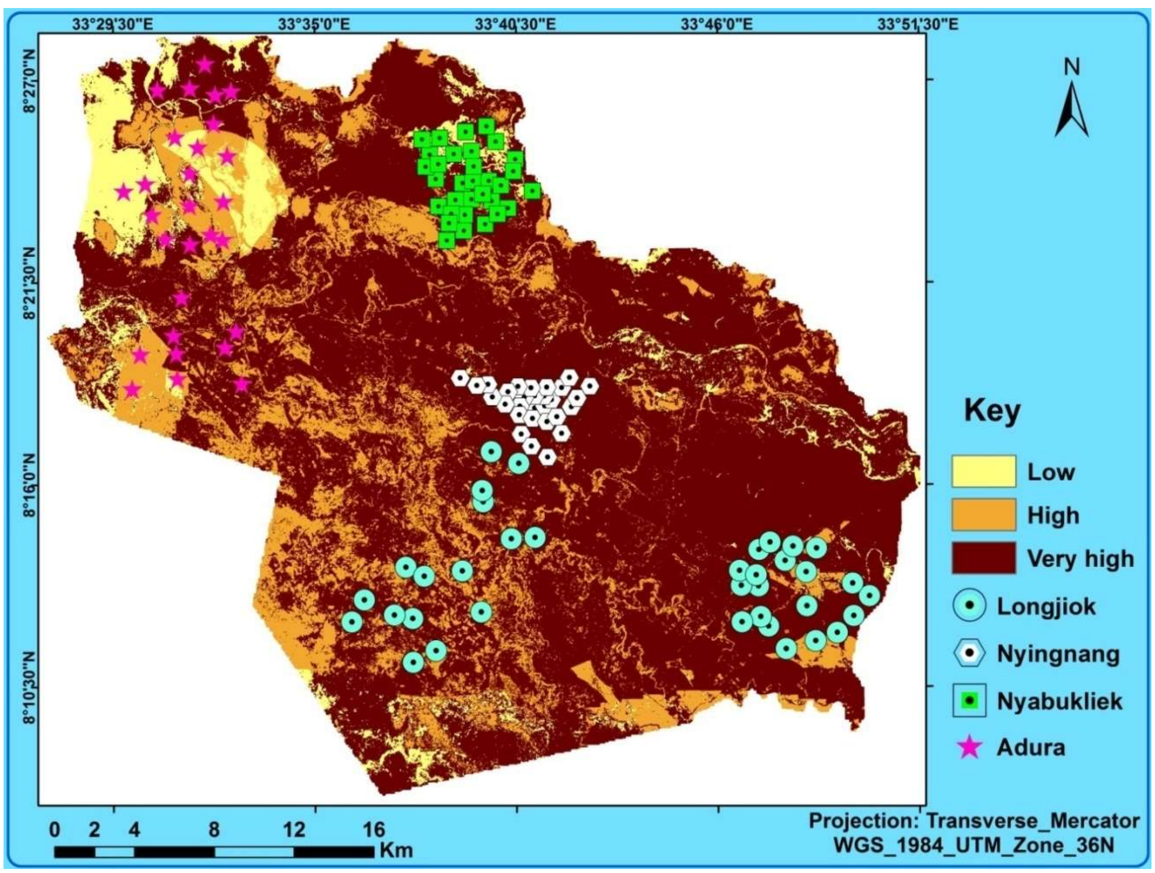

Figure 33. Malaria risk map with sampled household at *Kebeles*

CHAPTER FIVE

Conclusion and recommendation

5.1 Conclusion

The main aim of this study was the new GIS-approach that better visualizes malaria risks in Makuey Woreda, South Western Ethiopia. In addition Socio-economic data was collected through questionnaires from sampled population. Questionnaire items like demographic characteristics, impacts of malaria in community and mechanism to control malaria in the study area were included.

Out of the total area malaria hazard map predictable that to 40%, 39%, and 20.9% were subjected to very high, high, and low malaria hazard area respectively. About 80% of the study area exposed to high and very high malaria hazard risk level.

According to the element at risk or land use land cover analysis grass land covers about 47% at high risk level. Settlement area occupied 3.3% at moderate risk level, water body the smallest area coverage 0.3% very high risk level and 20% forests were very low risk level in the study area. Regarding to the vulnerability risk analysis the largest area coverage occupied 60% very high vulnerable risk level, 20% subjected to high and 19% low vulnerability malaria risk level.

Malaria risk analysis was produced by multiplying hazard, vulnerability and risk at elements in ArcGIS Spatial Analysis Tool using raster calculator. Its products out of the total area that majority of the study area fell at very high risk level 61% and followed 31.5% of the area subjected to high risk level, and low malaria risk level accounts only 7.5% of the total area.

Regarding the socio-economic data was analyzed their magnitude in frequency and percentage form. Most of respondents in each *Kebele* replied that their families were highly affected by malaria. Large household size highly correlated with malaria prevalence in the study area. Societies ITN used for another purpose like fishing activities, home building etc. Even though they used ITN to prevent malaria there is shortage of ITN access in majority of the study area. Households agreed that using ITN properly is the only option for malaria prevention, but the less awareness of communities leads to low utilization of ITN. Other preventive mechanism also used like seasonal house spraying, environmental sanitation and ITN distributing. However, still malaria is highly branch out and affected health situation along the residents of study area. From the result we can understand peoples live in this zone are under peril situation they need quick follow-up treatment and pre medications activities from concerned body.

5.2 Recommendations

As the finding of this study depicts that a small number of populations live in large boundary area. The large number of households and married more than one wife (polygamy) is culturally accepted in this ethnic groups leads to increase fertility rate in the region. Therefore based on the findings the researcher was providing the following recommendations.

- The resettlement program plotted by government, the *Woreda* administration should give attention for accomplishment of mission, so all infrastructures and service equally accessed to peoples. Besides regional government should try to avoided the outlook polygamy practice and improve moderate fertility rate to sustain economic status of children will develop strong body immunity.

- Considering the harsh climatic condition, the *Woreda* health office should construct health center a peoples who live far from the town. Based on the above malaria risk level, areas should categorize and performed the decision for first aid treatment should for preliminary shabby peoples and children.

- According to the respondents claim that using ITN effectively best option of malaria preventive methods, the *Woreda* health office should identify the best malaria prevention and control program like, anti – malaria drug provision, bed net distribution and house spraying by prioritizing based on the risk level of areas. And should be create strong link with government and nonprofit organization to fulfill the shortage of ITN in the study area. ITN distribution could give prioritizing for village areas which health center cannot accessed.

- Since the community have poor awareness about the modes of malaria transmission and control measures, health education targeting the population at risk will be necessary. The *Woredas'* health professionals should actuate peoples to keep their environmental sanitation and to cover over swamp areas surrounding their home.

- Proper data bases about detail patient data, the seasonal incidence of epidemics and about other related aspects of the malarias *Kebeles* should be made using GIS

- Based on malaria risk map it is essential to establish strong early warning system

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

- Being in this project try integrating socio-economic factors with environmental variables only with sampled household but, identifying each household characteristics of the entire study area makes more accuracy for identification of malaria risk zone so makes easier to control. So that other researcher or organization should be to study on this issue.

- Generally, the integrated method of data analysis GIS-based and socio-economic factors predetermination of malaria risk area helps management and control strategies over malaria transmission that conducted either by government or NGOs become effective. If all the above efforts could be supported by the output of malaria risk map, the result of prevention and control over malaria would be better than today's situation.

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Appendix 1

JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

Questionnaire for household survey

Dear Sir/Madam,

Objective: the main purpose of this questionnaire to gather information from sampled household about malaria prevalence that helps to develop malaria risk map which shows hotspots area Gis-based in Makuey woreda as partial fulfillment of the requirements the degree of Master of Science in GIS and remote sensing,.

On this year 2017 I am in accomplishing my study at Jimma University in M.sc program which a research title on malaria risk assessment: in Makuey woreda Gambella western Ethiopia. In this regard, I'm kindly requesting for your support in terms of time, and by responding to the attached questionnaire. Your truthful response will be crucial in ensuring the objective of research. The information gathered will only be used for the study and shall not be used to victimize any one and the respondents will remain anonymous and their names shall not be revealed to anyone.

Thank you for your valuable time on this.

Yours faithfully

Instructions:

For each of the following questions, please put a circle your answer that best describes the situation from given alternatives when you respond to the closed end questions (when necessary you may circle more than one options) and please also fill in your opinion in the blank space that provided where required for open ended questions.

I. General Information

1. Area identification

    A. Village___________

    B. Household No.____________

    C. Number of wife per husband

    1. One 2. Two 3. Three

2. Age:

    1. 20-30
    2. 31-40
    3. 41-50
    4. > 50

3. Sex:

    1. Male
    2. Female

4. Marital status:

    1. Married
    2. Single.
    3. Divorce
    4. Widow

5. Educational status:

    1. Illiterate
    2. Reading and writing

3. Primary school

4. Secondary school

5. College diploma and above

6. Others (Specify) ____

6. Occupation of household head

1. Private Business

2. Civil servant

3. Religious worker

4 Casual works

5. Farmer

6. Under subsidize

7. Others (Specify) ____

7. What is the household's most important source of earnings?

1. Agriculture

2. Self-employment

3. Wage employment

4. Pension, allowances, social security benefits, remittances

5. Profits, dividends, interest, royalty

8. What is your average monthly income in Ethiopian Birr?

1. below 500

2. 500 – 1000

3. 1000 – 2000

4. 2000 – 3000

5. above 3000

II. Malaria and environment

9. Is there any member of your family who has been in the past ten years affected by malaria?

1. Yes 2. No

10. If your answer to Q.9 is "No", what is the reason behind?

1. Effective use of insecticide net
2. Effective use of sprayed DDT
3. Using traditional medicine
4. Avoid ponds
5. High immunity resistance
6. Others___________________________

11. If your answer to Q.9 is "yes", how many members of your family were affected by Malaria per year?

1. One
2. Two
3. Three
4. above three

12. Regarding question No. 9 in the past ten years which age groups were more affected by malaria?

1. Two month -10 year
2. 11-20 year
3. 21-30 year
4. 31-40 year

13. How many times one person does affected by malaria within one year in your experience?

1. One
2.Two
3. Three
4. above three
5. >40

14. Where do you go for treatment when your families become seek by malaria?

    1. Traditional healer
    2. Health center/ clinic
    3. Pharmacy (drug shop)
    4. Malaria Control laboratory
    5. Others (specify) ______

15. Is there a health center in your locality?

    1. Yes
    2. No

16. If yes, how long it takes time to arrive to the health center.

    1. < 1 hour
    2. > 1hour

17. What time did it take you or member of your household to return back to normal condition?

    1. One week
    2. One month
    3. Two weeks
    4. More than a month

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

    1. Yes
    2. No

19. If your answer to Q.18 is "yes", how do you rate the level of impact?

    1. Very high
    2. High
    3. Moderate
    4. Low

20. Can we Control malaria?

    1. Yes
    2. No

21. If your answer to Q.20 is "yes", what are the mechanisms that you use to control malaria?

1. Insecticide treated bed net
2. Insecticide spraying
3. Avoid ponds
4. Cleaning environment
5. Traditional doctor

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

A. Whole family

B. Father and mother

C. Children

23. How much ITN do you have?

1. One
2. Two
3. Three
4. above three

24. From where did you get the ITNs?

1. Health center
2. Drug vendors
3. Religious institution
4. NGOs

25. Do have pond around your home?

1. Yes
2. No

26. If your answer to Q.25 is "yes", how many ponds are there?

A. One

B. Two

C. Three

D. above three

27. Referring question No.25 estimate the distance of pond from your home.

    1. 1-10m
    2. 10-20m
    3. 20-30m
    4. More than 30m

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

    1. Awareness creation
    2. Distributing ITNs
    3. Strengthen the capacity of health centers
    4. Provide yearly house spraying
    5. Removing grasses around houses
    6. Environmental sanitation program

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

    1. Use ITN effectively
    2. House spraying
    3. Avoid ponds
    4. Environmental sanitation program
    5. Removing grasses around house

III. Information on Domestic Animals

30. How many domestic animals do you have?

    1. 1-10
    2. 21-30
    3. 31-40
    4. >41
    5. None

31. How much far from your house the Animas' resident
    1. < 1000 m
    2. 1000 -2000 m
    3. 2000 – 3000m
    4. > 3000m
32. Do you keep these livestock at night?
    1. Yes
    2. No

IV. Information on housing unit

33. What is the type of housing unit?
    1. Conventional (thatched roof, mud, bamboo, grass, papyrus other)
    2. Stone with cement
    3. Improved (blocket, bricks,)
    4. Concrete
    5. Others (specify)______________________________
34. What is the number of rooms in the housing unit?
    1. One
    2. Two
    3. Three
    4. Four
    5. above Four
35. Do you sleep outdoors at night time?
    1. Yes
    2. No

36. If your answer to Q.35 is <u>“Yes”,</u> what do you think is the reason?

1. High temperature
2. Keeping animals
3. Security problem
4. Shortage of rooms
5. Uncomfortable house
6. Others (specify) ____________________

Appendix 2

Questionnaires in Nuer language

JIMƐ YUNIBOTHTI

KƆLIC THÖÔCƆL THAANY KƐNE YUMƐNITI

BOK; THAANY ƔƆAA KƐNƐ GUAATH CIƐƐŊKÄ

THIECNI KƐ KUI LAT RITHÄÄCKÄ

CIŌT: BITHIRAT TƐTHPAY

THEEM: Ɛn ruac ɛ ca gɔrɛ , ɛ kui läri tin gör kɛ kɛ kui thiecni kă ji cieŋ kɛ kui juath in cɔali lɛrɛkɔɔn kiɛ malöria kɛ duɔp in dee gaŋ ni jɛ kɛ ɣöö derɛ duɔp cuɔp mi gɔa kɛ kui luäkă naath, kɛ riik tin jiekɛ kă juey in cɔali lɛrɛkɔɔn kiɛ malöria mɛn nyuɔth kɛ/kiɛ guɛckɛ kɛ guath mi baar kɛ theem min cɔali GIS Ka Makuey Warɛda.

Kɛ ruɔɔn 2017 kɛ kuen liŋɛlithni, dee gɔarä thuuk kɛ jɛn guath ɛmɔ kɛ degree in rɛwdɛ duel gɔrkă Jimɛ Yunibothti kɛ rijk tin jekɛ kă malöria kă Makuey warɛda, Gămbɛlɛ kuic jɔak ɣɔaa, Ithiöpia. Ɛ tëthlɔac mi diit kă ɣă kɛ ɣöö cia ɣă luäk kɛ thiecni titi kɛnɛ luɔc dun kɛ kɛ ɛ gɔa kă lat in lată.

Kɛn thiecni tin cia luɔc kɛ kɔr kă min ciaa kuɛn , bi kɛn dhil ɛ ti we kɛɛl kă jɛn ruac ɛ cia kuɛnɛ ka /cikɛ bia ti guac kɛ jɛn ruac ɛmɛ. Kɛ kɔr kă min ci kɛ lɔc /cɛ gör ɛn ɣöö bi ciötdu gɔr rɛy pec ɛmɛ.

Ci bɛdă tɛɛth kɛ luɔcdu kɛ kɛ!!!

Nyuɔ̱th duɔp lat- kä thiec kɛl kä kɛn titi, gol kɛl min la min gɔa ni jɛn kä tin ci kuɛn.

Kä guäth tin ca päl baaŋ, bi min lot rɔ kɛ jɛn thiec ɛmɔ dhil gɔa̱r thin agɔa.

I. PEK IN NHIAM

Lääri kä ram in thiëc kɛ̱.

1. Gua̱th ciëŋ ä

   1, Wec……………………………….

   2, Nombɔr duel………………………

   3, Pek män tin tee cieŋ…………………………..

2. Run

   1, 20-30

   2, 31-40

   3, 41-50

   4,> 50

3. wut/ciek

   1. Wut
   2. Ciek

4. Ta̱a̱ kuɛn

   1, Cɛ/caa kuɛn   2,Cɛ da̱k.   3, Ci määthdä liw.

5. Pe̱k gɔrkä .

   1, / Känɛ gɔa̱r.   2, Kilëth 1-4.   3, Kilëth 5-8.   4. Kilëth 9-12.   5. Diplöma.

   6. Mi̱ dɔŋ…………………………………………………………………………………...

6. Lät gua̱n cieŋ.

   1. Ta̱a̱jɛr.   2. Läät kumɛ   3. Läät duel kuɔth   4. La̱t tetni   5, Puɔ̱r ka̱a̱kni   6. Luääk la̱a̱tni
      7. Mi̱ dɔŋ………………………………………………………………………………

7. Ɛ duɔ̱p ɛ mith jek ji cieŋ miäth thinɔ?

1. Puɔ̱r ka̱akni 2. Tujäär 3. Läät kuumɛ 4. Juri dueli 5. Pïli yiöni

8. Kɛ yiöödi la jeki tɔ̱ kɛ pay?

1. <500ETB (ɛ be piny) 2. 500-1000ETB 3. 1000-3000ETB

4. 2000-3000ETB 5. >3000ET(ɛ we nhiam)

II. PEK IN RƐW DƐ

Lerɛkɔ̱ɔ̱n(malöria) kɛnɛ gua̱ath cieŋkä

9. Te kɛ raan rɛy dhɔarun mi cɛ käp kɛ juey in cɔali lerkɔ̱ɔ̱n(malöria) kɛ kɔr runi da̱ŋ wäl te ci we? 1. Ɣɔ̱ɔ̱n / ɣää 2. Ɣëëy

10. Mi luɔcdu kɛ thiec in ba̱ŋuandiɛn ɛ “ɣeey” ku luɔtdɛ la ŋu?

1. Ciaaŋ lokɛthiäy (laŋ) kä mi gɔa 2. Ga̱ŋ dueli kɛ wa̱l nyiäth 3. Ga̱ŋ nyiäth kɛ wal te wal

4. Päl puɔ̱li 5. Ruɔt pɔaany 6. Mi dɔ̱ŋ……………………………………………………

………………………………………………………………………………………………

11. Mi luɔcdu kɛ thiec in bäŋuandiɛn ɛ “ɣɔ̱ɔ̱n” kɛ naath da̱ŋdi caa käp ɛ lerɛkɔ̱ɔ̱n (malöria) rɛy runä?

1. Kɛl 2. Rɛw 3. Diɔ̱k 4. Diɔ̱k ɛ we nhiam

12. Ɛ känɛ kä thiec in ba̱ŋuandiɛn, kɛ naath tin te kä run tin kiɛn caa käp tɔ̱ ɛ juey in cɔali lerɛkɔ̱ɔ̱n (malöria) kɛ kɔr runi da̱ŋ wäl te ci we?

1. <10 2. 11-20 3. 21-30 4. 31-40

13. Ɛn lerɛkɔɔn (malöria) la raan ɛ käpɛ kä di rɛy runä?

1. Kɛl 2. Rɛw 3. Diɔk 4. Diɔk ɛ we nhiam

14. Ɛ guaath in mith la yiɛn wal ɛ jek thinɔ mi ca raan käp ɛ juey in cɔali lerɛkɔɔn (malöria)?

1. Wal wec te wal 2. Guath puɔlä puaany 3. Guath kökä wal 4. Thiɛlɛ guath mi we naath thin.

15. Te kɛ guath puɔlä puaany mi te rɛy dhɔarun?

1. Ɣɔɔn/ɣää 2. Ɣëëy

16. Mi luɔcdu kɛ thiec in wäldhiechdiɛn ɛ "ɣɔɔn" ɛn guath puɔlä puaany te kɛ kilomitiri di?

1. <1km 2. 1-3km 3. >3km

17. Ɛ kɔr guath mi nin di de raan pual puaany jek kɛ jɛ mɔ?

1. Juɔk kɛl 2. Juɔkni rɛw 3. Pay kɛl 4. Pay kɛl ɛ we nhiam

18. Mi ca raan käp ɛ lerɛkɔɔn, te mi yiärɛ kä lätku?

1. Ɣɔɔn /ɣää 2. Ɣëëy

19. Mi luɔcdu kɛ thiec in wälbädäkdiɛn ɛ "ɣɔɔn" deri pek bɛckä dɛ thɛm?

1. Bɛcɛ ɛ löŋ 2. Pärɛ 3. Bɛcɛ ɛ määth

20. Denɛ lerɛkɔɔn gaŋ?

1. Ɣɔɔn/ɣää 2. Ɣëëy

21. Mi luɔcdu kɛ thiec in jiɛnrɛwdiɛn ɛ "ɣɔɔn" ɛ duɔp in mith de gaŋ lerɛkɔɔnɔ?

1. Lokɛthiaay/lämakɔl 2. Wäl kɔaamni 3. Lokɛthiaay biäy

4. Yuɔp cieŋ 5. Tuɔny dueli 6. Math wal

22. Mi kăn yiɛn ITN, ɛŋa la jaa kăn dhɔrunɔ?

1. Ji cieŋ dial   2. Gua̱ncieŋ kɛnɛ mancieŋ   3. Gaat.

23. Ɛ ITN mi nin di te kɛ yiɛ?

1. Kɛl   2. Rɛw   3. Diɔ̱k   4. Diɔ̱k ɛ we nhiam

24. La yiɛn ITN ɛ jek ni?

1. Gua̱th puɔlă pua̱a̱ny   2. Gua̱th kökă wal   3. Dueli Kuɔth   4. Muktăpni lua̱k naath

25. Te yiɛn kɛ puɔ̱l ti thieek kɛ dhɔɔrun?

1. Ɣɔ̱ɔ̱n/ɣää   2. Ɣëëy

26. Mi luɔcdu kɛ thiec in jiɛnrɛw widɛdhieecdiɛn ɛ "ɣɔ̱ɔ̱n" kɛ puɔ̱l da̱ŋdi thiek kɛ yiɛ tɔ̱?

1. Kɛl   2. Rɛw   3. Diɔ̱k   4. Diɔ̱k ɛ we nhiam

27. Ɛ känɛ kă thiec in jiɛnrɛw widɛdhieecdiɛn, thɛ̈m kam puɔ̱li kɛnɛ cieŋ ɛ pek mi nin di?

1. <1km   2. 1-2km   3. >2km

28. Ɛ duɔ̱p in mith lăt kumɛ jɛ mɔ kɛ ga̱ŋ juath in cɔali lerɛkɔ̱ɔ̱n rɛy kɛbɛlɛ ka̱ dun?

1. Thöpni ŋiickă   2. La̱t ITN ɛ gɔa   3. Rep luăŋă dueli wal

4. Duăc wal duelikɛ ruɔ̱n   5. Puɔ̱r juaacni gekă cieŋ   6. Yuɔp cieŋ

29. Ɛ duɔ̱ɔ̱p in mith la̱t kɛ mɔ ɛ ji cieŋ kɛ ga̱ŋ jua̱th in cɔali lerɛkɔ̱ɔ̱n?

1. La̱t ITN ɛ gɔa   2. Duăc waldueli   3. Păl puɔ̱li   4. Yuɔ̱p cieŋ

5. Puɔr juaacni

III. PEK IN DIƆK DIƐ̈N

Lääri kɛ kui lɔykä ciɛŋ

30. Te yiɛn kɛ ɣɔk daŋ di?

1. 1-20   2. 21-30   3. 31-40   4. >40

31. Guath ciɛŋkä kɛnɛ ɣɔɔk te kɛ kam mi nin di?

1. < 1000m   2. 1000-2000m   3. 2000-3000m   4. >3000m

32. Laa ɣɔk ɛ gaŋi kɛ wäär?

1. Ɣɔɔn/ɣää   2. Ɣëëy

IV. PEK IN ŊUANDIƐ̈N

Lääri kɛ kui duel

33. Duelu ɛ duel in mith?

1. Duel juaacni   2. Duel muɔɔn   3. Duel paam   4. Duel paam mi we nhial

5. Mi dɔŋ……………………………………………………………………………………

34. Rɛy duel te rɛy dɛ kɛ tiäc daŋdi?

1. Kɛl   2. Rɛw   3. Diɔk   4. Ŋuaan   5. Ŋuaan ɛ we nhiam

35. Laa tɔci raar kɛ wäär?

1. Ɣɔɔn/ɣää   2. Ɣëëy

36. Mi luɔcdu kɛ thiec in jɛ̈ndiɔk widɛ̈ dhieecdiɛn ɛ "ɣɔɔn" ku luɔt dɛ laa ŋu?

1. Lëth piɛny   2. Gaŋ ɣɔɔk   3. Gaŋ riikni   4. Dak tiacni   5. Thiɛlɛ duel ti gow

Appendix 3

Ground truth point error matrix result

Class Name	Forest	Agriculture	Settlement	Grassland	Water body	Total Row
Forest	21	0	1	3	0	25
Agriculture	0	19	3	1	1	24
Settlements	0	2	16	1	0	27
Grassland	2	4	3	27	0	36
Water body	1	1	1	0	18	21
Total Column	**24**	**26**	**24**	**32**	**19**	**137**

Total Accuracy Results

Class Name	Total Classified	Number of Correct	Users Accuracy	Producer Accuracy
Forest	25	21	84%	87.5%
Agriculture	24	19	79%	73.03%
Settlement	16	21	76%	66.66%
Grassland	35	27	75%	84.37%
Water body	18	21	86%	94.73%
Total	127	101		

Overall Classification Accuracy = 79.5

Overall Kappa Statistics = 73.4

$$\hat{K} = \frac{N\sum_{i=1}^{\hat{K}} xii - \sum(Xit * Xti)}{\mathbf{N}^2 - \sum_{i=t}^{k}(Xit * Xti)}$$

$N = 127$

$xii = (21 + 19 + 16 + 27 + 18) = 101$

$\sum(Xit * Xti)$ =((25 *24) + (24 * 26) + (21 * 24) + (36 * 32) + (21 * 19))

3279 = (600+624+504+1152+399)

$$\hat{K} = \frac{(127 * 101) - 3279}{(127)^2 - 3279}$$

$$\hat{K} = \frac{12827 - 3279}{16129 - 3279}$$

$$\hat{K} = \frac{9548}{12850} \times (100\%)$$

$$\mathbf{\hat{K} = \underline{74.30\%}}$$

Where, $\hat{K}$, kappa coefficient statistics

N, total ground point

Xii, accurate classified for each LULC type

Xi, total column accuracy

Xt, total row accuracy

Appendix 4

GPS points of household sampled from four *kebeles*								
Adura					**Nyingnang**			
	Longitude	latitude	H.H No.		Longitude	latitude	H.H No.
1	554994	918687		1	571510	919177	
2	557222	919190		2	575891	915200	
3	560432	918926		3	575082	915782	
4	555306	920436		4	576573	916430	
5	557270	919238		5	576582	916397	
6	559642	920795		6	572353	918773	
7	557246	921274		7	57290	918882	
8	560097	921538		8	573128	918217	
9	557486	923167		9	578006	918789	
10	556047	927333		10	577054	917787	
11	557947	927820		11	576952	919219	
12	559646	928000		12	577382	918174	
13	559630	926089		13	576615	918688	
14	558995	926375		14	576363	917239	
15	557984	925872		15	575824	916986	
16	556698	926137		16	573743	917871	
17	554625	928561		17	573911	918503	
18	555666	928908		18	574433	918773	
19	557978	929407		19	575057	918680	
20	559849	930254		20	575158	917197	
21	558333	930762		21	574450	917349	
22	557233	931253		22	574535	917762	
23	559180	931922		23	575225	917711	
24	558698	934877		24	575765	917762	
25	560010	933564		25	576051	918107	
26	557910	933683		26	575714	918292	
27	556285	933590		27	575798	918747	
28	55969	933649		28	575217	918275	
				29	575040	918680	

GPS points of household sampled from four kebeles								
Longjiok					Nyabukliek			
	Longitude	latitude	HH No.		Longitude	latitude	HH No.
1	588846	907765		1	570848	926039	
2	587861	905574		2	575081	928598	
3	589301	906082		3	571689	926620	
4	590349	906421		4	57278	926881	
5	591206	907268		5	573903	927714	
6	591989	908284		6	570385	927806	
7	591163.	908897		7	573364	927411	
8	585544	909532		8	571100	927394	
9	588835	909543		9	571765	927386	
10	586528	907278		10	569593	931182	
11	587756	909988		11	574130	929549	
12	586972	906738		12	570486	931215	
13	586983	910951		13	573322	931005	
14	585639	906940		14	571580	928926	
15	587638	908692		15	572135	929801	
16	586992	909846		16	572994	929103	
17	586357	905549		17	570292	929195	
18	590527	910111		18	571613	928934	
19	584876	911148		19	571647	928960	
20	587765	908428		20	573347	931022	
21	571456	909530		21	572110	929077	
22	572541	907440		22	571134	930449	
23	572991	915615		23	571757	931510	
24	569022	905032		24	570991	927411	
25	572382	913578		25	573541	928825	
26	568096	907387		26	569779	929784	
27	572621	913525		27	574164	929549	
28	566191	906990		28	569955	930374	
29	568625	909715		29	574181	930879	
30	574155	914927		30	569711	929801	
31	570504	906884		31	571975	926350	
32	569049	911911		32	573995	930803	
32	568123	907387					
33	574737	909001					
34	573970	912520					
35	567526	905988					
36	587084	908232					

Appendix 5

GPS Points reading used for land use land cover map accuracy							
	Longitude	latitude	Land use type		Longitude	latitude	Land use type
1	555809	924087	Water body	71	556299	917253	Agriculture
2	578320	925992	Water body	72	568025	924530	Agriculture
3	565017	931897	Water body	73	565447	919956	Agriculture
4	572795	925103	Water body	74	581331	906150	Agriculture
5	575843	927579	Water body	75	577423	904861	Agriculture
6	566318	933961	Water body	76	574553	919914	Agriculture
7	576034	928056	Water body	77	573015	913718	Agriculture
8	566223	934469	Water body	78	565738	914758	Agriculture
9	574129	931739	Water body	79	581456	906192	Agriculture
10	566255	934342	Water body	80	563326	905568	Agriculture
11	574288	932342	Water body	81	568067	924155	Agriculture
12	566890	935041	Water body	82	582620	917627	Agriculture
13	574351	932310	Water body	83	555051	928480	Agriculture
14	567811	935930	Water body	84	553622	921632	Settlement
15	593835	915930	Water body	85	562036	928842	Settlement
16	590620	919185	Water body	86	554866	925045	Settlement
17	593743	916460	Water body	87	553596	922426	Settlement
18	590859	918801	Water body	89	555673	927493	Settlement
19	591851	917465	Water body	90	554059	924794	Settlement
20	593848	917386	Water body	91	555686	927426	Settlement
21	591838	917518	Water body	92	576496	916787	Settlement
22	572591	926959	Grassland	93	589755	921393	Settlement
23	552735	925483	Grassland	94	576699	921918	Settlement
24	572846	928996	Grassland	95	585217	920021	Settlement
25	555841	923701	Grassland	96	580966	917718	Settlement
26	567602	928945	Grassland	97	576953	916990	Settlement
27	558030	925686	Grassland	98	587689	922002	Settlement
28	567500	928792	Grassland	99	579933	921528	Settlement
29	560779	924974	Grassland	100	579121	916025	Settlement
30	567449	930778	Grassland	101	577597	922206	Settlement
31	560067	931949	Grassland	102	580340	918734	Settlement
32	569791	933273	Grassland	103	577597	922172	Settlement
33	556655	933323	Grassland	104	582609	916127	Settlement
34	569587	933323	Grassland	105	585809	917295	Settlement
35	559659	933833	Grassland	106	583557	917126	Settlement
36	562816	930574	Grassland	107	584946	916431	Settlement
37	589444	903844	Grassland	108	583252	916516	Settlement
38	572948	900739	Grassland	109	584505	917515	Settlement
39	586491	908630	Grassland	110	586266	586266	Settlement
40	565871	904048	Grassland	111	570521	904934	Forest
41	592448	912602	Grassland	112	566597	909963	Forest
42	567398	903539	Grassland	113	554455	921307	Forest
43	588476	912652	Grassland	114	563377	920388	Forest

44	574628	917337	Grassland	115	561936	921461	Forest
45	586134	921511	Grassland	116	571472	909288	Forest
46	568518	915962	Grassland	117	568222	909288	Forest
47	578446	922275	Grassland	118	567302	916616	Forest
48	570657	910921	Grassland	119	572146	911618	Forest
49	583029	921308	Grassland	120	569969	569969	Forest
50	569078	914180	Grassland	121	568222	909748	Forest
51	578294	924464	Grassland	122	568406	909104	Forest
52	566685	910616	Grassland	123	571472	909503	Forest
53	570809	911583	Grassland	124	564573	903064	Forest
54	586440	908732	Grassland	125	563622	912232	Forest
55	592346	931796	Grassland	126	563132	907050	Forest
56	556197	918609	Grassland	127	557827	909349	Forest
57	586745	898855	Grassland	128	557183	918885	Forest
58	555176	919540	Grassland	129	578095	921461	Forest
59	554927	931557	Agriculture	130	563745	904658	Forest
60	583286	904944	Agriculture	131	563806	904658	Forest
61	568940	907315	Agriculture	132	558257	913427	Forest
62	561081	929727	Agriculture	133	563377	905793	Forest
63	568981	907439	Agriculture	134	566781	920050	Forest
64	577630	904695	Agriculture	135	562120	917321	Forest
65	556465	926858	Agriculture	136	564542	916831	Forest
66	553513	926567	Agriculture	137	562488	906,498	Forest
67	570146	919124	Agriculture				
68	556507	926775	Agriculture				
69	575842	908853	Agriculture				
70	557172	930642	Agriculture				