ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUTE STUDIES

COLLEGE OF NATURAL SCIENCE

SCHOOL OF EARTH AND PLANETARY SCIENCES

GIS AND REMOTE SENSING BASED MALARIA RISK MAPPING IN FENTALE WOREDA, EAST SHOA ZONE, ETHIOPIA.

BY: ALEMAYEHU LEMESSA

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GIS AND REMOTE SENSING BASED MALARIA RISK MAPPING IN FENTALE WOREDA, EAST SHOA ZONE, ETHIOPIA.

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

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DECLARATION

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

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Acronyms

AAU	Addis Ababa University
ACMAD	African Centre of Metrological Application for Development
CSA	Central Statistical Agency
DEM	Digital Elevation Model
ETM+	Enhanced Thematic Mapper Plus
FDREMoH	Federal Democratic Republic of Ethiopia Ministry of Health
FIBIDP	Fentale Irrigation Based Integrated Development Project
GCP	Ground Control Point
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
km	Kilometer
km^2	Kilometer Squire
LULC	Land Use Land Cover
MoH	Ministry of Health
NMSA	National Meteorological Service Agency
NIAID	National Institute of Allergy and Infectious Diseases
SNNPR	Southern Nations, Nationalities, and People's Region
SRTM	Shuttle Radar Topography Mission
RBM	Roll Back Malaria
UN OCHA	United Nations Office for the Coordination of Humanitarian Affairs
USGS	United States Geological Survey
OWWDSE	Oromia Water Works Design and Supervision Enterprise
WHO	World Health Organization
m.a.s.l	Meter Above Sea Level

Abstract

Malaria is caused by infection of red blood cells with protozoan parasites of the genus Plasmodium. The parasites are inoculated into the human host by a feeding female anopheline mosquito. The objective of this study was to map malaria risk levels associated with each area in Fentale Woreda, East Shoa Zone, Ethiopia. Within the last decade, malaria cases in the study area started to decrease with some irregularities during occasions of epidemics. But still malaria is among the ten top diseases responsible for morbidity and mortality next to upper respiratory tract infection at this area. Climatic and topography factors, population density, land-use land-cover and proximity related factors (distance from rivers, irrigation canals, and lakes) are known to have strong influence on the biology of mosquitoes. Geographic Information System and Remote Sensing were used to investigate associations between such variables of malaria supporting factors and the distribution of the vector mosquito responsible for malaria transmission. The study used weighted overlay technique of multi-criteria evaluation in ArcGIS environment to come up with the final malaria risk map. Climate and topography factors malaria risk map of Fentale woreda indicated that majority of the study area (99.7%) fell under high malaria risk level. Regarding proximity related factors 7.3%, 53%, and 39.7% of the woreda was under high, medium and low malaria risk levels, respectively. Malaria risk map of the study area indicated that there is no area within Fentale Woreda with malaria free risk level. Almost all areas fell under malaria risk levels of high (7%) and moderate (93%). Kebelewise about 81% of the area which constitute about 17 kebeles fell in the moderate malaria risk level. The other 19% occupied by 4 kebeles were associated with high malaria risk level. Hence, malaria risk mapping using geographic information system and remote sensing is a worthwhile technique to produce malaria risk map of a particular area which show areas under different malaria risk levels which in turn make malaria control and prevention system cost effective, not time taking, easily manageable and sustainable.

Keywords: Malaria, GIS, Remote Sensing, and Multi-Criteria-Evaluation

1. Introduction

1.1. General Background

Malaria is caused by infection of red blood cells with protozoan parasites of the genus *Plasmodium*. The four *Plasmodium* species that infect humans are *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium ovale* and *Plasmodium malariae*. Increasingly, human infections with the monkey malaria parasite, *Plasmodium knowlesi*, have also been reported from the forested regions of South-East Asia (WHO, 2010).

The parasites are inoculated into the human host by a feeding female anopheles mosquito (WHO, 2010). There are about 400 different species of *Anopheles* mosquitoes throughout the world, but only some 60 of these are vectors of malaria under natural conditions, and only 30 are vectors of major importance. Each species have different behavioral pattern. Several species of *Anopheles* can be found in most malarial areas, and different species occur in different parts of the world. Highly efficient species, such as *A. gambiae*, *A. arabiensis* and *A. funestus*, predominate in sub-Saharan Africa, while less efficient vectors, such as *A. stephensi* and *A. minimus*, predominate in Asian countries. *A. dirus* is an efficient vector in the forests of South-East Asia (WHO, 2005).

The large, round numbers that delineate the immense and persistent burden of malaria have become a familiar part of discussions in the global public health forum: 3 billion people at risk of infection in 109 malarious countries and territories and around 250 million cases annually, leading to approximately 1 million deaths (WHO, 2009).

Malaria burdens individuals and nations with substantial economic costs. Personal expenditures for malaria prevention include insecticide treated nets, insecticide treated nets retreatment kits, mosquito coils, insecticide sprays, and other protective items. Expenditures on treatment may include doctors' fees, antimalarial drugs, transport to health facilities, and lost wages for caregivers. Public expenditures include government spending to maintain health facilities and health care infrastructures, publicly managed vector control activities, and malaria education and research. In some countries with a heavy malaria burden, the disease may account for as much as 40 percent of public health expenditure, 30–50 percent of inpatient admissions, and up to 50 percent of outpatient visits. Additional costs of malaria include lower labor productivity (because of sickness and death). This results in lower incomes for individuals and families and lower economic growth in malarious nations. Economists believe that malaria is responsible for a “growth penalty” of up to 1.3 percent per year in some African countries. When compounded over the years, this penalty leads to substantial differences in the gross domestic product (GDP) between countries with and without malaria (USAID, 2007).

Malaria is seasonal in most parts of Ethiopia, with unstable transmission that lends itself to the outbreak of epidemics. The transmission patterns and intensity vary greatly due to the large diversity in altitude, rainfall, and population movement. Areas below 2,000 m.a.s.l. are considered to be malarious or potentially malarious. These areas are home to approximately 68% (52 million) of the Ethiopian population and cover almost 75% of the country’s landmass (MoH, 2007).

Epidemiology of vector borne diseases is changing fast with the availability of data using new methods of spatial data collection like GPS and remote sensing. The GPS has been used mainly for field data collection and remote sensing by means of aerial photographs and satellite imageries has succeeded in providing descriptive climatic and landscape features (Saxena *et al*., 2009). All GIS packages have the ability to produce high quality thematic or topographic maps from the feature data stored within the system. Datasets such as topographic maps, aerial photographs, satellite imagery and complex databases can be combined and visualized concurrently (Wyatt and Ralphs, 2003). With GIS tools it is also possible to overlay accurate spatial maps of an area which can display disease events, climatic and topographic variables and land-use patterns and simultaneously examine the relationship between these, enabling new and critical insights to be made to the disease and its transmission localities (Mendis, 2009). The use of satellite data with GIS also provides an opportunity to integrate up-to-date environmental information, local knowledge and recent historical trends in a way which draws attention to areas of change and potential problems. Such information, along with local epidemiological, entomological and socio-economic data, could undoubtedly improve our understanding of the dynamics of malaria transmission and, therefore, our options for control. These could contribute to malaria control planning in establishment and regular updating of localized environmental stratification which will help identify areas of differing transmission patterns, provision of a system which allows near real-time monitoring and surveillance of the environmental factors influencing transmission, and supply of a component of an early warning system to indicate epidemic potential (Connor *et al.,* 1998).

1.2. Statement of the Problem

According to Fentale Woreda health office, in 2010 malaria was the second top disease responsible for high morbidity and mortality in the Woreda. Seasonal rain, over flow of Awash River during high rainy season, impounded water and the geographic location which is typical for the breeding of mosquito contributed a lot for the prevalence of malaria. Presence of large and small scale irrigation schemes in the area associated with lower water management skill of the local people also favor breeding of mosquito which will aggravate malaria prevalence in the area. Severity of malaria increases at the rainy seasons putting higher pressure on the activity of the local people whose livelihood is totally dependent on crop production and livestock rearing. It reduces labor, time for on farm follow up, livestock supervision and children school attendance consequently resulting in decline of agricultural production, economic dependency, high school dropouts and social crisis.

The problem is gets more due to 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. But this is time taking and lacks early response in cases epidemics happen. This results in large amount of damage in economy and life of people residing at this area. Therefore, malaria control and prevention system should be aided with improved or new method which can alleviate this problem.

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

With GIS and remote sensing it is possible to produce different thematic and attribute maps for each malaria supporting factors and malaria risk level for the study area. This in turn helps in the malaria control and prevention system of emergency response, preparedness, preventive measures, community awareness, identification of health facility accessibility and its location.

1.3. Objectives

1.3.1. General Objective

- The overall purpose of the study is to develop malaria risk map of Fentale Woreda in order to identify potentially malarious areas using Geographic Information System and Remote Sensing as to make every activities of malaria control and prevention system easily manageable, not time consuming, cost effective and sustainable.

1.3.2. Specific Objectives

- To see temporal malaria trend of the study area.
- To assess malaria risk levels of the study area in terms of major climatic, topographic and different proximity related malaria risk factors.
- To produce land-use/land-cover and population density map of the study area and relate with the impact each of them have on malaria prevalence.
- To identify, classify, and map malaria risk level for each kebele.

1.3.3. Limitations of the Study

- Lack of kebelewise well documented malaria cases and other organized temporal and spatial malaria related data over a long period of time.
- Population data at locality level which is very important for detail study was not available.

2. Literature Review

2.1. Understanding Malaria

In ancient Rome, as in other temperate climates, malaria lurked in marshes and swamps. People blamed the unhealthiness in these areas on rot and decay that wafted out on the foul air. Hence, the name is derived from the Italian, "*mal aria,*" or bad air (NIAID, 2007). In 1880, scientists discovered the real cause of malaria was a one-cell parasite called plasmodium. Later they discovered that the parasite is transmitted from person to person through the bite of a female Anopheles mosquito, which requires blood to nurture her eggs (RBM and Kivinnoforum, 2006). This is the only type of mosquito that can spread malaria. The mosquito becomes infected by biting an infected person and drawing blood that contains the parasite. When that mosquito bites another person, that person becomes infected (Silvani, 2010).

2.2. Cause of Malaria

Malaria is caused by a single-celled parasite from the genus *Plasmodium*. More than 100 different species of *Plasmodium* exist. They produce malaria in many types of animals and birds, as well as in humans (NIAID, 2007). The four *Plasmodium* species that infect humans are *Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale* and *Plasmodium malariae* (WHO,2010). Each parasite has a distinctive appearance under the microscope, and produces a somewhat different pattern of symptoms (NIAID, 2007):

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

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

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

Plasmodium ovale is rare, can cause relapses, and generally occurs in West Africa.

2.3. Factors for the Prevalence of Malaria

2.3.1. Climatic Factors

Malaria is influenced by climatic factors such as temperature, precipitation and relative humidity (Dahal, 2008; Oluleye and Akinbobola, 2010). It influences the development, reproduction, and survivorship of anopheline mosquitoes and malaria parasites (Zhou *et al*., 2004).

2.3.1.1. Temperature

Temperature plays an important role in the variability of malaria transmission by regulating the development rate of mosquito larvae and influencing the survival rate of adult mosquitoes. 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 (Grover-Kopec *et al*.2006). 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 (*An. gambiae*) 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 (ACMAD, 2009). Mosquitoes generally develop faster and feed earlier in their life cycle at a higher frequency in warmer conditions. In addition, the Plasmodium parasite multiplies more rapidly in the mosquito in higher temperatures (Gilles and Warrell, 1993, as cited in Grover-Kopec *et al*.2006). But the chance of mosquito survival is low at extreme temperatures i.e. temperatures below 5°C and temperatures above 40°C (in some reports 35°C) are deadly for the mosquito (Marj *et al*.,2008).

2.3.1.2. Rainfall

Rainfall increases the breeding 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). 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. It is beneficial to mosquito breeding if it is moderate, but may destroy breeding sites and flush out the mosquito larvae when it is excessive (Michael and Martens, 1995 as cited in Devi and Jauhari, 2006).

2.3.2. Terrain Factors

Terrain features mainly include elevation, slope, and aspect. The mechanism of terrain factors influence on vector-borne disease lain in the fact that different terrain feature support different land cover, thus, provide certain habitats suitable for some vectors. For example, grass land, is suitable for mice, vector of plague, while swamp is fitting for snails and mosquitoes (Liu *et al.*, 2006). Topographic patterns affect the spatial distribution of mosquitoes and susceptibility level of human immune system (Zhou *et al.*, 2004).

2.3.2.1. Elevation

The relationship between malaria prevalence and altitude may be related to availability of optimal conditions for the development of malaria parasites in the mosquito vectors. It has been established that the developmental rates increase from zero at a low temperature threshold, reach a maximum at an optimal temperature and decrease rapidly to zero at an upper, lethal temperature (Lactin *et al.*, 1995 as cited in Mboera *et al.*, 2006). It is certainly true that the incidence of malaria has increased in some highland areas, and it is perfectly acceptable to cite temperature as a limiting factor in transmission; vectors such as *Anopheles gambiae* have been reported at altitudes up to 3,000 m above sea level, but endemic malaria disappears above 1,800–2,000 m (Reiter, 2008). Malaria prevalence is observed up to 3500 m.a.s.l eventhough it decreases with increase in altitude (Graves *et al.*, 2009). Minimum temperature for parasite development of *P. falciparum* and *P. vivax* approximates 18^0C and 15^0C, respectively, limiting the spread of malaria at higher altitudes (Patz *et al*., 2008).

2.3.2.2. Slope

Slope is an important habitat characteristic for many species (Jenness, 2007). Steeper slope does not favor plant and animal dwelling relative to gentle slopes. It is a measurement of how steep the ground surface is[1]. The steeper the surface, the greater the slope. Slope is measured by calculating the tangent of the surface. The tangent is calculated by dividing the vertical change in elevation by the horizontal distance as illustrated in figure 1.

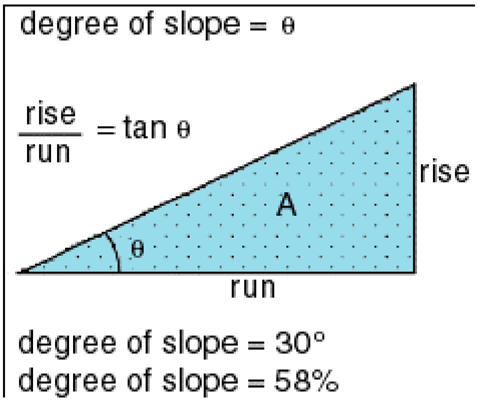

Fig. 1. Slope Diagram

Slope can be described in percent or degree. Percentagewise slope is the tangent (slope) multiplied by 100. Percent Slope = Height / Base * 100

To express slope in degree arctangent of the slope is used.

Degrees Slope = ArcTangent (Height / Base)

2.3.3. Anthropogenic Factors

Infectious diseases, like malaria, can emerge as a result of natural or unnatural changes to the environment. Beyond the normal environmental determinants, anthropogenic determinants can influence the distribution of the disease by directly modifying the behavior and geographical distribution of the *Anopheles* mosquitoes (Aron and Patz, 2001, as cited in Stockett, 2008). Over the past two centuries anthropogenic factors such as agriculture, irrigation, increase in population size, migration, and war have all influenced the spatial distribution pattern of malaria (Stockett, 2008).

2.3.3.1. Agriculture and Irrigation

Population explosion has led to an increased demand for food that is far exceeding normal agricultural production. In order to meet this need, many governments have instituted large-scale irrigation projects. Although crop irrigation provides a solution to alleviating the demand for much needed food resources, it also can introduce malaria in local communities at much higher rates (Stockett, 2008).

Irrigation creates an ideal habitat for mass-production of mosquitoes (Reiter, 2008; Senzanje *et al*. 2002). Through the creation of larval habitats, reservoirs can promote enhanced populations of certain vectors. From the evidence of Koka reservoir in Ethiopia, shoreline puddles and seepage pools downstream of the dam were found to provide an ideal breeding habitat for Anopheles mosquitoes. A higher abundance of breeding sites, in combination with high productivity (i.e., as indicated by larval density), resulted in much greater numbers of adult mosquitoes in those villages located close to the reservoir than in those located further away (Solomon *et al.*, 2009).

The clearing of forests for crop production, and the tilling of moist soil often exposes small pools of standing water, which allows mosquitoes to breed. Availability of livestock is another key factor for the transmission of malaria. Livestock attract mosquitoes. So when the opportunity arises, the mosquitoes will then feed on the nearby human populations (Mayer and Pizer, 2008 as cited in Stockett, 2008).

2.3.3.2. Urbanization and Increase in Population Size

Rapid unregulated urbanization often leads to an increase in or resumption of 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 (Martens and Hall, 2000).

2.3.3.3. Migration, War and Civil Strife

The movements to and from malarious areas have epidemiologic importance. People who move can be categorized as either active transmitters or passive acquirers. Active transmitters harbor the parasite and transmit the disease when they move to areas of low or sporadic transmission. Passive acquirers are exposed to the disease through movement from one environment to another; they may have low-level immunity or may be non-immune, which increases their risk for disease (Martens and Hall, 2000). If a community has lived in a non-malarial area, or an area with low and seasonal transmission, and moves into an area with high transmission, all age groups will be very vulnerable to disease and there is a potential for a serious outbreak. Movement of people carrying malaria into an area that is free of malaria but where the vector is present may lead to an outbreak in the non-immune host population (WHO, 2004).

In times of conflict, mass movements of people, e.g. soldiers and refugees, often promote malaria transmission. The breakdown of public health services, damage to water distribution and drainage systems, and the destruction of homes often exacerbate the situation. High concentrations of people in camps for displaced persons can also be disastrous (Reiter, 2008).

2.3.3.4. Land use land cover

Land-use/land-cover is a critical environmental factors associated with vector-borne disease. Different kinds of land cover indicate different types of residential areas suitable for various vectors. Vegetation type and density are two vital variables to predict type and abundance of some vectors (Liu *et al*., 2006).

Productivity of malaria vectors is significantly higher in aquatic habitats located in farmlands compared with those in swamps and forests. Pupation rate was significantly greater and development time was shorter in habitats in farmlands compared with other land cover types (Munga *et al*., 2006). Land cover affects the temperature of larval habitats directly and food conditions and other factors indirectly, but the synergistic effects of these factors may be more significant to larval survivorship (Munga *et al*., 2006).

2.4. Global Distribution of Malaria

Normal Determining Factors, Mosquitoes and their vector-borne diseases, are found throughout the world, except in areas that are permanently frozen over. Approximately 75% of all mosquito species reside in the world's tropical and subtropical regions (Stockett, 2008). Today approximately 40% of the world's population mostly those living in the world's poorest countries are at risk of malaria. The disease was once more widespread but it was successfully eliminated from many countries with temperate climates during the mid 20th century. Today malaria is found throughout the tropical and sub-tropical regions of the world and causes more than 300 million acute illnesses and at least one million deaths annually (RBM and Kivinnoforum, 2006).

2.5. Malaria in Ethiopia

Malaria is a leading public health problem in Ethiopia. Almost 75%of the land is malarious and an estimated 48 million (68%) of the population lives in areas at risk of malaria. With the existing 61% of potential health service coverage, each year five to six million malaria cases are reported from health facilities throughout the country. More than four million clinical cases are reported annually and it is the number one cause of outpatient department attendance, hospital admission and deaths. During an epidemic, the burden of disease is far higher; some sources suggest a threefold increase in caseload. Cyclic epidemics with a period of five to eight years occur in most parts of the country following climatic changes. All age groups are particularly vulnerable to severe malaria during these periods due to a lack of developed immunity (UN OCHA, 2004).

Due to its extraordinarily diverse topography and climatic conditions, the epidemiology of malaria in Ethiopia is more variable and unstable than in any other country in Africa. Highland fringe areas at altitude range of 1500-2500m.a.s.l (northern and central area) and lowland arid areas (eastern and southeastern area) at altitude ranges of below 1500 m.a.s.l. are prone to malaria epidemics. Some areas in the western lowlands, however, have relatively stable transmission (UN OCHA, 2004).

Most of the transmission occurs between September and December, after the main rainy season from June to August. Certain areas, largely in the western and eastern part of the country including parts of Oromia, experience a second minor transmission period from April to May, following a short rainy season from February to March (President's Malaria Initiative, 2010).

Large-scale malaria epidemics were reported from June – December 2003. Most of the areas affected were in the Oromia, Amhara, SNNPR and Tigray regions. According to reports from the Regional Health Bureau, a total of 3,698 villages in 211 districts in the four most populated regions were affected resulting in over two million clinical malaria cases and 3000 deaths. However, these figures represent only a fraction of the actual magnitude of the problem as the reporting system does not capture the majority of cases occurring in communities that have limited access to the health facilities. Therefore, the number of clinical cases and deaths can exceed what is stated above because of in Ethiopia, only 27% of cases related to fever have been shown to visit health facilities and the majority of cases and deaths occur at home (UN OCHA, 2004).

2.6. Burden of Malaria

In 2008, there were an estimated 243 million cases of malaria worldwide. The vast majority of cases (85%) were in the African Region, followed by the South-East Asia (10%) and Eastern Mediterranean Regions (4%) (WHO, 2009). Malaria accounted for an estimated 863 000 deaths in 2008, of which 89% were in the African Region, followed by the Eastern Mediterranean (6%) and the South-East Asia Regions (5%) (WHO, 2009). Ninety percent of deaths due to malaria occur in Africa south of the Sahara mostly among young children. It kills an African child every 30 seconds. Many children who survive an episode of severe malaria may suffer from learning impairments or brain damage. Pregnant women and their unborn children are also particularly vulnerable to malaria, which is a major cause of prenatal mortality, low birth weight and maternal anemia (RBM and Kivinnoforum, 2006).

Malaria contributes up to 38 percent of the total labor days lost to production per annum. The impact of malaria includes loss of life, loss of productive time, burdening of health services, increased costs of disease control and a decrease in the welfare of affected individuals and communities (Senzanje *et al*., 2002).

Malaria results in morbidity and sometimes mortality. Incapacitation of the economically active population also affects the quantity and quality of labor supply to the household because the sick abstain completely or partially from work during the period of illness. The potential effect of malaria therefore lies in the productive time (labor time) lost by the sick and the family members who divert productive time on the farm to care for the sick. Reduced farm labor may adversely affect adoption of labor-intensive technologies. In the event of death of adults, the supply of farm labor is affected in addition to the loss of farming knowledge, which slows the acquisition and diffusion of agricultural innovations. Although new knowledge is needed for innovations in agriculture, knowledge that has been accumulated by farmers has been found to be useful in creating new technology and innovations. Knowledge that spills over from one farmer to another is an effective way of disseminating technology in rural areas. Such opportunities are lost when a farmer dies from malaria or other illness (Asenso-Okyere *et al*., 2009)

Malaria is a significant impediment to social and economic development in Ethiopia. In endemic areas, it has affected the population during planting and harvesting seasons, cutting down productive capacity at a time when there is the greatest need for agricultural work. The disease has also been associated with loss of earnings, low school attendance, and high treatment cost. During epidemics, health facilities are overwhelmed with patients and many resources are diverted to deal with the emergency (MoH, 2009; President's Malaria Initiative, 2010). Generally, the impact of malaria diagrammatically illustrated in figure 2 (Asenso-Okyere *et al*., 2009).

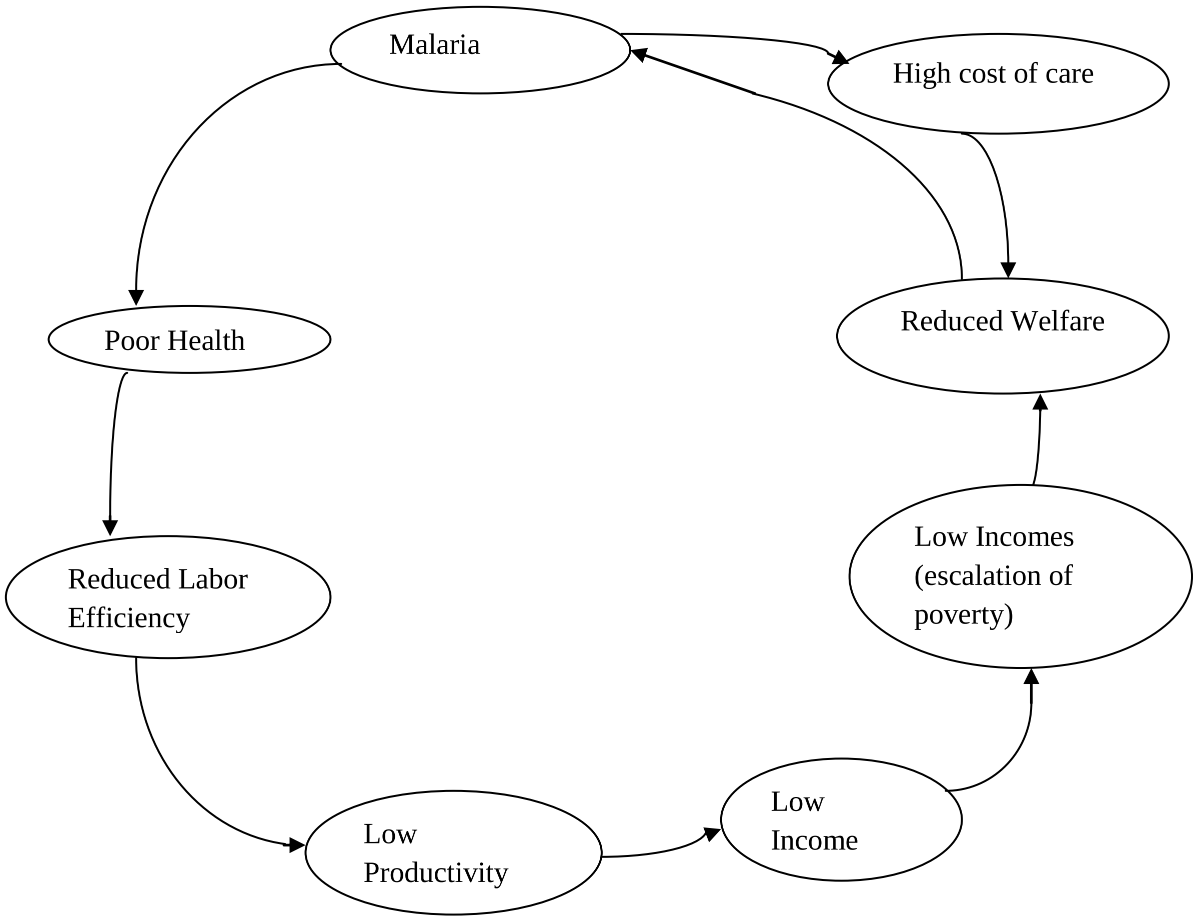

Fig. 2. The vicious circle of malaria and household poverty

2.7. Spatial Technology

Spatial technology is a field of information technology that acquires, manages, interprets, integrates, displays, analyzes and uses datasets focusing on the geographic, temporal and spatial references. Spatial technology includes wide array of the technologies such as Geographic Information System (GIS), Remote Sensing and Global Positioning System (GPS) (Saxena *et al.*, 2009).

2.7.1. Geographic Information System

GIS is computer based system that can deal with virtually any type of information about features that can be referenced by geographical location. This system is capable of handling both locational data and attribute data about such features. That is not only GIS permit the automated mapping or display of the location of features, but also this system provide relational database capability for recording and analyzing descriptive characteristics about the features. For example, a GIS might contain not only a "map" of the location of roads but also the database of descriptors about each road. These “attributes” might include information such as road width, pavement types, speed limit, number of traffic lanes, date of construction, and so on (Lillesand and Kiefer, 1994).

GIS is an umbrella term which integrates wide range of datasets available from different sources including remote sensing and GPS. Therefore, GIS is often termed as core of spatial technology having built-in power to analyze integrated dataset and to present the results as useful information to assist decision making (Saxena *et al.,* 2009).

2.7.2. Remote Sensing

Remote sensing is the art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 1994). This is possible due to the existence or the generation of force fields between the sensing device and the sensed object (Konecny, 2003).

Remote sensing principle uses waves of the electromagnetic spectrum. The energy radiates from an energy source. A passive (naturally available) energy source is the sun. An active energy source may be a lamp, a laser or a microwave transmitter with its antenna. The radiation propagates through a vacuum with the speed of light, *c*, at about 300000km/second. It reaches an object, where it interacts with the matter of this object. Part of the energy is reflected toward the sensor. At the sensor carried on a platform, the intensity of the incoming radiation is quantized and stored. The stored energy values are transformed into images, which may be subjected to image processing techniques before they are analyzed to obtain object information (Konecny, 2003).

Remote sensing is applicable in wide range of fields. Land use land cover mapping, geologic and soil mapping, agricultural applications, forestry applications, rangeland applications, water resource applications, water pollution detection, flood damage estimation, urban and regional planning, wetland mapping, wildlife ecology application, archaeological applications, environmental assessment, and land use suitability evaluation are some major areas where remote sensing is applicable (Lillesand and Kiefer 1994; Sabins 1997).

2.8. GIS and Remote Sensing in Health

Remote sensing data enable scientists to study the earth’s biotic and abiotic components. These components and their changes have been mapped from space at several temporal and spatial scales since 1972. A small number of investigators in the health community have explored remotely sensed environmental factors that might be associated with disease-vector habitats and human transmission risk (Saxena, 2009).

The powerful tools of the spatial technology have revolutionized the way the epidemiological research now being carried out. Spatial technology has clearly defined the epidemiology of disease vis-a-vis environmental factors by identifying the spatial limits of the disease prevalence and risk mapping with relevant risk factors. The relationships between the disease prevalence and vector distribution could have never been so comprehensively studied without this technology. Space based images has made getting information for vast and inaccessible areas easy and collection of data and sophisticated judgment and analysis possible (Saxena, 2009). Advances in computer processing and in geographic information system and global positioning system technologies facilitate integration of remotely sensed environmental parameters with health data so that models and risk maps for disease surveillance and control can be developed (Beck *et al*., 2000).

The application of remote sensing and GIS in identifying and monitoring environmental factors associated with vector borne disease is certainly viable. However, remote sensing and GIS will not be a robust and reliable epidemiological technique until we have make all the mechanisms clear and have developed a sound understanding of all the links among remotely sensed data, environmental factors and the spatial temporal patterns of epidemic (Liu *et al*., 2006).

2.9. Role of Geographic Information System and Remote Sensing in Malaria Risk Mapping

In the Global Malaria Eradication Programme half a century ago "geographical reconnaissance" which entailed the detailed and manual mapping of malaria vector breeding places unaided by computers, was an integral component of malaria programmes for the planning, implementation and monitoring of operations (Mendis, 2009). Since then 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 (Saxena *et al*., 2009). The relevance of GIS technologies to malaria control lies in the fact that the global spectrum of malaria epidemiology is broad, and as varied as the natural diversity of the parasite, the mosquito vector and the biological constitution of the human host. The disease varies in its prevalence, intensity, seasonality and clinical features depending on a multitude of local determinants such as the prevalence, location and nature of water bodies in which the mosquito vectors breed, and their relationship to human habitation and behavior. These in turn are affected by environmental factors such as climate, surface water distribution, elevation and prevailing flora and fauna in the area. Therefore geographical, meteorological and topographical attributes of a locality become important determinants of malaria (Mendis, 2009). However, with GIS tools it is possible to overlay accurate spatial maps of an area to examine the relationship between the parameters and aggregating them in order to enable new and critical insights to be made to the disease and its transmission localities (Mendis, 2009).

Affordable hardware and software for using GIS and remote sensing are now available hence properly used GPS, Remote Sensing, and GIS could allow the location and quantification of malaria risk to be determined in a more accurate, time and cost-effective way. Using the easy access opportunity, many maps of global malaria risk distribution in space and time have been prepared using GIS (Sithiprasasna *et al.,* 2005).

Mapping the global distribution of malaria is motivated by a need to define populations at risk for appropriate resource allocation to combat the disease (Saxena *et al*., 2009). Now management of malaria is easier with the help of the malaria risk maps demonstrating hot areas with risk factors.

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).

3. Materials and Methods

3.1. Description of the Study Area

3.1.1. Location

Fentale Woreda is located in East Shoa Zone of Oromia Regional State in Ethiopia as illustrated in figure 3. Its geographical extent ranges from 957472m North to 1012110m North in its south-north, and 572157m East to 620655m East in its west-east. It covers about 1532 km^2. It consists of about 18 rural kebeles, 2 towns, and Metehara Sugar Factory Farm Estate. Metehara, Fentale woreda main town, is founded at a distance of 96 and 200kms from Adama and Addis Ababa respectively. It is found on the main road from Addis Ababa to Djibouti. Another town of Fentale woreda, Haro Adi, is found within a short distance on the sub-road taking from the main town, Metehara, towards Metehara Sugar Factory.

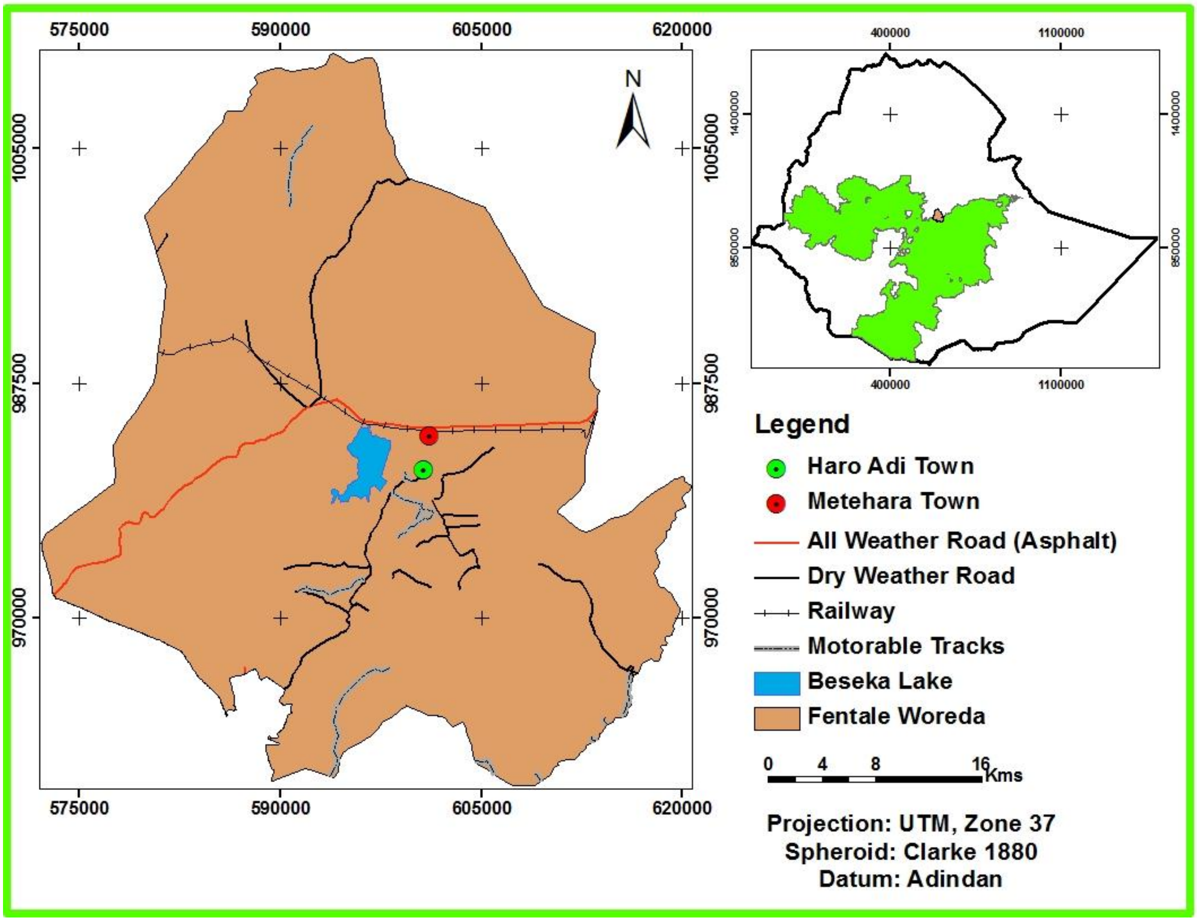

Fig. 3. Location Map of the Study Area

3.1.2. Demographic Characteristics

The total population of Fentale woreda was about 81,740 (CSA, 2007). Out of this number, 43266 and 38474 describe the number of male and female respectively. The proportion of male to female for the woreda was 53% and 47% respectively. About 61,218, (75%) of the population of this woreda live in rural area. From this number, 32,822 and 28, 396 describe the number of male and female respectively. 25% of the populations of the woreda live in Metehara and Haro Adi towns. From the total population of 20522 within these towns, about 10,444 (51%) and 10,078 (49%) are male and female respectively.

3.1.3. Topographic Structure

The topography of Fentale Woreda constitutes flat, gentle, sloppy and mountainous landscapes. Its elevation ranges between 862m.a.s.l-1997m.a.s.l. as described in figure 4.

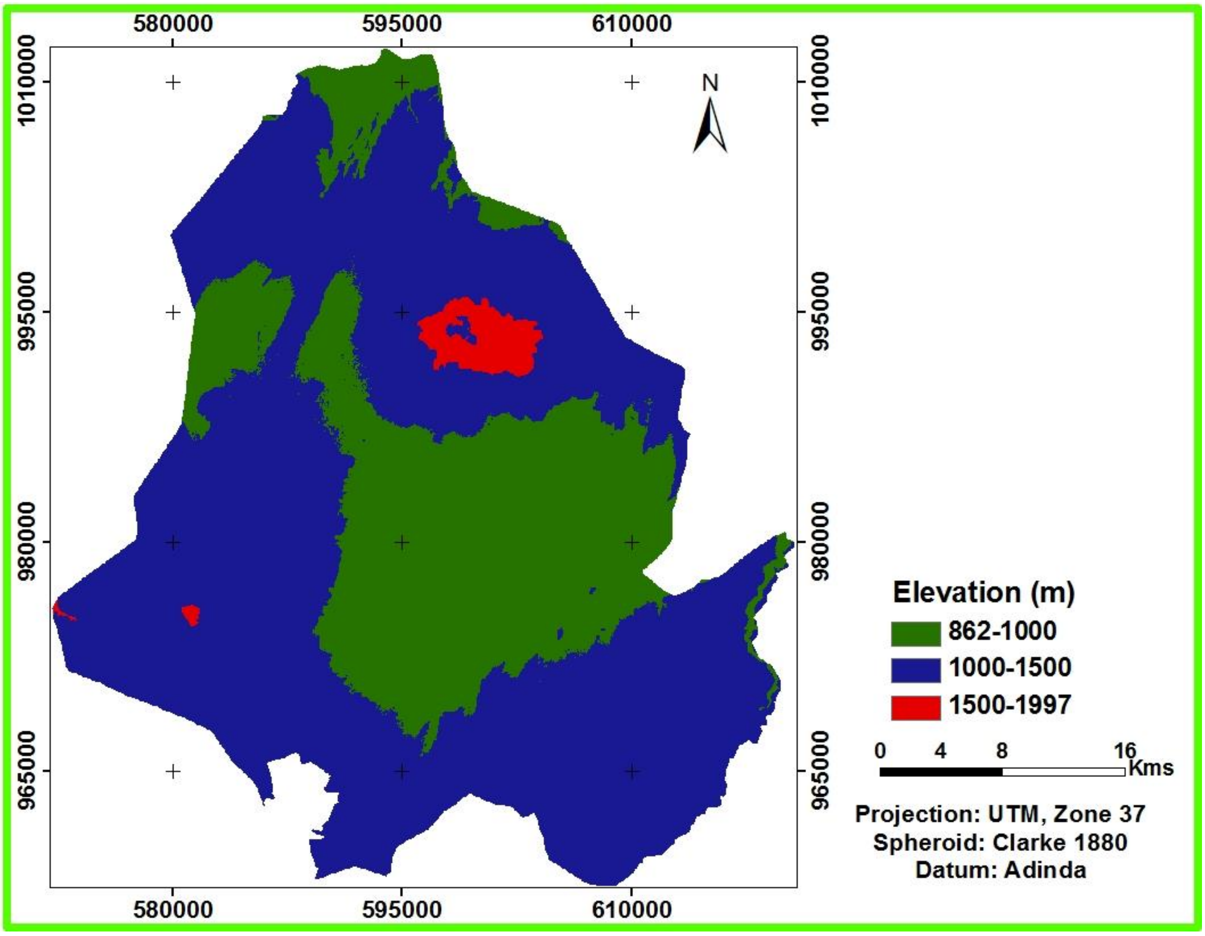

Fig. 4. Topographic Structure of the study area

Difference in elevation between the deepest and the most elevated topography is 1135 m.a.s.l. The Northern tip of the woreda is dominated by flat laying areas where as the Southern tip and South Western part is largely occupied by gentle surface. In the North Western part, Fentale Mountain takes the pick elevation within the Woreda.

3.1.4. Sources of Water

Eventhough Fentale Woreda receives lower amount of annual rain fall, it has large surface water potential relative to its neighboring Woredas.. Awash river is one of the main perennial rivers of Ethiopia and cross through Fentale Woreda. It originates from the upper central highlands and travels long distance up to its destination in the deserts of Afar region collecting large volume of water from several tributaries. On its way to its destination, it is utilized for different purposes. It is source of drinking water both for human and livestock, feeds numerous small scale and large scale irrigation schemes like Metehara Sugar Factory Farm Estates and other food processing industries in the area. Other large rivers called: Arba, Wanga and Kesem also flow in this woreda as described in figure 5.

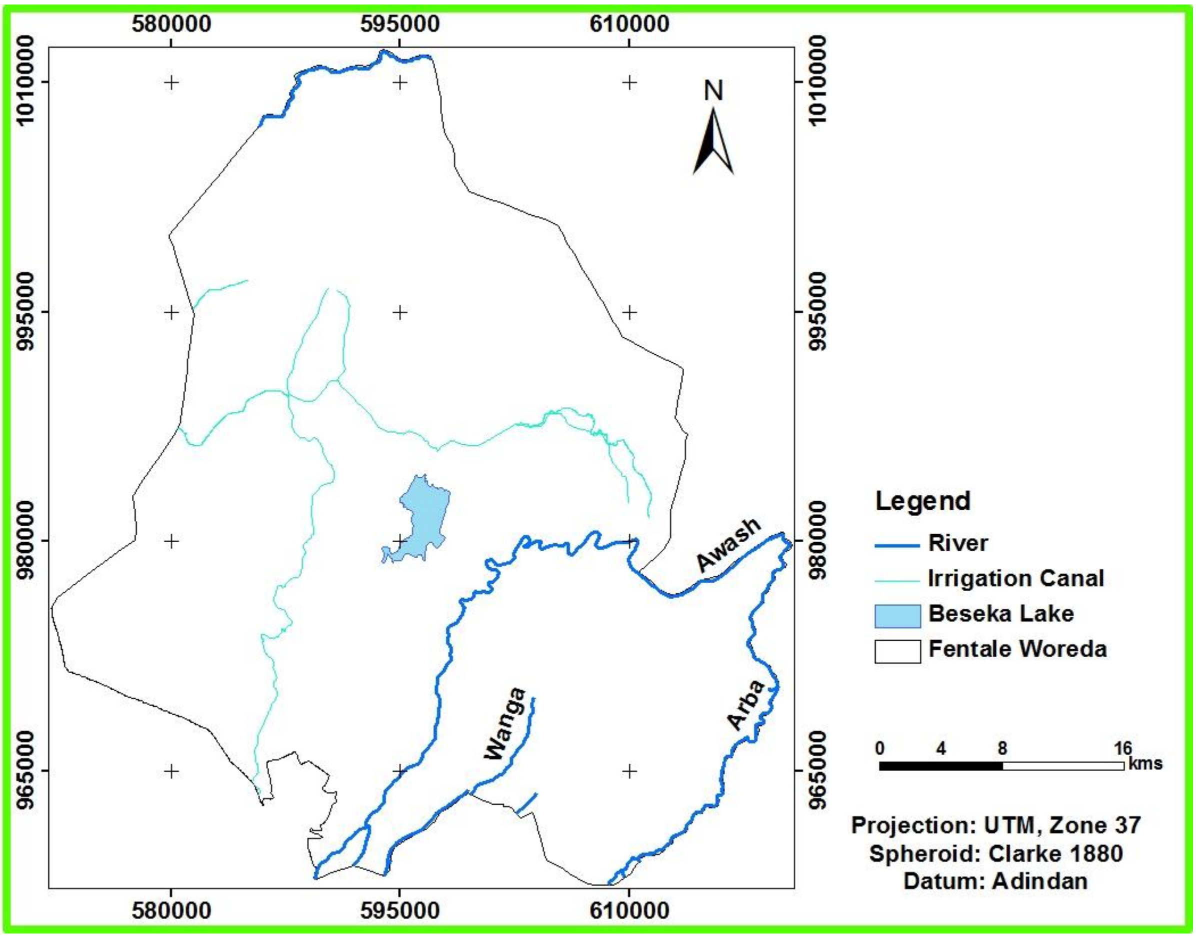

Fig. 5. Water Sources of the Study Area

Lake Beseka which is characterized by rapidly expanding saline water is also source of surface water with limited use for some parts of the study area.

3.1.5. Climate

The climate of Fentale area exhibits typical characteristics of arid and semi-arid environments. Its mean minimum and mean maximum monthly temperature ranges between 12.8^{0}C-20.9^{0}C and 31.0^{0}C-36.7^{0}C respectivelly as described in figure 6. Its mean monthly temperature within a year ranges between 21.9^{0}C to 29.2^{0}C in the months of December and June. The yearly maximum temperature ranges from 32.7 to 34.8^{0}C while the minimum temperature ranges from 16.5 to 18.8^{0}C.

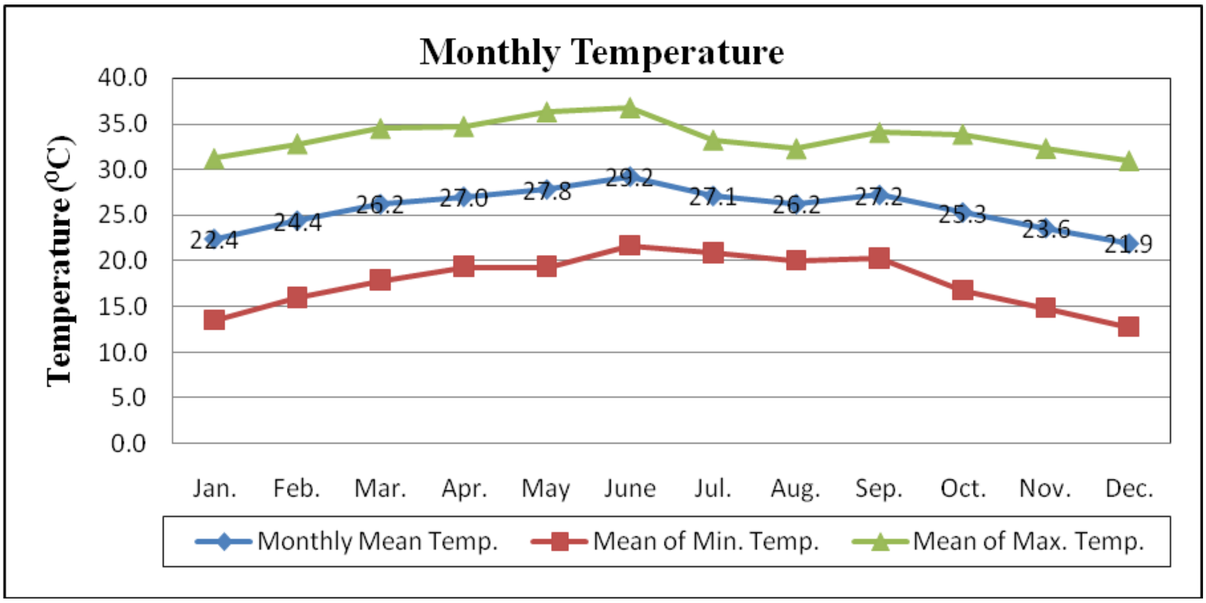

Fig. 6. Mean monthly, mean max. and mean min. monthly temperature of Metehara from 1980 to 2009.

Source: NMSA

The mean annual rainfall of the study area is about 502mm with erratic and scarce occurring two or three times yearly. The main rainfall season, which accounts for the largest total rainfall of the year occurs from July to September, and this season is locally termed as *Ganna* (which means main rainy season in *Afaan* Oromo). In good years the area also experiences some amount of rainfall in the month of December. The other rainfall regime, called *Afrasa*, occurs from February to April. The later is very important for the Karrayu pastoralists in particular, since it comes at the point when herds and human exhaust by the long dry season (OWWDSE, 2008). The mean monthly rainfall of the area ranges between 5.4 mm and 118.3 mm in the months of November and July, respectively. These and others are described graphically in figure 7.

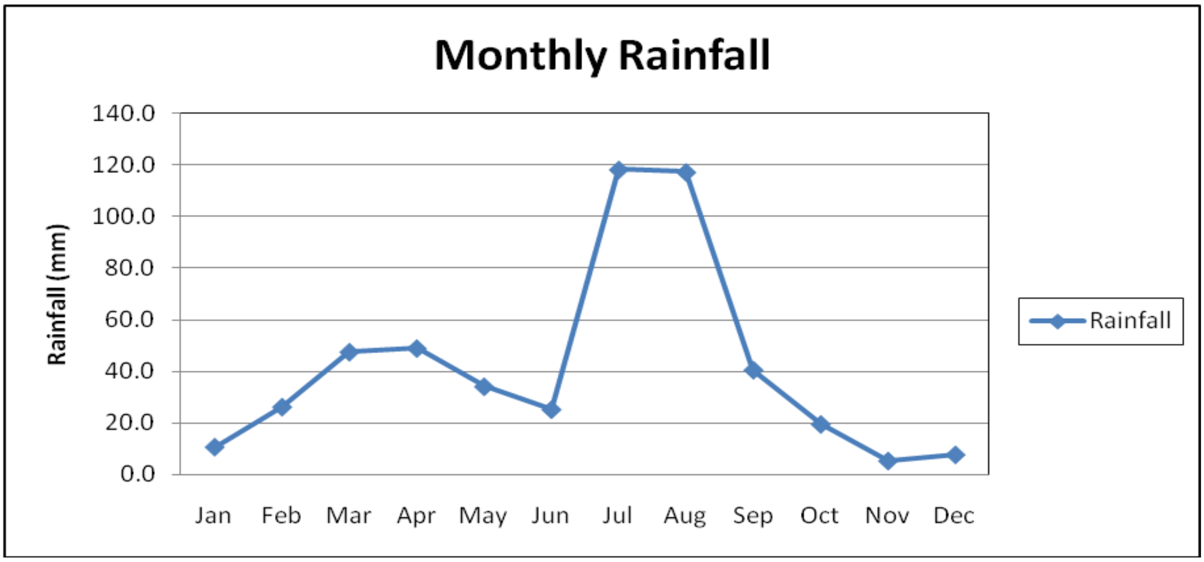

Fig. 7. Mean monthly rainfall of Metehara from 1980 to 2009.

Source: NMSA

3.1.6. Temporal Malaria Trend

Fentale woreda health office stated that relative to the far past years malaria cases started to decrease over the last decade except during occasions of epidemics. But still it is the number two desease in the area which is responsible for mortality and morbidity. Figure 8 indicates that the temporal number of malaria cases over years were being declining with some irregularities.

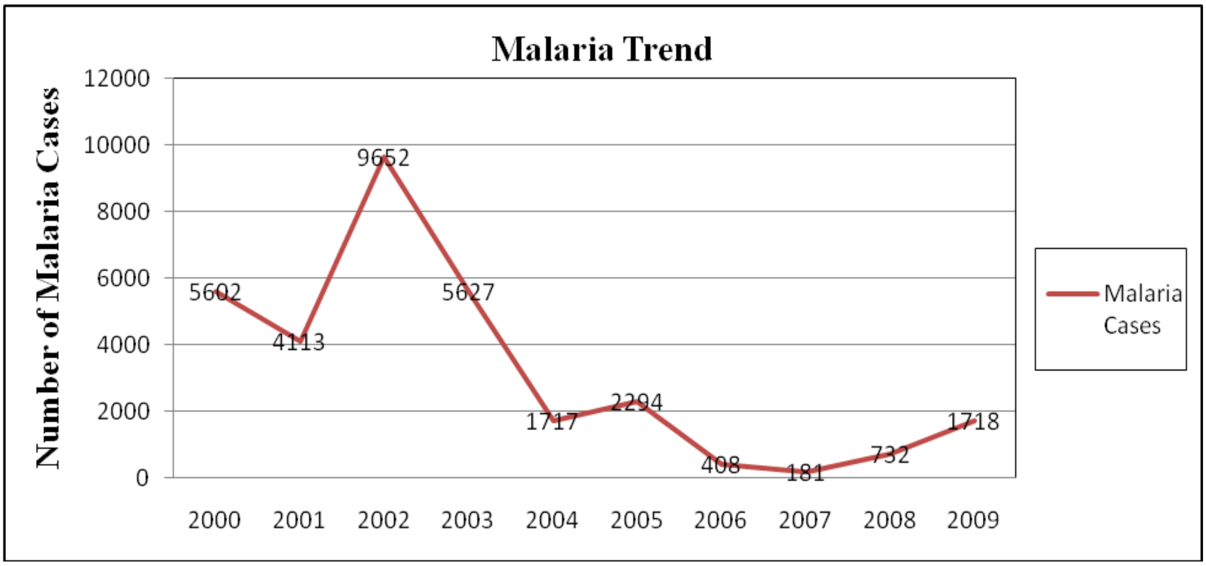

Fig. 8. Temporal Trend of Malaria Cases (2000 to 2009).

Source: Merti Hospital and Fentale Woreda Health Office.

In the last ten years, the maximum malaria case was recorded during the year 2002 followed by the year 2003 with number of cases 9652 and 5627 respectivelly. This were due to the epidemics caused in the area at that times. The number of total cases within a year exceed the stated number due to the fact that in Ethiopia, only 27% of cases related to fever have been shown to visit health facilities and the majority of cases and deaths occur at home (UN OCHA, 2004).

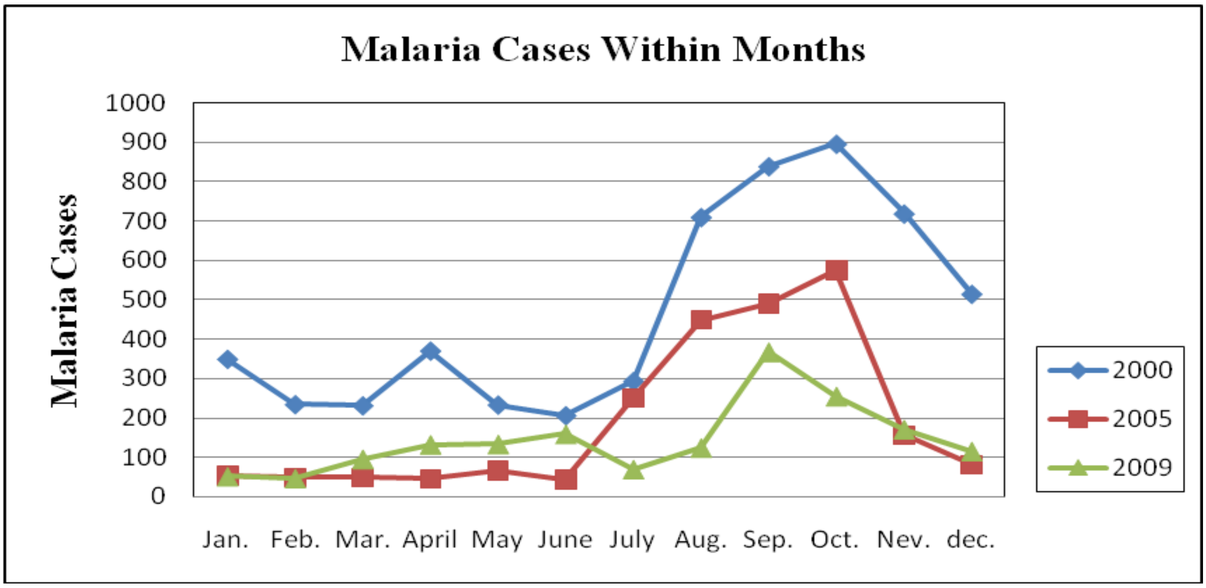

Fig. 9. Malaria Cases within a Month of the Years 2000, 2005, 2009.

Source: Merti Hospital and Fentale Woreda Health Office.

Malaria cases in the years 2000 and 2005 started to increase in the month June and reached the highest at the month of october as indicated in figure 9. This is associated with the main rainy season of the area which starts at July and stays upto September. But in 2009 it started to increase at July and reached the maximum in the month of September. This indicates there was lag of rainfall during this season since rainfall is a driver of seasonality of malaria cases (Briet *et al.*, 2008). Similarly, malaria cases within a month for the other years from 2000-2009 are attached in the appendix.

The figure also indicates there is malaria case increment after the rain stopped. This is due to land-use land-cover existing during these times favor mosquito breeding through providing shade, moisture, and even food for the male mosquito as the effect of last gone rain retains. But after the harvest of agricultural production and continues dry season it starts to decline due to no suitable condition like enough amount of moisture within vegetations, different impounded water bodies for egg laying and the likes.

The relationship between malaria prevalence and rainfall corelates posetivelly with lag of two weeks to a month depending on the mosquito spicies (Devi *et al.,* 2006). The lag time is due to the processes getting accomplished between the onset of rains and appearance of malaria cases. After a heavy rain, there is a possibility for water to recede so as to provide new breeding sites. Further, time is needed for larvae to hatch, mature pupae and form adults, for the adult female to find an infected host and become infected itself and for completion of sporogonic development of malaria parasite within the vector. Additional time may be required for the infected mosquito to bite an uninfected host (Devi *et al.,* 2006).

Generally this area is characterized by seasonal malaria with a frequent occurrence of epidemics, often from September to December, following the heavy rainfall season (Zinaye *et al.,* 2010).

3.1.7. Farming System

The major farming systems being practiced in the area are pastoralism, agro-pastoralism and mixed farming in order of their importance. Forced by the problem of food shortage and decreasing of livestock, which is the result of recurrent drought and shortage of rainfall which again resulted in animal (cattle in particular) feed shortage and led to the perish of a large number of cattle, a number of people who were previously pastoralists are gradually being engaged in agro-pastoral way of life (OWWDSE, 2008).

According to Fentale Woreda Pastoral Development Office out of the total 18 rural kebeles eight of them were practicing pastoralism; five of them were engaged in agro-pastoralism and the rest have been practicing mixed farming. But with the development of irrigation canal, some of the pastoralist kebeles have been started to practice sedentary farming and most of them will be included in irrigation based agriculture in the near future with the completion of irrigation canal development expansion to the unreached areas.

3.1.8. Livelihood

Livestock and crop production are the main source of income for the population of this area. Small portion of the population living in the two towns is engaged in different trade activities and services for travelers from the central to peripheral part of the country and vice versa. The two towns are found on the main import-export route of the country and on the main road leading to eastern towns and chat (*Catha edulis*) producing zones creating suitable environment for the service providers. Significant number of inhabitants also lead their life being employed in factories and selling labor.

3.1.8.1. Crop Production

Maize, teff, haricot bean and recently to some parts of the area, where there is beginning of irrigation practice, various types of vegetables such as onion and tomato are being grown at large. The major constraint with regard to crop cultivation in the area has been inadequate and erratic rainfall which makes the crop dry before it reaches the seed filling and uncompleted growth cycle of the crop.

3.1.8.2. Livestock Production

The main livestock species commonly exist in Fentale woreda are cattle, goat, sheep, camel, and donkey. Goat and sheep are mostly used for source of meat for food and as means of income generation after sold in the local market. Cattle and camel are sources of milk. Donkey and camel are used as means of transportation to bring production to market.

3.2. Materials

Different materials and softwares have been used based on the relevance to different activities and processes towards the accomplishment of the research. Type of materials and softwares used in this study and their respective sources are annexed at the end of the document.

3.3. Data Collection

Different data of primary and secondary sources were collected from field survey and respective institutions. Climatic data which constitute temperature and rain fall of the study area was taken from National Metrological Service Agency (NMSA). Shapefiles of the study area which is comprised of different thematic and attribute data of road and its type, rivers and its type, existing town, rural kebeles, and woreda boundary were taken from CSA of Ethiopia. GPS has been used to collect locations of different types of health institutions within the study area and GCPs which has been used in land use land cover classification. Elevation and other topographic data were taken from SRTM data of USGS. Other ancillary input data were used from different government offices, field survey and observations, and focus group discussions which were undergone with malaria control experts.

3.4. Methodology

Malaria risk of an area is the function of climate, topography, land-use/land-cover, population, and proximity related risk factors. To see the effect of each factors, climate, topography, land use land cover, population density, and proximity related risk levels of malaria were produced from climate, topography, land-use land cover, population density, and proximity related factors respectively. Weight was given to each risk factor in multi-criterion-evaluation system. Finally, weighted overlay was applied to generate the final malaria risk map of the study area. Figure 10 shows the general methodological framework used for this study.

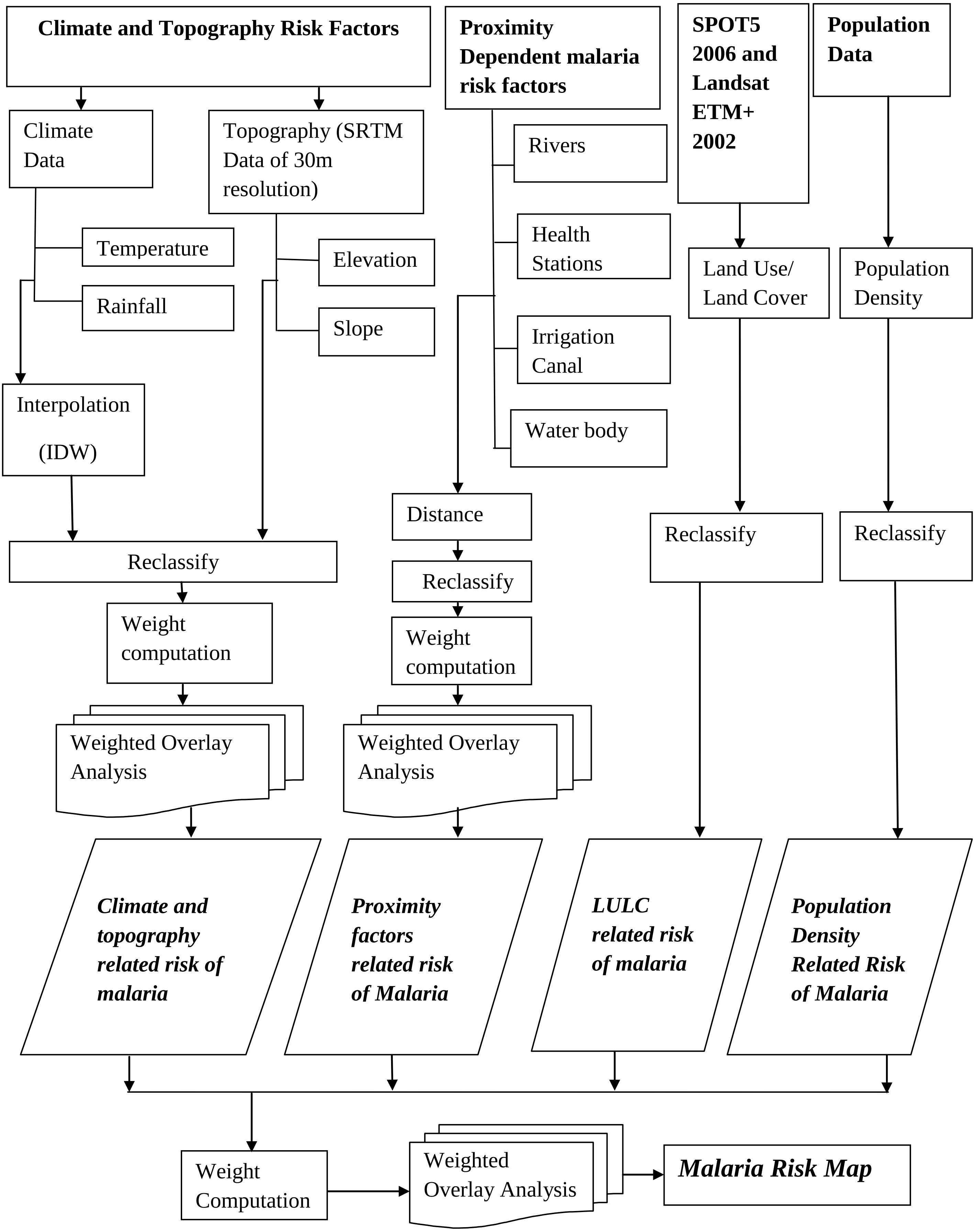

Fig. 10. Methodological framework

3.4.1. Sources of Data

Facts and figures were gathered from different related researches, literatures, woreda health office and malaria experts to be used in the methodology part of this study. These were described in the literature and table 2 below.

Table 1. Facts and Figures used within the methodology

No.	Factors	Descriptions
1	Temperature	➢ 26^0C Suitable temperature for larvae development (Messay *et al*., 2009). ➢ Higher incidence of malaria at 18°C to 32°C (ACMAD, 2009). ➢ Minimum temperature for development of *P. falciparum* and *P. vivax* approximates 18^0C and 15^0C, respectively (Patz *et al*., 2008). ➢ The optimum temperature for both vector and parasite for the transmission of malaria is 25-27^0C (McMichael *et al.*, 1996 as cited in Bashir *et al*., 2003). ➢ Temperature from approximately 21°-32°C is most conducive for malaria transmission[2]
2	Altitude	➢ In Africa, altitudes above 1,000-1,500 m.a.s.l. are considered safe from malaria. But local condition and climate change should be cautioned[2] ➢ In Ethiopia Highland fringe areas at altitude range of 1500-2500m.a.s.l. (northern and central area), lowland arid areas (eastern and southeastern area) at altitude ranges of below 1500m.a.s.l are prone to malaria epidemics (UN OCHA, 2004). ➢ Endemic malaria disappears above 1,800–2,000 m (Reiter, 2008). ➢ Areas below 2,000 m.a.s.l are malarious/ potentially malarious (MoH, 2008).
3	Rainfall	➢ Rainfall is a driver of seasonality of malaria cases (Briet *et al*., 2008) ➢ Beneficial if it is moderate, but may destroy breeding sites and flush out the mosquito larvae when it is excessive (Michael and Martens, 1995 as cited in Devi and Jauhari, 2006).

4	Distance from Water Source	➢ Villages located close to the reservoir associates with large number of adult mosquitoes than those located further away (Solomon *et al.*, 2009). ➢ Reservoirs, irrigation canals, and dams are closely associated with the increase of a variety of parasitic diseases that are water dependent[2] ➢ Mosquito can travel up to 4 km in search of a blood meal from water body (Peter, 2010). ➢ Mosquitoes are abundant within 1 km Radius of the breeding site (Watery area) (Peter, 2010; Jude, *et al*. 2010).
5	Distance from health institutions	➢ Areas within 5km radius is considered as an area with good access to health institutions[3] ➢ Areas found within 3 Km radius from a health facility is assumed to be less risky than areas found beyond this distance (WHO, 2003 as cited in Arega, 2009). ➢ 2-5km, physical accessibility of health institutions (Ali *et al* 2008).
6	LULC	➢ Regarding LULC malaria risk: sandy soil, Bare soil, and Dry vegetation; Forest and bush land; rain fed farm land and water body; and irrigated farm land show risk levels low, medium , high, and very high respectively (Dambach *et al.* 2009). ➢ Unregulated urbanization and increase in population number results in increase of malaria prevalence (Martens and Hall, 2000). ➢ Irrigation creates an ideal habitat for mass-production of mosquitoes (Reiter, 2008; Senzanje *et al*., 2002)
7		➢ About 70-90 per cent of the risk of malaria is considered due to environmental factors (Sivani, 2010).
8	Particulars to the Study Area	➢ Beseka Lake is salty water. It does not favor mosquito breeding with the same rate with other clean water does. But its effect on malaria prevalence increases with increase in its over flood to other soil type other than its native place. ➢ Rivers over flood during rainy seasons so that its area coverage and suitability for mosquito breeding increases. Beseka Lake is currently expanded to Metehara and Haro Adi towns. ➢ Most of the time vegetation cover of the area is relatively with low water holded in since the area is in the rift valley zone. This affects the humidity at the area which is important for mosquito breeding.

3.4.2. Climate and Topography Related Malaria Risk

3.4.2.1. Climate Related Malaria Risk

Climatic data, temperature and rainfall, of the study area were interpolated from 11 nearest meteorological stations surrounding the study area. The stations are Shola Gebeya, Meteteh Bila, Balchi, Awash Sebat Kilo, Awash Arba, Sabure, Bedayu, Metehara, Wolenchiti, Abomssa and Nura-Era as described in figure 11.

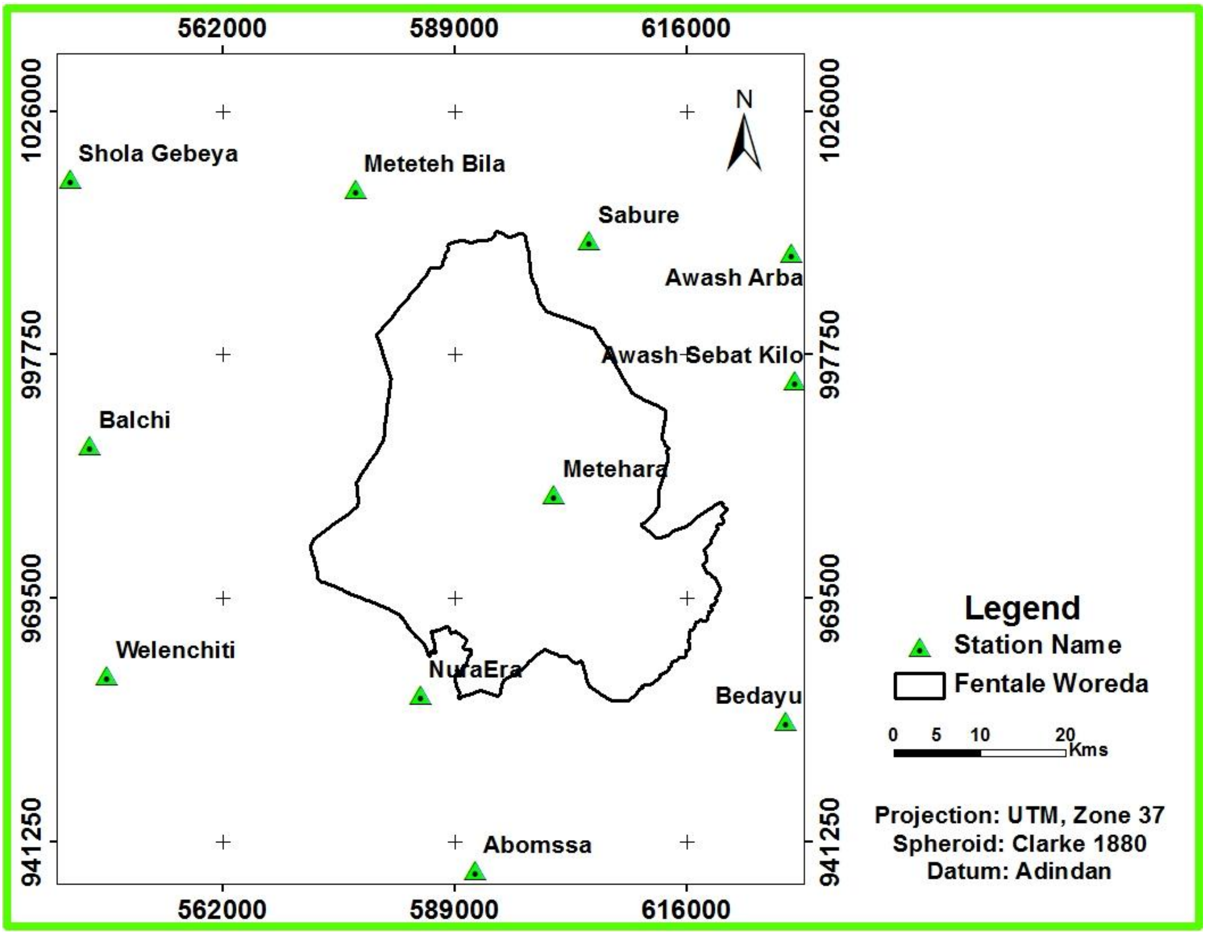

Fig. 11. Map of Meteorology Stations surrounding the study area

3.4.2.1.1. Temperature Related Risk of Malaria

Plasmodium parasite does not survive well below 15^{0}C and if it does, it cannot transmit malaria due to the dormancy of the parasite at this temperature. Hence, areas with such temperature value are malaria free with respect to temperature related malaria risk. Both the vector and the parasite start to multiply slowly as temperature increase above 15^{0}C up to 20^{0}C. Mosquito and the plasmodium parasite stars to multiply at moderate, high and very high rate at temperatures 20-23^{0}C, 23-25^{0}C, and 25-27^{0}C respectively. But as temperature increases further, mosquito breeding and parasite development start to decrease. Accordingly, temperature values of 27-32^{0}C and >32^{0}C were seen associated with temperature related malaria risk levels of high and low respectively. Mean of maximum and minimum temperature of each month first, then that of each year of 30 years (1980-2009) were computed from monthly maximum and minimum temperature of about 11 stations taken from NMSA of Ethiopia. These, means of maximum and minimum of 30 years, were again computed for the average single value. These values were used for surface interpolation in ArcGIS using Spatial Analyst's Tool by Inverse Distance Weight (IDW) method and classified into seven classes, <15, 15-20^{0}C, 20-23^{0}C, 23-25^{0}C, 25-27^{0}C, 27-32^{0}C, and >32^{0}C; and these were reclassified into Malaria free, low, medium, high, Very high, high, and low respectively based on the relationship between malaria prevalence with respect to temperature. Values 0 to 6 consiquetively were given for the above classes and these were assigned new values of 1, 2, 3, 4, and 6 with very high, high, moderate, low, and malaria free respectively. The study area fell in the temperature class values of 20-23^{0}C, 23-25^{0}C, and 25-27^{0}C for which corresponding temperature related malaria risk level of medium, high and very high respectively were seen as described in figure 12.

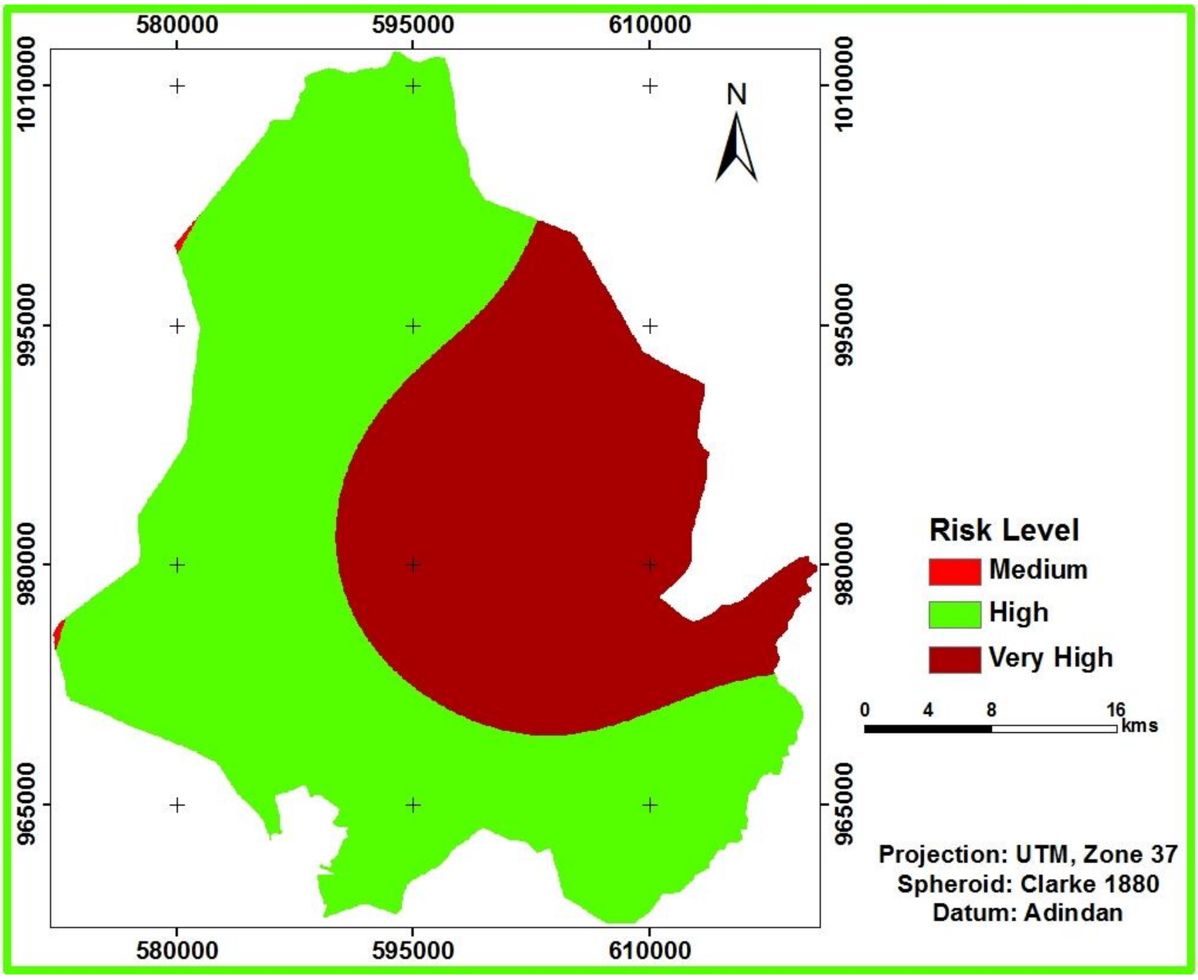

Fig. 12. Temperature Related Malaria Risk Level

3.4.2.1.2. Rainfall Related Risk of Malaria

It is well known that water either from rainfall or canals, rivers, and other sources are important for mosquito breeding through favoring where to lay its eggs. Therefore areas with high source of either sources of water are more suitable for mosquito breeding provided that the areas are found under suitable temperature condition. Eventhough an increase in temperature and rainfall increases mosquito breeding, it should be known that this is up to some maximum limit beyond which the relationship could be reversed. High rainfall destroys mosquito larvae from its stable habitat. Accordingly, rainfall amounts of <550mm, 550-700mm, and 700-1000mm were seen associated with rainfall related malaria risk levels of low, medium and high respectively as shown in the figure 13.

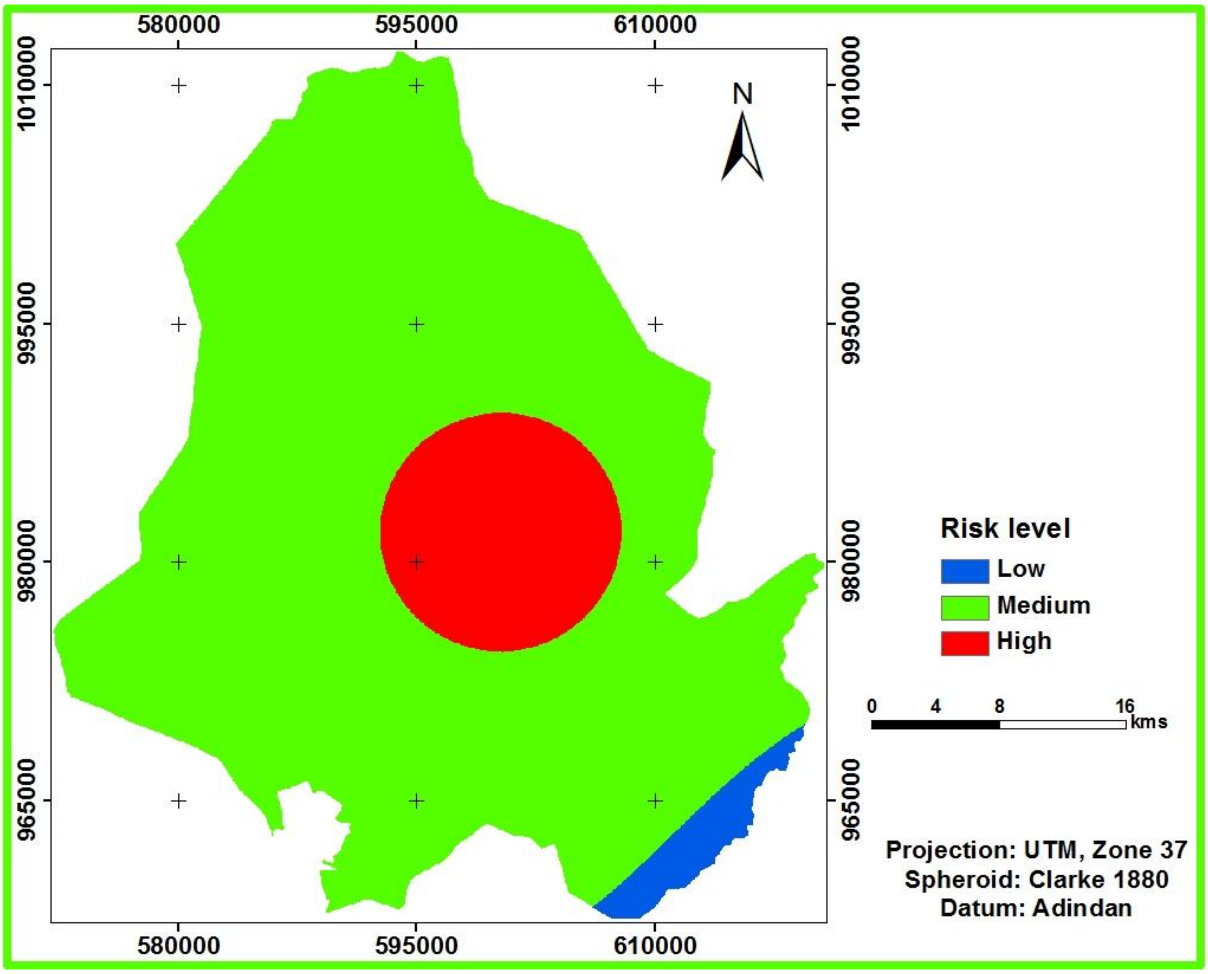

Fig. 13. Rainfall Related Malaria Risk Level

3.4.2.2. Topography Related Risk of Malaria

Topography of an area determines the elevation, and slope of a particular area. This in turn determines the type of biological organisms and physical characteristics prevailing in that particular area. It also determines the prevailing micro climate. These factors together are helpful indicators as to which disease causing vectors are prevailing in the area based on their natural requirement for their existence.

3.4.2.2.1. Elevation Related Risk of Malaria

Elevation of the study area was derived from STRM data of 30m resolution. This were classified into three classes of 862-1000m, 1000-1500m and 1500-1997m based on the relationship between elevation and malaria stated in the table above and assigned values of 1, 2 and 3 respectively. These values were seen associated with elevation related malaria risk levels of very high, high, and medium respectively as described in figure 14.

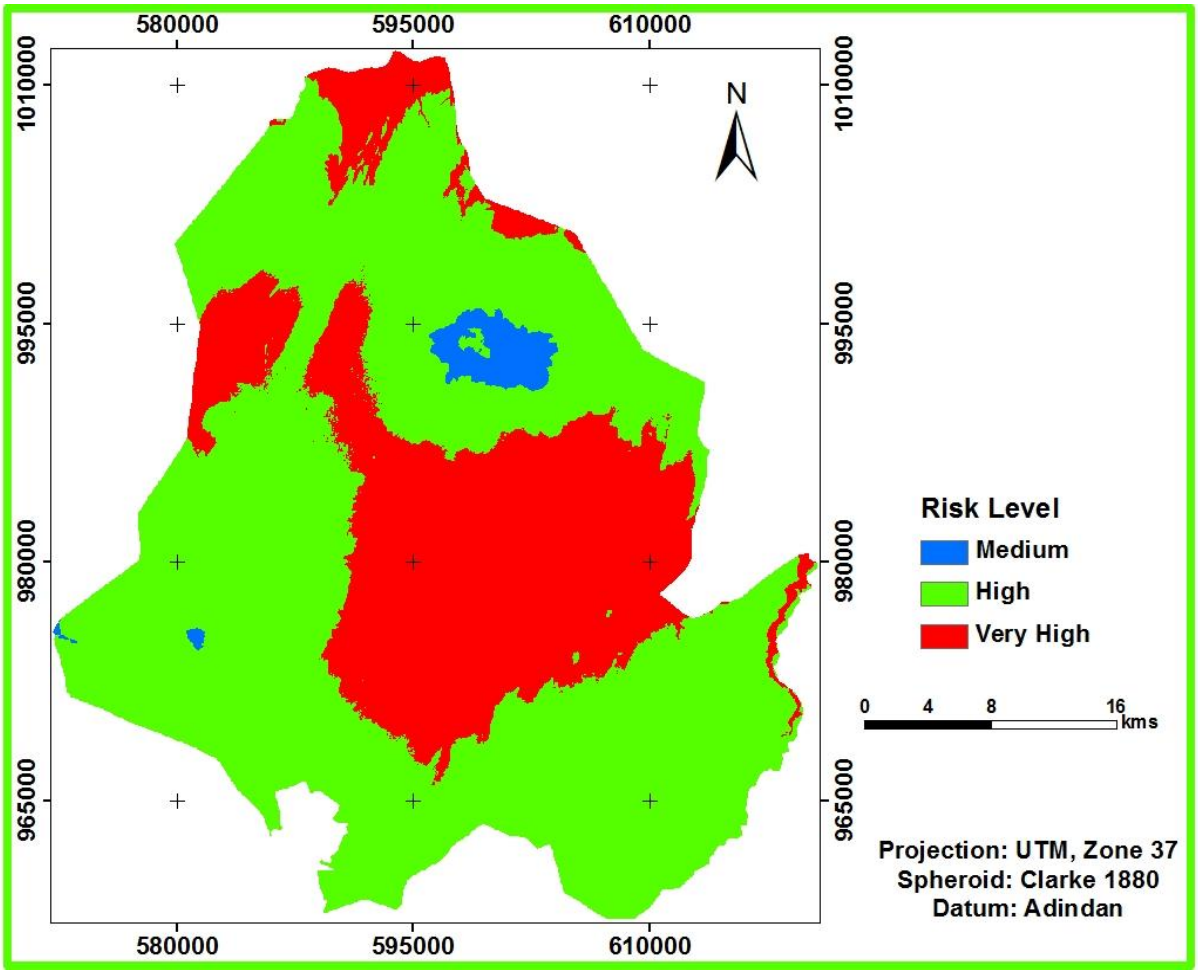

Fig. 14. Elevation Related Malaria Risk Level

3.4.2.2.2. Slope Related Risk of Malaria

Slope of an area describes the relative verticality of a particular area. Area with higher slope is usually typical characteristics of fragile, mountainous, and unstable physical area of the earth. This affects mosquito breeding in two ways: It does not support varieties of vegetation and animal population so that there could be low factors to favor mosquito breeding.

Secondly, unstable slope does not hold water at a particular place. But mosquitoes need still water to lay their eggs and progress to the next development cycle. Therefore, plain and gentle slopes favor mosquito breeding than sloppy areas. According to FAO, (1976) and malaria experts of the study area, slope classes 0-5%, 5-8%, 8-15%, 15-30% and >30% are the appropriate classes to indicate the level of existence of watery body or marshy area and vegetation within a particular area.

Accordingly, areas with 0-5% slopes have high probability to have water bodies and marshy areas and vegetations whereas as the slope increases this starts to decline. Therefore, areas with low and high slope classes are with high and low slope related malaria risk levels respectively. Based on this fact, slope classes 0-5%, 5-8%, 8-15%, 15-30% and >30% were seen associated with slope malaria risk levels of very high, high, medium, low and very low respectively as described below in figure 15.

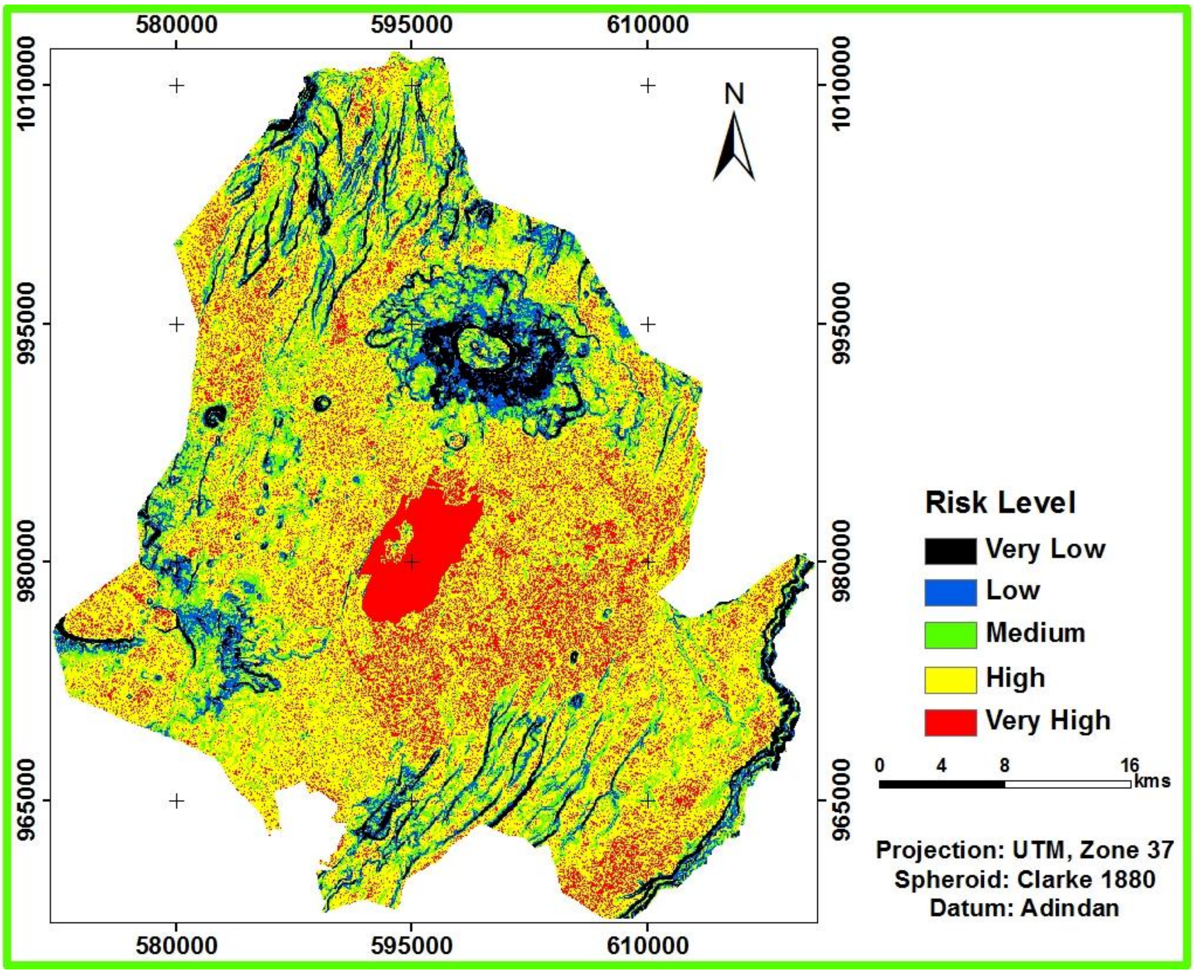

Fig. 15. Slope Related Malaria Risk Level

3.4.3. Proximity Related Malaria Risk Factors

3.4.3.1. Distance from rivers

Breeding of mosquito is related with different water sources. River is one among several of these. Mosquito requires still or slow moving water to lay its eggs and to complete its life cycle to be an adult. But river is not conducive for this since it disturbs and destroys the eggs and larvae during its movement with pressure in need of its stability. Water diverted from rivers for different purposes and in case of over flow becomes still and favor mosquito egg laying. This influences the particular area with increased mosquito breeding and malaria prevalence.

For this study, Euclidean distance from rivers was calculated from the rivers within the study area using spatial analyst tool in ArcGIS. This was classified into classes with a distance of <1000m, 1000-2000m, 2000-3000m, 3000-5000m, and >5000m; and these were seen associated with very high, high, medium, low, and malaria free area, river related malaria risk levels respectively as described in figure 16.

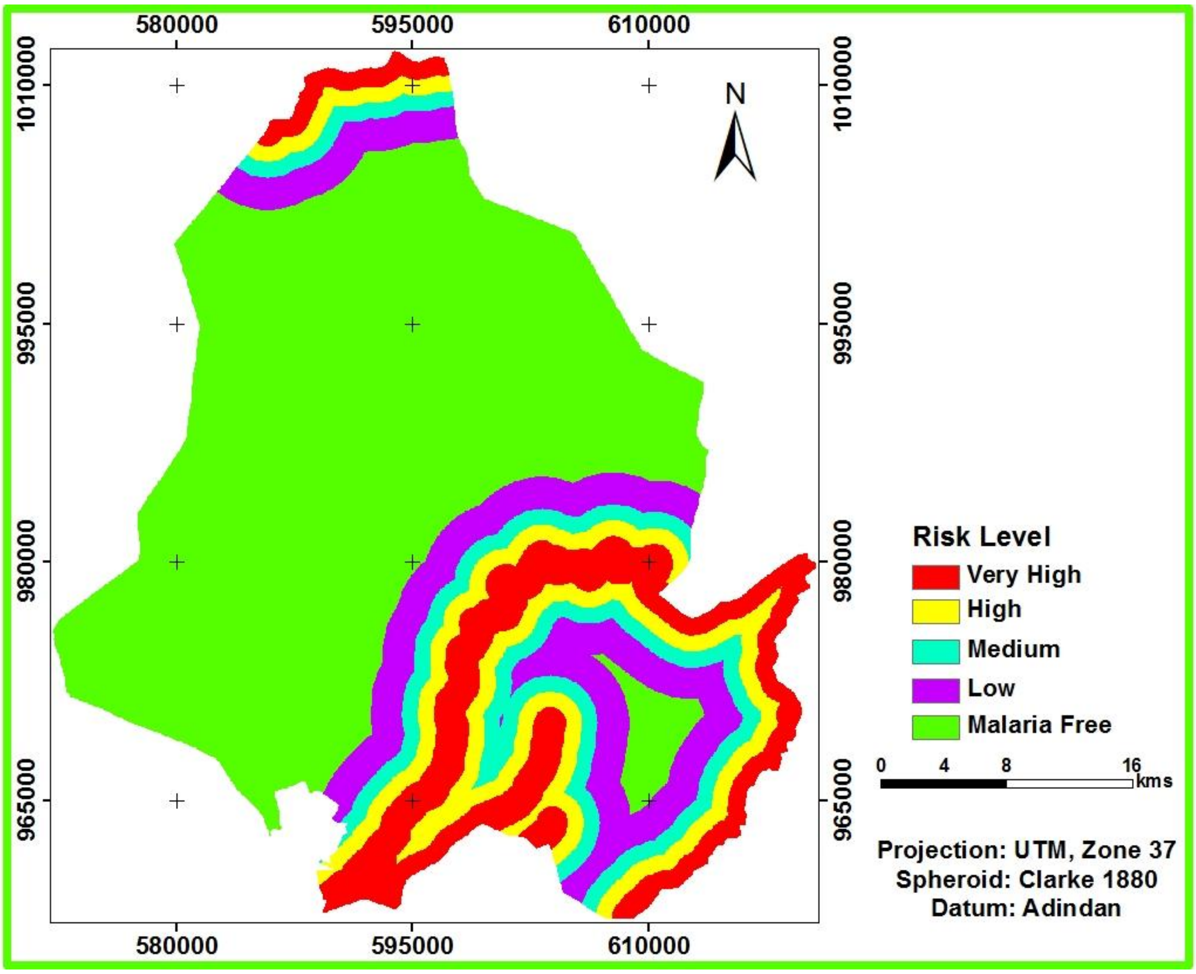

Fig. 16. River Related Malaria Risk Level

3.4.3.2. Distribution of Health Institutions and Malaria Prevalence

Presence 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 accessibility 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.

To identify health institutions accessibility and for their effect for those inaccessible areas, spatial location of health institutions within the study area were collected with GPS on field survey for accessible areas and from Woreda Health Office for those at remote and accessibility were limited. The type and spatial distribution of them are illustrated in figure 17.

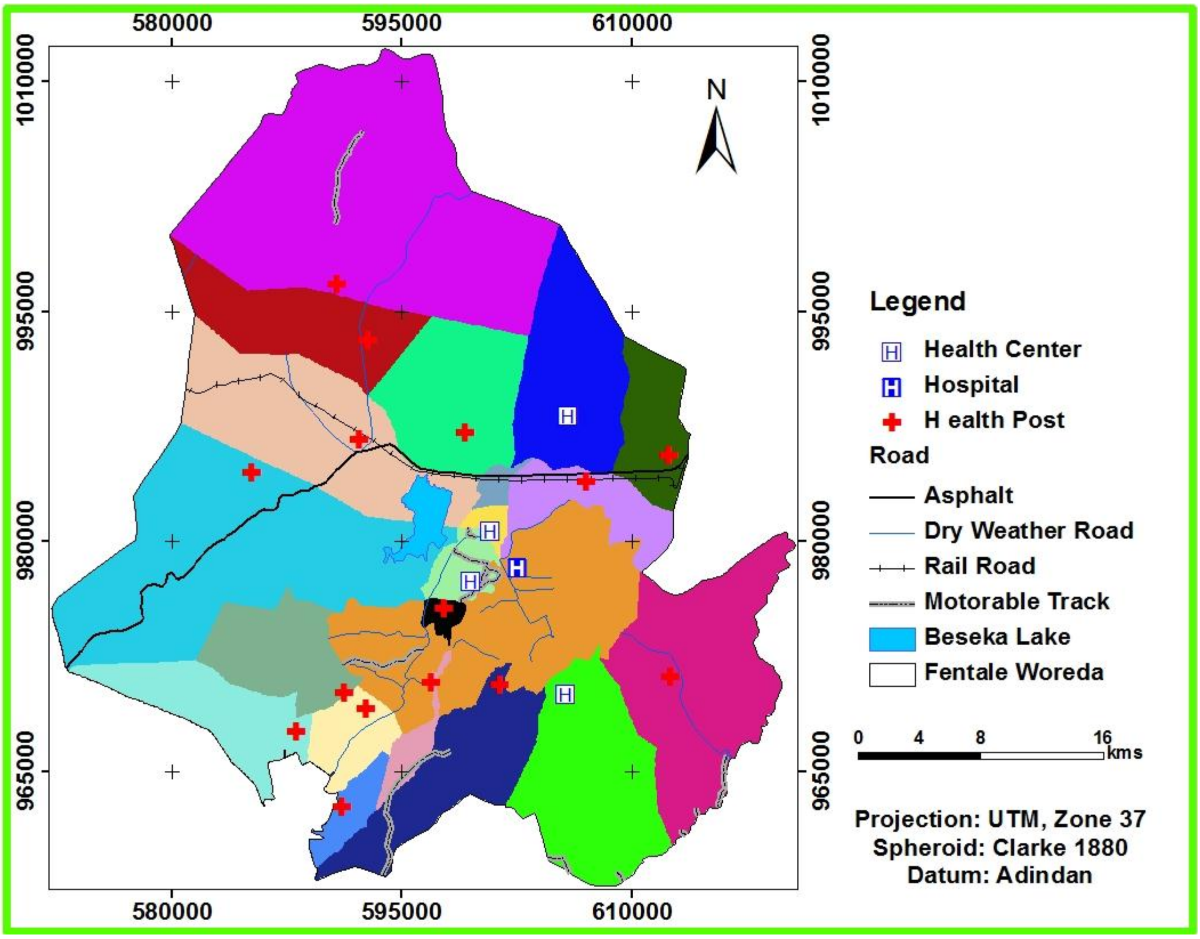

Fig. 17. Spatial Distribution of Health Institutions in the Study Area

Source: Fentale Woreda Health Office

There are 23 health institutions in Fentale Woreda. The figure includes 3 health posts which later upgraded into health center. These were excluded for proximity analysis as they are located within the same compound to serve for the same population. Accordingly, 20 health institutions of which one hospital, four health centers, and fifteen health posts are used to see for their relationships with malaria prevalence.

Having located spatial distribution of health institutions, Euclidean distance from each health institutions were calculated and reclassified into classes of <3000m, 3000-5000m, 5000-7000m, and >7000m; and these were assigned malaria risk levels of low, medium, high, and very high respectively as described in figure 18.

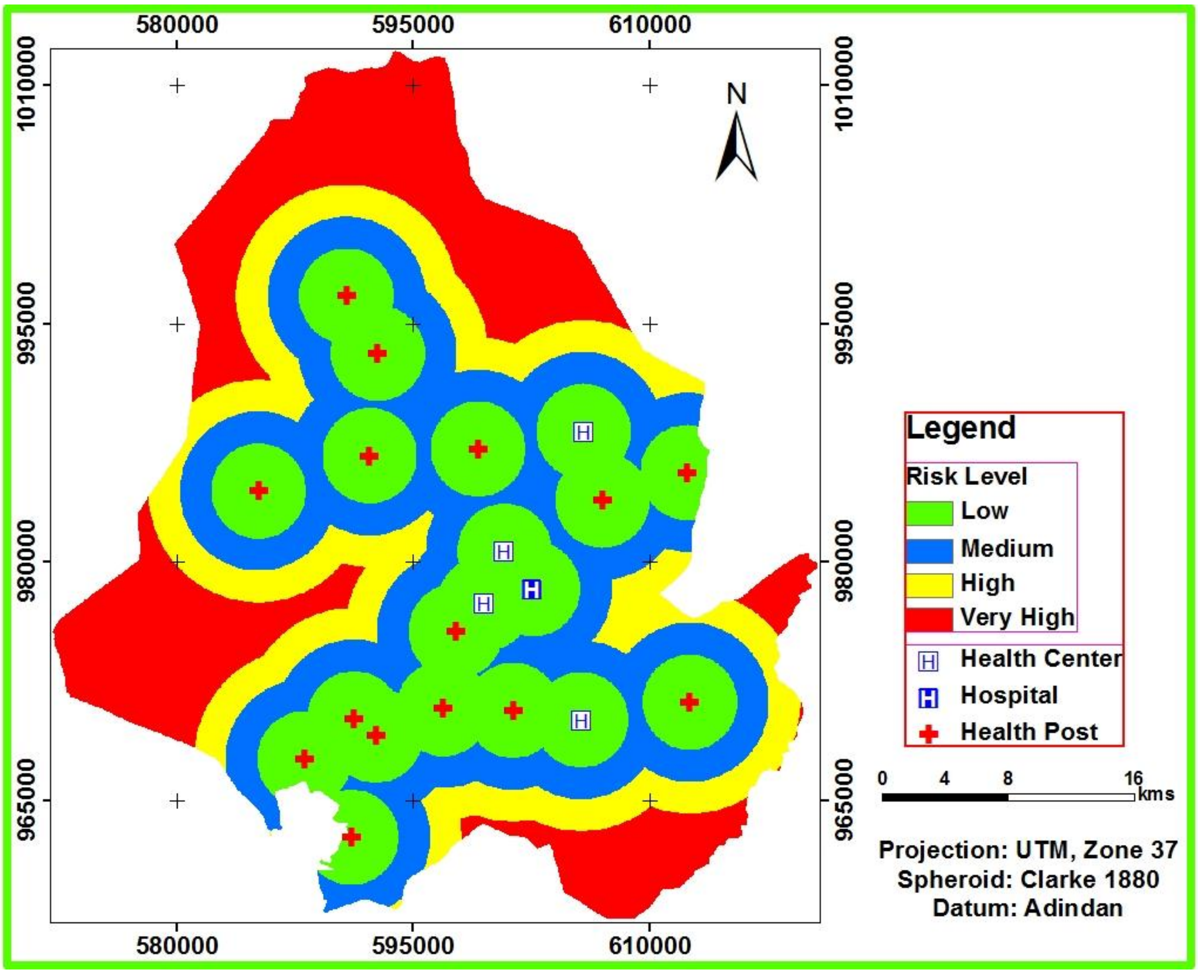

Fig. 18. Proximity to Health Institutions and Related Malaria Risk Level

3.4.3.3. Irrigation Canal Effect on Malaria Prevalence

Areas which are very near to irrigation canals are more suitable for mosquito breeding than areas which are far from it. This is due to the opportunities created by the water within the canal and linkages from it for egg laying. By their nature most of the time mosquitoes do not fly long distance from their habitat, most of the time they fly up to 2kms so that their abundance decreases with an increase in distance from irrigation canals. Hence irrigation canal distance related malaria risk level also decreases with an increase in distance from it due to the decrease in suitable habitat for the mosquitoes.

Shapefile of irrigation canal within the study area was taken from Fentale Woreda Environmental Protection and Land Administration Office. Euclidean Distance was calculated from each canal and classified into five classes of <500m, 500-1000m, 1000-2000m, 2000-3000m, >3000m; and these were associated with respective irrigation canal distance related malaria risk levels of very high, high, medium, low, and free from malaria respectivelly as described in the figure 19.

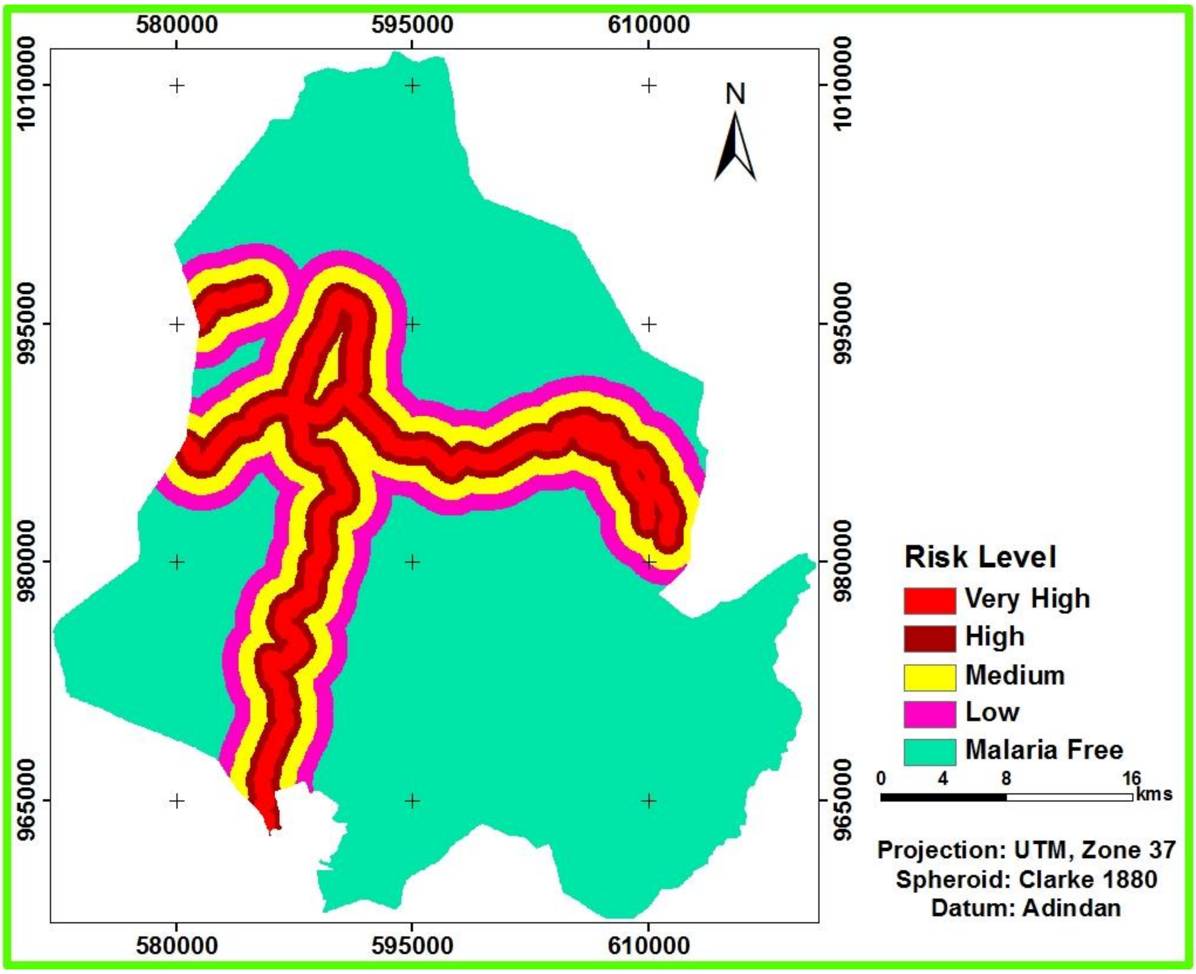

Fig. 19. Distance from Irrigation Canal and Related Malaria Risk Level

3.4.3.4. Effect of Water Body on Prevalence of Malaria

Water body (Water not moving) is a typical place for mosquito breeding. Such type of water body in the study area is Beseka lake. Baseka lake is expanding at alarming rate recently. But the impact it has on malaria prevalence is small compared with clean water. This is due to its salt content and other chemicals constutuent which is not conducive for mosquito breeding.

Still, the impact it has on malaria prevalence should be considered as stated by experts from Fentale Woreda Health Office, particularly when it over floods as the current time.

Eventhough Beseka lake does not favor mosquito breeding at its orginal place, it starts to support larvea development as soon as it leaks to different soil type other than that of its native place soil type. The probablity to get the overflooded water is vast for those areas which are near to the lake than for those area relativelly at far distance. Therefore, areas found near to the lake are at higher malaria risk level with respect to this factor than areas which are relativelly at far distance.

Euclidean distance from Beseka lake to other areas were calculated using Spatial Analist tool in ArcGIS environment. This were classified into five classes of <500m, 500-1000m, 1000-2000m, 2000-3000m, and >3000m; and these were reclassified into high, medium, low, very low, and malaria free area respectivelly based on the level of risk level for malaria prevalence. This is described in figure 20.

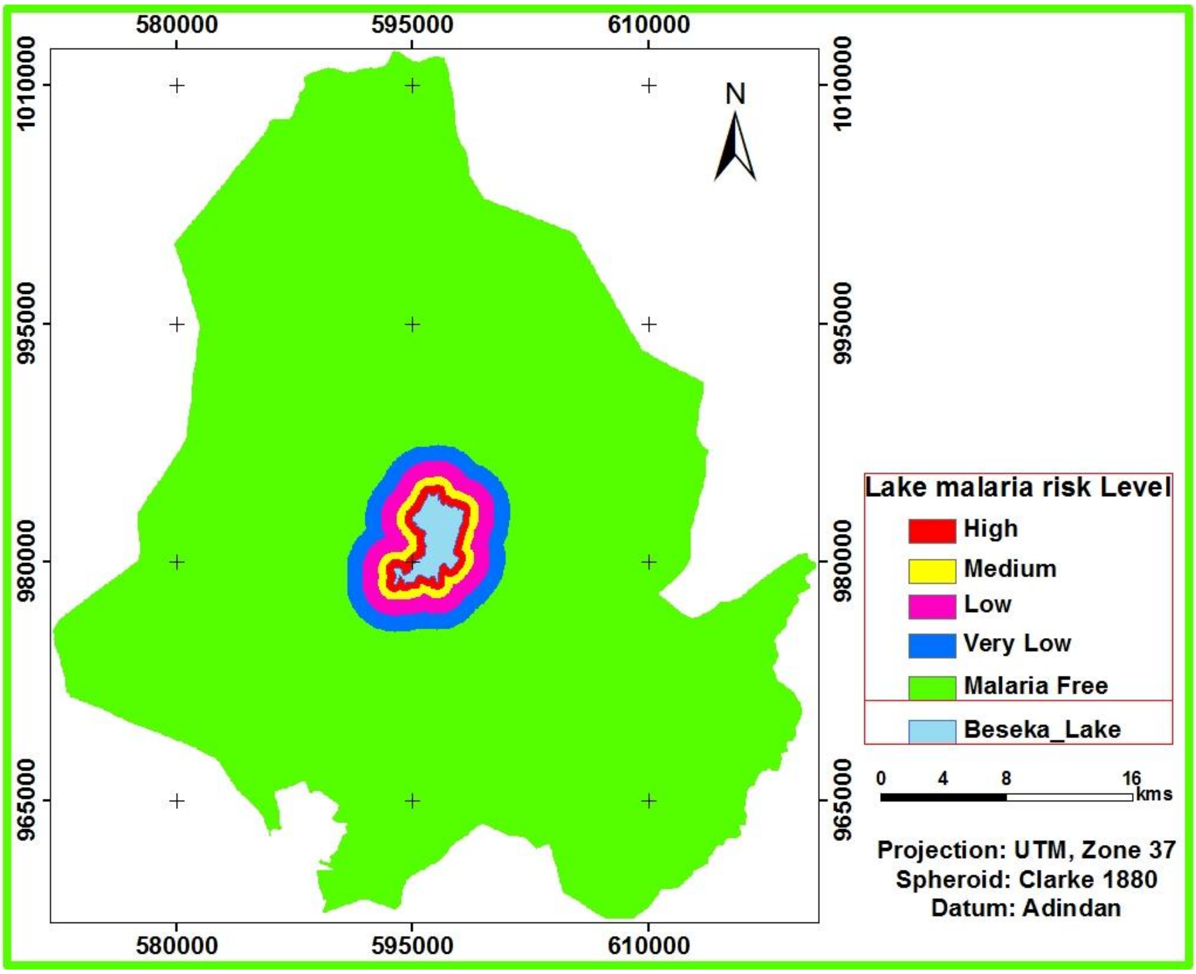

Fig. 20. Distance to Beseka Lake and Related Malaria Risk Level

3.4.4. Land-use Land-cover

Different kinds of land-use land-cover indicate different types of residential areas suitable for various vectors (Liu *et al*., 2006).

3.4.4.1. Satellite Image Classification

To identify land use land cover of the study area, landsat ETM+ imagery of raw 54 and path 168 acquired on 02, 26, 2002 and SPOT5 of the year 2006 were merged. SPOT5 has spatial resolution of about 5m where as the landsat ETM+ is with 30m. In order to assimilate together and carry out further processes the two images' cell size should be the same. For this purpose SPOT5 image were taken into 30m cell size and were fitted with that of landsat ETM+. Supervised image classification aided with representative land-use/land-cover types (which were taken using GPS for ground truthing during field survey) were used to train the classification algorithm in ERDAS Imagine software. The image was classified into main land-use/land-cover types. They are described below and illustrated in figure 21:

Settlement: This is built-up areas in which the construction inputs are largely from cement and concrete as in the case of the two towns and Metehara Sugar Factory settlements. In addition to this, there are houses built from mud and wood as construction materials input in these areas. It also describes a typical Kereyu (local people) house prevailing largely in the rural parts of the study area which is made from local grass and wood.

Farmland: land used for cultivation of crops on rain feed agriculture. It is scarcely distributed and mainly used for the production of maize, teff and haricot bean. Population of the area were largely pastoralists in the near past but recently they are trying to adapt themselves with crop production as their main livelihood, livestock production, is decreasing from time to time. Therefore areas under crop production are increasing from time to time.

Bush-shrub-land: this ranges from dwarf to medium height thorny acacia species. On average it measures about 2.5 meters. *Acacia tortilis and Acacia nubica* are the dominant species in the area. These are largely used by the local peoples for the production of charcoal which supplement their livelihood especially during the dry season of the year.

Acacia Woodland: This is dominantly *Acacia Senegal* with medium height which is larger than the bushes and shrubs. It measures up to 5 meters. This is found over small amount of the study area. Locally it is used for the construction of houses and scarcely for the source of fire wood.

Irrigation Farmland: It is farm estate which is occupied by Metehar Sugar Factory. It is used for the production of sugarcane which is used as an input for the production of sugar. Recently FIBIDP developed irrigation canal which takes water from Awash River to some kebeles for the farmers. With this, the local people are producing mainly maize and others like onion and haricot bean in small amount.

Fallow land: open uncultivated land which could be cultivated in the next season. This includes both which are found in the irrigation and rain feed farm lands. This can be ploughed farmland but not seeded or farmlands which are not ploughed after the last harvest but left fallow for one or more harvesting seasons.

Grassland: this is mostly found where bushes, shrubs and acacia wood lands are scarcely distributed. It is the main source of grazing land for the livestock population.

Water Body: This describes water body laying over an extended land surface for long period of time. Beseka is the lake expanding at an alarming rate with unknown factor in this area. Its water is salty that it is not used for drinking and food preparation.

Rock Outcrop: is a molten rock laying over an extended land surface as a result of volcanoes. It is unfertile and does not support crop production. It is not compact enough to support construction of houses for residential purpose. Currently this area is not serving for any use type.

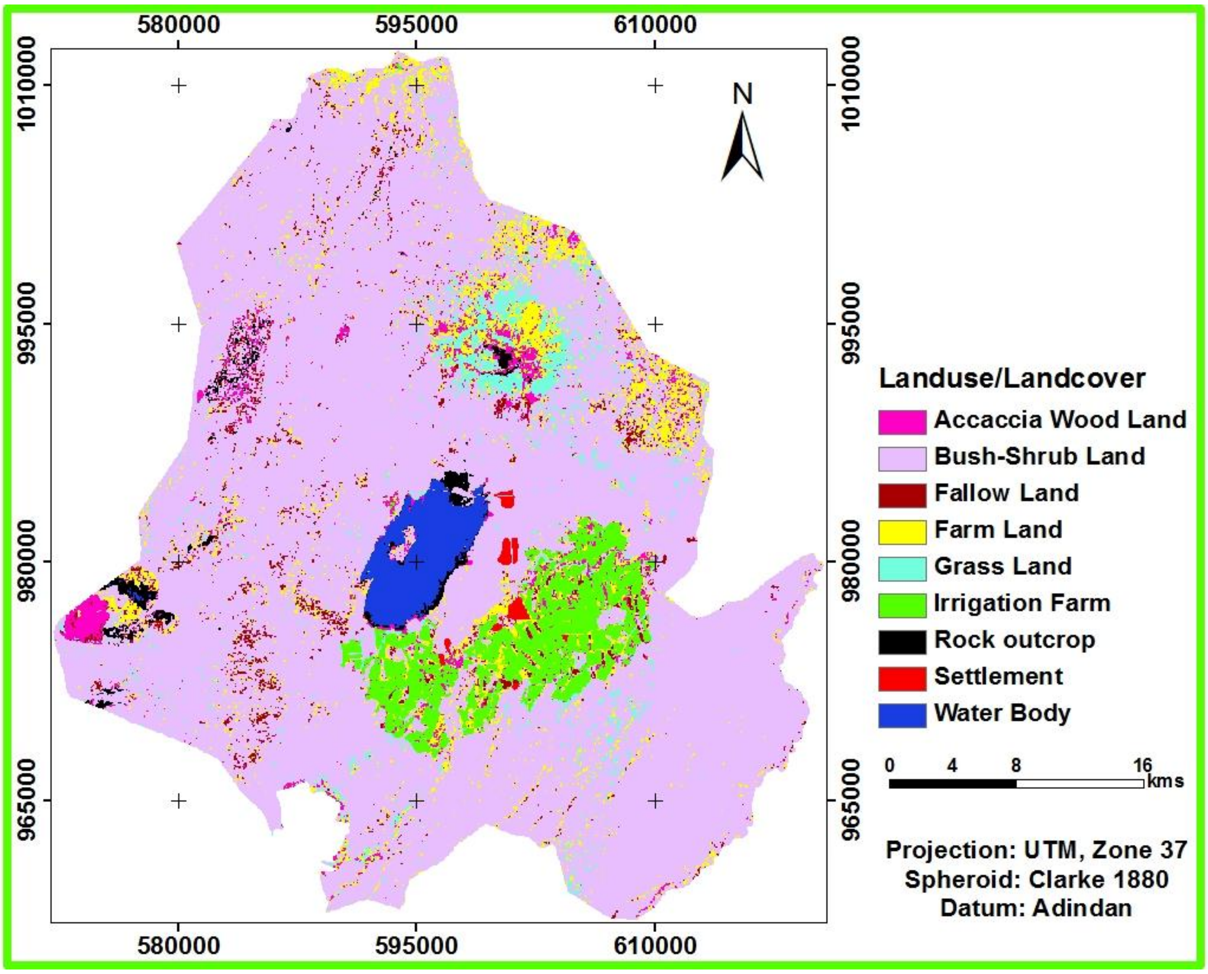

Fig. 21. Land-use/Land-cover map

Significant amounts of land were changed into Irrigation farms after the establishment of FIBIDP since 2006. These were addressed through updating the classified image with the shape file of irrigation farm plots obtained from Fentale Environmental Protection and Land Administration Office.

The area coverage and proportion of each land-use/land-cover type of the study area is summerized in table 3.

Table 2. LULC of the Study Area

S/N	Land use Land cover Type	Area in km^2	Percentage (%)
1	Irrigation Farm	85	5.5
2	Settlement	6	0.5
3	Farm land	89	6
4	Grass land	50	3
5	Water body	38	2
6	Fallow land	31	2
7	Bush shrub land	1178	77
8	Acacia wood Land	39	3
9	Rock outcrop	16	1
	Total	**1532**	**100**

3.4.4.2. Accuracy Assessment

Classification is not complete until its accuracy is assessed (Lillesand and Kiefer, 1994). One of the most common means of expressing classification accuracy is the preparation of a classification error matrix. Accordingly, classification error matrix was prepared using the image used for this study, ground truth during field survey and the final classified LULC map. The result indicated that an overall classification accuracy of 87.89% and overall kappa statistics of 0.7900. The kappa coefficient 0.7900 implies that 79% of errors were avoided that could be generated by completely random classification. Producer and user accuracy ranges from 50.00%-100% and 72.73%-100% respectively as described in table 4.

Table 3. Accuracy Assessment for Land-use Land-cover of the study Area

CD	IF	Se	FLW	FL	WB	BSL	AWL	RC	GL	RT	CLT	NC	PA (%)	UA (%)	CK
IF	8	0	0	2	0	1	0	0	0	11	11	8	61.54	72.73	0.7127
Se	0	1	0	1	0	0	0	0	0	1	1	1	100.0	100.0	1
FLW	1	0	9	0	0	0	0	0	0	11	11	9	50.00	81.82	0.8044
FL	2	0	0	17	0	0	0	0	0	19	19	17	77.27	89.47	0.8848
WB	0	0	0	0	12	0	0	1	0	13	13	12	92.31	92.31	0.919
BSL	1	0	9	2	0	152	3	0	3	170	170	152	98.06	89.41	0.7316
AWL	1	0	0	0	0	0	6	1	0	8	8	6	66.67	75.00	0.7409
RC	0	0	0	0	1	0	0	3	0	4	4	3	60.00	75.00	0.745
GL	0	0	0	0	0	2	0	0	17	19	19	17	85.00	89.47	0.8858
CT	13	1	18	22	13	155	9	5	20	256	256	225			

Overall Classification Accuracy =87.89%

Overall Kappa Statistics = 0.7900

Land cover categories: IF= Irrigation Farm, Se= Settlement, FLW= Fallow Land, FL= Farm Land, Water Body, BSL=Bush-Shrub Land, Acacia Wood Land, RC= Rock outcrop, and GL=Grass Land

Accuracies: Overall classification accuracy= 87.89%, Overall kappa statistics= 0.7900, PA= Producer's Accuracy, UA= User's Accuracy, KC= Kappa coefficient

Totals: RT= Reference Total, CT= Column Total, NC= Number correct, CLT= Classified Total,

RT = CT

3.4.5. Assigning and Aggregating Criterion Weights, and Overlaying the Risk Factors

3.4.5.1. Climate and Topography Risk Factors

Temperature, rainfall, elevation and slope were rated for their relative importance in IDRISI Andes decision support system based on Pairwise Comparison 9 Point rating Scale. The value assigned for each of them is based on the level of their influence on malaria prevalence relative to each other. These were identified from prior researches and discussions held with malaria experts working at the study area. Here one should consider that different factors' influence level may vary from place to place so that the local condition should be considered carefully before deciding for their relative influence. Accordingly, the pairwise rating and weight computed for each factors in IDRISI Andes software were described below in figures 22 and 23 respectively.

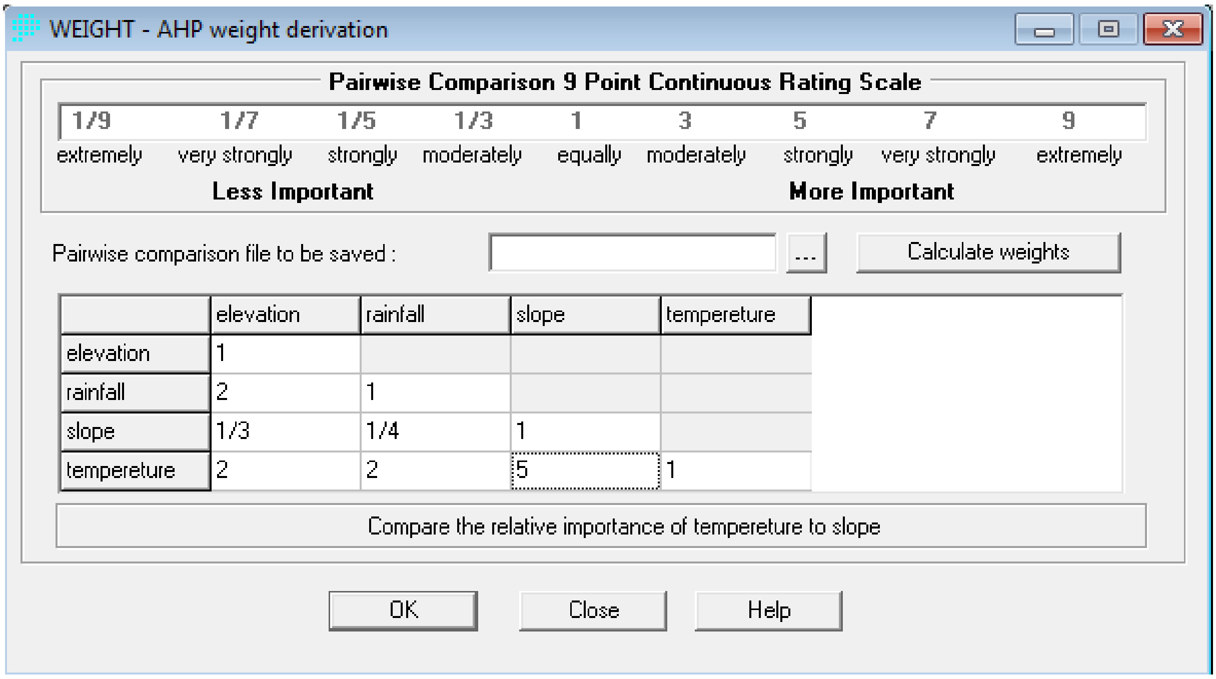

Fig. 22. Climate and topography AHP Weight Derivation

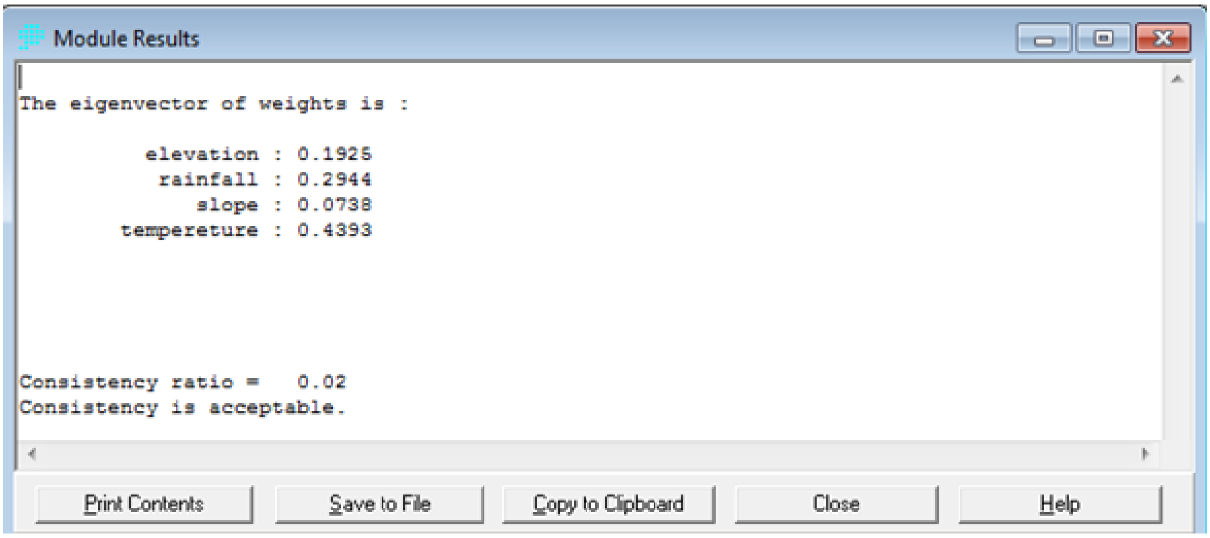

Fig. 23. Module Results of Climate and Topography Malaria Risk Factors Weight Description

The consistency ratio for the Eigenvector of weights is within an acceptable range with the value 0.02.

Using the above computed weights in ArcGIS spatial analyst tool, overlay analysis with weighted overlay method which overlays several rasters using a common measurement scale and weights each according to its importance, the final map for climate and topography risk indicator of malaria prevalence was produced.

The Eigenvector of weights, risk Levels within each factor and value associated with each risk level were described in table 5.

Table 4. The Eigenvector of weights of Climate and Topography

S/N	Climate and Topography Risk Factors	The Eigenvector of weights	Percentage Weight (%)	Values Assigned	Risk Level within the factors
1	Elevation	0.1925	19.25	1 2 3	Very High High Medium
2	Rainfall	0.2944	29.44	2 3 4	High Medium Low
3	Slope	0.0738	7.3	1 2 3 4 5	Very High High Medium Low Very Low
4	Temperature	0.4393	43.93	1 2 3	Very High High Medium

3.4.5.2. Proximity Related Malaria Risk Factors

Level of proximity related malaria risk factors determines malaria prevalence in one way or the other. Using the same procedures as the above one, proximity factors were put in IDRISI Andes software for pairwise comparison and weight were computed for each factors. The level of importance of each factor in pairwise rating scale; and computed weight, values assigned and associated risk level for each factor is described in figure 24 and table 6 respectively. The consistency ratio is 0.01 which is in acceptable range below the maximum limit to be in the acceptable range.

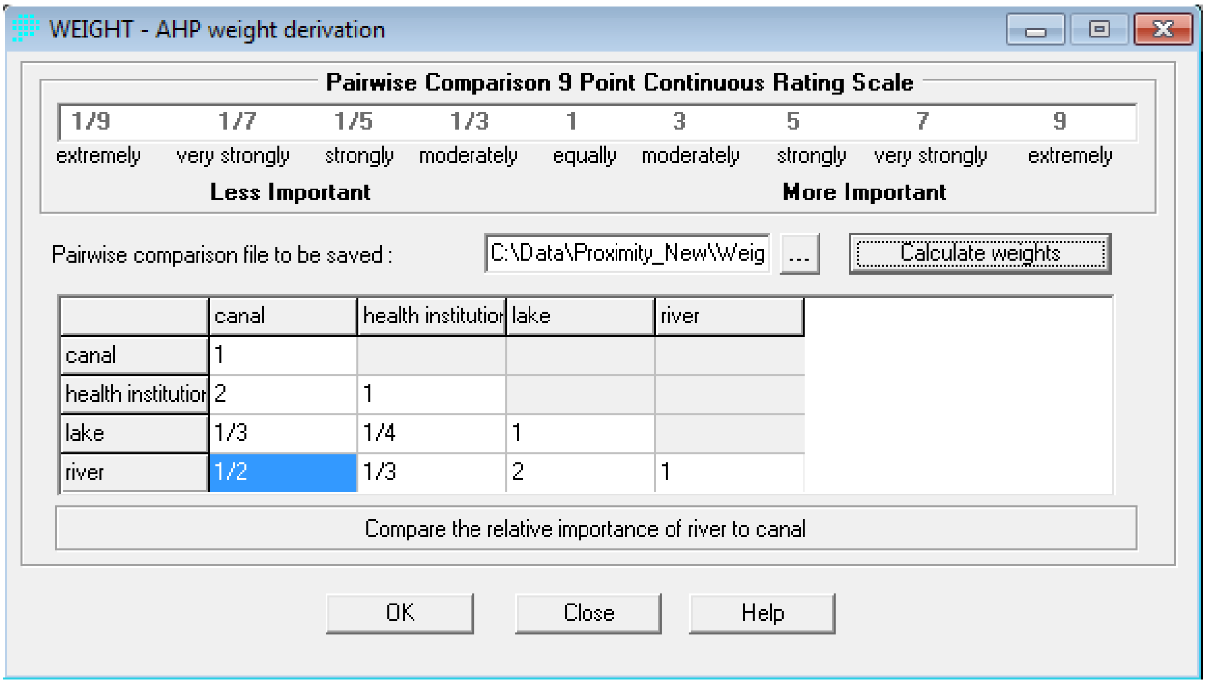

Fig. 24. AHP Weight Derivations for Proximity Related Malaria Risk Factors

Table 5. The Eigenvector of weights of Proximity Related Malaria Prevalence Risk Factors

S/N	Proximity Related Risk Factors	The Eigenvector of weights	Percentage Weight (%)	Risk Level within the factors	Values Assigned
1	Irrigation Canal	0.2772	28	Very High High Medium Low Malaria Free	1 2 3 4 6
2	Health Institution	0.4673	47	Very High High Medium Low	1 2 3 4
3	Lake	0.0953	9	High Medium Low Very Low Malaria Free	2 3 4 5 6

4	Rivers	0.1601	16	Very High High Medium Low Malaria Free	1 2 3 4 6

Using the above computed weights in ArcGIS spatial analyst tool of overlay analysis with weighted overlay method which overlays several rasters using a common measurement scale and weights each according to its importance, the map for proximity related malaria risk factors were produced.

3.4.5.3. Climate and Topography, Proximity, LULC, and Population Risk Factors

Climate and topography, proximity, LULC and population risk factors came together and rated for their importance, weight computed and weight overlaid using the same procedure with the above ones as described in figure 25 and 26.

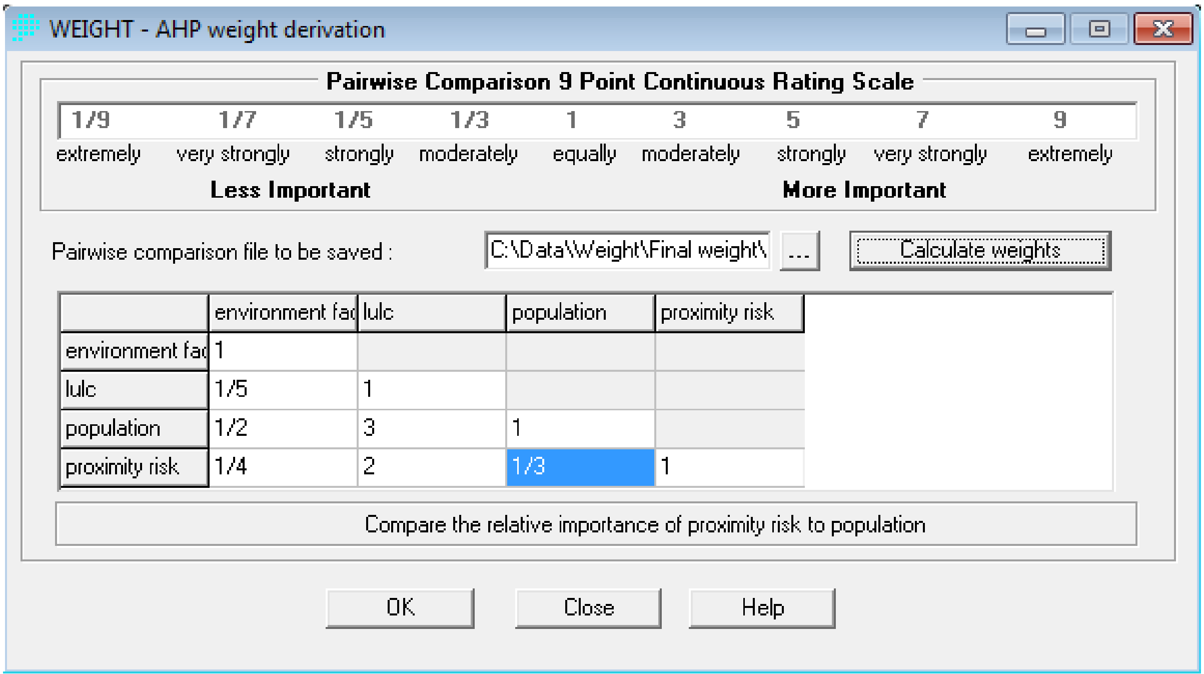

Fig. 25. AHP Weight Derivations for Main Factors to Produce Final Malaria Risk Map

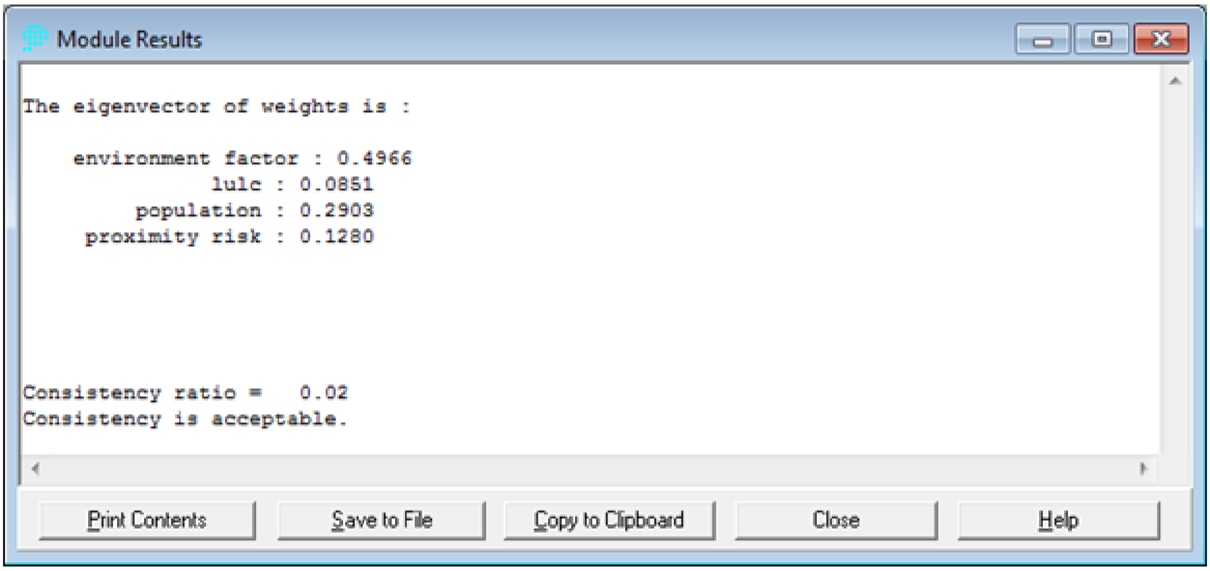

Fig. 26. Module Results of Main Malaria Factors Weight Description

The consistency ration is 0.02 which shows that it is acceptable as it is below the maximum limit of 0.1 to be in the acceptable range. And these values were used in ArcGIS environment of spatial analyst tool for weighted overlay analysis of the final malaria risk map of Fentale Woreda. The details used for weighted overlay is summarized in table 7.

Table 6. Factors used for Malaria Risk Mapping of the Study Area

S/N	Risk Factors	The Eigenvector of weights	Percentage Weight (%)	Risk Level within the factors	Values Assigned
1	Climate and Topography risk factors	0.4966	49.66	High Medium	2 3
2	Land use land cover Risk factors	0.0851	8.51	Very High High Medium Low Very Low	1 2 3 4 5
3	Population Density risk factors	0.2903	29.03	Very High High Medium Low	1 2 3 4
4	Proximity risk factors	0.1280	12.80	High Medium Low	2 3 4

4. Results and Discussion

4.1. Climate and Topography Related Risk of Malaria

As the climate and topography risk map in figure 27 depicts the majority of the study area fall within high malaria risk level with about 1528km^2 of total spatial coverage. Medium risk level was detected over about 4km^2 of the study area. Proportionwise as summarized in table 7, high and medium risk levels cover 99.7% and 0.3% respectively of the study area. Thus, the result apparently showed that the climatic and topographic set up of the woreda favor mosquito growth and development which favors malaria prevalence. It also correlates similarly with the facts stated in different researches. The area posses mean annual temperature of 21.9^{0}C to 29.2^{0}C and altitude of 862-1997m.a.s.l. But areas within temperature of 18°C to 32°C and below 2000 m.a.s.l. are potential malarious areas (ACMAD, 2009; MoH, 2008). This also indicates, the area is suitable for mosquito breeding and malaria prevalence with respect to these factors.

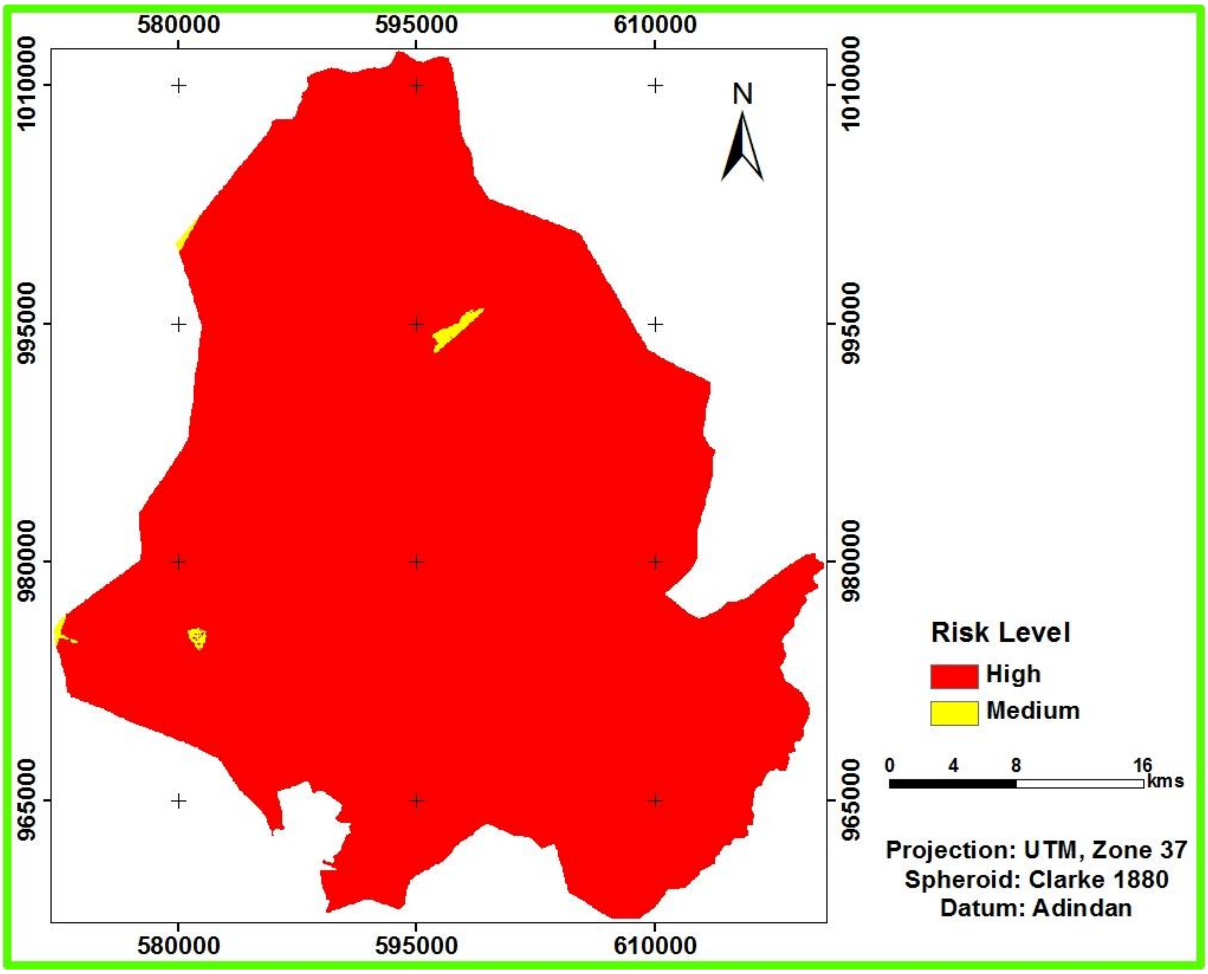

Fig. 27. Climate and Topography Related Malaria Risk Map of the Study Area

Table 7. Climate and Topography Related Malaria Risk of the Study Area

S/N	Climate and Topography Malaria Risk Level of the Study Area	Area in km^2	Percentage (%)
1	High	1528	99.7
2	Medium	4	0.3
	Total	**1532**	**100**

4.2. Proximity Factors Related Malaria Risk

Figure 28 indicates a map produced from the aggregation of proximity factors of health institutions, Irrigation canals, Lake and rivers. As the map indicates, malaria risk levels of high, medium, and low are prevailing in the study area with the proportion of 7.3%, 53%, and 39.7% respectively. Risk level high was observed at the periphery of the study area far from health institutions and near to water sources. Areas within high accessibility of health institutions and relatively far from water sources are observed to associated with low risk level. This is due to health accessibility determine the level of disease prevalence in a particular area through working on prevention and control activities. The other factors, rivers, lake and irrigation canals create suitable condition for mosquito breeding hence increase the level of malaria prevalence at that area.

This draws a parallel agreement with the fact villages located closer to water sources are associated with large number of adult mosquitoes than those located further away (Solomon *et al.*, 2009). Also similar result from research conducted in Tigray with one factor on the impact of small dams on malaria prevalence were seen. The rate of infection among children near dams was seven times greater than in communities with no dams (Ghebreyesus *et al*, 1999). Table 8 summarizes the risk levels and area coverage of each with respect to proximity malaria risk factors.

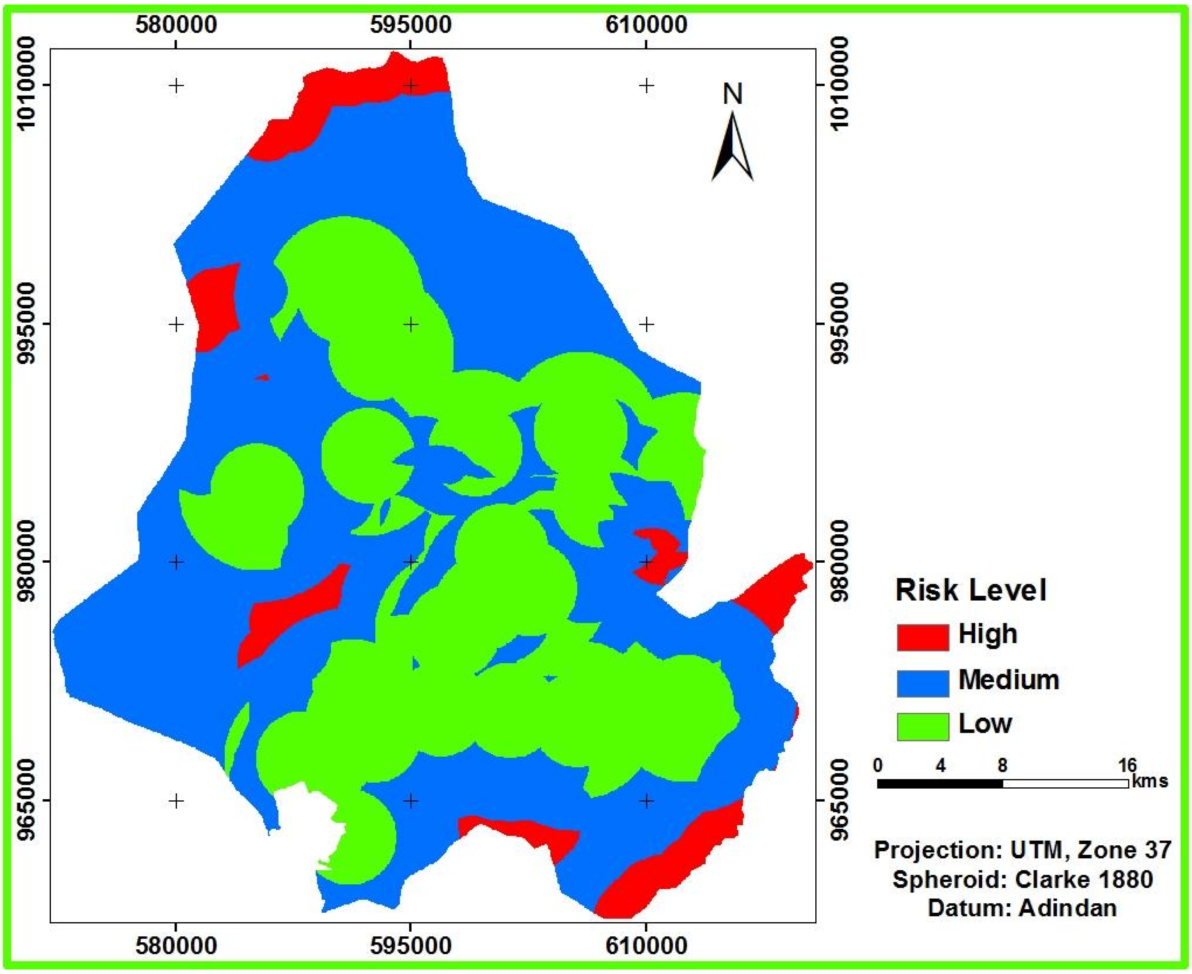

Fig. 28. Proximity Factors Related Malaria Risk map of the Study Area

Table 8. Proximity factors related malaria risk levels and their area coverage

S/N	Proximity Factors Risk level	Area in km^2	Percentage (%)
1	High	112	7.3
2	Medium	812	53
3	Low	608	39.7
	Total	**1532**	**100**

4.3. Land-Use Land-Cover Related Malaria Risk

As stated in several researches, different kinds of land cover indicate different types of residential areas suitable for various vectors (Liu *et al*., 2006). It affects the temperature of larval habitats directly and food conditions and other factors indirectly, but the synergistic effects of these factors may be more significant to larval survivorship. Pupation rate is significantly greater and development time is shorter in habitats in farmlands compared with other land cover types (Munga *et al*., 2006). Irrigation introduces malaria into local communities at much higher rates (Stockett, 2008). Water body favors mosquito breeding to the level highly riskfull for the local populations. But in this study area the existing water body is Beseka Lake which is salty in its nature and laying over the soil which is the result of volcanoes. These factors prevented mosquitoes not to breed at this area at higher rate like it does in other clean water bodies. But the effect it has at its native area and when it over flood to other soil types is different and needs further study.

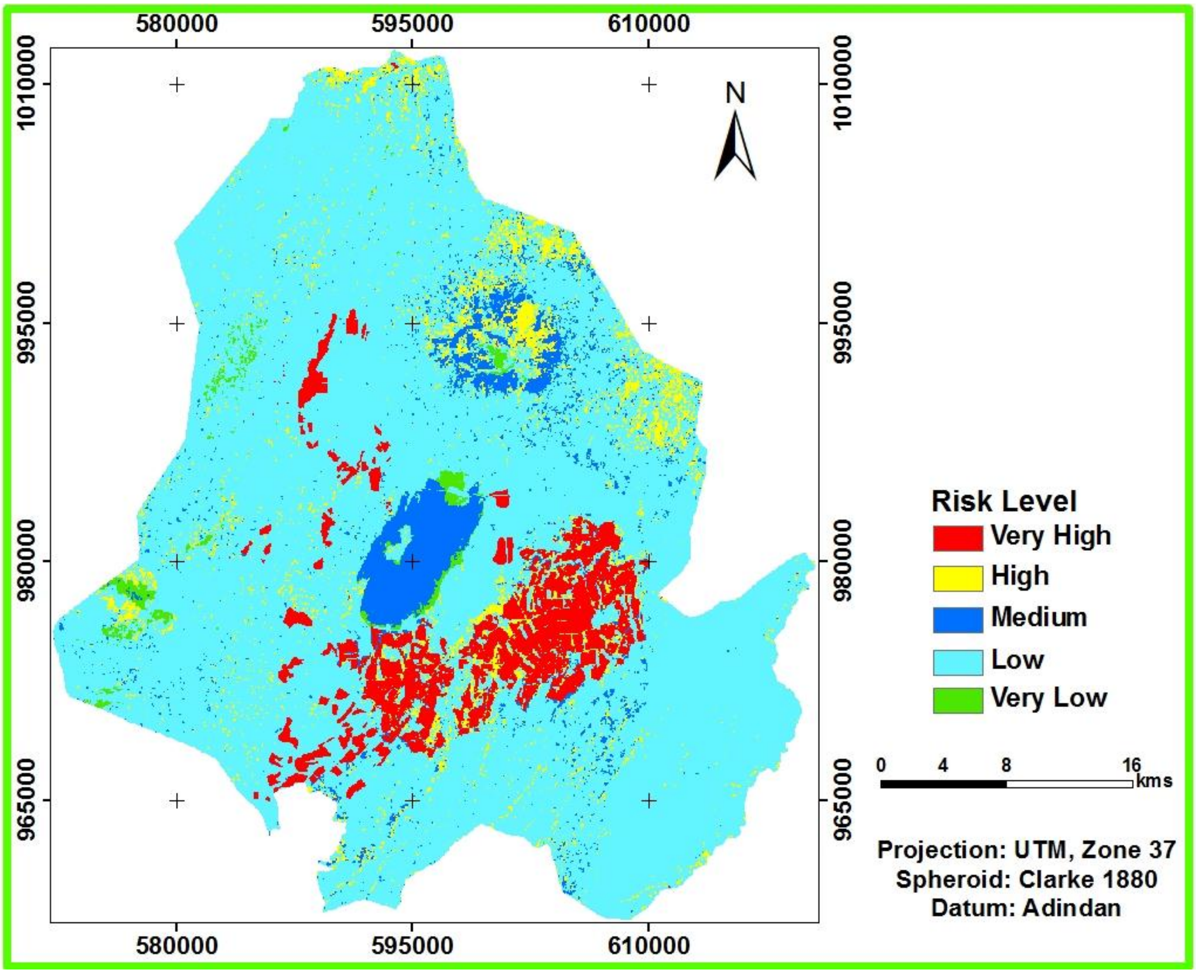

Fig. 29. Land-use/Land-cover Related Malaria Risk Level Indicator Map of the Study Area

Bush shrub land, and acacia wood land in the study area favor mosquito breeding with low level. This is due to low moisture and biomass content as it is within the rift valley and support different predators which preys on mosquito. Land covered by rock outcrop is not suitable for mosquito breeding. Accordingly, irrigation and settlement areas describe very high malaria risk level. Others: farm land; grassland and water body; fallow land, bush-shrub land and acacia wood land; and rock outcrop were showed malaria risk levels of high, moderate, low and very low respectively as illustrated in figure 29.

With respect to land-use/land-cover malaria risk indicator, significant part of the study area which is about 80% of the total extent of the woreda fell under low risk level. Other risk levels very high, high, moderate, and very low covered 7.6%, 5.7%, 5.7% and 1% of the total study area respectively as summarized in table 9.

Table 9. Land-use/land–cover Related Malaria Risk Level and Area Coverage

S/N	Land use land cover type	Risk Level	Area in km^2	Percentage (%)
1	Irrigation Farm	Very High	115	7.6
2	Settlement			
3	Farm land	High	88	5.7
4	Grass land	Moderate	88	5.7
5	Water body			
6	Fallow land	Low	1225	80
7	Bush shrub land			
8	Acacia wood Land			
9	Rock outcrop	Very Low	16	1
	Total		**1532**	**100**

4.4. Population Density and Distribution Related Malaria Risk

Population distribution and density of this area indicates four categories. The first one is the very highly populated areas of Metehara and Haro Adi towns with about 1000 persons/km^2. The second and third categories are the highly and moderately populated areas within Metehara Sugar Factory with up to 600 and 300 persons/km^2 respectively. The fourth group is the sparsely populated rural areas with less than 150 persons/km^2. The experience of malaria experts at this woreda showed that with respect to population density, the rural residing people face lower risk level due to limited movement of population from other area to their area with malaria diseases within their blood and lower probability of contact with people who have already acquired the disease within themselves since they are living far apart from each other over large area. High population density associated with high population movement have high risk for malaria prevalence and drainage system problem which produce water impoundments within the areas which in turn results in high malaria risk level.

Based on this, population density of the study area were classified into <150, 150-300, 300-600, and >600 persons/km^2 for which low, medium, high and very high respectively were their respective malaria risk levels as illustrated in figures 30.

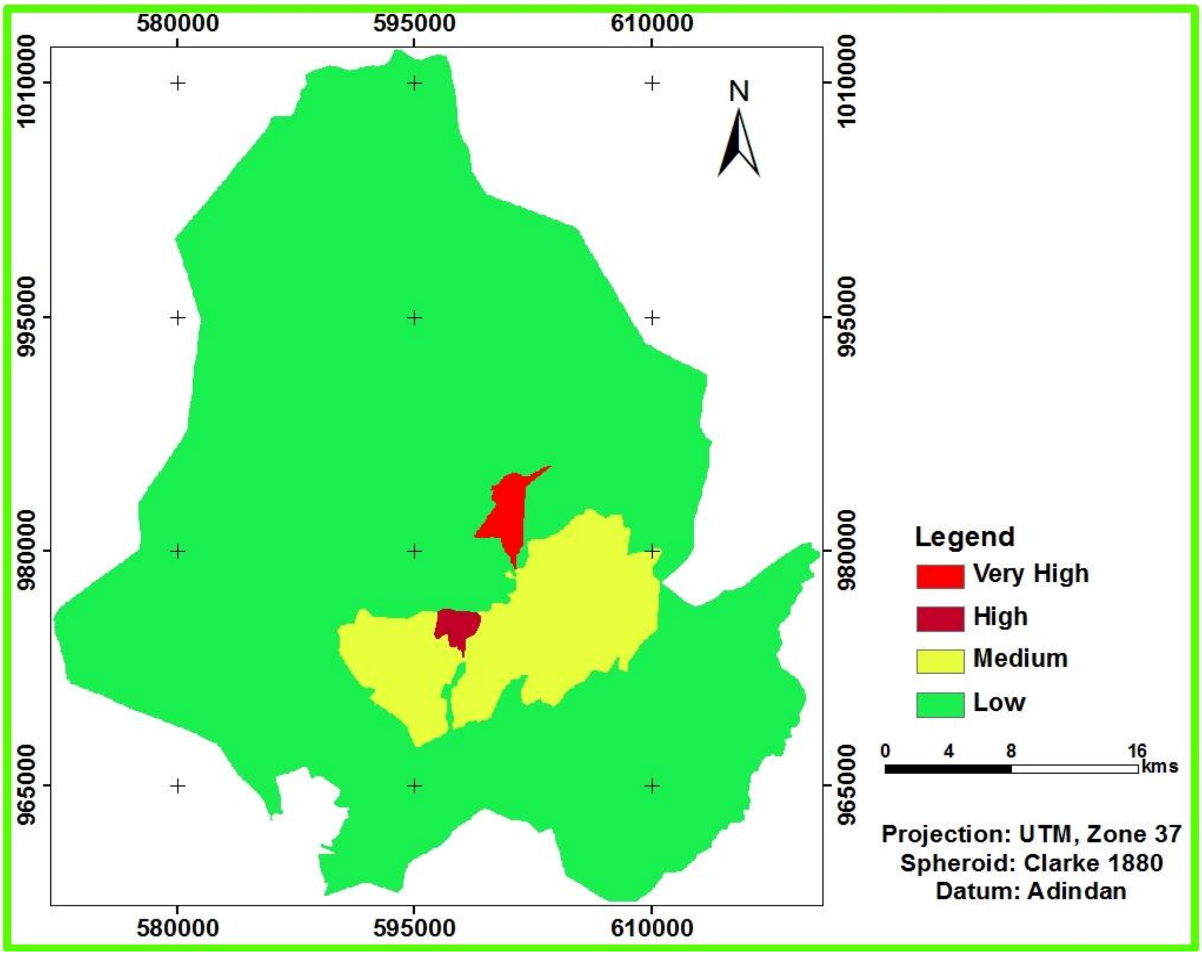

Fig. 30. Population Density Related Malaria Risk Level

This matchs with the idea population density is the factor for malaria prevalence rate: increase in population and unregulated urbanization often leads to an increase in or resumption of 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 (Martens and Hall, 2000).

The study area is largely occupied by local population. They are living over about 1370 km^2. As stated above they are sparsely populated over a large area so that low level of malaria transmission with respect to their density was observed in this area. Accordingly, population density related malaria risk levels within the study area and the area over which they are prevailing are described in table 10.

Table 10. Summary of Population Density Related Malaria Risk Level

S/N	Population Density Malaria Risk Level	Area in km^2	Percentage (%)
1	Very High	11	0.7
2	High	5	0.3
3	Medium	146	10
4	Low	1370	89
	Total	**1532**	**100**

4.5. Malaria Risk Map of the Study Area

Malaria risk map of the study area illustrated in figure 31 described that there is no malaria free area in the study area. The majority of the study areas fell in the moderate (93%) risk level. High risk level covered about (7%) of the study area. Low risk level observed in insignificant portion of the study area. Very high, very low and malaria free risk levels were not observed in the area. However, a small shift in one or more factors could lead from high to very high malaria risk level. Therefore, these risk levels should not be ignored as it may happen based on some shift of conditions in favor of the risk factors. The area covered by each risk levels and their portion is summarized in table 11.

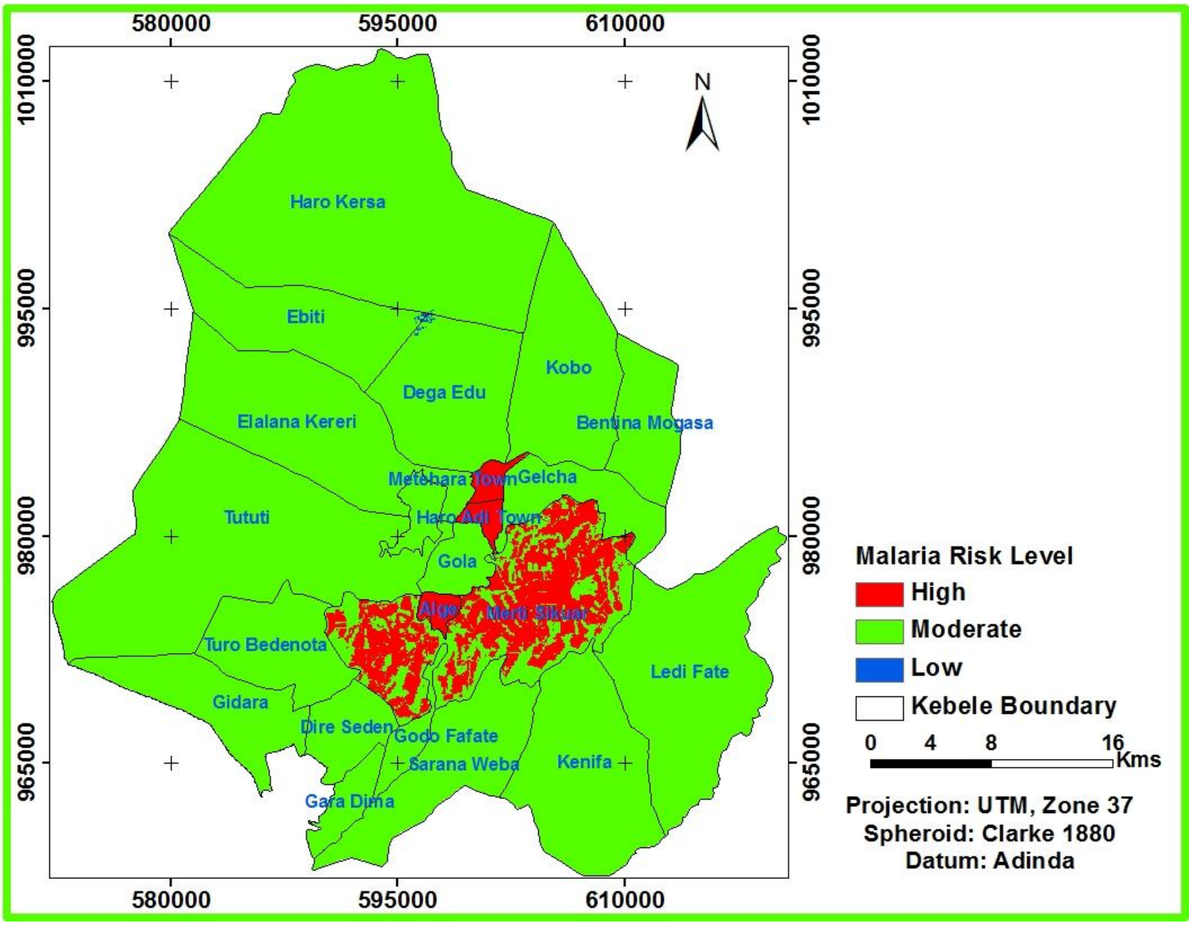

Fig. 31. Malaria Risk Map of the Study Area

Table 11. Malaria Risk Levels and their Area Coverage

S/N	Malaria Risk levels of Fentale Woreda	Area in km^2	Percentage (%)
1	High	106	6.9
2	Moderate	1425	93
3	Low	1	0.1
	Total	**1532**	**100**

Kebelewise, out of the total 21 kebeles, four kebeles in the study area (the two towns of Metehara and Haro Adi, Alge, and Merti Sukuar) were seen fell in high malaria risk level. About seventeen of the rest fell under moderate malaria risk level. High and moderate risk levels covered about 19% and 81% of the study area respectively as summarized in table 12. Risk level low is observed in negligible parts of the study area in the border of Ebiti and Dega Edu kebeles.

Table 122. Kebelewise Malaria Risk Level Distribution

S/N	Malaria Risk levels	Number of Kebeles	Percentage (%)
1	High	4	19
2	Moderate	17	81
3	Low	Negligible	-
	Total	**21**	**100**

4.6. Malaria Risk Levels of the Study Area in terms of some Malaria Risk Factors

This is done through relating some factors within the methodology to the malaria risk map of the study area. In the malaria risk map, high malaria risk level is associated with population density of 150-300, 300-600 and >600 persons/km^2; rainfall of 550-700mm, and 700-1000mm; elevation of 862-1000 m.a.s.l.; LULC types of settlement and irrigation farm land; and temperature of 23-25^{0}C, and 25-27^{0}C as summarized in table 13.

Table 133. Comparison of Malaria Risk Levels of the Study Area with Risk Factors

Risk level	**Description**				
	Population Density (persons/km^2)	**Rainfall** (mm)	**Elevation** (m.a.s.l.)	**LULC**	**Temperature** (^{0}C)
High	150-300, 300-600, and >600	550-700 700-1000	862-1000	Settlement, Irrigation farmland	25-27 23-25
Moderate	<150	<500 550-700 700-1000	1000-1500 1500-1997	Acacia wood land, bush-shrub land, fallow land, farm land, lava, water body, grassland	20-23 23-25 25-27
Low	<150	550-700	1500-1997	Grass land, lava	20-23

In terms of the risk levels, moderate, high and very high population density related malaria risk level; medium and high rainfall related malaria risk level; very high elevation related malaria risk level; very high malaria risk level related to LULC types; and high to very high temperature related malaria risk levels were observed. Moderate malaria risk level in malaria risk map fell in population density of <150 persons/km2; in rainfall related malaria risk classes of <500,550-700, and 700-1000; in elevation related malaria risk classes of 1000-1500 and 1500-1997; LULC types of acacia wood land, bush-shrub land, fallow land, farm land, lava, water body, grassland; and temperature of 20-23^{0}C, 23-25^{0}C, and 25-27^{0}C. These factors in terms of their malaria risk levels describe, low malaria risk level related to population density; low to high rainfall related malaria risk level; high and medium elevation related malaria risk levels; very low to high LULC related malaria risk level; and medium to very high temperature related malaria risk levels.

As described in the above paragraphs different factors may indicate different malaria risk levels for the same area but the overall impact of these all factors determine the level of malaria prevalence at particular area. Hence, the aggregation of these factors described high, moderate, and low malaria risk levels were prevailing in the study area.

5. Conclusion and Recommendations

5.1 Conclusion

In this study GIS with remote sensing and GPS data were used in identification, association, characterization, and final malaria risk map production for the study area. Accordingly, climatic and topographic factors malaria risk level, proximity factors malaria risk level, land-use land-cover malaria risk level and population density malaria risk level were come together as to possible to examine for their aggregate impact on malaria prevalence of the study area.

Climate and topography factors malaria risk map of the study area indicated that majority of the area fell under malaria risk level of high with 99.3% of the total area coverage of the woreda. Moderate risk level occupies 0.3% under the same variable. Proximity factors related malaria risk level is important indicator of malaria risk of a particular area. Related with this, high, medium and low risk levels were observed in the study area with 7.3%, 53%, and 39.7% respectively. Land-use land-cover and population density malaria risk map of the study area showed that populations living in highly populated and irrigation farm areas fall under very high malaria risk level. Those areas, the rural parts, which are scarcely populated, take low risk level with regard to population density malaria risk.

Malaria risk map of the study area showed that there is no area within Fentale Woreda with malaria free risk level. Most areas fell under malaria risk level of high and medium with 7% and 93% of the total study area respectively. Low risk level observed in negligible part. Kebelewise about 81% of the area which constitute about 17 kebeles fell in the risk level of moderate malaria risk level. The other 19% occupied by 4 kebeles showed largely high malaria risk level with moderate risk level prevailing over smaller parts of them.

Generally, GIS and remote sensing based malaria risk mapping considering appropriate mosquito harboring factors is a worthwhile technique to know the risk level associated with each area and it enables to support public health officers in space and time so as to control and predict malaria spread over extensive areas. Moreover, the risk map can be beneficial for public warning and awareness.

5.2 Recommendations

- Malaria risk map of the study area indicated that most of the areas in this Woreda are with risk level of high and medium. But increases or decrease in value of one or more factors shift the situation to very high or other risk levels. Therefore, to make the information up to date, GIS and remote sensing based monitoring and early warning system should be integrated in malaria control and prevention activities in order to easily manage each activity towards alleviating malaria from the area.

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

- Beyond the parameters used for malaria risk analysis in this study, other variables which can contribute for malaria prevalence like income level of the household, housing type, awareness level of the population and others can affect malaria prevalence. Therefore, it is better to integrate these factors with the already used parameters for better exactness.

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Appendixes

1. Materials and Softwares

Table 1. Materials and softwares used for the study

No.	Materials/Softwares	Sources	Importance
1	ArcGIS9.3	AAU GIS Lab	Spatial data analysis, management and integration.
2	ERDAS IMAGINE 9.1	AAU GIS Lab	Image Processing
3	IDRISI Andes	AAU GIS Lab	For Spatial Multi Criteria Decision Making
4	3DEM	AAU GIS Lab	Prepare SRTM data for further process
5	Microsoft office Packages	AAU GIS Lab	Data analysis, report writing
6	Computer	AAU GIS Lab	Integrate data and softwares
7	Garmin GPS	Contract	Field data collection
8	Digital Camera	Personal	Field observation acquisition

2. Health Stations Coordinate Points

Table 2. Health Station Coordinate Points

No.	Ke beles	X-Coordinate	Y-Coordinate	UTM Zone (Adindan)
1	Banti	612441	985554	37
2	Kobo	605834	988153	37
3	Gelcha	607046	983823	37
4	Fate	612585	971113	37
5	Kenifa	605696	970005	37
6	Saranaweba	601366	970590	37
7	Godo Fate	596954	970710	37
8	Gara Dima	591113	962613	37
9	Dire Saden	592664	969039	37
10	Gidara	588132	967528	37
11	Turo Bedeno	591274	970066	37
12	Tututi	585232	984387	37

13	Elalana Kerori	592261	986603	37
14	Dega Edu	599150	987046	37
15	Hero Kersa	590811	996674	37
16	Debiti	592785	993069	37
17	Gola	599553	977317	37
18	Alge	597720	975585	37
19	Merti	602623	978252	37
20	Metehara Town	600826	980606	37

3. Malaria Cases

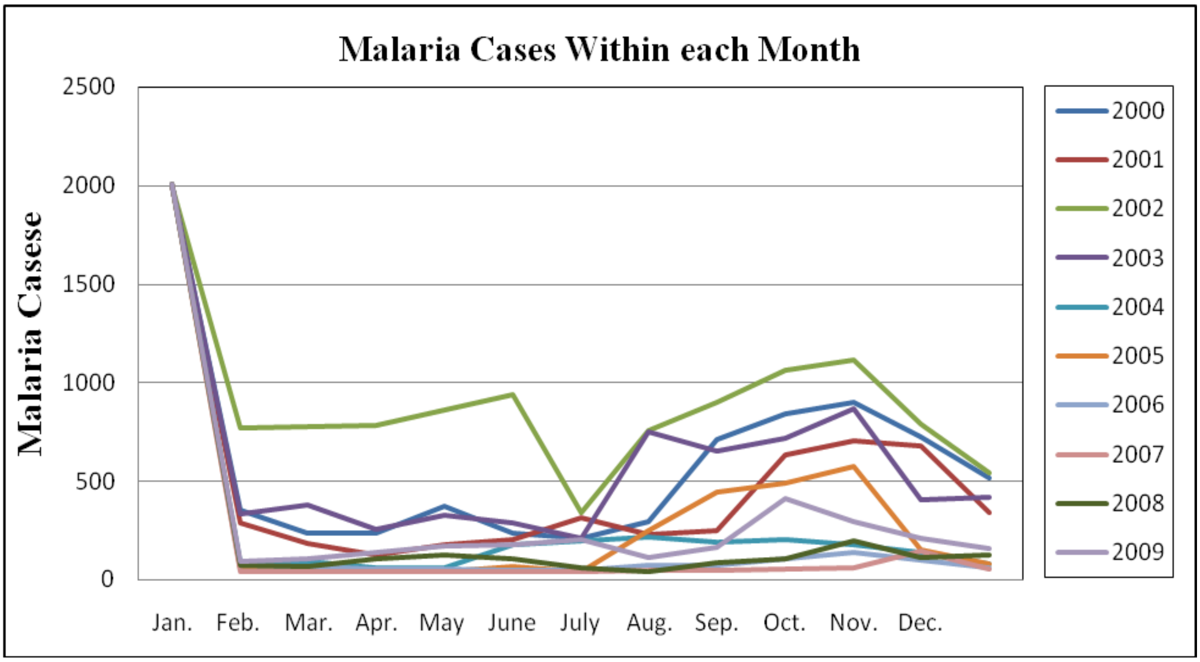

Fig. Malaria Cases Within each months of the years from 2000-2009

Source: Merti Hospital and Fentale Woreda Health Office

5. Photographs Taken During Field Survey

Plate:1 Typical Mosquito Breeding Area around Metehara Town

Plate: 2 Expansion of Beseka Lake to Residential Areas

Plate: 3 Typical Mosquito Breeding Area Taken Around Residential Area within Merti Sugar Factory Farm Estate

Plate: 4 Bush Shrub land