Web GIS in Decision Support to Control Malaria, Case Study in Tiro Afeta Woreda, Oromia Region, Ethiopia

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

MASTER OF SCIENCE

In

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

By

MERON MEBRATU

Under the guidance of

Dr. Dagnachew Legesse
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JUNE 2010

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ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

Web GIS in Decision Support to Control Malaria, Case Study in Tiro Afeta Woreda, Oromia Region, Ethiopia

By
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D E C L A R A T I O N

I here by declare that the dissertation entitled "Web GIS in Decision Support to Control Malaria, Case Study in Tiro Afeta Woreda, Oromia Region, Ethiopia" has been carried out by me under the supervision of Dr. Dagnachew Legesse, Department of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2008-2010 as a part of Master of Science programme in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa
Date: June 11, 2010

(Meron Mebratu)

C E R T I F I C A T E

This is certified that the dissertation entitled "Web GIS in Decision Support to Control Malaria, Case Study in Tiro Afeta Woreda, Oromia Region, Ethiopia" is a bonafied work carried out by Meron Mebratu under my guidance and supervision. This is the actual work done by Meron Mebratu for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

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ABSTRACT

Malaria remains a major public health threat killing millions of people every year. Morethan 17 million people are at risk of malaria in Oromia regional state of Ethiopia. Therefore, the objective of this study is aiming at assessing areas prone to malaria, to analyze the incidence of malaria with climatic conditions particularly rainfall in Tiro Afeta Woreda of Oromia. Further, integrating malaria data into a decision support system (DSS) that can provide information within shortest period of time, so that, decision makers get prepared to make better and faster decisions which can reduce the damage and minimize the loss. This paper attempts to asses and produce malaria prone areas maps including the most important natural factors. Further analysis was made regarding malaria incidence and rainfall using remote sensing and geographical information system techniques. Moreover, it was attempted to develop a decision support system (DSS) using the available open source technologies which may help in providing the required information which is more organized and helps in preparing the prevention of the disease. From the study it is indicated that almost all of the study area i.e. 99.78% is prone to malaria mainly due to the natural factors particularly rainfall and altitude. It was also evident that the peak malaria transmission occurred immediately after the rainy season's, implying the direct relationship between malaria incidence and rainfall. Since the peak malaria transmission coincides with the planting and harvesting season, the socio-economic impact of malaria is very significant. As a result, epidemics detection and preparedness should further be assessed and strengthen.

Key words: malaria, epidemic, Remote Sensing, Geographical Information Systems, Decision Support System.

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ACRONYMS

AAU	Addis Ababa University
AHP	Analytic Hierarchy Process
CDC	Central Disease Control
CSA	Central Statistics Agency
DBMS	Database Management System
DSS	Decision Support System
E.F.Y	Ethiopian Fiscal Year
ESRI	Environmental Systems Research Institute
FEWS	Famine Early Warning System
FMoH	Federal Ministry of Health
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GPS	Global Positioning System
HIV	Human Immunodeficiency Virus
IFPRI	Ethiopian Development Research Institute
JZHB	Jimma Zone Health Bureau
MS4W	MapServer 4 Windows
OGC	Open Geospatial Consortium
ORHB	Oromia Regional Health Bureau
OSHPD	Office of Statewide Health Planning and Development
PDA	personal digital assistant
QGIS	Quantum GIS
RBM	Roll Back Malaria
RFE	Rainfall Estimate
RS	Remote Sensing
SRTM	Shuttle Radar Topography Mission
TB	Tuberculosis
TCC	The Carter Center
USGS	United States Geological Survey
WFS	Web Feature Service
WHO	World Health Organization
WMS	Web Map Service

CHAPTER-I INTRODUCTION

1.1 Background

Malaria transmission and spatial distribution in Ethiopia, is mainly determined by the diverse eco-climatic conditions. The most important climatic factors that influence malaria transmission are temperature, rainfall, and humidity along with altitude which is the most important variable. Depending on the climatic conditions and altitude, Ethiopia is classified into climatic zones, namely, the cold zone locally known as “Dega”; the hot zone, “Kolla”; and areas of average climatic conditions, known as “Weyna Dega.”

The cold zone, which covers areas higher than 2,500 meters (m) above sea level, has a mean annual temperature of 10–15^{0}C. This highland area is considered free of local malaria transmission. The midland area, ranging in altitude from 1,500–2,500m with a mean annual temperature between 15–20^{0}C, has diverse malaria transmission patterns. In the hot lowland zone, located in areas below 1,500m above sea level, where the mean annual temperature varies from 20–25^{0}C, malaria transmission is endemic, and its intensity and duration are mainly dictated by the amount and duration of rainfall (Ghebreyesus T et al., 2006). In the midland zone, where temperature is a determining factor, malaria transmission often occurs in areas below 2,000m, while areas between 2,000 and 2,500m may become affected during epidemics (Negash K et al. 2005, CSA 2005). Currently, areas <2,000 meters of altitude are considered malarious. Based on this altitudinal variation and associated with the malaria transmission, areas of the country are categorized as shown in *(fig 1.1).*

In 2005–2006, the annual health and health-related indicators of the Federal Ministry of Health (FMoH) reported malaria as a leading cause of morbidity and mortality in the nation. The annual average number of malaria cases based on clinical diagnosis (typically without laboratory confirmation) reported by health facilities over the 2001– 2005 period was 9.4 million (range 8.4–11.5). National estimates of the actual number of cases at the population level (again, based on clinical diagnosis) are estimated to be higher (on the order of 10–12 million with 60–70% and 30–40% of the cases due to *P.falciparum* and *P. vivax*, respectively (FMoH, 2008).

Mean annual precipitation, in general, ranges from 800 to 2,200 millimeters (mm) in the highlands (>1,500m) and varies from less than 200 to 800mm in the lowlands (<1,500m). Rainfall decreases northwards and eastwards from the high rainfall pocket area in the southwest and seasonality is not uniform. The western half of the country has two distinct seasons (wet from June–September and dry from November–February), with the rainfall peak occurring in July and August. The central and most of the eastern part of the country have two rainy periods and one dry period. The south and southeastern parts of Ethiopia have two distinct dry periods (December–February and July–August) and two rain seasons (March–June and September–November). The major malaria transmission season is from September to December, following the main rainy season from June to September and a shorter transmission season from April to May following the short rainy season from December to February (CSA, 2005).

Malaria transmission exhibits a seasonal and unstable pattern in Ethiopia, with transmission varying with altitude and rainfall. The major malaria transmission season in the country is from September to December, following the main rainy season from June/ July to September. There is also a shorter transmission season from April to May following the shorter rainy season in some parts of the country (FMoH 2007/08).

Due to the unstable and seasonal pattern of malaria transmission, the protective immunity of the population is generally low, and all age groups are at risk of infection and disease. A large household survey conducted by The Carter Center (TCC) in three regions in late 2006–early 2007 reported a prevalence of 4.1% (4.6% in Amhara, 0.9% in Oromia, and 5.4% in Southern Nations, Nationalities, and People’s Region (TCC, 2007).

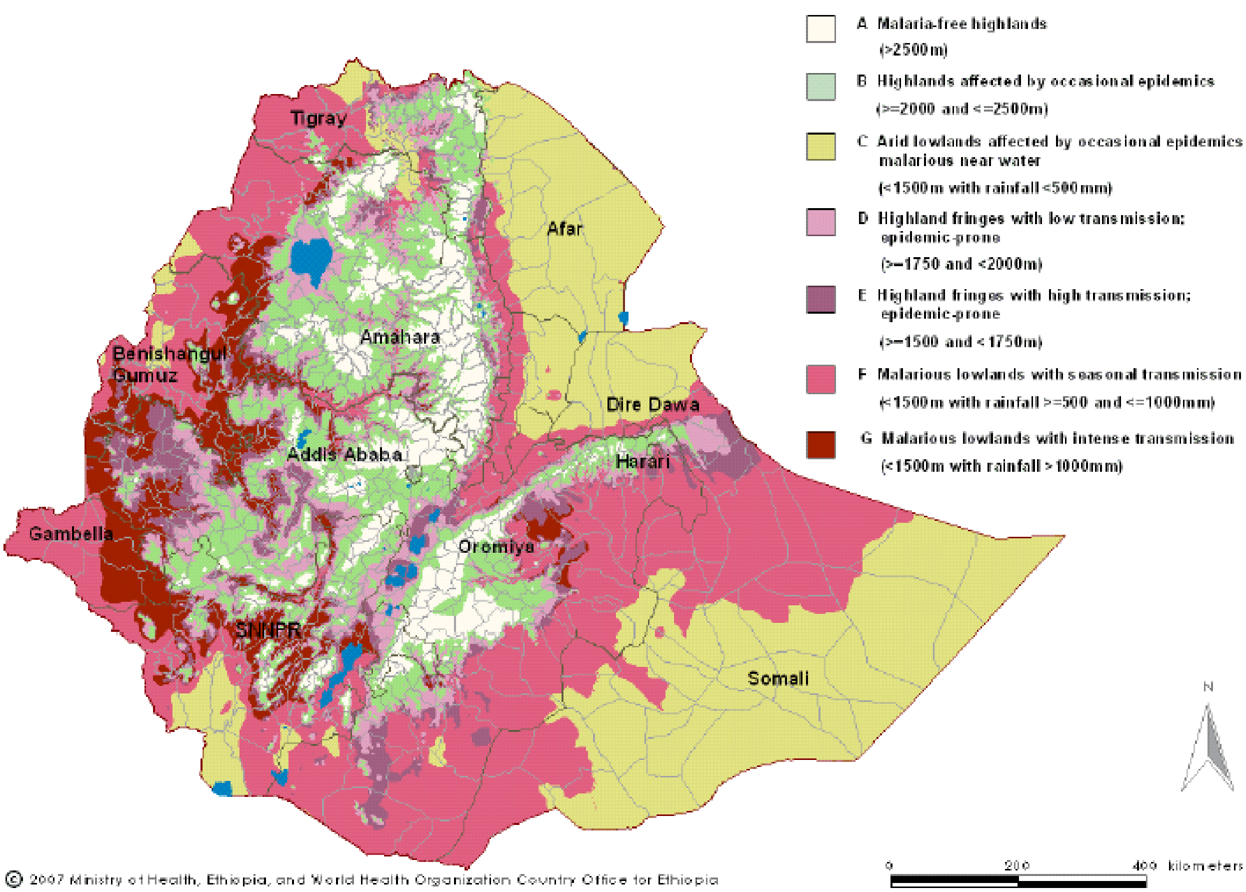


Fig 1.1 Map of Malaria Epidemiological Profile of Ethiopia

1.2 Problem Definition

In accordance with the FMoH, malaria is ranked as the leading communicable disease in Ethiopia, accounting for approximately 30% of the overall Disability Adjusted Life Years (DALYs) lost. Approximately 75% of the country is malarious with about 68% (50 million) of the total population of 73 million living in areas at risk of malaria.

Malaria is reported to cause 70,000 deaths each year. Furthermore, in 2008/2009, malaria was the first cause of outpatient visits, health facility admissions and in-patient deaths, accounting for 12% of out-patient visits and 9.9% of admissions. However, as 36% of the population does not have access to health care services, these figures probably under-represent the true burden of malaria in the country. It is a major epidemic that is killing many people everyday and this in turn is affecting the socio economic aspect of the country. As a result it is an important issue that needs more attention and dedication in order to minimize the problem.

The effectiveness of Web-based GIS in disaster management is proven in several global scale disaster incidents such as the recent Tsunami which is the largest ever disaster intervention in human history (Maged N et al., 2006). One of the most important powers of GIS is the capability to publish and share geo-spatial information on the Internet among large numbers of people. By sharing this information on the Internet, accessibility, time response, and understandability are drastically improved compared to conventional paper distribution of maps or character based Web systems. Users will have more freedom to choose information or layers to see and synthesize maps that will fit their own requirements.

Publishing and sharing geo-spatial data in the health sector are increasingly becoming important and popular tasks in various applications (Boulos MN et al., 2001). Since successful data sharing is very important in emergency responses, it is feasible to apply this type of web-based DSS in order to manage outbreaks resulted from Malaria.

In those lines, the present project will attempt to assess malaria prone areas, identify the relation between malaria incidence and the contributing factors, and finally design a Web-based GIS DSS for managing malaria epidemics with the best available open source tools.

1.3 Scope of the Research

Oromia Regional State is the largest of the Ethiopia's 9 Regional States, covering one third area of the country. According to the FMoH, more than 17 million persons are at risk of infection in Oromia; 1.5 to 2 million clinical cases reported annually, with malaria accounting for 20-35% of outpatient consultations, and 16% of hospital admissions. Malaria is the leading cause of death accounting for 18-30% of all hospital deaths. However, this research tries to give solution to very restricted areas taking into consideration the time given for the research work. As a result, in terms of area, the research is limited to Tiro Afeta Woreda. With regard to the assessment of malaria prone areas the research also focuses on the relation between the incident of malaria and socio economic factors.

In the analysis part the factors considered are limited depending on their importance, influence and data availability. Therefore, for the assessment of malaria prone areas the factors taken are temperature, rainfall, altitude and distance from rivers. While examining malaria incidence the factor used is rainfall amount. Moreover, concerning malaria prone areas comparison was made based on population.

1.4 Objectives of the Research

General Objective

The basic objective of the study is to identify malaria prone areas, show the distribution and relation between socio-economic factors with malaria incidence in the study area mainly using Remote Sensing and Geographical Information System. Along with, develop a web based GIS decision support system which helps in providing information for decision making process.

Specific Objectives

The specific objectives include:

- To identify factors that contribute for malaria incidence in the study area;
- To map malaria prone areas;
- To assess the pattern and relationship between malaria incidence and major climatic variable (Rainfall) ;
- Integration of health data in a GIS;
- Producing web-maps in accordance with the user's requirements

1.5 Organization of the Research

The thesis is organized in seven chapters. Chapter one provides research background, problem definition, objectives and scope of the research. Chapter two provides a literature review of application of DSS, use of RS/GIS technology in the study and control of malaria, including basic concepts, factors and history of malaria. Chapter three provides description and background of the study area. Chapter four describes the methodology and analysis. Results and discussion are contained in Chapter five, and finally Chapter six is about conclusion and recommendations.

1.6 Limitation of the Research

The main limitation of the study was the unavailability of well documented relative humidity data over extended years, and lack of a geo-referenced population distribution map of the study area. There was also lack of standardization for rainfall classification in relation with malaria transmission.

CHAPTER-II LITERATURE REVIEW

2.1 Some Concepts Regarding Malaria

2.1.1 Malaria

Malaria is an infectious disease caused by a parasite, *Plasmodium*, which infects red blood cells. Malaria is characterized by cycles of chills, fever, pain and sweating. Historical records suggest malaria has infected humans since the beginning of mankind. The name "mal 'aria" (meaning "bad air" in Italian) was first used in English in 1740 by H. Walpole when describing the disease. The term was shortened to "malaria" in the 20th century. C. Laveran in 1880 was the first to identify the parasites in human blood. In 1889, R. Ross discovered that mosquitoes transmitted malaria (Charles D, 2009).

Malaria is one of the most common infectious diseases and an enormous public health problem. The disease is caused by protozoan parasites of the genus Plasmodium. Five species of the plasmodium parasite can infect humans; the most serious forms of the disease are caused by Plasmodium falciparum which can be liffe -theatening. Malaria caused by Plasmodium vivax, Plasmodium ovale and Plasmodium malariae causes milder disease in humans that is not generally fatal. A fifth species, Plasmodium knowlesi, causes malaria in macaques but can also infect humans. This group of human-pathogenic Plasmodium species is usually referred to as malaria parasites (Wikipedia, 2009).

Malaria is resulted based on different natural (environmental) or socio-economic factors. Some of these include migration from malarious to non-malarious areas, drought which implies malnutrition that decreases the immunity of oneself. As a result, these will directly/ indirectly contribute for the existence of malaria in that place.

2.1.2 Factors that Govern the Emergence of Malaria

Malaria is essentially an environmental disease since the vectors require specific habitats with surface water for reproduction, humidity for adult mosquito survival and the development rates of both the vector and parasite populations are influenced by temperature (Ashenafi M, 2003). Interannual climate variability is an important determinant of epidemics in parts of Africa (Najera, J. A et.al, 1998: cited in Thomson M. C., et al. 2006) where climate drives both mosquito vector dynamics and parasite development rates (Thomson, M. C et. al., 1996: cited in Thomson M. C., et al. 2006).

Malaria incidence can be identified based on three major indicators. These are: (1) Morbidity and Mortality Indicator, (2) Entomological Indicator; and (3) Meteorological Indicators. These indicators include altitude, temperature, rainfall, relative humidity. Relative humidity of 60 and above is considered as favorable environment for the breeding of mosquito. However, due to lack of data about relative humidity it couldn't be included in the study. Thus, the area is characterized by the same amount of temperature throughout, the analysis regarding malaria incidence was made based on rainfall.

The three main climate factors that affect malaria are temperature, precipitation, and relative humidity (Pampana, 1969: cited in Colleen Reid, 2000). Climate predicts, to a large degree, the natural distribution of malaria (Bouma and van der Kaay, 1996: cited in Colleen Reid 2000).

- **Temperature**

Temperature affects many parts of the malaria life cycle. The duration of the extrinsic phase depends on temperature and on the species of the parasite the mosquito is carrying. The extrinsic cycle normally lasts nine or ten days, but sometimes can be as short as five days (Bradley et al., 1987: cited in Colleen Reid 2000). As the temperature decreases, the number of days necessary to complete the extrinsic cycle increases for a given Plasmodium species. P. vivax and P. falciparum have the shortest extrinsic incubation times and therefore are more common than P. ovale and P. malariae (Oaks et al., 1991: cited in Colleen Reid 2000). The extrinsic phase takes the least amount of time when the temperature is 27°C. The time required for development of the ookinete, the egg of the parasite, in the midgut of the Anopheline mosquito, decreases as temperature increases from 21°C to 27°C (Patz et al., 1998: cited in Colleen Reid 2000). Below 20°C, the life cycle of P. falciparum is limited. Malaria transmission in areas colder than 20°C can still occur because Anophelines often live in houses, which tend to be warmer than external temperatures. Larval development of the mosquito also depends on temperature (Russell et al., 1963: cited in Colleen Reid 2000). Higher temperatures increase the number of blood meals taken and the number of times eggs are laid by the mosquitoes (Martens et al., 1995: cited in Colleen Reid 2000).

The intersections of the ranges of minimum and maximum temperature for parasite and vector development determine the impact of changes in temperature on malaria transmission. The minimum temperature for mosquito development is between 8-10°C, the minimum temperatures for parasite development are between 14-19°C with P. vivax surviving at lower temperatures than P. falciparum. The optimum temperature for mosquitoes is 25-27°C, and the maximum temperature for both vectors and parasites is 40°C (McMichael et al., 1996: cited in Colleen Reid 2000). There are some areas where the climate is optimal for malaria and Anopheles mosquitoes are present, but there is no malaria. This is called “Anophelism without malaria” which can be due to the fact that the Anopheles mosquitoes present do not feed primarily on humans (Bruce-Chwatt, 1985: cited in Colleen Reid 2000) or because malaria control techniques have eliminated the parasite. If any changes, whether environmental or otherwise, were to occur to bring another species to the area that does act as a vector for human malaria, then the potential for outbreaks of malaria is very high since there is no immunity in the human population there.

- **Precipitation/ Rainfall**

Anopheline mosquitoes breed in water habitats, thus requiring just the right amount of precipitation in order for mosquito breeding to occur. Little is known about the biology of this aquatic phase (Oaks et al., 1991: cited in Colleen Reid 2000). However it is known that different Anopheline mosquitoes prefer different types of water bodies in which to breed (Nagpal and Sharma, 1995: cited in Colleen Reid 2000). Too much rainfall, or rainfall accompanied by storm conditions can flush away breeding larvae. Not only the amount and intensity of precipitation, but also the time in the year, whether in the wet or dry season, affects malaria survival (Russell et al., 1963: cited in Colleen Reid 2000). Rainfall also affects malaria transmission because it increases relative humidity and modifies temperature, and it also affects where and how much mosquito breeding can take place (Pampana, 1969: cited in Colleen Reid, 2000).

Different malaria vectors use a variety of sites in which to lay their eggs (irrigation canals, tire ruts, mangrove swamps, pools, etc.) as long as the water is clean, not too shaded and, for most species, relatively still. In many semi-arid areas these sites are only widely available with the onset of the seasonal rains unless dry season irrigation is undertaken. The association between rainfall and malaria epidemics has been recognized for many decades (WHO, 2005) but while increasing precipitation may increase vector populations in many circumstances by increasing available anopheles breeding sites, excessive rains may also have the opposite effect by flushing out small breeding sites, such as ditches or pools (Fox RM, 1957: cited in P. Ceccato et. al, 2005) or by decreasing the temperature, which in regions of higher altitude can stop malaria transmission.

- **Relative Humidity**

Relative humidity also affects malaria transmission. Plasmodium parasites are not affected by relative humidity, but the activity and survival of Anopheline mosquitoes are. If the average monthly relative humidity is below 60%, it is believed that the life of the mosquito is so shortened that there is no malaria transmission (Pampana, 1969: cited in Colleen Reid 2000). The survival rate of adult insects is often thought to increase or decrease in relation to a factor called saturation deficit. Saturation deficit is derived by subtracting the actual water vapor pressure from the maximum possible vapor pressure at a given temperature. Evidence for other vectors (tsetse, ticks, culicoides) suggests that saturation deficit is an important environmental variable in larval and adult survivorship (P. Ceccato et. al, 2005).

- **Wind**

Wind may play both negative and positive roles in the malaria cycle because very strong winds can decrease biting by mosquitoes, while at the same time extending the length of the flight of the mosquito. During a monsoon, wind has the potential to change the geographic distribution of mosquitoes (Russell et al., 1963: cited in Colleen Reid 2000).

- **Climate and vector succession**

In addition to changing the amount and rate of transmission of the vectors and parasites that are already in a certain location, changing the climate of an area can allow the introduction of different vectors and parasites that may be more efficient. Since P. malariae and P. ovale have longer extrinsic cycles, some mosquitoes do not live long enough to transmit them. However, if environmental conditions change in ways that would increase the survival time of those mosquitoes, then they would be able to transmit other species of malaria that were not present in that area before (Pampana, 1969: cited in Colleen Reid 2000).

2.2 Malaria Distribution and Burden in the World

Malaria is a vector-borne infectious disease that is widespread in tropical and subtropical regions, including parts of the America, Asia, and Africa. Each year, there are approximately 350–500 million cases of malaria, (CDC) killing between one and three million people, the majority of whom are young children in Sub-Saharan Africa (Snow RW et al., 2005). Ninety percent of malaria-related deaths occur in Sub-Saharan Africa.

In some countries with a heavy malaria burden, the disease may account for as much as 40% of public health expenditure, 30-50% of inpatient admissions, and up to 50% of outpatient visits (www.rbm.who.int).

Malaria is not just a disease commonly associated with poverty but also a cause of poverty and a major hindrance to economic development. Tropical regions are affected most, however malaria's furthest extent reaches into some temperate zones with extreme seasonal changes. The disease has been associated with major negative economic effects on regions where it is widespread. During the late 19th and early 20th centuries, it was a major factor in the slow economic development of the American southern states (Humphreys M, 2001).

A comparison of average per capita GDP in 1995, adjusted for parity of purchasing power, between countries with malaria and countries without malaria gives a fivefold difference ($1,526 USD versus $8,268 USD). In countries where malaria is common, average per capita GDP has risen (between 1965 and 1990) only 0.4% per year, compared to 2.4% per year in other countries (Sachs J et al., 2002). Poverty is both cause and effect, however, since the poor do not have the financial capacities to prevent or treat the disease. The economic impact includes costs of health care, working days lost due to sickness, days lost in education, decreased productivity due to brain damage from cerebral malaria, and loss of investment and tourism (Greenwood BM et al, 2005).

2.3 The Burden of Malaria in Africa

Malaria is especially a serious problem in Africa, where one in every five (20%) childhood deaths is due to the effects of the disease. An African child has on average between 1.6 and 5.4 episodes of malaria fever each year. And every 30 seconds a child dies from malaria (www.who.int).

Malaria is a leading cause of morbidity and mortality in the developing world, especially sub-Saharan Africa where the transmission rates are highest and where it is considered to be a major impediment to economic development (Robert V et al., 2003).

Given its impact on populations and the gravity of its pathology, malaria remains one of the most significant infectious diseases. Malaria is a leading cause of morbidity and mortality in the developing world, especially sub-Saharan Africa where the transmission rates are highest and where it is considered to be a major impediment to economic development (Sachs J et al., 2002).

According to Africa Malaria Report 2003, about 90% of all malaria deaths in the world today occur in Africa south of the Sahara. This is because the majority of infections in Africa are caused by *Plasmodium falciparum*, the most dangerous of the four human malaria parasites. It is also because the most effective malaria vector – the mosquito *Anopheles gambiae* – is the most widespread in Africa and the most difficult to control. An estimated one million people in Africa die from malaria each year and most of these are children under 5 years old. Malaria affects the lives of almost all people living in the area of Africa defined by the southern fringes of the Sahara Desert in the north, and altitude of about 28° in the south. Most people at risk of the disease live in areas of relatively stable malaria transmission – infection is common and occurs with sufficient frequency that some level of immunity develops. A smaller proportion of people live in areas where risk of malaria is more seasonal and less predictable, because of either altitude or rainfall patterns. People living in the peripheral areas north or south of the main endemic area or bordering highland areas are vulnerable to highly seasonal transmission and to malaria epidemics. In areas of stable malaria transmission, very young children and pregnant women are the population groups at highest risk for malaria morbidity and mortality. Most children experience their first malaria infections during the first year or two of life, when they have not yet acquired adequate clinical immunity – which makes these early years particularly dangerous.

Alternatively, nowadays in Africa, malaria is understood to be both a disease of poverty and a cause of poverty. Annual economic growth in countries with high malaria transmission has historically been lower than in countries without malaria. Economists believe that malaria is responsible for a growth penalty of up to 1.3% per year in some African countries. When compounded over the years, this penalty leads to substantial differences in GDP between countries with and without malaria and severely restrains the economic growth of the entire region (www.rbm.who.int).

2.4 History of Malaria

Malaria has infected humans for over 50,000 years, and malarial protozoa may have been a human pathogen for the entire history of the species (Joy D *et al.,* 2003). Close relatives of the human malaria parasites remain common in chimpanzees (Escalante A et al., 1998). References to the unique periodic fevers of malaria are found throughout recorded history, beginning in 2700 BC in China (Cox F, 2002). Malaria was once common in most of Europe and North America, where it is no longer endemic (Norman G. Gratz), though imported cases do occur.

Scientific studies on malaria made their first significant advance in 1880, when a French army doctor working in the military hospital of Constantine in Algeria named Charles Louis Alphonse Laveran observed parasites for the first time, inside the red blood cells of people suffering from malaria. He, therefore, proposed that malaria is caused by this protozoan, the first time protozoa were identified as causing disease (Alphonse L, 2006). For this and later discoveries, he was awarded the 1907 Nobel Prize for Physiology or Medicine. The protozoan was called Plasmodium by the Italian scientists Ettore Marchiafava and Angelo Celli (Ettore M, 2007). A year later, Carlos J. Finlay, a Cuban doctor treating patients with yellow fever in Havana, provided strong evidence that mosquitoes were transmitting disease to and from humans (Tan SY et al., 2008). This work followed earlier suggestions by Josiah C. Nott, and work by Patrick Manson on the transmission of filariasis (Chernin E, 1977).

However, it was Britain's Sir Ronald Ross working in the Presidency General Hospital in Calcutta who finally proved in 1898 that malaria is transmitted by mosquitoes. He did this by showing that certain mosquito species transmit malaria to birds and isolating malaria parasites from the salivary glands of mosquitoes that had fed on infected birds. For this work Ross received the 1902 Nobel Prize in Medicine. After resigning from the Indian Medical Service, Ross worked at the newly-established Liverpool School of Tropical Medicine and directed malaria-control efforts in Egypt, Panama, Greece and Mauritius (CDC, 2004). The findings of Finlay and Ross were later confirmed by a medical board headed by Walter Reed in 1900, and its recommendations implemented by William C. Gorgas in the health measures undertaken during construction of the Panama Canal. This public-health work saved the lives of thousands of workers and helped develop the methods used in future public-health campaigns against this disease.

The first effective treatment for malaria came from the bark of cinchona tree, which contains quinine. This tree grows on the slopes of the Andes, mainly in Peru. A tincture made of this natural product was used by the inhabitants of Peru to control malaria, and the Jesuits introduced this practice to Europe during the 1640s, where it was rapidly accepted (Kaufman T et al., 2005). However, it was not until 1820 that the active ingredient, quinine, was extracted from the bark, isolated and named by the French chemists Pierre Joseph Pelletier and Joseph Bienaimé Caventou (Kyle R et al., 1974).

In the early twentieth century, before antibiotics, patients with syphilis were intentionally infected with malaria to create a fever, following the work of Julius Wagner-Jauregg. By accurately controlling the fever with quinine, the effects of both syphilis and malaria could be minimized. Although some patients died from malaria, this was preferable to the almost-certain death from syphilis (Raju T, 2006).

Although the blood stage and mosquito stages of the malaria life cycle were identified in the 19th and early 20th centuries, it was not until the 1980s that the latent liver form of the parasite was observed (Krotoski W *et al.* 1982, Meis J et al., 1983). The discovery of this latent form of the parasite finally explained why people could appear to be cured of malaria but still relapse years after the parasite had disappeared from their bloodstreams.

Malaria causes about 250 million cases of fever and approximately one million deaths annually (WHO, 2008). The vast majority of cases occur in children under 5 years old; (Greenwood BM et al., 2005) pregnant women are also especially vulnerable. Despite efforts to reduce transmission and increase treatment, there has been little change in which areas are at risk of this disease since 1992 (Hay S et al., 2004). Indeed, if the prevalence of malaria stays on its present upwards course, the death rate could double in the next twenty years (Breman J, 2001). Precise statistics are unknown because many cases occur in rural areas where people do not have access to hospitals or the means to afford health care. As a consequence, the majority of cases are undocumented (Breman J, 2001).

Although co-infection with HIV and malaria does cause increased mortality, this is less of a problem than with HIV/tuberculosis co-infection, due to the two diseases usually attacking different age-ranges, with malaria being most common in the young and active tuberculosis most common in the old (Korenromp E et al., 2005). Although HIV/malaria co-infection produces less severe symptoms than the interaction between HIV and TB, HIV and malaria do contribute to each other's spread. This effect comes from malaria increasing viral load and HIV infection increasing a person's susceptibility to malaria infection (Abu-Raddad L et al., 2006).

Malaria is presently endemic in a broad band around the equator, in areas of the Americas, many parts of Asia, and much of Africa; however, it is in sub-Saharan Africa where 85– 90% of malaria fatalities occur (Scott P L, 2005). The geographic distribution of malaria within large regions is complex, and malaria-afflicted and malaria-free areas are often found close to each other (Greenwood B et al., 2002). In drier areas, outbreaks of malaria can be predicted with reasonable accuracy by mapping rainfall (Grover-Kopec E et al., 2005). Malaria is more common in rural areas than in cities; this is in contrast to dengue fever where urban areas present the greater risk (Van B et al., 2005). For example, the cities of Vietnam, Laos and Cambodia are essentially malaria-free, but the disease is present in many rural regions (Trung H et al., 2004). By contrast, in Africa malaria is present in both rural and urban areas, though the risk is lower in the larger cities (Keiser J et al., 2004). The global endemic levels of malaria have not been mapped since the 1960s. However, the Welcome Trust, UK, has funded the Malaria Atlas Project (Hay SI et al., 2006) to rectify this, providing a more contemporary and robust means with which to assess current and future malaria disease burden.

2.5 History and the Situation of Malaria in Ethiopia

2.5.1 History

Ethiopia had approximately 4% of all cases in the African Region in 2006. Malaria is present everywhere except in the central highlands. Epidemics are frequent, the last having occurred in 2003–2004. Over half the cases are caused by *P. falciparum*. The number of reported malaria cases decreased from an average of 3.2 million (excluding the epidemic year, 2004) to 2,532,645 in 2008, of which over 986,000 were tested (39%) by either microscopy or a RDT, and 460,000 cases were confirmed. The reported number of malaria deaths in children under 5 years fell from an average of 1866 during 2001–2006 to only 1169 in 2008 (a decrease of over 37%) (WHO, 2009). The unstable nature of malaria transmission is characterized by frequent focal and cyclical epidemics of irregular interval ranging from 5–8 years.

In the Ethiopian highlands, several large-scale epidemics have been documented since 1958. In that year, an estimated 150,000 people died during a widespread epidemic of malaria in the highlands (Fontaine RE et al., 1958). Several epidemics have been reported since then. Abnormal transmission of unusual proportions affected the highlands and highland-fringe areas in 1988 and 1991–92, which was associated with abnormally increased minimum temperature. In 1998, widespread epidemics occurred in the highlands, and, in the most recent epidemic in 2003, more than 2 million clinical malaria cases and 3,000 deaths were reported from 3,368 villages in 211 districts (Negash K, et al, 2005).

2.5.2 Malaria Transmission in Ethiopia

Malaria is a major public health problem in Ethiopia; it contributes up to 20% of under-five deaths. Tragically, in epidemic years, mortality rates of nearly 100,000 children are not uncommon. In the last major malaria epidemic in 2003, there were up to 16 million cases of malaria - 6 million more than an average year.

Out of an estimated 9 million malaria cases annually, only 4-5 million will be treated in a health facility. The remainder will often have no medical support. It is estimated that only 20 per cent of children under five years of age that contract malaria are treated in a facility.

P. Falciparum and P. Vivax are the two dominant parasite species in the region with relative frequency of 60% and 40%, respectively. This proportion varies from place to place and from season to season. In malaria epidemic situations, *P. falciparum* is the dominant parasite species that causes severe manifestations and almost all malaria deaths happen due to infection by this parasite. Moreover, the biological diversity of *P. falciparum and* its ability to develop resistance to a number of anti-malarial drugs has been a major challenge in malaria chemotherapy (FMoH, 2004).

Malaria is prevalent in 75 per cent of the country, putting over 50 million people at risk (out of a countrywide population of 77 million). The disease accounts for seven per cent of outpatient visits and represents the largest single cause of morbidity. Large scale epidemics tend to occur every 5-8 years in certain areas due to climatic fluctuations and drought-related nutritional emergencies.

Children and pregnant mothers are among the most vulnerable. Drought related malnutrition, poor health and no sanitation can leave a weak immune system open to attack from malaria. It can also worsen the effects of malnutrition through malaria-related diarrhea and anemia.

Malaria is also known to speed up the onset of AIDS in anyone who is HIV positive. Those living with HIV in high-risk areas are also amongst the most vulnerable.

2.5.3 Factors of Malaria in Ethiopia

According to the FMoH, the most influential and important environmental factors for the occurrence of malaria in Ethiopia are rainfall, temperature and altitude. However, previously as shown in *(fig 1.1)* the country is categorized as malarious and non malarious only based on one environmental factor i.e. altitude. Therefore, this study tries to investigate malaria prone area including other environmental factors namely rainfall, temperature, altitude and distance from rivers.

Altitude has long been recognized as an important determinant of malaria being endemic. However, most of the areas affected by epidemics are areas located between 1000–2000m. (Tulu, 1993). Besides, in Ethiopia malaria epidemics tend to occur in areas which are found below 2,200m a.m.s.l. (FMoH, 2008). Now, transmission of malaria is expanding in to areas which were previously free of malaria. It was revealed that the limit has moved up to 2,500 m. (Negash et al., 2005). In this study, altitude of up to 2,500 m, above which due to low temperature mosquito survival is greatly reduced and malaria transmission does not occur.

2.5.4 National Malaria Control Programme

Interventions against malaria in Ethiopia first started in the late 1950s in response to the 1958 epidemic. The service was organized by what was then called the Malaria Eradication Service, a pilot project established for 15 years. The Malaria Eradication Service provided malaria diagnosis and treatment with chloroquine and spraying of houses with DDT. With the change of approach from malaria eradication to control in 1972, the malaria control program in Ethiopia was re-organized as a vertical program operating across the country through 17 zonal and 70 sector offices. Laboratory diagnosis and treatment services and seasonal spraying operations were provided through the sector offices.

In 1993, the vertical Malaria Control Program was reorganized in line with the government's plan to democratize and decentralize the health services. In the decentralized system, planning and implementation of malaria prevention and control activities belong to the Regional Health Bureaus, while the federal level is mandated to handle policy and guideline development and capacity building. During the eradication and vertical program era, malaria control personnel were trained in the Malaria Reference Training Center in Nazareth/Adama. Separate basic training for malaria control personnel is not currently provided, and training on basic malariology has little emphasis in the training curricula of health professionals. The newly engaged cadre of health extension workers does receive training on malaria as part of their training on the main 16 health packages that are part of their curriculum.

Following the launch of the Roll Back Malaria (RBM) Partnership in 1998, Ethiopia convened a national consensus-building workshop in March 2000 and started a coordinated action against malaria with its local and international partners. The RBM partners developed a five-year National Strategic Plan for Malaria Prevention and Control (2001–2005) and conducted an RBM baseline survey in 14 districts in 2001 to document baseline information prior to the launch of large-scale interventions (FMoH, 2008).

2.6 Experiences of Using RS and GIS in Public Health

More than 150 years ago, public health experts realized the use of maps in analyzing the location of the disease-related happenings. In 1840, Robert Cowan in Glasgow-England, used maps to show relationship between crowd and incidence of yellow fever. He recognized that in regions where there is too much immigration, this disease was more epidemic. Also in 1843, he showed epidemically incidence of typhus on a map which involved all of the infected houses (Burrough, P, 1986). Since then, GIS have been continuously used for the analyses of spatial health related data. During this period, the more GIS analytical capabilities were developed, the more advanced and comprehensive spatial models were developed by the collaboration of experts in both areas of GIS and epidemiology and health care.

Nowadays, especially in the new century, different GIS applications or modules for health care applications have been designed and accomplished in many countries. In the followings, some experiments in applying GIS for public health affairs are discussed. Malaria was studied and modeled, in Amazon area, using GIS in international research development center of epidemic diseases. Aims of this study were: comparing risk of being affected by Malaria in different social groups and in different environmental condition, studying effects of social and economical factors on prevalence of disease, understanding influences of environmental and economical factors on disease and perceiving general situation of Amazon agricultural regions from viewpoint of prevalence among people. Finally, GIS and statistical software and data were used to study the relationship between different factors and Malaria (Bretas, G., 1995). In 2002, Office of Statewide Health Planning and Development (OSHPD), in California USA, established a powerful system for resource and facility management. In this project, using the results of need analyses, the conceptual model was designed. In the next step, classes, subclasses and available relations and so on was defined in software. Then, the collected data was entered and the final system was created to respond to the desired requirements (Goodchild, M., 2003).

In 2002, a project in Karnataka was accomplished for dividing regions and specifying local domain of health area responsibility. Reason for performing this study, was referred to the disproportion between population of region and location of health center. Final goals were to control and supervise health center operations in their responsibility region, to optimize use of available health resources and to cover clients' needs. The result was a GIS with the ability of performing special analyses, such as: zoning regions, finding the best location for facilities (Wen Hsiang, W., 2000).

In 2002 in Ayuthaya, Thailand, GIS was used for examining effects of different factors on public health, showing disease distribution, performing specific analyses, visualization and providing of information on health care and also helping in different decision making. Data used in this study include: population data, data concerning infectious diseases and their occurrence locations. In this study, dependence of spreading disease on time was studied using statistical regression analyses. One of the advantages of this study is the simultaneous use of spatial and statistical analysis which provides powerful tool for decision making process. Among all examined diseases, pneumonia had a direct relation with time and highest dependence coefficient (94 %) and its distribution in crowded areas was high (Keola S et al., 2002).

In 2003, Eastern Europe international health organization started to estimate diseases as a result of water pollution by means of GIS to specify pollution resources and direction of occurring diseases. In this research, primary studies determined system requirements for managing and taking care of disease and also factors that cause them. Then, some of disease intensifying factors and data related to them was gathered. Finally, GIS was used as a managing system to store and recover data, display and recognize temporal and spatial association of disease (WHO, 2002). In 2006, a project was accomplished by environmental conservation organization in order to control WN virus, in Pennsylvania, USA. This virus could spread easily and quickly in every environment. In this study, GIS was used for gathering and combination of data from different resources and for creating a central geo-database to provide relation between different data centers. Environmental sampling was accomplished by means of dynamic GIS technology and wireless GIS. In the resulted system, users could determine prevalence direction, extent of spreading and number of affected people (ESRI, 1999).

2.7 The Application of RS and GIS in Malaria Study

Nowadays, health and health care are considered as an important factor in the quality of life of individuals. In fact, the development of public health and diseases management plays a significant role in cultural, social and economical development of any society. The most important goals of each public health organization involve environment health, control of diseases, health education and prevention, medical and nursing actions for early diagnosis, control and management of diseases (Ghazban F., 2003).

During the last twenty years, the development of GIS and satellites for earth observation have made it possible to make important progress in the monitoring of the environmental and anthropogenic factors which influence the reduction or the re-emergence of the disease. Analyses resulting from the combination of GIS and RS have improved knowledge of the biodiversity influencing malaria. A better understanding of the stratification of malaria and the burden of the disease on the population is in–progress (Craig MH *et al.*, 1999; Omumbo *et al.*, 2004). This knowledge can help decision-makers to better allocate limited resources in the fight against the disease.

RS and GIS techniques can also help epidemiologists to identify vector focuses. These technologies, allow them to relate disease occurrence indexes and environmental characteristics, enabling the exact observation of geographic area and the determination of how some physical factors (rivers, mountains, vegetation) can influence the spreading or controlling of the disease (Cline BL, 1970). Besides that, the use of these techniques can improve the ground data acquisition and information accuracy (Wood BL et al, 1992).

GIS appeared useful for medical research and epidemiology. Health geography is already indispensable for public health surveillance, seems useful to identify inequities in health care delivery, and to efficiently help allocate and monitor healthcare resources. Geographical visualizations may be helpful for both studying spatial epidemiology and helping to assess the best distribution of healthcare units based on current needs (Jean-Baptiste R et al., 2005).

2.8 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a structured technique for dealing with complex decisions. Rather than prescribing a "correct" decision, the AHP helps the decision makers find the one that best suits their needs and their understanding of the problem (www.wikipedia.com).

Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. The AHP provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. It is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education (www.wikipedia.com).

Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood—anything at all that applies to the decision at hand (www.wikipedia.com).

Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time. In making the comparisons, the decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations (Saaty T et al. (2008-06), cited in www.wikipedia.com).

2.9 The Importance and Application of Web GIS Decision Support System

GIS can be defined as the science and technology related to the gathering, storage, manipulation, analysis and visualization of geo-referenced data. Using a GIS, we can combine different data and generate information required for decision making.

GIS and DSS are mechanisms that can be used to provide managers with information needed to make sound resource management decisions. Usually, concentration of a disease in particular areas statistically indicates the unusual presence of some factors that cause the disease. Moreover, the co-occurrence of such factors in an area increases the happenings of the disease dramatically. Such correlations make it necessary to study and compare the spatial distribution and pattern of both the diseases and their assumed factors. GIS can be used to analyze and compare such patterns.

The first step in making such activities possible is to map and monitor the time and location of disease happenings. Usually the spatial data collected are either in the form of points representing the location of individual patients or the settlements along with other attributed data, or in the form of polygons representing regions or urban districts along with disease statistics and other attributed data. In a GIS, using such geographical data and the linked statistical and attribute data, many thematic maps can be generated that directly guide the managers towards better and information-based decisions.

One of the most important capabilities of GIS is the capability to publish and share geo-spatial information on the Internet among large numbers of people. Sharing of geo-spatial information is an important and effective way of working in many kinds of applications. Geo-spatial information includes not only maps or locations of landmarks/facilities, but multiple attribute data, socio-economic data, ground photos, aerial photographs, satellite images, etc., which may have static or dynamic characteristics. By sharing this information on the Internet, accessibility, time response, and understandability are drastically improved compared to conventional paper distribution of maps or character based Web systems. Users will have more freedom to choose information or layers to see and synthesize maps that will fit their own requirements (Maged N et al., 2006).

With the introduction of WMS specification and also OGC Web Feature Service (WFS), it has become easy to publish and share any geo-spatial information on the Internet. WMS, which is currently popular in actual applications, basically creates maps (PNG – Portable Network Graphics, or JPEG formats) of the requested area, which standard browsers can render. Thus, users do not have to copy huge data sets to local systems. WFS supplies users with only the geographic features that satisfy their filtering criteria.

The use of mobile devices will further expand the efficiency and utility of WMS. Maps and data can now be retrieved using PDA devices in the field, and surveyors using such devices in the field are able to upload/update maps or other data on remote servers, which can then be shared immediately. Publishing and sharing geo-spatial data in the health sector are increasingly becoming important and popular tasks in various applications since successful data sharing is very important in emergency responses and disaster informatics.

CHAPTER-III THE STUDY AREA

3.1 Location

The study area is found in Jimma zone that is in the Oromia regional state of Ethiopia. It is geographically located at $7^0 48'0''$ - $8^0 11'0''$ North latitude and $37^O 5'30''$ - $37^O 24'0''$ East longitude. It is found around 380 km from the capital city; Addis Ababa covering an area of 928 sq. km. Tiro Afeta woreda consists of two towns and 27 kebeles with a total population of 133,011. The location map of the study area is shown in *(fig 3.1)*.

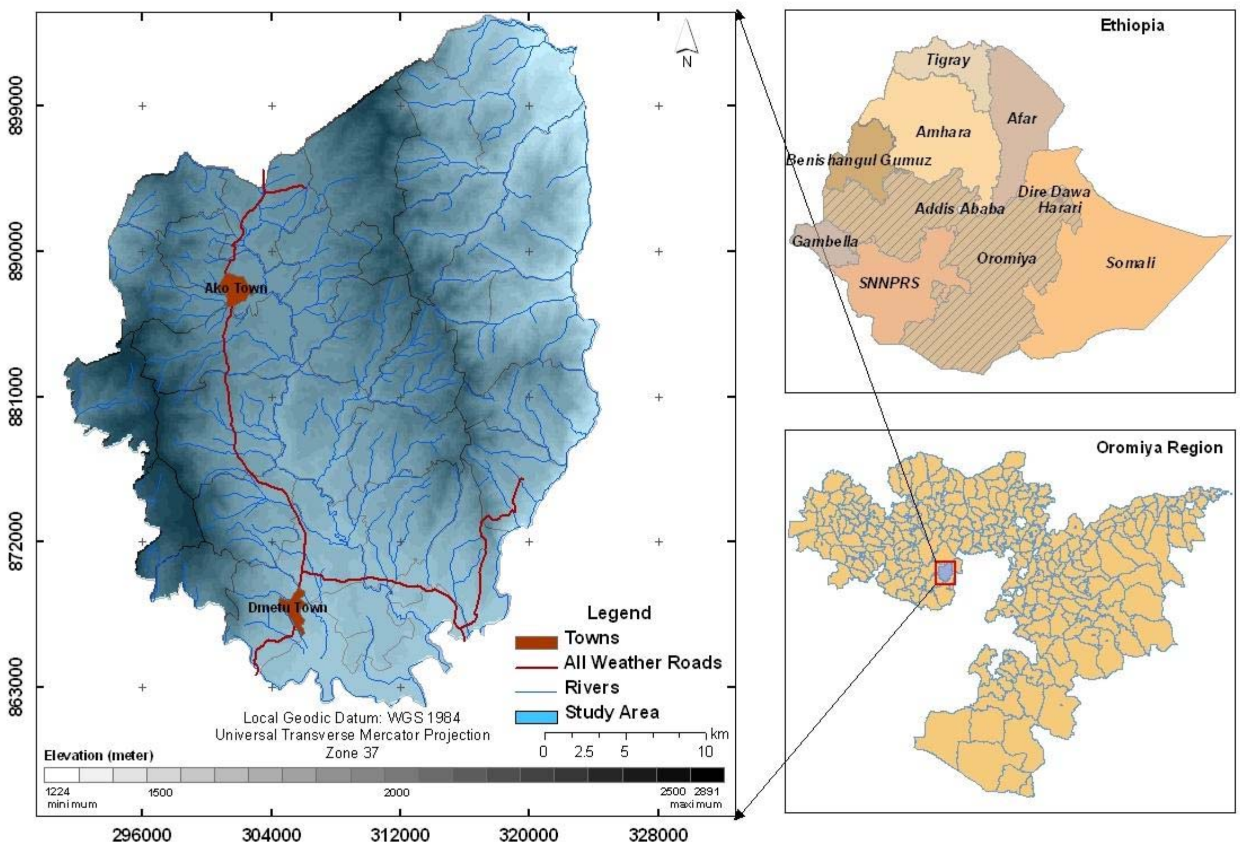


Fig 3.1 Location Map of Tiro Afeta Woreda

3.2 Topography

The study area is situated in the western part of the Oromia region at an altitude ranging 1224 – 2891m a.s.l. As indicated in (*fig 4.2)*, the area is characterized by flat lying topography with some scattered hills at the western and central part. The above topography is also represented by hot to warm sub-humid ecological zones.

3.3 Population

In this research, the population is provided by the last 2007 census conducted by the CSA. Tiro Afeta woreda is consists of twenty-seven kebeles and two towns with a total population of 133,011. The two towns, Ako and Dmetu are with a total population of 2,266 and 3,041, respectively. Population by kebeles is clearly shown in (*fig 3.2)*. At first glance, one can notice that the central kebeles are highly populated with more than 5000 inhabitants. The rest kebeles are located along with the boundary of the woreda are rather with a lesser population size.

3.3.1 Population Density

Population density indicates the number of people per area. From the map shown in (*fig 3.3)* one can depict that Tiro Afeta woreda is characterized by an average population density ranging 100-250 people per sq. km. These areas cover the central part, while the two towns Ako and Dmetu are densely populated with more than 1000 inhabitants per sq. km. Moreover, Aomochala and Koechagbe kebeles are with a population density of 500-1000 and 250-500 people per km, respectively.

The growth of population and urbanization is another factor in the determination of health events such as epidemics of malaria. Water storage and inadequate water disposal can provide habitat for mosquitoes, particularly in rapidly expanding urban areas. (Paul R, 2001). Alternatively, one of the causes for the expansion of population is migration resulted from the movement of people. Infected people in pursuit of work can introduce malaria to areas where it is rare. Non-immune people are at high risk if they move to areas of transmission. Extensive road building and modern transportation have greatly exacerbated this factor. (Paul R, 2001) In general, the traveling of people from malaria endemic areas to non-malarious areas could result and increase the occurrence of malaria in the area.

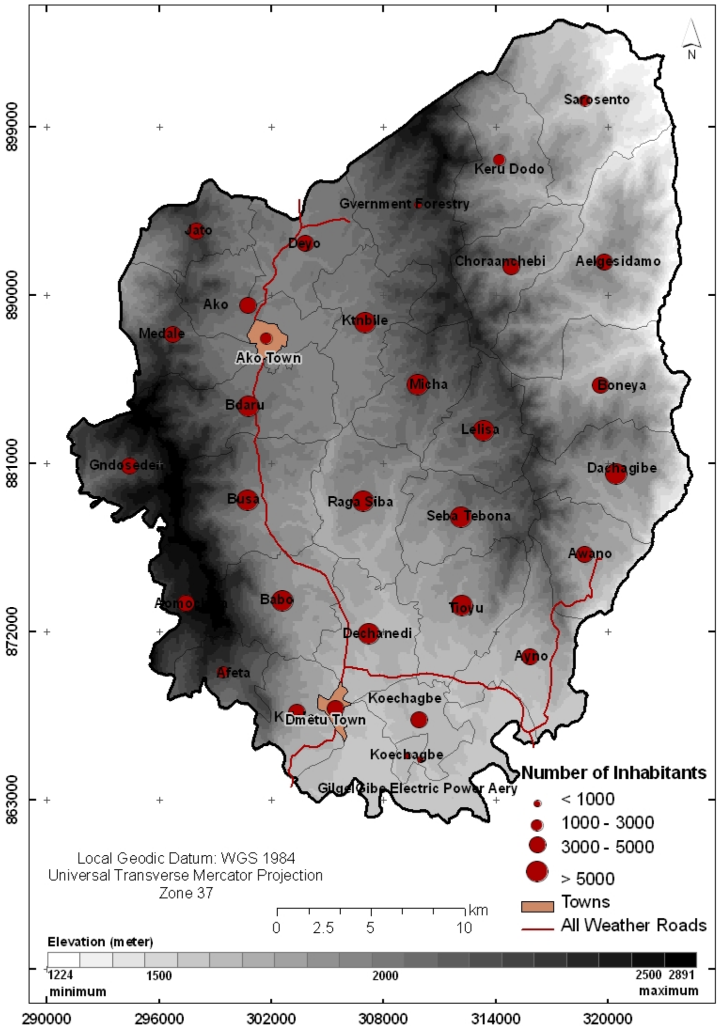


Fig 3.2 Population Map of Tiro Afeta Woreda

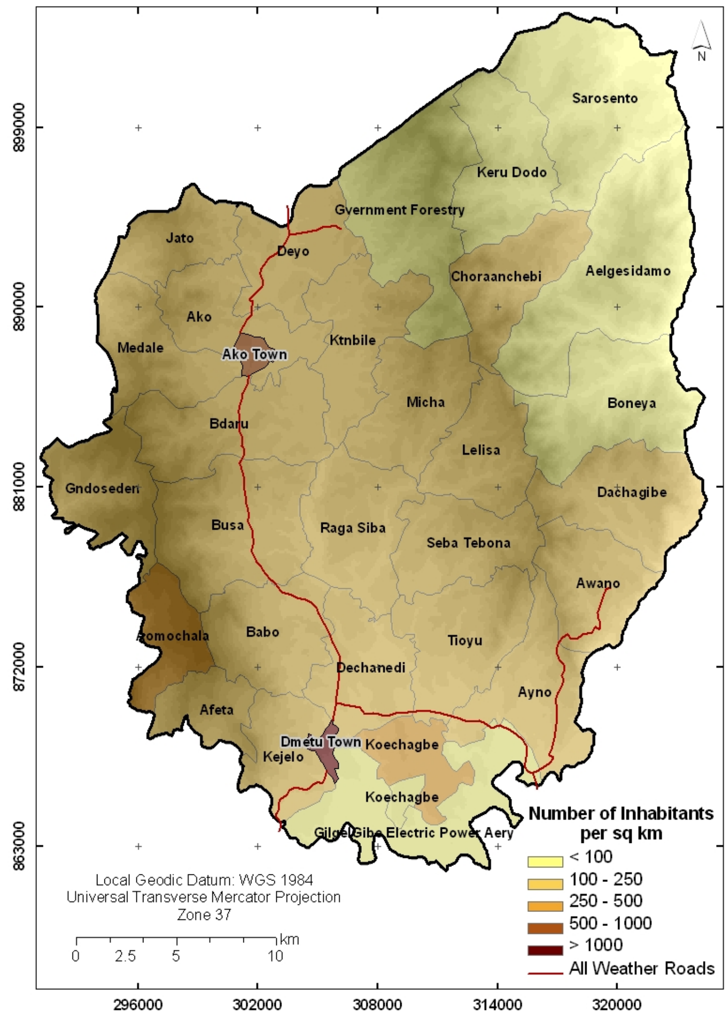


Fig 3.3 Population Density Map of Tiro Afeta Woreda

3.4 Distribution of Health Facilities

In Tiro Afeta woreda there are total 31 health facility centers (1 health centre, 3 clinics and 27 health posts). Accordingly, 1 facility would be for 4,291 persons. The ratios are based on all present facilities calculated for the total population. The map in (*fig 3.4)* shows the kebeles health facilities repartition. Health facilities imply the existence of health workers which creates more awareness among the society and this in turn might contribute to the decrease of malaria incidence and burden to some extent. If there is awareness, the society will be more prepared and work on the situation to prevent malaria.

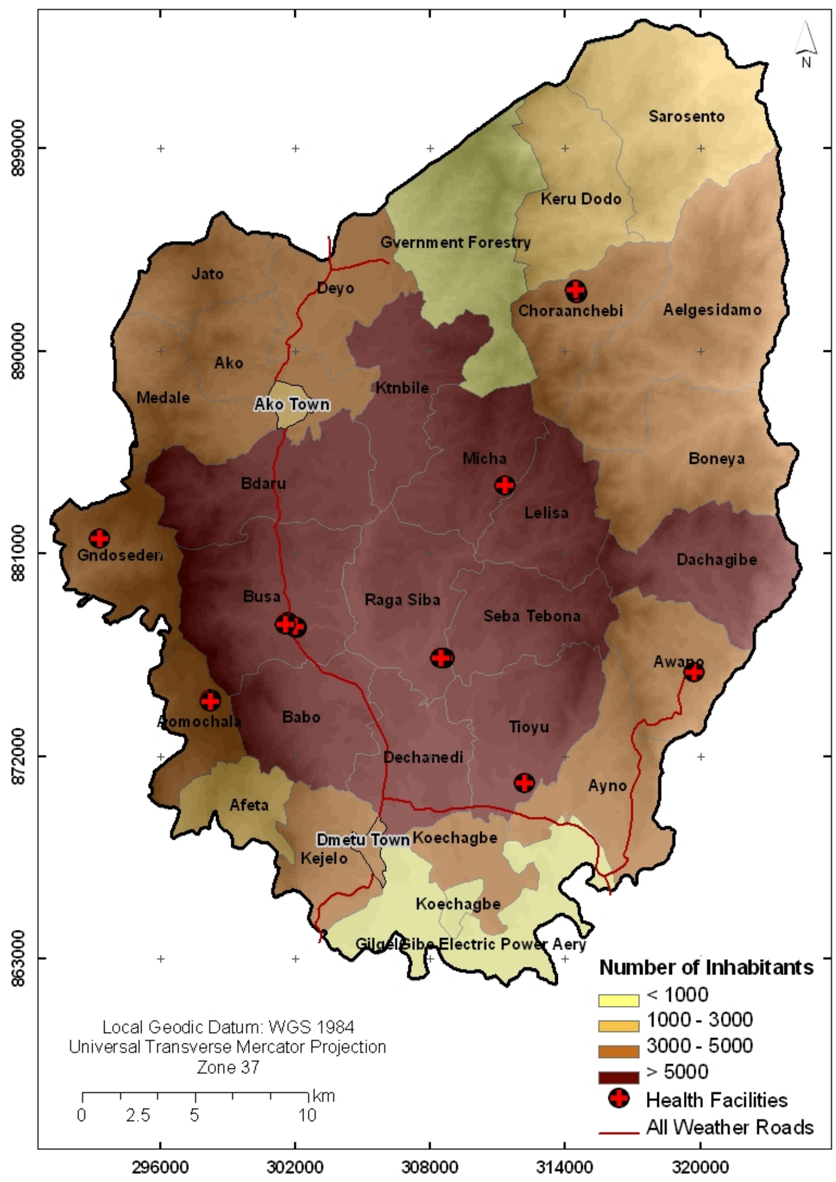


Fig 3.4 Health Facilities Map of Tiro Afeta Woreda

CHAPTER - IV METHODOLOGY AND ANALYSIS

4.1 Data Sources

Data were collected and analyzed in order to meet the objectives of the study. To conduct this research the input data was taken from various offices and sources where relevant information was available. Accordingly, the list of data gathered from the respective organizations is shown in *table 4.1*.

Table 4.1: List of Data and Sources used for the Study

Item	Data type	Source	Remarks
1	Literature	Different Books	
2	Altitude	CSA	90m SRTM data
3	Rainfall Estimate (RFE)	FEWS Net	2007 – 2009 G.C
4	Satellite Temperature	IFPRI	35 years until 2004 G.C
5	Satellite Rainfall	IFPRI	35 years until 2004 G.C
6	Medical	ORHB, JZHB	2000 – 2002 E.F.Y
7	Census	CSA	2007 G.C
8	Health Facility Location	CSA	GPS
9	Study Woredas Boundary	CSA	Shapefiles

4.2 Research Methodology and Analysis

The research aims at the assessment of malaria prone areas in relation with environmental factors and tries to analyze malaria incidence with some of the natural and socio economical factors using RS and GIS techniques. Moreover, a decision support system which helps and provides information for the decision makers has also been developed. Therefore, in the following sections, the application of the techniques and the analysis is discussed in detail.

4.2.1 Assessment of Malaria Prone Areas

The datasets required for the assessment of malaria prone areas were derived using the available different RS and GIS techniques. Rainfall and Temperature data gathered for the 35 years until the year 2004 G.C obtained from IFPRI were extracted for the study area using the spatial analysis tool of ArcGIS.

Drainage density doesn't necessarily indicate the occurrence of malaria, since the existence of malaria rather more related with stagnant water. Therefore, rivers will be more conducive for malaria if related with temperature and altitude. As a result, first, areas located at an elevation less than 2000 meters were extracted by attribute using the ArcGIS's spatial analysis extension tool. Then, by overlaying the raster data with the rivers shapefile the selection was made for rivers below 2000 meters altitude. Then, distance from rivers was calculated again using the spatial analysis tool.

All the derived datasets were classified accordingly. Then the next step was reclassification. The reclassification was done into different classes using the spatial analysis tool giving the value 5 for more suitable attributes and the rest accordingly depending on their suitability. After all the rainfall, temperature, altitude and distance from rivers were reclassified; weight is given to each dataset depending on their intensity of importance using IDRISI software. This helps to avoid biased and subjective judgment towards giving the weight to each dataset. While reclassifying the factors the files were saved as tiff formats since IDRISI accepts certain raster formats. Then using this software, the files were imported using Government/Data Provider Formats and were saved as compatible formats for further use in IDRISI. Then using the GIS analysis – decision support tool the weight was given to each factor using pairwise comparison. While giving the weight for each dataset the software provides a value ranging from 1/3 – 9 indicating their intensity of importance, see *(fig 5.1 & table 4.2)*. The weight was given until it reaches the acceptable consistency ratio which is less than 0.10.

Table 4.2: Description of Intensity of Importance in Pairwise Comparision

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

Then using the raster calculator in ArcGIS, the percentages acquired from the weight were multiplied with the respected datasets and are added. The output resulted with higher values indicating suitable conditions. The overall method in the assessment of malaria prone areas is plainly shown in (*fig 4.1)*.

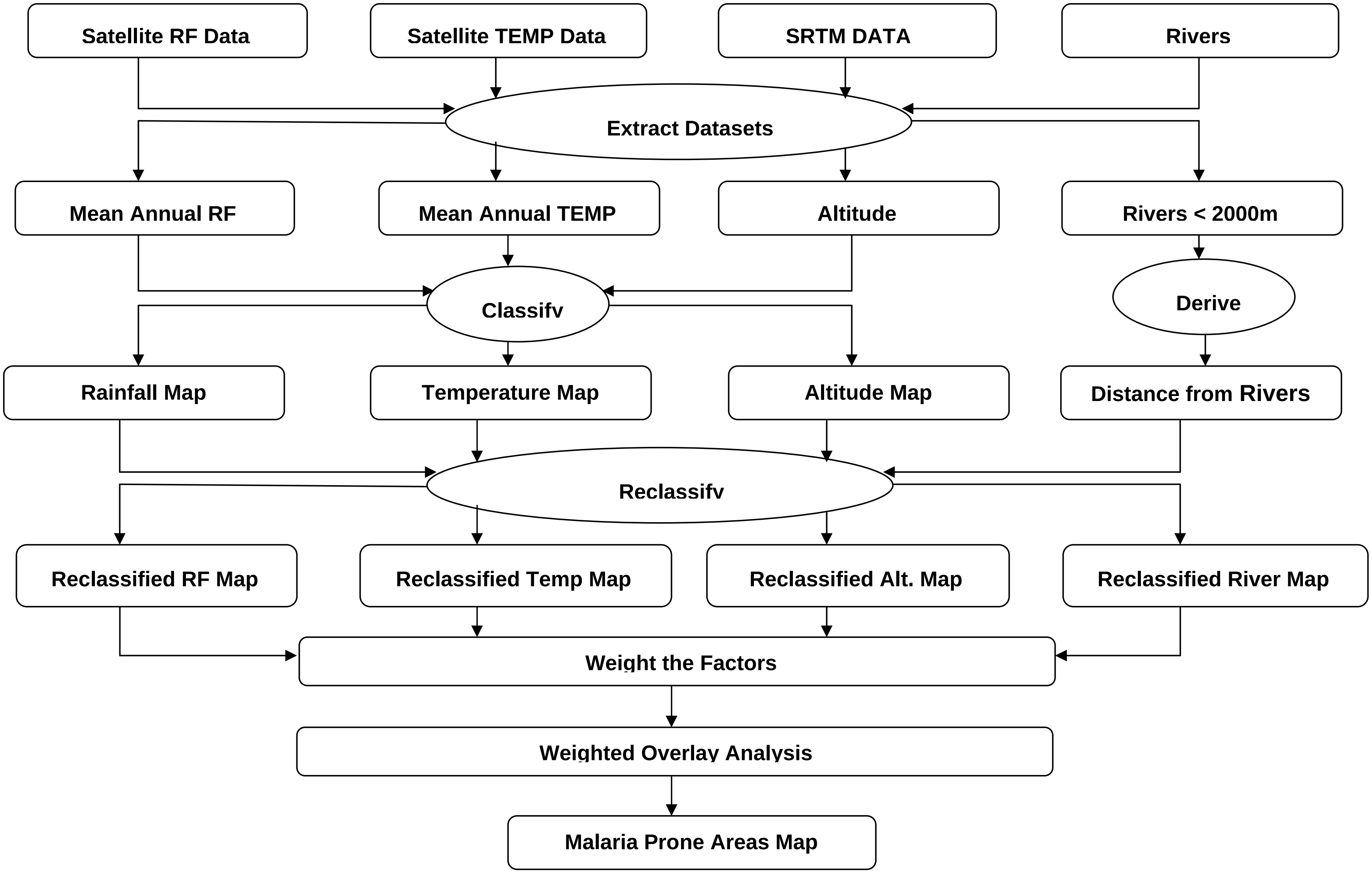


Fig 4.1 Schematic Representation of the Methodology

4.2.1.1 Altitude

The elevation layer was classified based on the extent of malaria prevalence at different altitudes *(fig 4.2)*. The layer was further reclassified into four classes and new values were assigned to each class. Based on this classification, 5, 3, 2 and 1, values were given to elevation ranges of <2000m, 2000-2200m, 2200-2500m and >2500m, respectively. Accordingly, the classes were labeled in the *(fig 4.3)* as very high, moderate, low, and malaria free based on the level of susceptibility to malaria incidence.

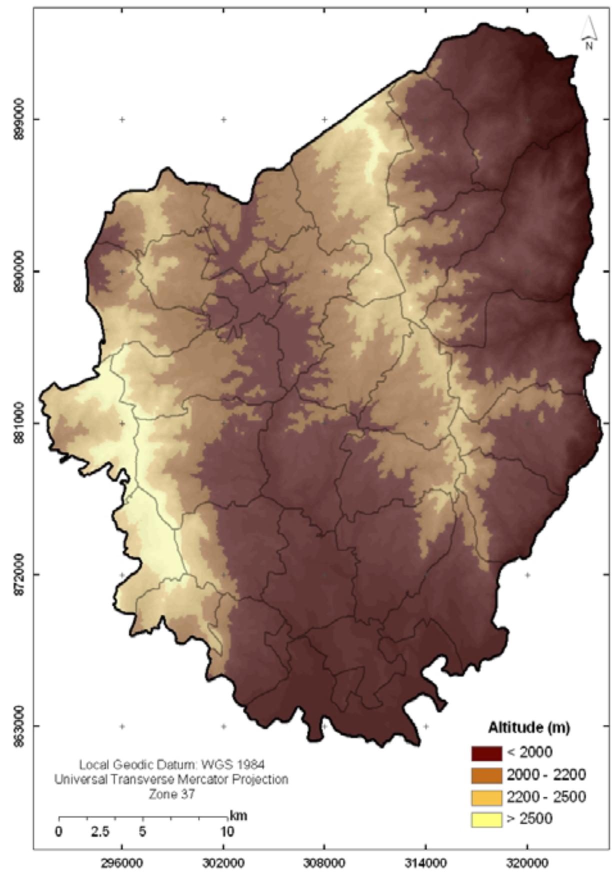


Fig 4.2 Altitude Map of Tiro Afeta Woreda

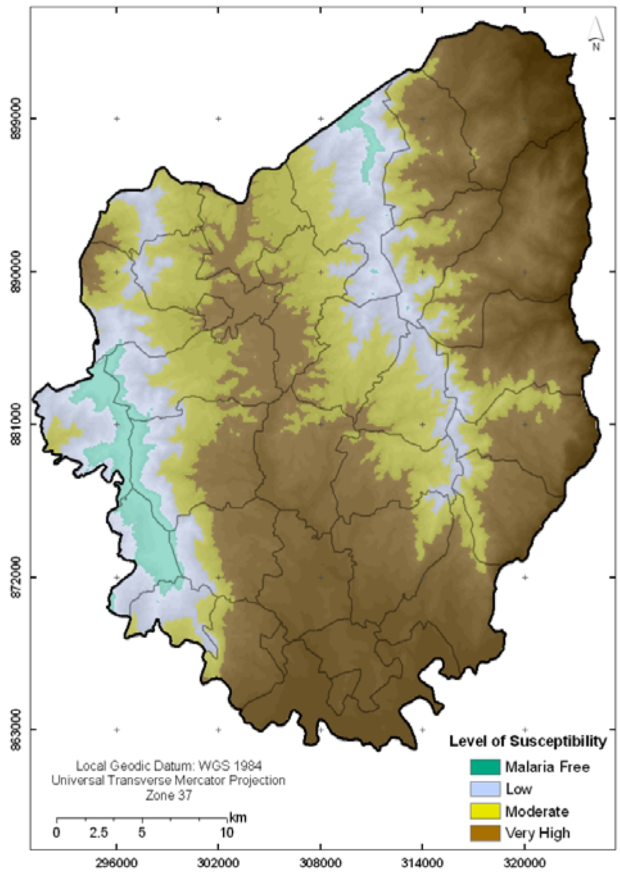


Fig 4.3 Reclassified Altitude Map

4.2.1.2 Rainfall

The satellite rainfall data is classified *(fig 4.4)* having classes <1500mm and >1500mm and assigned values 3 and 5 respectively. The computed rainfall data was further reclassified. Then, each class shown in *(fig 4.5)*, was labeled as moderate and very high based on the degree of susceptibility of the area to malaria. In other words, areas with higher rainfall are highly susceptible to malaria than those with relatively low amount of rainfall.

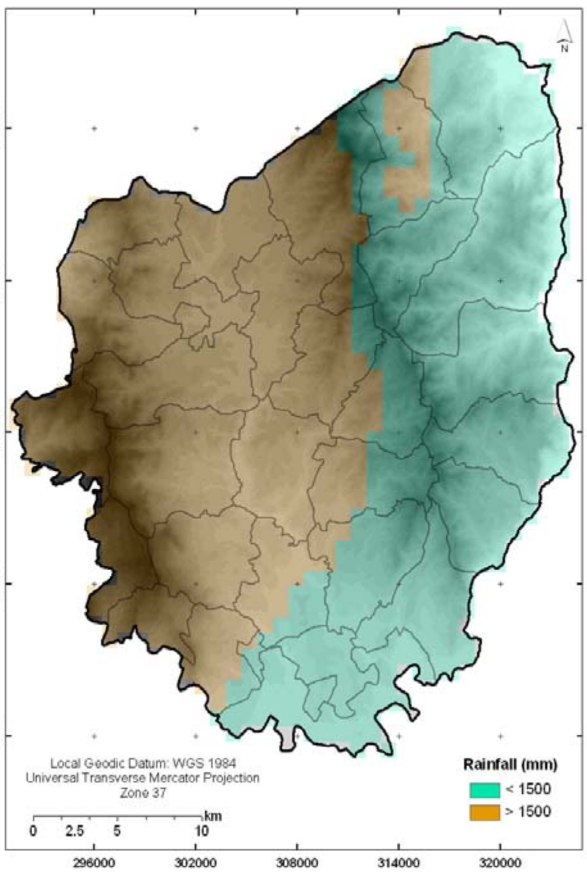


Fig 4.4 Map of Mean Annual Rainfall

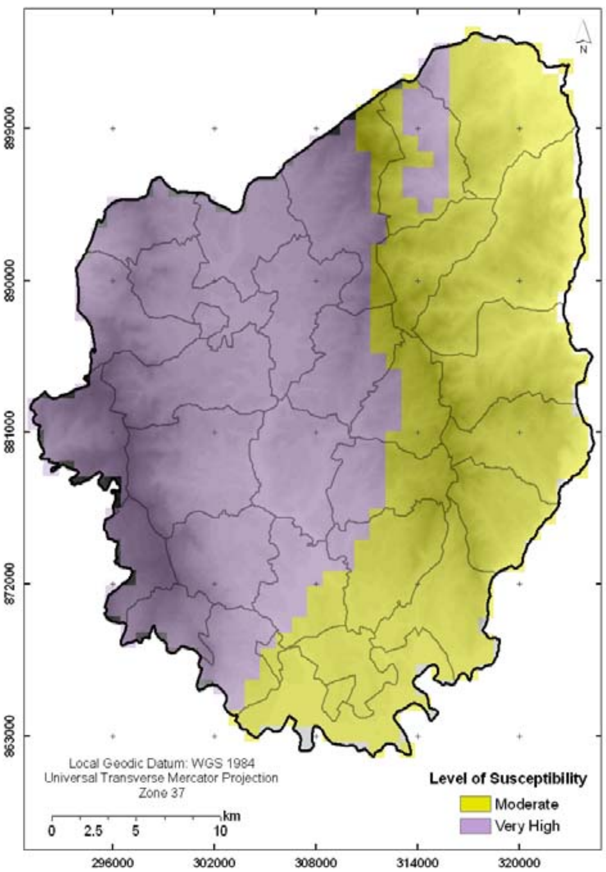


Fig 4.5 Reclassified Mean Annual Rainfall Map

4.2.1.3 Temperature

Temperature is also another important factor determining malaria transmission. Therefore the satellite temperature data is classified *(fig 4.6)* having classes >20^{0}C, 15-20^{0}C, and <15^{0}C and assigned values 5, 3, and 1 respectively. The computed temperature was further reclassified. Then, each class shown in *(fig 4.7)*, beginning from the class with the highest value, was labeled as very high, moderate, and malaria free based on the degree of susceptibility of the area to malaria. In other words, areas with higher temperature are highly susceptible to malaria than those with relatively low temperature.

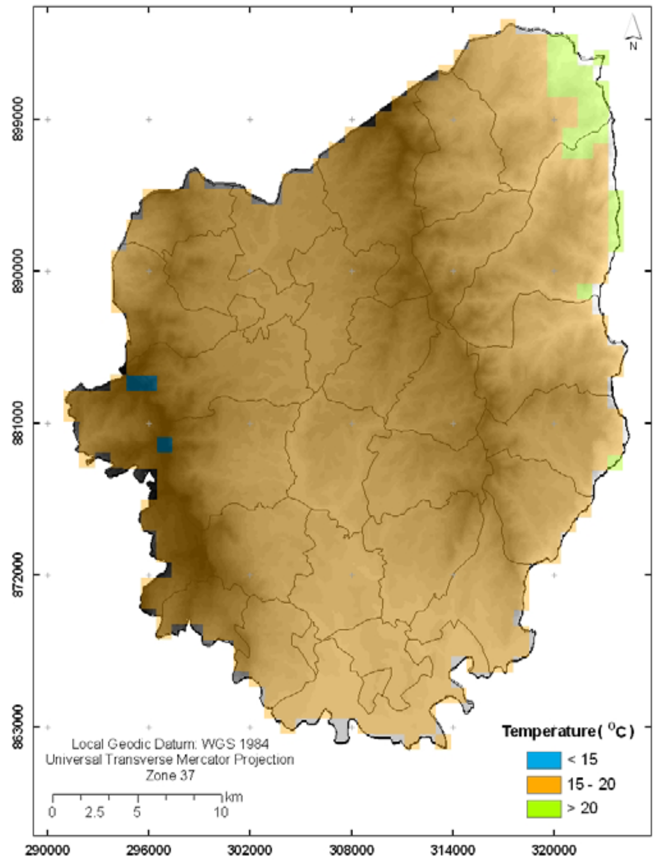
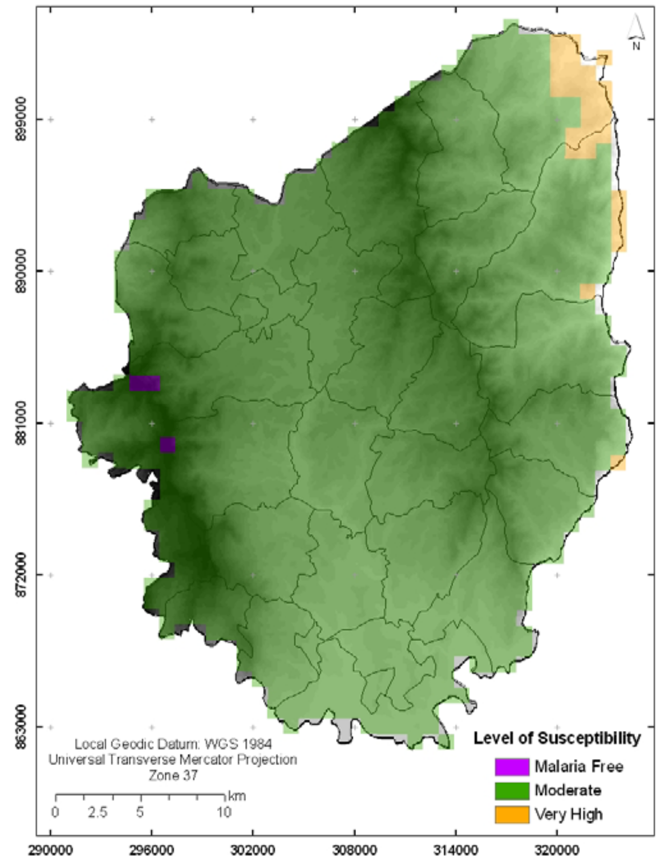


Fig 4.6 Map of Mean Annual Temperature



4.7 Reclassified Mean Annual Temperature Map

Fig

4.2.1.4 Distance from Rivers

Breeding and early prevalence of anopheles mosquito is done in water basins. Different literatures indicate that mosquitoes have typical flight ranges up to 2 kms depending upon species (Kaya *et al*., 2002). Since the fly range of mosquitoes is limited, the abundance of mosquitoes can be found around rivers where there are still waters. Conducting irrigation practices and construction of dams contribute towards creating favorable condition for the breeding of mosquitoes. In the study area, specifically due to the construction of the Gilgel Gibe dam, largely contributes for malaria to be prevalent through out the year in the area.

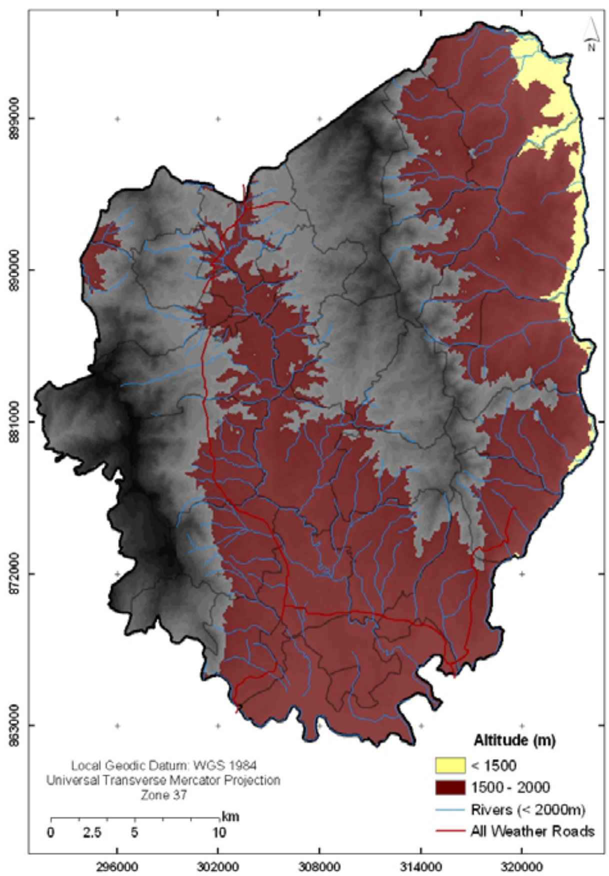


Fig 4.8 Map of Rivers < 2000m Altitude

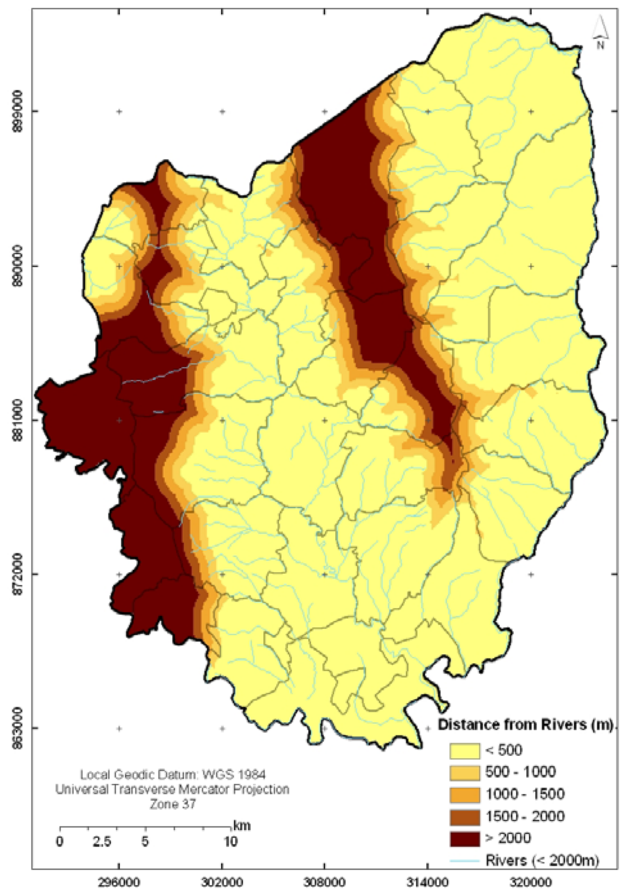


Fig 4.9 Map of Distance from Rivers

Altitude and temperature are more related factors where altitude decreases with the amount of temperature increases. As a result, rivers found at an altitude less than 1500 meters *(fig 4.8)* are used in the analysis, since these considered as malaria risk areas (FMoH, 2008). The lower altitude indicates higher temperature which is conducive for the breeding of mosquito. Alternatively, sides of rivers are also responsible for stagnant water. Therefore distance from rivers calculated *(fig 4.9)* having classes <500m, 500-1000m, 1000-1500m, 1500-2000m, and >2000m and assigned values 5,4,3,2 and 1 respectively. The computed distance was reclassified based on the maximum distance that mosquitoes can fly. Then, each class shown in *(fig 4.10)*, beginning from the class with the highest value, was labeled as very high, high, moderate, low, and malaria free based on the degree of susceptibility of the area to malaria. In other words, areas near to river(s) are highly susceptible to malaria and those areas far from river(s) are less susceptible.

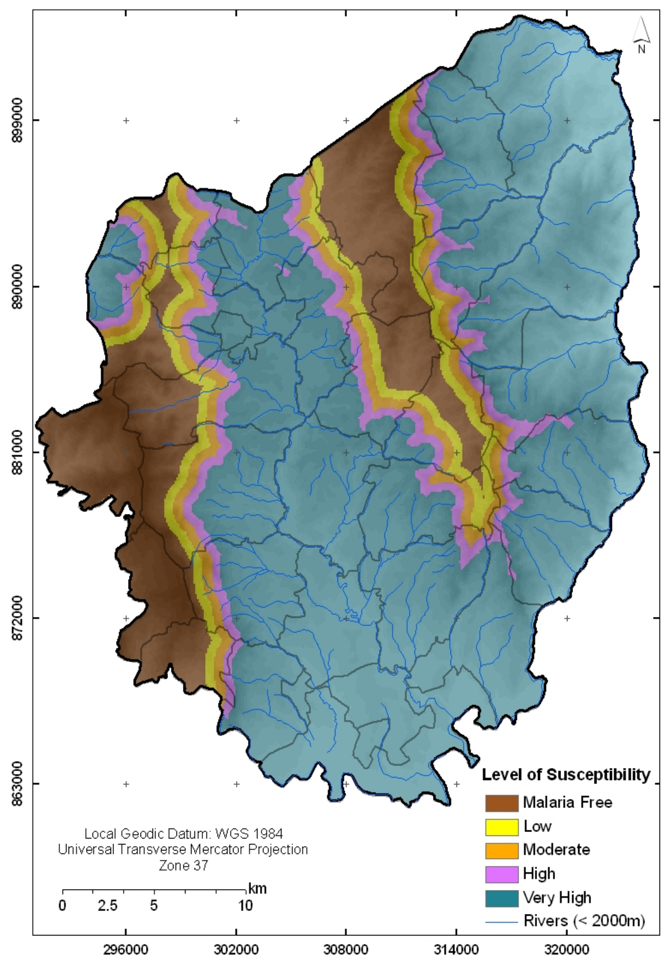


Fig 4.10 Reclassified Map of Distance from Rivers

4.2.2 Analysis of Malaria Incidence

In the analysis of malaria incidence, rainfall satellite data and malaria cases were considered. The RFE satellite data was downloaded from USGS site and extracted using Windisp software. In order to use and manipulate the data using ArcView the extensions such as; the Batch Grid Toolbox, Spatial Analysis were enabled. During this, anyone can make the setting default to avoid setting up every time an ArcView opens. Then using the Batch toolbox the first step was setting FEWS image projection. Afterwards, import FEWS Windisp images for analysis, there is no need of setting the projection again until one finishes his/her project.

The ORHB recording system follows the Ethiopian fiscal year which directly related with the budget year. Therefore, the year began with the month July (Hamle) and ends in June (Sene). As a result, to match the malaria cases with rainfall satellite data and construct the analysis, the RFE data is calculated parallel to the related months. The corresponding month and year of the ORHB and the RFE data are clearly stated in *tables 4.3 – 4.5*. Then, the calculation was made with the help of map calculator in spatial analysis extension which is found in ArcView.

Table 4.3: List of Months and Years of ORHB (2000 and 2001 E.F.Y)

ORHB Budget Year		**Corresponding Month/Year in E.C**		**ORHB Budget Year**		**Corresponding Month/Year in E.C**	
Month	**Year**	**Month**	**Year**	**Month**	**Year**	**Month**	**Year**
July	2000	Hamle	1999	July	2001	Hamle	2000
August	2000	Nehasse	1999	August	2001	Nehasse	2000
September	2000	Meskerem	2000	September	2001	Meskerem	2001
October	2000	Tekemet	2000	October	2001	Tekemet	2001
November	2000	Hidar	2000	November	2001	Hidar	2001
December	2000	Tahesas	2000	December	2001	Tahesas	2001
January	2000	Tir	2000	January	2001	Tir	2001
February	2000	Yekatit	2000	February	2001	Yekatit	2001
March	2000	Megabit	2000	March	2001	Megabit	2001
April	2000	Miazia	2000	April	2001	Miazia	2001
May	2000	Genebot	2000	May	2001	Genebot	2001
June	2000	Sene	2000	June	2001	Sene	2001

Table 4.4: List of Months and Years of ORHB and RFE Data (2000 E.F.Y)

ORHB Budget Year		Corresponding Year in G.C		Corresponding RFE Data		
Month	**Year**	**Month**	**Year**			
July	2000	Jul 08 – Aug 06	2007	rfe070702	rfe070703	rfe070801
August	2000	Aug 07 – Sep 11	2007	rfe070802	rfe070803	rfe070901
September	2000	Sep 12 – Oct 11	2007	rfe070902	rfe070903	rfe071001
October	2000	Oct 12 – Nov 10	2007	rfe071002	rfe071003	rfe071101
November	2000	Nov 11 – Dec 10	2007	rfe071102	rfe071103	rfe071201
December	2000	Dec 11 – Jan 09	2007/08	rfe071202	rfe071203	rfe080101
January	2000	Jan 10 – Feb 08	2008	rfe080102	rfe080103	rfe080201
February	2000	Feb 09 – Mar 09	2008	rfe080202	rfe080203	rfe080301
March	2000	Mar 10 – Apr 08	2008	rfe080302	rfe080303	rfe080401
April	2000	Apr 09 – May 08	2008	rfe080402	rfe080403	rfe080501
May	2000	May 09 – Jun 07	2008	rfe080502	rfe080503	rfe080601
June	2000	Jun 08 – Jul 07	2008	rfe080602	rfe080603	rfe080701

Table 4.5: List of Months and Years of ORHB and RFE Data (2001 E.F.Y)

ORHB Budget Year		Corresponding Year in G.C		Corresponding RFE Data		
Month	**Year**	**Month**	**Year**			
July	2001	Jul 08 – Aug 06	2008	rfe080702	rfe080703	rfe080801
August	2001	Aug 07 – Sep 10	2008	rfe080802	rfe080803	rfe080901
September	2001	Sep 11 – Oct 10	2008	rfe080902	rfe080903	rfe081001
October	2001	Oct 11 – Nov 09	2008	rfe081002	rfe081003	rfe081101
November	2001	Nov 10 – Dec 09	2008	rfe081102	rfe081103	rfe081201
December	2001	Dec 10 – Jan 08	2008/09	rfe081202	rfe081203	rfe090101
January	2001	Jan 09 – Feb 08	2009	rfe090102	rfe090103	rfe090201
February	2001	Feb 08 – Mar 09	2009	rfe090202	rfe090203	rfe090301
March	2001	Mar 10 – Apr 09	2009	rfe090302	rfe090303	rfe090401
April	2001	Apr 09 – May 09	2009	rfe090402	rfe090403	rfe090501
May	2001	May 09 – Jun 08	2009	rfe090502	rfe090503	rfe090601
June	2001	Jun 09 – Jul 08	2009	rfe090602	rfe090603	rfe090701

After matching the ORHB data with the related RFE data, the rainfall data were calculated for 2000 and 2001 E.F.Y. Next, all the calculated data were imported with ArcGIS and later extracted to the study area since the original USGS RFE data were available at East Africa level. Afterwards, the data were exported to dbf files for further analysis and to be correlated with malaria cases using Excel.

The processed RFE data was analyzed with the malaria cases by the number of affected people and the amount of rainfall. The analyses were made for 2000 and 2001 E.F.Y based on months. For 2000 E.F.Y, the malaria cases were obtained from 3 kebele’s health facilities where as the analysis for the 2001 E.F.Y were made based on the woreda’s malaria cases as a whole. The results obtained from this analysis are shown in *(fig 5.6 & 5.7)*.

4.2.3 Development of Decision Support System

This section explains the steps and procedures followed in the application and implementation of the Web GIS DSS. These processes are going to be software installation, the development and the implementation of the DSS.

One of the objectives of this study is to develop a decision support system in which the necessary information will be disseminated to the users through the internet. To successfully develop the system, the most important thing is to correctly define the user’s requirements. Data acquisitions and related activities are going to be implemented based on the user requirements. Data management is the most important part of GIS. (Ozdilek et.al) Therefore, data is significant in the fulfillment of the requirement and the development of the Web GIS.
Government and non-governmental organizations involved in providing health services; and particularly the woreda health office is expected to be the user of this DSS. The user is interested in seeking of general or detailed information regarding the malaria incidents such as the mortality rate in general, number of malaria cases, the number of affected people in age, sex etc. In order to accomplish these requirements the DSS is going to provide the mechanism to facilitate the process of browsing data, generating required specific information and the like.

Once the requirements have been identified, the next step is going to be designing the system. Like most of the internet applications, Web GIS is based on the simple server/client model. In a server/client system a computer acts as a client that sends requests to the server computer, the server computer processes the requests, and then sends the results back to the client. (Kim et al., 1998 cited in O. Ozdilek et.al) The basic architecture of the system is shown in *(fig 4.11)*. There are many possible ways to construct a web-based map system; the main challenge is selecting the appropriate technology. Since the system must be compatible with open-source environment the available options are limited.

With respect to the required functions the selected software for the development of the DSS are Quantum GIS (QGIS) and MapServer 4 Windows (MS4W). The MS4W application is simple to apply and easy to install. MS4W contains default installations of Apache, PHP, Mapserver, Mapscript, MrSID, OGR/PHP Extension and different application such as Chameleon, MapLab, mapbender, gmap, geomoose, etc…To configure MS4W, it only needs to simply extract or unzip the package and then start Apache which results a page as shown in *(fig 4.12).* After the successful installation of the MS4W, the application development and user Interface designing has been followed. These basic processes are discussed in the following sections.

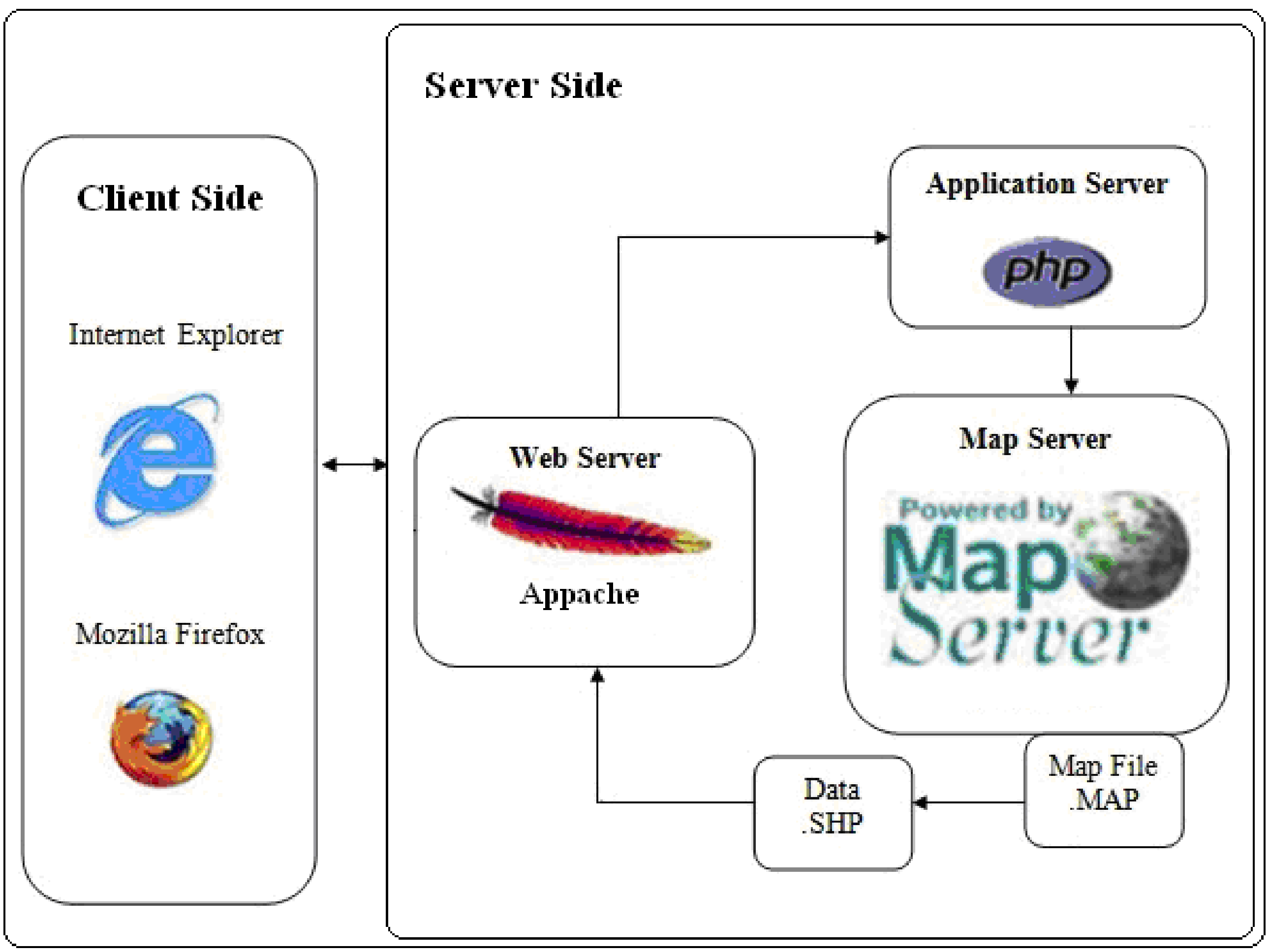


Fig 4.11 Basic Architecture of Client Server System

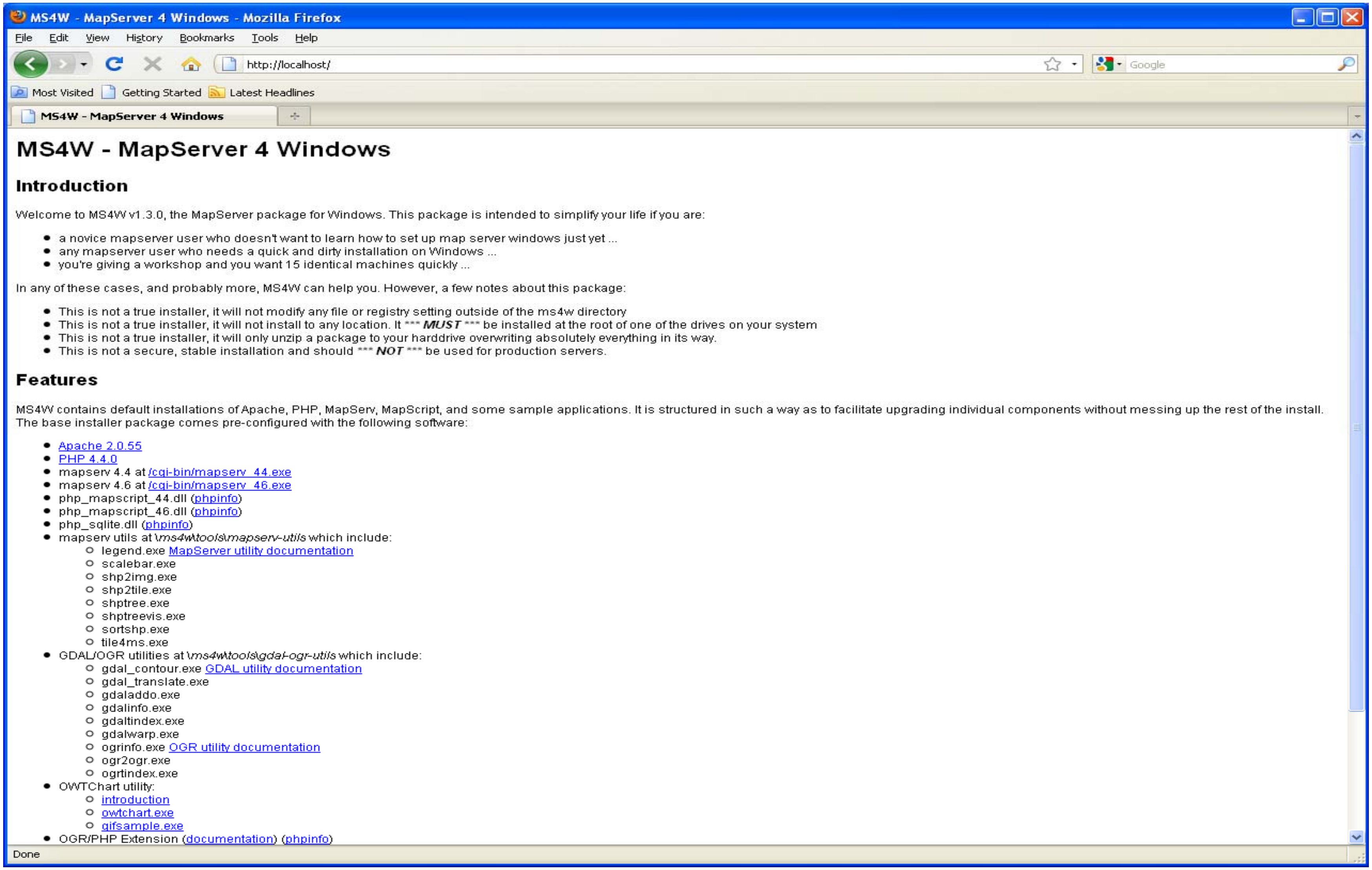


Fig 4.12 MapServer 4 Windows Apache Test Page

4.2.3.1 Preparation of Mapfile

Mapfile is one of the components and heart of MapServer which is a necessary element in the production of any geographic map. It defines the relationships between objects, points, MapServer to where data was to be drawn (MapServer). The most important concept that everyone should understand before using mapfiles to configure MapServer is a “Layer”. A layer is the combination of data plus styling.

QGIS is good at creating a mapfile from the project file. Therefore, the 1st step was arranging the raster and vector layers that are going to be used in MapServer and save it as a project file using QGIS. Then create the mapfile using the MapServer export tool.

Mapfile is the configuration file, which consists of the parameters required to display a map. It describes the location of the shapefile, extents, projection, reference map, layers, classes, symbol and style scaling is done for different layers to avoid disordering of layers and labels.

4.2.3.2 Interface Design

The user Interface has been developed using the Chameleon application found in MS4W. The first step is running the chameleon application using the initialization file. Next the application is going to be build and configured. Finally, launch the application using any web browser.

One of the main purposes of this application is to build a simple and user friendly interface which require no prior knowledge of GIS, so that anyone could navigate through and acquire any information as per his/ her requirement. Therefore, some customizations have been done towards making the website more attractive and easy to use.

CHAPTER- V RESULTS AND DISCUSSION

5.1 Assessment of Malaria Prone Areas

The weighted overlay analysis was made based on the reclassified datasets. These datasets (factors) were given weights depending on their importance and the resulting consistency ration produced by IDRISI is shown in *(fig 5.1)*. Based on this weight the overlay analysis was done. AHP and factors with their corresponding weight and classification are also shown in *(fig 5.2) and table 5.1,* respectively.

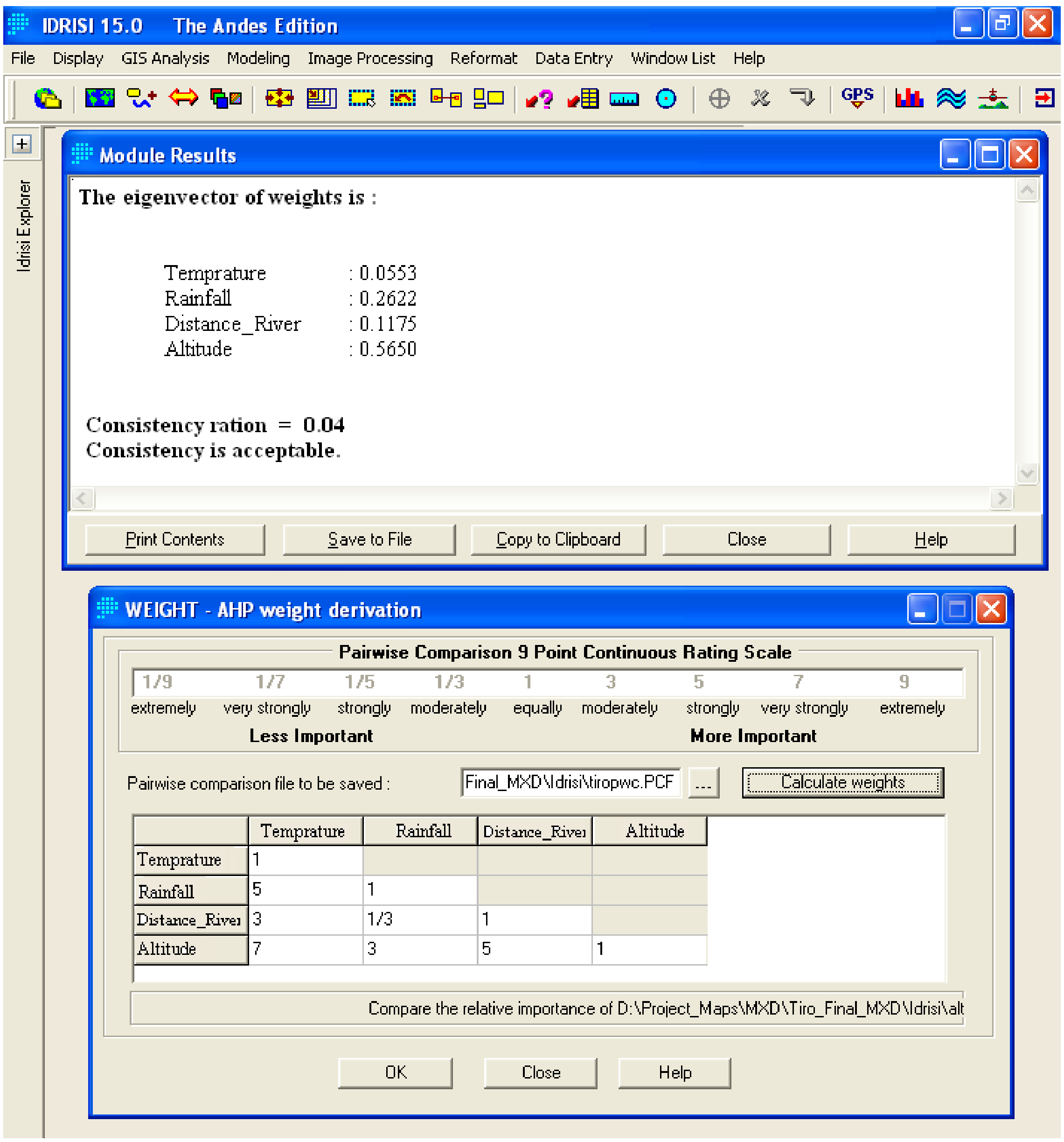


Fig 5.1 Consistency Ratio of Weights

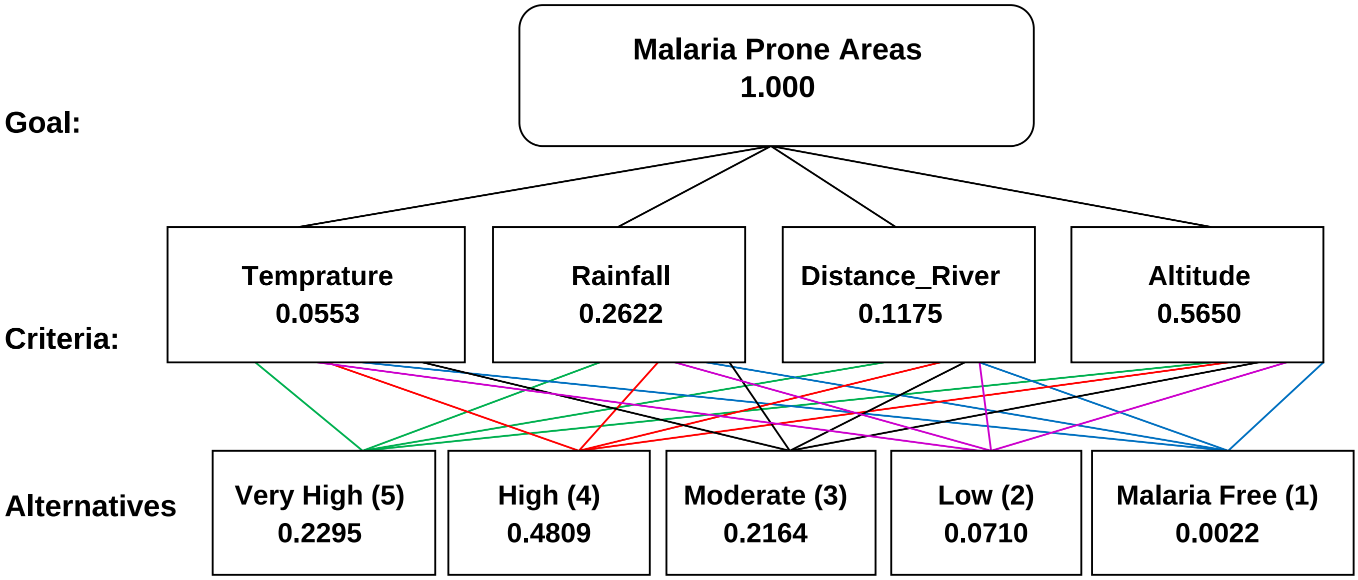


Fig 5.2 AHP of Identification of Malaria Prone Areas

Table 5.1: Weight of Malaria Prone Factors

Factors	***Weight***	***Class***	***Ranking***	***Susceptibility***	***References***
Altitude	0.5650	<2000m 2000-2200m 2200-2500m >2500m	5 3 2 1	Very High Moderate Low Malaria Free	Tulu (1993) Ghebreyesus (2006)
Distance from river	0.1175	0-500m 500-1000m 1000-1500m 1500-2000m > 2000m	5 4 3 2 1	Very High High Moderate Low Malaria Free	Kaya *et al*. (2002) Negasi **(**2007)
Rainfall	0.2622	> 1500 < 1500	5 3	Very High Moderate	Agroecological Zones
Temperature	0.0553	> 20 15-20 < 15	5 3 1	Very High Moderate Malaria Free	Ghebreyesus (2006)

After the overlay analysis of the five factors namely; altitude, rainfall, temperature and distance from rivers; malaria prone areas map in *(fig 5.3)* was produced. From the resulted map one can observe that susceptibility to malaria directly related with rainfall and temperature. That is, with the increase in the amount of rainfall and temperature there is an increase in the susceptibility to malaria. On the other hand, it inversely related with distance from rivers and altitude i.e. with the decrease in altitude and distance from rivers the susceptibility to malaria increases.

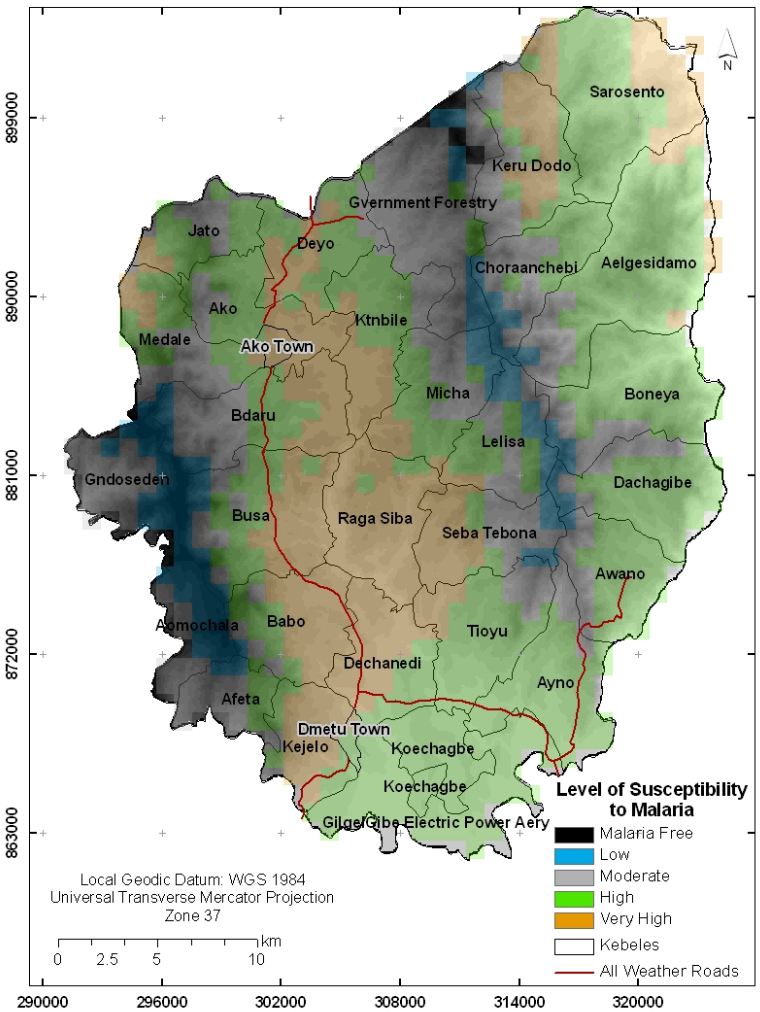


Fig 5.3 Map of Malaria Prone Areas in the Study Area

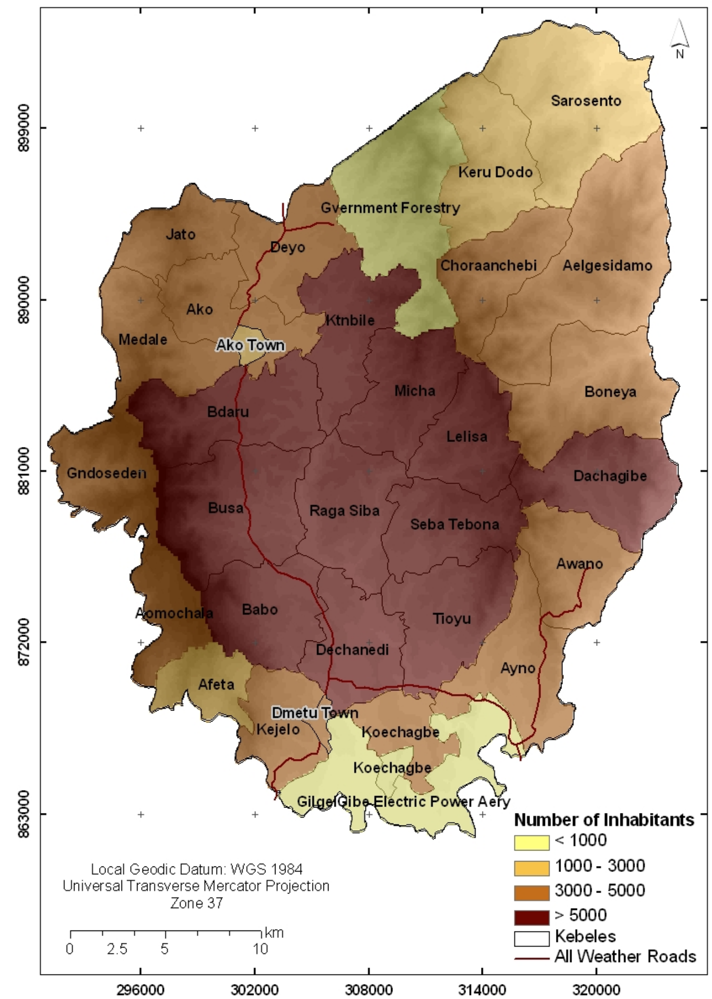


Fig 5.4 Map of Population Size by Kebeles

Based on the result obtained, it is tried to analyze malaria prone areas with the population since the main victims are the people. Therefore, from the map *(fig 5.4)* one can observe that Ayno, Kejelo, Boneya etc…are among kebeles with population size ranging 3000-5000 where they are highly susceptible to malaria. Moreover, from the highly populated kebeles, with number of inhabitants > 5000; Babo, Dechanedi and Raga Siba are also very highly susceptible to malaria.

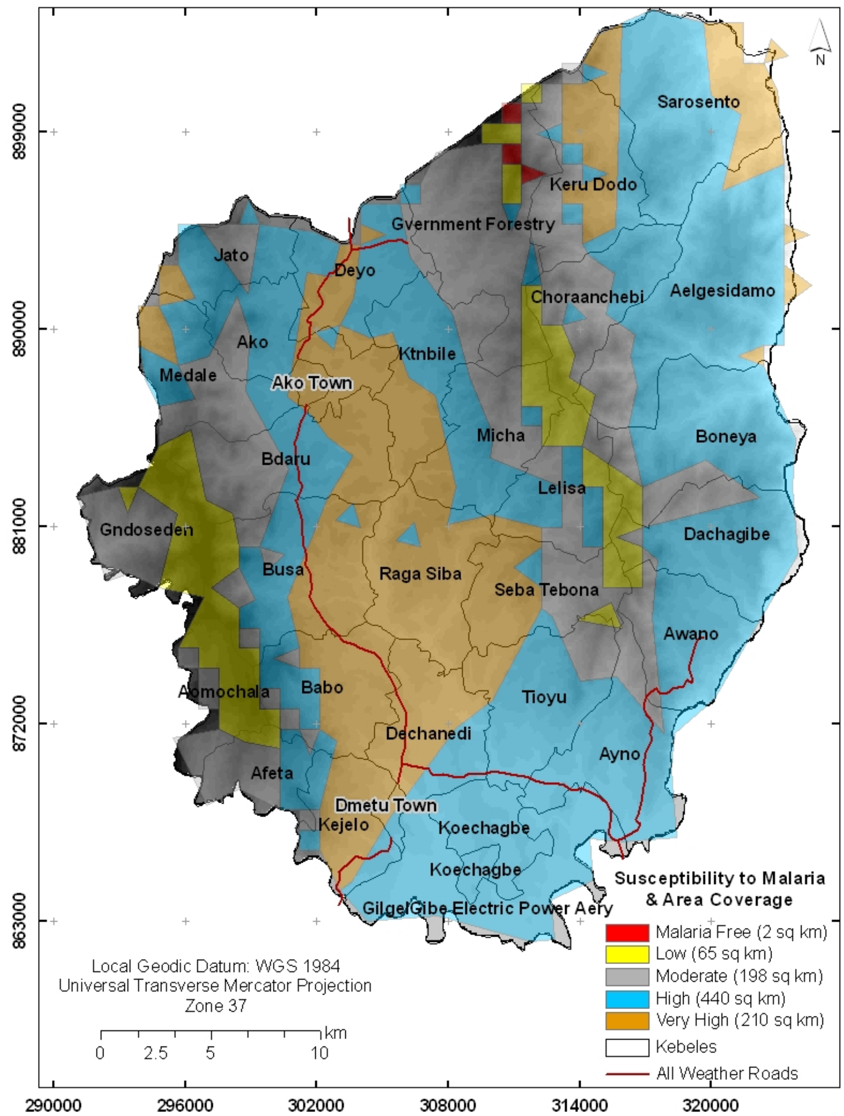


Fig 5.5 Area Coverage Map of Malaria Prone Areas

The map in *(fig 5.5)* illustrates that 210 Km^2, 440 Km^2, 198 Km^2, and 65 Km^2, representing 22.95%, 48.09%, 21.64%, and 7.10% of the total area is subject to very high, high, moderate and low level of susceptibility to malaria. The remaining i.e. only 2 Km^2 (0.22%) of the total area is free from malaria. Hence, from these figures it is possible to conclude that about 99.78% of the total area in Tiro Afeta woreda is highly susceptible to malaria.

According to the zonal health office, among the 27 kebeles, 24 are considered as malaria endemic areas. Kebeles such as Ayno, Dechanedi, Koechagbe, Tioyu, and Kejelo are among the hot malaria endemic kebeles where the zonal and woreda health offices give more attention and dedication. Consequently this is supported by the findings obtained from the study as shown in *(fig 5.3 & fig 5.5)* where these kebeles are identified as areas that are highly and very highly susceptible to malaria.

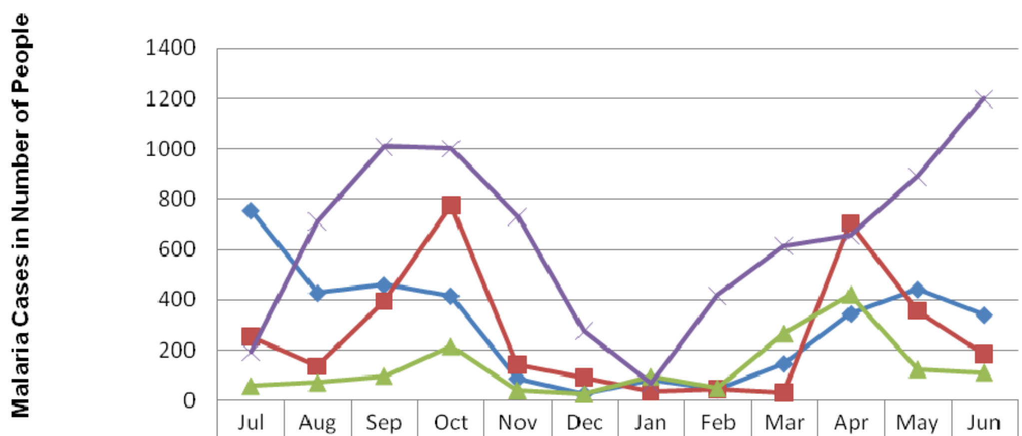
5.2 Analysis of Malaria Incidence

In the case of Ethiopia, the existence of malaria is more or less directly related with climatic conditions especially rainfall. Either the intensity or the scarcity of rainfall contributes a lot for the occurrence of malaria. Increase in the amount of rainfall would create excess amount of water resulting in more breeding sites for mosquitoes. On the other hand, scarcity in the amount of rainfall would decrease flow from rivers ensuing the creation of pools which are favorable for the breeding of mosquitoes. In general, rainfall can promote transmission by creating ground pools and other breeding sites, but heavy rains can have a flushing effect, cleansing such sites of their mosquitoes. Drought may eliminate standing water, but cause flowing water to stagnate. Thus, in arid areas, prolonged drought may cause malaria to decline, whereas in areas where rainfall is normally abundant, vast numbers of mosquitoes can be produced and “drought malaria” may follow. The same applies to artificial streams in irrigated regions and storm drains and sewers in urban areas. Drought may also stimulate people to store water in cisterns, drums and other man-made containers that serve as breeding sites. (Paul R, 2007) Therefore, based on this the analysis was made between the rainfall and malaria incidence.

Tiro Afeta woreda is found in Jimma zone, which is one of the oldest zones in Oromia region. According to ORHB, the unique feature of Jimma zone is the rainy season that last up to the end of November with conductive and ambient temperature and moisture. Therefore the area is highly prone to malaria epidemics due to the presence of these precipitating factors and hydro-electric power projects that supports unmanageable mosquito breeding sites.

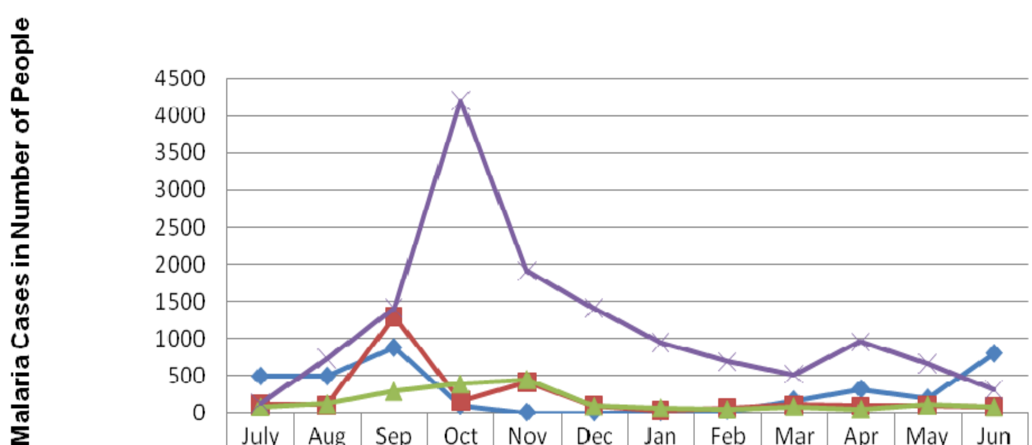
The resulted chart in *(fig 5.6)* shows that the amount of rainfall received was higher at the months of July, August and September with 756, 427, and 459mm respectively. From this, it is also evidently shown that immediately after these months the number of malaria cases has increased particularly for Koechagbe and Ayno Kebeles where it remains the same for Dimtu but with larger number of cases. For the months of November, December, January and

February the number starts to decrease following the decrease in the amount of rainfall. Then again the malaria case starts to increase with the increase in the amount of rainfall at March.



	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mean RF (mm)	756	427	459	416	87	26	83	43	146	345	441	340
Koticha Gibe kebele	253	136	395	777	141	92	33	44	30	705	357	185
Ayino kebele	58	71	98	215	41	26	95	50	267	422	125	112
Dimtu Clinic	192	712	1009	1002	733	277	69	418	616	656	890	1200

Fig 5.6 Malaria Cases by Months in three kebeles for the 2000 E.F.Y



	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mean RF (mm)	490	490	878	98	0	0	2	20	170	318	193	799
Koticha Gibe kebele	116	108	1299	168	418	95	29	65	106	92	98	86
Ayino kebele	72	115	285	384	442	80	60	37	75	43	97	69
Dimtu Clinic	118	719	1404	4212	1906	1407	938	684	510	946	654	302

Fig 5.7 Malaria Cases in the Study Area for the 2001 E.F.Y

As for the 2001 E.F.Y as shown in *(fig 5.7)* one can depict that the peak malaria transmission occurred on October, December, and September with a total malaria cases of 3220, 1407 and 1233 persons respectively. The highest amount of malaria cases recorded on October which is immediately after where the amount of rainfall received is the highest throughout the year. In general, from both graphs it is observed that the peak transmission of malaria occurs in months August to November which is exactly after the main rainy season. This in turn indicates that the direct relationship between rainfall and the incidence of malaria.

Ethiopia's economy is based on agriculture, accounting for almost half of GDP, 80% of exports, and 80% of total employment. (FMoH, 2007/08) Since the peak malaria transmission coincides with the planting and harvesting season, the economic impact of malaria is very significant, as the country's economy is based on agriculture.

5.3 Decision Support System

Real time information helps to be informed before the incidence of malaria having the necessary influential environmental factors and data. However, here in Ethiopia the recording, data management methods are not well developed and organized and this makes it difficult to accomplish the acquired objective. However, this research tried to contribute to some extent by providing a more organized system regarding malaria situation in the woreda. The system helps by providing up to date information about malaria which enables to be more organized, prepared in the prevention of the disease.

5.3.1 Developed User Interface

Layer list on the left side is consists of all layers that were formatted and arranged using QGIS. Each layer is provided with two options of visible and active. When the page is loaded for the first time, it is set to display all the layers. Therefore, the user has to manually uncheck the buttons and update depending on his/her area of interest.

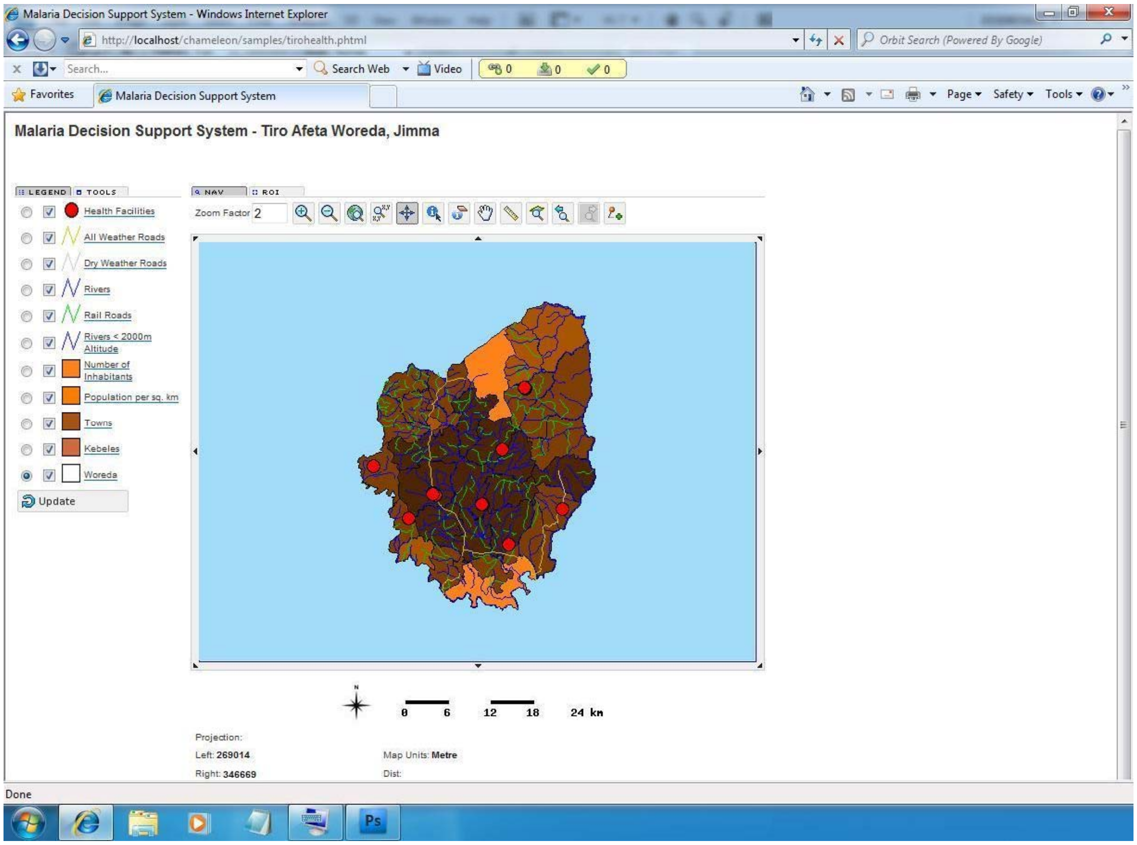


Fig 5.8 Developed Interface of the Malaria DSS of Tiro Afeta Woreda

5.3.2 Toolbar

These are the basic tools necessary to work with map. They enable the user to easily navigate through the site. It includes zoom in, zoom out, zoom full to extent, measure distance etc… All the features in the toolbar are shown in *(fig 5.9)*.

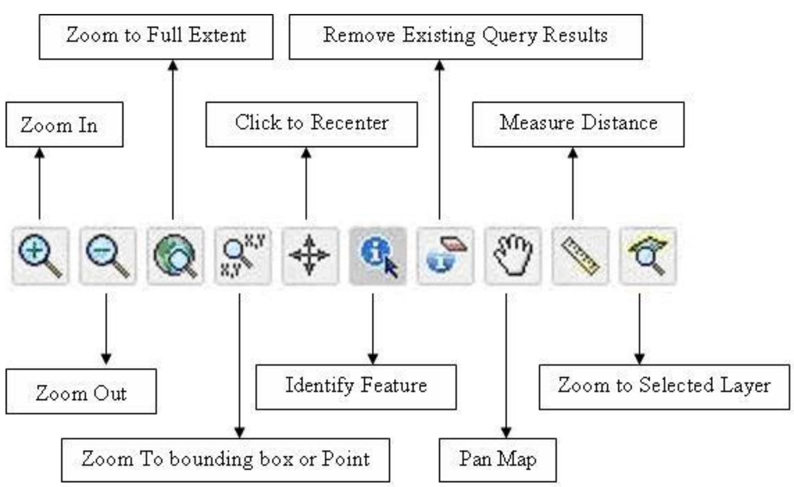


Fig 5.9 Features in the Navigation Toolbar

5.3.3 Different Functions of the Tool Buttons

There are different functions provided by the system with the help of the various tools available. The tools were arranged in two columns, one on the left panel and the other on the top frame. These tools are represented by buttons and one has to mouse over so that the function of each icon will dynamically displayed in the form of tool tip. Some of the functions include zoom in, zoom out, pan map, identify feature and map tips. Map tips provides the user to retrieve the information depending on their interest such as population size by kebeles, population density by kebeles, malaria case by age, malaria case by sex etc. There are also reference tools with the map coordinates shown on the bottom where the x and y coordinates displayed with the mouse position. Moreover, distance from two points is also provided in meters. Some of these outputs that can be retrieved from the site are shown *(fig 5.10 – fig 5.13).*

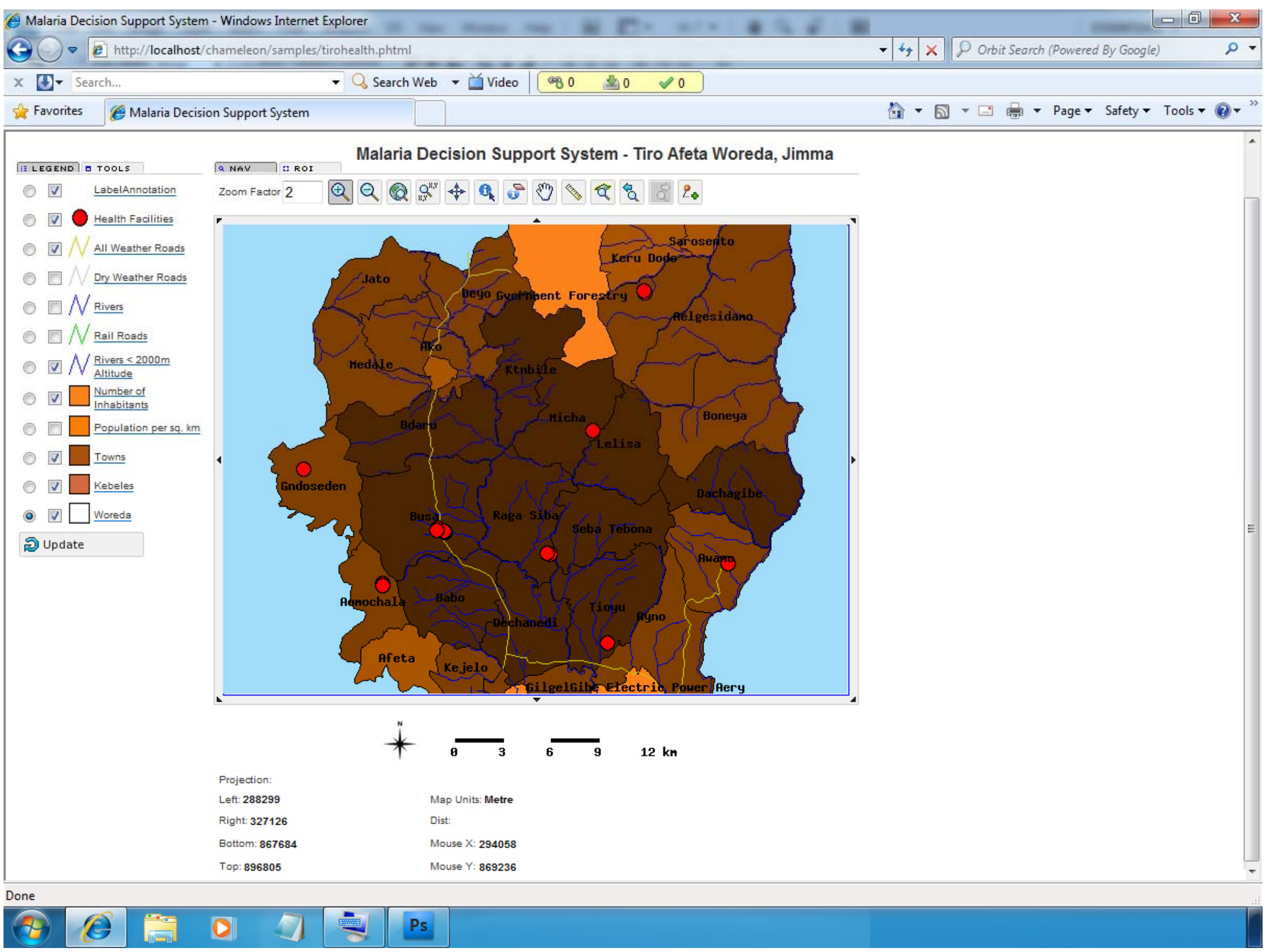


Fig 5.10 Zoom to Kebeles with larger number of Inhabitants

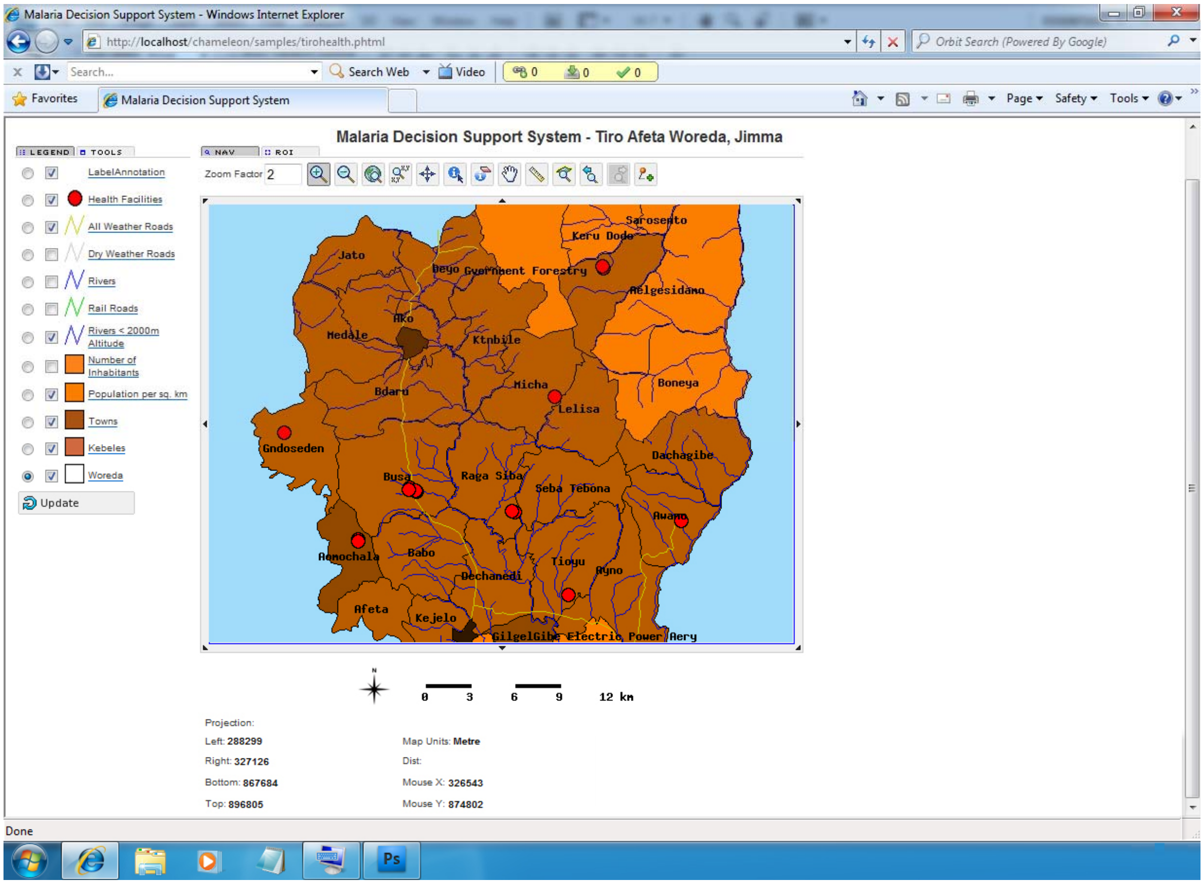


Fig 5.11 Zoom to Kebeles with higher Population Density

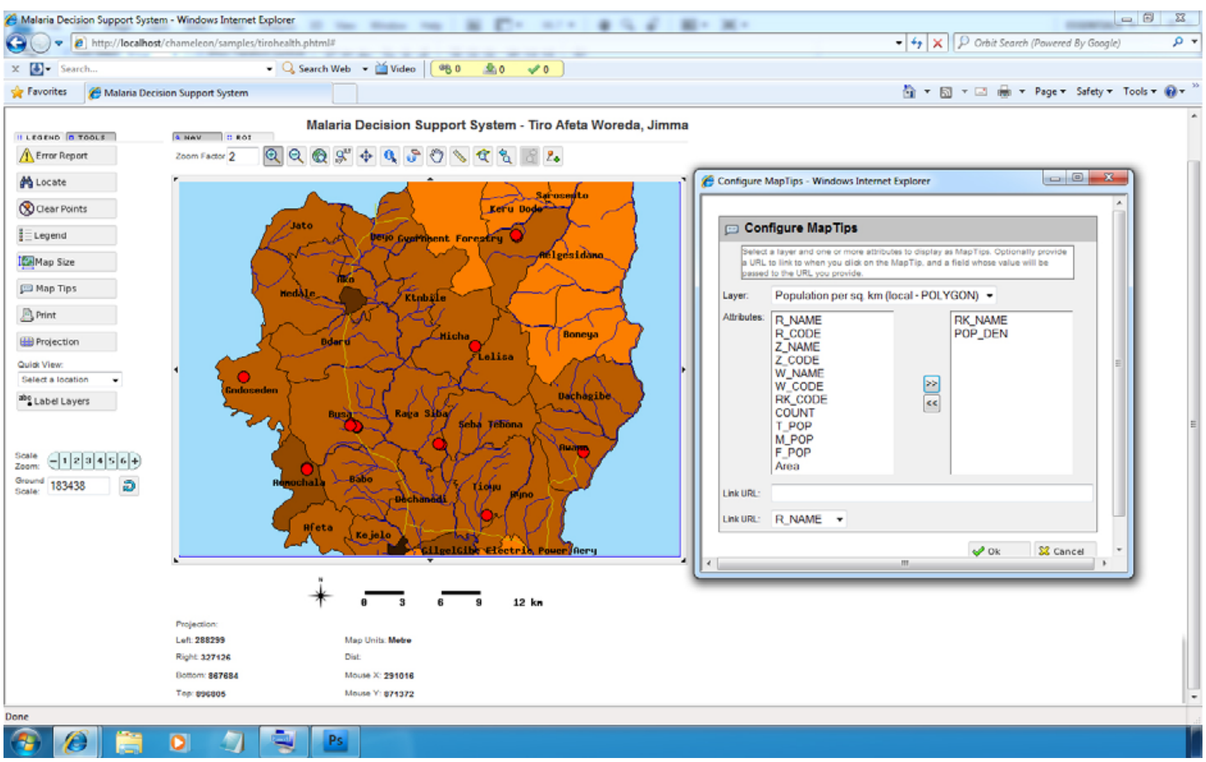


Fig 5.12 Map Tips Dialog Box

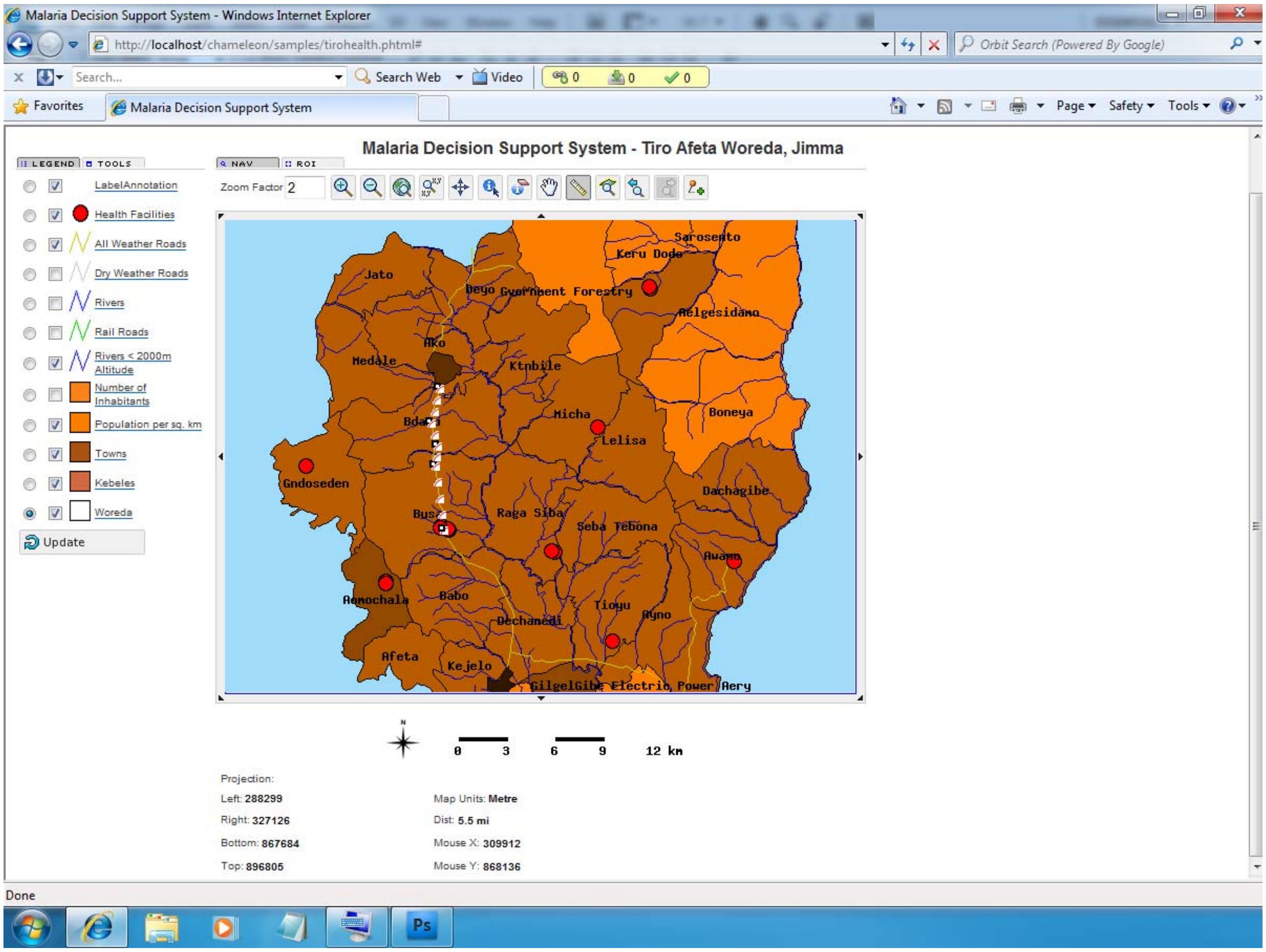


Fig 5.13 Distance Measure from Health Facility to Ako Town

The beneficiaries of this DSS are going to be the Tiro Afeta woreda, the zonal health bureaus as well as the FMoH. The advantage of this system is the access to health data via internet and requires no prior knowledge of GIS in order to use the system. Moreover, the system has been developed using open source technologies. Open source technologies are chosen for the reason that proprietary software forces to spend more money unnecessarily for yearly license, maintenance etc., and this is not reasonable for developing countries like Ethiopia. However, there should be an internet service in order to have access to the information and this is one of the limitations faced by the system.

CHAPTER-VI CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

According to FMoH reports, approximately 70,000 people die of malaria each year in Ethiopia. In Oromia also, malaria is considered to be the most important communicable disease. Three quarters of the region, i.e. 262 of 297 (88%) districts and 4,237 of 6,765 (63%) municipalities, are considered malarious, accounting for over 17 million persons at risk of infection. There are an estimated 1.5 to 2 million clinical cases per year, with malaria accounting for 20-35% of outpatient consultations, 16% of hospital admissions, and 18-30% of hospital deaths in the region.

This study aims at producing malaria prone areas, analyzing malaria incidence and developing a decision support system in Tiro Afeta woreda which is located in oromia region. From this study it is indicated that almost all of the study area is prone to malaria. It is also recognized that susceptibility to malaria is directly related with rainfall and temperature; whereas, it is inversely related with altitude and distance from rivers. Moreover, it is evident that a larger number of inhabitants are living in kebeles that are highly susceptible to malaria. In addition, it is observed that the number and repatriation of heath facilities is not enough as compared with the population size. Based on the assessment, it is also recognized that susceptibility to malaria is very high around the Gilgel Gibe arena following the dam project.

The study also showed that there is a positive relationship between malaria case and rainfall since it resulted immediately after the main rainy season. This was evident for the 2000 E.F.Y where the peak malaria transmission occurred for Dimtu, Koechagbe and Ayno kebeles in September and October that is immediately after the rainy seasons of July and August where the area received the largest amount of rainfall. As for the 2001 E.F.Y, it is also observed that the peak transmission resulted in the month of October which is immediately after the month of September where the largest amount of rainfall has been received throughout the year. Therefore, it is possible to conclude that there is a positive and direct relation between malaria incidence and rainfall. That is, with the increase in the amount of rainfall there is a higher possibility of increasing in the number of malaria cases.

Since the likelihood of malaria epidemic to occur becomes high, this needs special follow-up. As a result, epidemics detection and preparedness of the woreda should further be assessed and strengthen. Therefore, the developed DSS helps to some extent by providing up to date information which enables the decision makers to get prepared to make better and faster decisions which can reduce the damage and minimize the loss.

6.2 Recommendations

Recommendations drawn based on the findings of this study are stated as follows:

1. Government and public organizations involved in health activities and services should encourage the use of mapping application.

2. The FMoH should setup framework for data sharing between offices at the regional, zonal, woreda and even at kebele levels.

3. If time and finance are available, since malaria is the number one epidemic that's killing millions of people, it is suggested that further study should be conducted with the remaining malarious areas at the zonal, regional or even at country level.

4. The woreda should develop the capacity to use GIS and remote sensing technology for the effective assessment of malaria prone areas. There are various ways in which the health sector can benefit from mapping application in the area and indeed other underdeveloped economies.

5. The DSS is still in its development phase providing basic information that helps and facilitates the decision making process to some extent. Therefore, it is advised that further improvements be made in generating an advanced and integrated web-based information system that can process and move information in real time, allowing public health authorities to monitor events at hundreds or thousands of public health facilities at once.

6. From the study, it is observed that prone to malaria is high around at the Gilgel Gibe dam. Therefore, it is advised that further detailed study be conducted regarding the impact of the dam project on the occurrence of malaria since it might have contributed to some extent.

7. As indicated in the study, malaria transmission is higher after the rainy seasons which coincide with the planting and harvesting period. As a result, it recommended that further study should be made in assessing the impact of malaria on the economy relating with the agricultural production.

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