Telemark University College

CHANGES IN THE SPREAD OF MALARIA IN ETHIOPIA: CASE STUDY FROM AWASSA AND HOSSANA AREA 2006-2007

By Ashenafi Woldemichael Woime (ID No. 042624)

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Abstract

Malaria is one of the world's most serious and complex public health problems. Four distinct specious of *Plasmodium* parasites, which are *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae* and *Plasmodium ovale*, is transmitted between individuals by *Anopheles* mosquitoes. Each year, it causes an estimated 400-500 million cases and up to 2 million deaths, mostly children (WHO 1998, Guinovart et al. 2006). Malaria has been a major challenge to both public health and socio-economic development particularly, in countries of sub-Saharan Africa. The nature of the topography and variations in climatic conditions indicates the long history of malaria in the Southern Nation Nationalities and Peoples Regional State (SNNPRS), particularly in Awassa and Hossana town and the country as a whole.

The existing knowledge and distribution of malaria in Ethiopia has not been fully updated since an Italian investigator first established it in 1930s. For example, it was known that malaria transmission only occurred in areas below 2,150 m above sea level; now the limit has moved up to 2,500 m (Federal Democratic Republic of Ethiopia Ministry of Health (FDROEMOH) 2004). Although elevation is important, factors such as rainfall, temperature and precipitation levels play an important role in determining its intensity (Malakooti et al. 2000).

The purpose of this writing is to find indications of relations between the spread of malaria and altitude, precipitation and area of open water surfaces. In addition to this, it is to look into the historical background of the malaria in Awassa and Hossana, and to give some possible solution on how to prevent malaria epidemics. The data collected during the fieldwork through questionnaire has shown that the number of malaria-infected individuals in the household has significant association with educational status of the householders ($\chi^2 = 8.81$, $P = 0.0122$). It has connection with the presence or absence of drainage facilities, and the household's family size ($t = 21.7693$, $P = 0.0021$). The place of work and the workers has shown little or no association with malaria ($\Phi = 0.227$, $P = 0.0611$). In the study areas, malaria has no significant association with the income of the householders directly.

Summary

Malaria remains as a major problem of the health of the majority of the population of Ethiopia as well as both Awassa and Hossana. The problem has been badly aggravated in areas where the physical environment is conductive for the breeding of *Anopheles* mosquitoes and the development of *Plasmodium* in the mosquito. Due to this, human beings have not inhabited the majority of the lowland areas of the country. In contrast to this, the highlands are densely populated because of their favourable climate that hampers the development of major tropical diseases such as malaria, shistosomiasis, river blindness, and so on. Therefore, the highlands' resources have been exhausted and people have been forced to look for other fertile lands of the lowlands. Hence, the movement of people from the highlands to lowlands have continued exposing these people to different tropical diseases.

Awassa and Hossana are also places where the highland population has recently migrated from the densely populated highland areas to look for job and better life. Before four decades, the areas were sparsely populated. Especially in Awassa, people did not try to migrate for permanent settlement because of the fear of malaria. However, the physical environment of Awassa and Hossana has also been favourable for the production of cereal crops, specially wheat, maize and barely. In this way the interaction of people, who migrate from highland for better life, with mosquitoes and *Plasmodium* started and led the development of malaria as well.

Thus, the exposure of the highland population who had less or no immunity to malaria had aggravated the problem of malaria. Mortality due to malaria increased rapidly. However, the gradual expansion of different infrastructures, particularly health facilities reduced both mortality and morbidity caused by malaria.

Moreover, the malaria eradication/ control programs and the establishment of Awassa and Hossana health centre and district hospital had reduced the problem of malaria until the end of 1980s. However, according to Ministry of Health (2004), in 2002 the spread of malaria has become localized, and end up in large-scale epidemics in 2003. Since then, the occurrence of malaria epidemics has been more frequent and

widespread. As a result, it becomes a major health threat of the population of both Awassa and Hossana.

Due to the availability of permanent water bodies, unlike most parts of the country malaria transmission is perennial in Awassa and Hossana. However, because of the seasonal nature of the rainfall a high number of malaria cases are recorded after the summer and the spring rainfall seasons.

With regard to species of *Plasmodium*, *P. falciparum* is the dominant species that accounted for about 80 % of the total malaria patients followed by *P. vivax* that accounted for the remaining 20 %. *Anopheles gambiae* is the dominant vector species of malaria in the areas. Based on health station documents, the narration of the elderly people and the field observation; I, the researcher, realized that the following are major reasons for the spread and reemergence of malaria in Awassa and Hossana.

- The unbalanced proportion of the existing health infrastructures and the increasing population is one major problem.
- Large population movements from the highland areas to both Awassa and Hossana and vice versa are also an important factor for the increasing problem of malaria in both areas.
- There is little research made on the susceptibility of *Plasmodium* to anti-malaria drugs and *Anopheles* mosquitoes to insecticide in Awassa and Hossana. Documents assert that drug resistant malaria and insecticide resistant mosquitoes are major hindrances for malaria control in the country (FDROEMOH 1997).
- Poor personal protection is another that contributes for the rapidly growing problem of malaria in Awassa and Hossana.
- Shortage of insecticide- treated bed nets at community level.

From the collected data at the household level during the fieldwork, the researcher has realized that in the study areas:

- There is significant association between educational level of the householders and malaria ($P = 0.0122$). Specially, there is significant difference in the mean number of malaria infected individuals in the households that are headed by low level educated householders and high level educated householders.

- Income and malaria have no significant association (Fig. 7.2). Even the lowest and the highest income groups of households have insignificant differences regarding number of malaria patients.
- Family size has strong association with malaria occurrence (P = 0.0001). The mean number of malaria infected individuals in households with bigger family size is higher than the smaller family size.
- The absence of drainage around residential houses has shown association with high number of malaria infected individuals in the household.
- The places of the workers and malaria infection have association. Outdoor workers are more attacked than indoor workers.
- The use of malaria preventive methods such as net (both impregnated and unimpregnated), insecticide spraying, anti-mosquito coils and so on are very limited.
- Traditional methods of prevention like, the use of mosquito repelling plants and smoke of wood prevail in the area.

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1. INTRODUCTION

1.1. Objectives

The overall aim of this research is to analyze the general situation of malaria, which is a major public health problem in Ethiopia. More specifically, the research has the following objectives:

- to assess the epidemiology of malaria in the study areas.
- to investigate the history of malaria in Ethiopia.
- to identify the socio-economic characteristics of individuals who are more vulnerable to malaria.
- to look into the major physical and socioeconomic factors which are the main causes for the spread of malaria and the epidemiology of malaria in Ethiopia.
- The work is based on both literature study and field works.

1.2 Situation of the malaria problem

Malaria epidemics remain a major public health problem for the world population. Mainly developing African countries especially those sub-Saharan are seriously affected by this disease. According to WHO report, in 1997 out of 52.2 million total deaths of the world, 17.3 million were due to parasitic diseases. Malaria imposes a great deal of financial burden on the countries' economy and on the societies by reducing productivity.

A variety of factors cause the increasing rate of malaria epidemics including complacence and policy changes that led to reduce funding for malaria control programs in the 1970s and 1980s. The emergence of drug resistance, human population growth and movement, land-use change, and deteriorating public health infrastructure are some of the important factors for the increasing rate of malaria epidemics (Lindsay and Birley 1996).

Malaria, which is one of the most ancient infectious diseases, is present in 101 countries. It is a major health problem in 90 countries where an estimated 40 % of the total world population currently lives in areas with malaria (WHO 1997, 1998). In most malaria-free countries with a developed public health infrastructure, the risk of sustained malaria transmission after reintroduction is low. Other areas may become at risk due to climate change. Almost the whole area of tropical Africa is situated where malaria is endemic and 90 % of the total malaria incident of the world occurs in this area. In addition to this, more than half a billion people of Africa is at great risk from malaria (WHO 1993a). Children and women are the most vulnerable groups. The direct and indirect costs of malaria in sub-Saharan Africa exceed $2 billion per year (WHO 1997).

At low temperatures (14-19 °C) a small increase in temperature can greatly increase the risk of malaria transmission. However, high temperature (> 40 °C) is lethal to mosquito and the parasite. In areas where mean annual temperature is close to the physiological tolerance limit of the parasite, a small temperature increase would be lethal to the parasite, and malaria transmission would therefore decrease (Bradley 1993, Lindsay and Birley 1996, Teklehaimanot et al. 2004).

Malaria is common to the tropical regions and it is mainly the result of the physical environments of the regions such as low altitude, favorable temperature, rainfall and standing surface water. The physical and human environments are also responsible for the spread of malaria. Among the human environments, the following are the major factors that intensify the problem of malaria:

-low educational level of the population;

-land use changes related to large development activities, particularly those activities that are related to the development of water resources and road building;

-mass movement of refuges and displaced persons from one place to another due to war, political turmoil, work and natural hazards; and

-economic activities like agriculture, tourism, water transportation and trade.

The increasing global population growth without the presence of safe water and other sanitation facilities and with low provision of health facilities and health personnel is also a cofactor for the growing problem of the disease. Furthermore, climatic change which is caused by environmental degradation such as deforestation could partly be responsible for the changing pattern of the disease.

1.3 At National Level, Ethiopia

Malaria is a major public health problem in Ethiopia that threatens the life of millions of people every year. Today with the increasing rate of population growth, the problem of malaria is aggravated and over 40 million people of the country live in malaria epidemic areas (FDROEMOH 2004).

As Ethiopia is found in Africa south of Sahara, which is favorable for the breeding of *Plasmodium*, the health hazards caused by malaria are very serious. Furthermore, it remains the major disease of public health in the country. Ethiopia is a tropical country, with high temperature through out the year. The availability of many rivers and lakes provides favorable environments for the breeding of *Anopheles* mosquitoes and the development of the malaria parasite. However, because of the seasonal nature of rainfall in most parts of the country, the nature of malaria is unstable and characterized by inflicted high incidence of mortality in the country. The movement of people has been facilitated by the armed conflict that lasted for more than three decades in the country. Besides, the expansions of resettlement program and labor forces in agro-industrial development areas play a great role for the spread of the problem by colonization of new areas which have never been settled by human beings. The movement of domestic as well as foreign tourists, the construction of dams for irrigation and hydroelectric power, fishing activities around malarious lakes, poverty and illiteracy play their own role in the spread of malaria.

Despite, different efforts have been made to control the problem of malaria; epidemics have still been more frequent and wide spread in recent years. In Ethiopia, the epidemic-affected areas are highlands or highland fringe areas where the immune system of the population is weak and thus all age groups are frequently affected. The magnitude of the problem in 2002/03 has worsened. The disease has been reported as the first cause of morbidity and mortality. This accounts 15.5 % out-patient consultation, 20.4 % admissions and 27.0 % in-patient deaths. The number of reported malaria cases in non-epidemic years was 5-6 million (FDROEMOH 2004). However, populations that have health service coverage are about 61 % and this figure represents only a fraction of malaria cases reported by health facilities.

1.4 In the Study Area, Awassa and Hossana

In general in SNNPRS and in particular in Awassa and Hossana, malaria is the leading threat of the health of the population. Different sources of zone health offices and the area hospitals show that most of the deaths are caused by malaria in recent years. Malaria is the major reason for inpatient and out-patient treatments in hospitals and clinics of the area. Among ten top diseases, malaria is the most important resurgent disease that causes a great deal of morbidity and mortality in Awassa and Hossana as well. In 2003, there were 3,763,136 people at risk and 1,128,941 cases in the SNNPRG (Kimbi et al. 2005).

In the past four years, malaria ranks first among the leading ten top diseases in the areas. *Plasmodium falciparum* and *Plasmodium vivax* are the two dominant parasite species with relative frequency of 60 % and 40 % respectively (FDROEMOH 2004). This proportion varies from zone to zone 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.

2. THE MALARIA DISEASE

2.1 Introduction

Malaria is an infectious disease transmitted into humans by the bite of infected female mosquitoes of the genus *Anopheles*. The pathogen which causes the disease is a parasite protozoa of the genus *Plasmodium*. There are four species of this parasite: *Plasmodium* *vivax, Plasmodium malariae, Plasmodium ovale* and *Plasmodium falciparum* (Phillips 1983). They have similar symptoms and it is difficult to make species differentiation without laboratory studies.

The first symptom of the disease, the fever pattern resembles that seen in early stages of many other bacterial, viral and parasitic diseases. The first three species *(P. vivax, P. malariae and P. ovale)* may cause severe illness, but they are hardly fatal. However, the fourth specie *(P. falciparum)* causes much more serious and progressive illness, besides it some times leads to coma and death within a few days of infection (Phillips 1983).

2.2 Mode of Transmission of the Parasite

The development of human *Plasmodia* starts with sporozoites being injected into the blood stream after the man is bitten by infected female mosquito (Phillips 1983). The parasite has three main phases. These are: Liver phase, Blood phase and Mosquito phase (Phillips 1983, Knell 1991, America Public Health Association (APHA) 1995, Pålsson 1999).

The sporozoites are injected by the mosquito into the human beings and they enter the liver. This process can take place within 30 minutes after the parasite (the sporozoites) being injected into human blood. In the liver cells, the sporozoites develop into tissue schizonts and they undergo asexual division. This is called *schizogony* or *merogony,* and the parasites are called *meronts* (Knell 1991, APHA 1995).

Thousands of merozoites, depending upon each individual species, are produced in each meront. In the case of *P. falciparum* and *P. malariae*, the development of all parasites in the liver takes place at about the same time. However, in the case of *P. vivax* and *P. ovale* some of the parasites change into hypnozoites. When other parasites develop, the hypnozoites lie dormant in the liver cells to develop months or years later and causes the illness to breakout (Knell 1991, APHA 1995).

The hypnozoites start to grow later following the same sexual reproduction as the sprozoites that do not become hypnozoites. Six to fourteen days after infection, depending upon the species, the merozoites leave the tissue and enter the blood where they invade the blood cells. The period from the time of infection until the first appearance of the merozoites in eryhocytes is called prepatent period and it is short for *P. falciparum* and long for *P. malariae* (Knell 1991, APHA 1995, Pålsson 1999).

After the merozites invaded the red blood cells, they become erythrocytic trophozoites and mature schizont. Finally they grow and divide into 8-16 new merozoites depending upon each species of the parasite. This process is known as *blood schizogony*. The process of schizogony in the blood continues at regular intervals. In the case of *P. falciparum, P. vivax* and *P. ovale*, it occurs every 48 hours (tertian) and in the case of *P. malariae*, it occurs every 72 hours. This is a repeated process until the increasing parasitaemia is inhabited by immunity or by chemotherapy. This asexual development of the parasite is associated with the clinical symptom of the disease. As the disease progresses some merozoites develop into male (micro) and female (macro) gametocytes. If they are transferred to a new mosquito, they further develop into sprozoites and can be transmitted to another person (Knell 1991, APHA 1995, Pålsson 1999).

2.3 Clinical Symptoms

Plasmodium falciparum – this parasite has been identified by many names: autumnal fever, malignant tertian malaria, and cerebral malaria (Phillips 1983, Knell 1991, APHA 1995). The incubation period is usually 7 to 14 days. It is the most serious malaria infection which has fever (in non-immune patients it exceeds 40 ^{o}C), chills, sweats, cough, diarrhoea, respiratory distress, headache, shock, renal and liver failure, pulmonary and cerebral edema, coma and death. Case fatality rates among untreated children and non-immune adults exceed 10 % (FDROEMOH 2004).

Plasmodium vivax, Plasmodium ovale and *Plasmodium malariae* – in many respects, they may be grouped together as the "relapsing" malaria. They are not life threatening except in the very young and very old people, and patients with concurrent disease or immunodeficiency. The incubation period is usually 10 to 15 days, but in a few strains it may extend up to some months. In the last 2 or 3 days of the incubation period, illness may begin with indefinite malaise and a slowly rising fever which lasts for several days. This symptom is accompanied by headache, limb pains, backache, anorexia, and sometimes nausea and vomiting. In the case of *vivax* and *ovale* infections, true relapses following periods with no parasitemia may occur at irregular intervals for up to 5 years. However, in the case of *malariae* infection, it may persist for as many as 50 years with recurrent febrile episodes (Phillips 1983, Brian 1989, APHA 1995, FDROEMOH 2004).

2.4 Diagnosis and Treatment

Diagnosis

Laboratory confirmation of the diagnosis is made by demonstration of malaria parasite in blood films. This is done by spreading a small drop of blood on a microscope slide and allowing it to dry and then stain with Fied's or Giemsa stain (Whittle and Boele van Hensbroek 1994)

Treatment

Due to regional variation in drug sensitivity, anti-malaria chemotherapy is a very complex issue. However, generally there is clear distinction in the treatment of
1) the three relapsing malaria which are hardly chloroquine resistance,
2) mild *P. falciparum* malaria in a semi-immune or immune individual, and
3) a life threatening severe *P. falciparum* malaria in non-immune children and adults (Whittle and Boele van Hensbroek 1994).

The most important anti-malaria drugs which are commonly in use are shown in table 2.1 and 2.2:

Table 2.1 Oral treatment of mild to moderate malaria (source: FDROEMOH 2004)

Drug	Adults Dosage	Children Dosage
Chloroquine	600 mg/kg base followed by 300 mg/kg 12 hourly x 3	10 mg base/kg followed by 5 mg/kg 12 hourly x3
Fansidar	3 tablets (1500 mg/kg sulfadoxin/75 mg/kg pyrimethamine)	25 mg/kg sulfadoxine and 1.25 mg/kg pyrimethamine
Quinine	600 mg/kg salt/8 hourly for 7 days	10 mg/kg/8 hourly for 7 days
Mefloquine	15 mg/kg single dose, or 25 mg/kg (given as 15 mg/kg followed by 10 mg/kg after 12 hours)	15 mg/kg single dose, or 25 mg/kg (given as 15 mg/kg followed by 10 mg/kg after 12 hours)
Halofantrine	8 mg/kg/8 hourly x 3	8 mg/kg 8 hourly x 3

Artemisinin (Qingnasou) - is very active against *P. falciparum* rings as well as the later stages of the parasite. It is given orally or by rectal suppository and should only be used for treatment but not for prophylaxis.

Chloroquine – is used for the treatment of the relapsing strains. It is usually taken orally. It remains the most ideal drug for treatment and prophylaxis because of its low cost and relative lack of side effects. However, *P. falciparum* has developed resistance to this drug in most parts of the world.

Halofantrine – is effective in multi-drug resistant *P. falciparum* infection. However, resistance is recorded in South East Asia. Hence, to treat *P. falciparum*, it requires multi-dose regimen.

Mefloquine – is effective against multi-drug-resistant strains; however, it is developing resistance in South East Asia. It is given orally in single dose and it is effective in rapidly clearing parasitamia and alleviating symptoms. It is not recommended for children under eight years.

Primaquine – is the only drug that is effective against the hepatic forms of *P. vivax* and *P. ovale.* It should not be taken by pregnant women, children under four years and any condition that predisposes to granulocytopenia, such as erythematosus.

Fansider (pyrimethamine + sulfadoxine) – is used for the treatment of uncomplicated mild to moderate chloroquine-resistant *P. falciparum* malaria. In east Africa, Latin America and South East Asia, resistance has been developed. It is not recommended during pregnancy and lactation.

Quinine – is unpleasantly bitter drug. No contraindication to the oral administration of the drug within the above dosage (Whittle and Boele van Hensbroek 1994).

Table 2.2 Oral treatment of Sever malaria (Source: FDROEMOH 2004)

Drug	Adults Dosage	Children Dosage
Quinine	20 mg salt/kg loading dose over 4 hours followed by 10 mg/kg/ 8 hourly for 7 days. 20 mg salt/kg loading dose in two divided doses followed by 10 mg/kg/ 8 hourly for 7 days.	20 mg salt/kg loading dose over 4 hours followed by 10 mg/kg/ 8 hourly for 7 days. 20 mg salt/kg loading dose in two divided doses followed by 10 mg/kg/ 8 hourly for 7 days.
Artemether	3.2 mg/kg loading dose followed by 1.6 mg/kg / daily for two days.	

Note: In both cases, in areas of quinine resistance non-pregnant adults and children over 10 years may, in addition, be given oral tetracycline 250 mg four times a day for 7 days.

2.5 Prevention and Control

Different measures can be taken to prevent the problem of malaria. This can be done by individuals, community and/or government. The following are the most important measures of preventing and controlling methods of malaria (Whittle and Boele van

Hensbroek 1994, APHA 1995).

I. Public and individual measures- include:

● wearing long sleeves and pants during the dusk-to-dawn period;

● sanitary improvements, such as filling and draining areas of impounded water;

● installing screens and using bed nets; particularly the use of impregnated bed nets increases the effectiveness of the bed net;

● larvicides and biological control, for example using larvivours fish; and

● nightly spraying of screened living and sleeping quarters with insecticides.

II. Chemoprophylaxis- is not advised by the WHO at community level. However, individuals particularly those non-immune travelers are recommended to use chemoprophylaxis, even pregnant women after the first trimester and infants over 3 months as well. Since the geographic distribution and species drug sensitivity of malaria parasites can change rapidly, it is important to have the recent information about drug patterns. Chemoprophylaxis should be started 1 week before travel and continued for 4 to 6 weeks following return from endemic area.

III. Government-the responsibilities include:

● provision of technical and material assistance to regions for epidemic control;

● coordinate overall regional capacity building in manpower, logistics and finance, so that the control of malaria can be effectively implemented at all levels;

● monitoring, evaluation and follow up of the implementation of the national malaria control strategies; and

● dissemination of meteorological information to regional levels for early warning and epidemic forecasting purposes.

2.6 Vaccine Development

The successful elimination of smallpox by vaccination has greatly stimulated the search for a malaria vaccine. However, unlike smallpox, the complexity of the life cycle of malaria parasite makes the effort much more difficult, since infection of both host and vector has to be considered (Brain 1989). Despite these difficulties, a massive international effort by the scientific community has been underway. The research, which is mainly based on biomedical science, is oriented towards the goal of producing vaccines against (TDPIR 1989, Whittle and Boele van Hensbroek 1994):

I. the sporozoites inoculated into man when the mosquito bites- this helps to prevent infection. Infection can take place from one person to another during asexual blood stage, for instance, during blood transfusion from an infected person.

II. the asexual blood stage of the parasite in man- the idea is to prevent clinical malaria. This type of vaccination has shown 50 % protection against *P. falciparum.*

III. the sexual stages of the parasite in the mosquito (gametocyte antigens)-this helps to block transmission. The failure of the above and other research efforts makes the development of vaccination against malaria very difficult in short period of time.

2.7 Immunity to Malaria

Even if the term immunity means the refractoriness or a very efficient protection of individuals against a disease, malaria immunity is not an easy concept which can easily be understood by a layman (Pampana 1969). In other infectious diseases, the disease lasts a few days or weeks inside the body of an individual. Then it leaves an effective and sometimes lifelong protection against a further invasion of the infection. This kind of effective immunity does not occur and full protection against re-infection is exceptional and it does not last the whole life. Even if it is not possible to get full protection from the disease, Pampana (1969) classifies malaria immunity into innate, acquired and racial immunity.

Innate immunity- this immunity is primary or inborn. The mechanism of this immunity, though, is found in few individuals, and it consists in reduction of the number of merozites in the plasma. Because of this defense mechanism a few of the merozites penetrate to the erythrocytes. Due to reduction in the multiplication of merozites, there would be no development of infection.

Acquired immunity- this type of immunity develops while the infection proceeds in the body of the infected individual. Acquired immunity is first revealed in the recovery from the primary attack in the absence of treatment, often while parasites are still present in the blood but in greater numbers than at the onset of the attack. This type of immunity is associated with the presence of parasite in the body of the individual. Protection from re-infection will not last long after the parasite disappeared from the body.

Special characteristic of acquired immunity for malaria is protection against re-infection. This is possible only if the individual infected with the same kind of parasite. It means acquired immunity is species specific. The ease of the development of acquired immunity and the duration in the body also vary according to the different species of *Plasmodium*.

In *vivax* malaria, immunity is easily developed and it stays long in the body. Whereas in the case of *Plasmodium falciparum* the development of acquired immunity takes a very long period and it is the most rapid to be lost. Immunity to *Plasmodium malariae* develops more rapidly and has been found to persist for at least 15 years. Immunity to *Plasmodium ovale* is lost easily. In hyperendemic and holoendemic regions, most people after frequent exposure to the parasite will have developed a level of immunity. They also become immune or hyper immune to all strains of malaria in the locality. However, this type of immunity will be lost if the person leaves the endemic area (Whittle and Boele van Hensbroek 1994).

Racial immunity and Genetic factor- the susceptibility of individuals to the *Plasmodium* species is sometimes influenced by the genetic factor of the individual. This kind of immunity develops from the adaptation of immediate environment by the individual. Such adaptations tend to optimize the performance of the individuals in such a way that their body can resist the harsh condition imposed by the environment in which they live. In this case these individuals are more advantageous than the other groups in such circumstances.

The sickle cell gene of some West African people reduces their susceptibility to clinical infection (Whittle and Boele van Hensbroek 1994). Desowitz (1980) has also presented that it was because of the sickle cell traits that the West African agriculturists colonized the malarious areas of the savanna region. It is believed that about 45 % of the West African people that live in malaria endemic areas have the sickle cell traits.

Another important genetic factor that protects individuals from being infected with malaria is lack of Duffy blood group antigens, which are necessary for the invasion of red blood cell by *Plasmodium vivax* (Whittle and Boele van Hensbroek 1994). For instance, because of lack of these antigens black Americans in the USA have a *vivax* infection rate lower than that of the whites. In addition to the above immunities to malaria, it is also possible to acquire immunity transplacentally from mother to child (Whittle and Boele van Hensbroek 1994). This type of immunity is called *passive immunity*.

2.8 Drug Resistance

The drug resistant problem of malaria has dual faces: the resistance of the *Plasmodium* and resistance of the *Anopheles* mosquito. According to WHO (1996a), the origins of drug resistance to the *Plasmodium* are inadequate regimens, poor drug supply, and poor quality and misuse of drugs. This problem is particularly great in the treatment and control of *falciparum* malaria. Almost in all endemic countries, except in Central America and Caribbean countries, resistance to chloroquine has been found. Besides, resistance to multiple drugs is common in South East Asian countries.

The mosquito resistance to different insecticides is another important problem which creates a serious obstacle to malaria control efforts. Many *Anopheles* mosquitoes have already developed resistance to the three classes of insecticides available for public health use. Moreover, some mosquitoes are becoming resistant to pyrethorids, widely promoted for bed net and curtain impregnation. Patz et al. (1996) states that since 1947, more than 50 mosquito species in the world have developed resistance to insecticides.

2.9 Epidemiology

Malaria is one of the most widely distributed parasitic diseases in the tropics. However, on the globe it extends up to 60° north and 40° south of latitudes. Its distribution in the world is not uniform (Figure 2.1). Different species of *Plasmodium* are found in different countries. *Plasmodium falciparum* is predominantly found in the warm and moist parts of Africa, the Middle East, Asia, Haiti, the Caribbean Islands, and Central and South America. *Plasmodium vivax* is dominant in the tropical and subtropical parts of Asia and in Eastern Africa and in some temperate regions such as in the Middle East and Iran. It is not found in the natives of West African. Though *P.* malariae is much less common than *P. falciparum* and *P. vivax,* it is widely distributed throughout the tropics. *Plasmodium ovale*, which is uncommon species of malaria, occurs in Africa and South America (Brian 1989, Whittle and Boele van Hensbroek 1994).

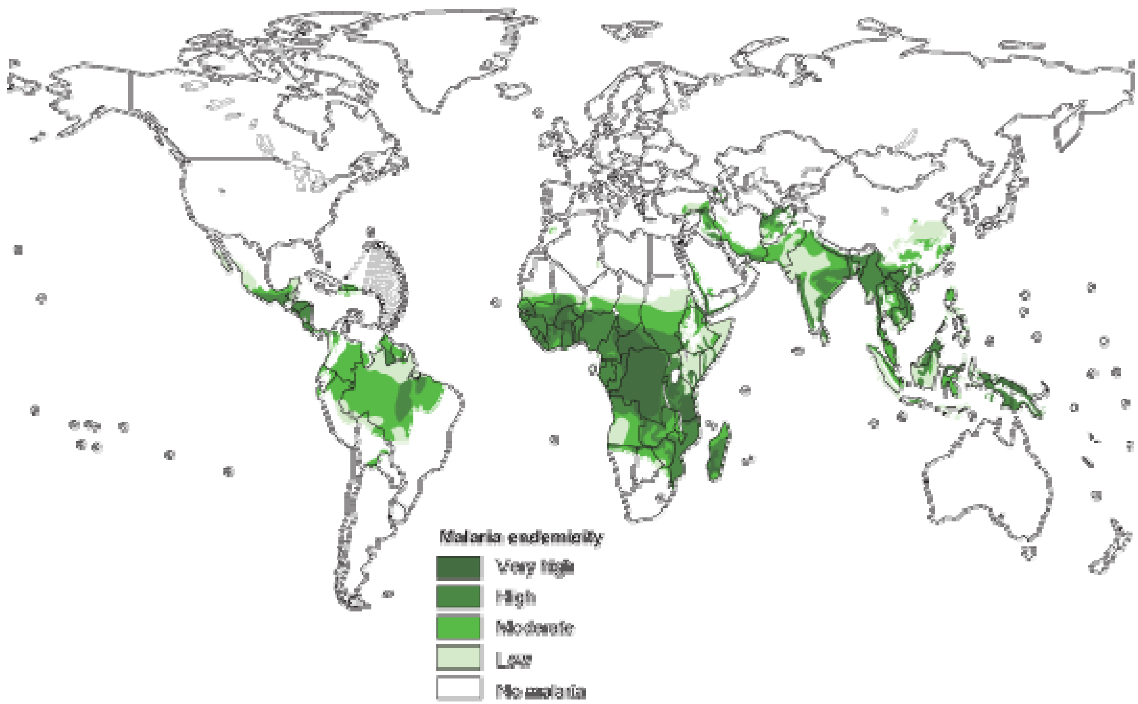

Figure 2.1 Global distribution of malaria transmission risk, 2003 (Source: World malaria report 2005)

The variation of malaria epidemiology is not limited by continents or between countries. There is also variation in the distribution of *Plasmodium* in a single country. McGregor (1989) states two extreme occurrences of malaria in different parts of a country. In one extreme malaria might be unstable, occurring in epidemics separated by intervals of low incidence of malaria. Unstable malaria occurs when there is sudden development of circumstances which are conductive for the transmission of infection at levels far above the usual period of occurrence. In this case it occurs as an acute febrile illness and it affects all age groups and result in high mortality and morbidity. At the other extreme malaria could be stable, in such a way that there is very little difference in the incidence of its occurrence from year to year. In this condition, transmission is usually perennial and it attacks the community intensely. The most attacked groups are children, however, adults usually develop immunity and they are less affected.

The epidemiology of malaria in a given country is determined by different factors (Brain 1989, McGregor 1989). These are conductive environments for the transmission, the presence of suitable *Anopheles* mosquitoes, the presence of *Plasmodium*, and the presence of a reservoir of the parasite. In some exceptional cases, there might be malaria without being fulfilled the above conditions. This occurs when the parasite is taken by travelers and immigrants while they are traveling from endemic areas. This type of malaria is called imported malaria.

3. THE GEOGRAPHY AND FACTORS AFFECTING MALARIA DISTRIBUTION IN ETHIOPIA

3.1 Physical Environment

3.1.1 Location

Ethiopia is a tropical country which is located in the horn of Africa, between 3^{o} 25’ and 14^{o} 54’ North latitudes and between 33^{o} and 48^{o} East longitude (Shibeshi 2001). Moreover, Ethiopia has now become one of the land-locked countries, since the independence of Eritrea. Due to higher altitudes in most parts of the country the physical and biotic environments as well as the type of food production are similar with that of temperate regions.

3.1.2 Topography

Ethiopia has a total area of 1.14 million km^2 and a country of great geographic diversity (http://www.ethemb.se/ee_eth.html). It has high and rugged mountains, flat-topped plateau, and deep gorges, incised river valleys, and rolling plains. About half of all the highlands of Africa above 2000 m are found in Ethiopia (Schaller 1972, Kloos et al. 1988). Besides, altitudes of the country range from the highest peak at Ras Dejen (4620 meter above sea level) to the depression of Kobar sink (110 meters below sea level).

The highlands

Most of the highlands are located in the interior part of the country and they are divided into two broad highland regions. These are:

a. The western highlands- these are massive with an average height of 1600-2600 m. They are bounded by the western escarpment of the rift valley in the east and western lowlands in the west and stretch from the northern part of the country to the south western part. The western highlands occupy the north central massifs in the north and the south western highlands in the south west. The north central massifs include the highlands of Tigray, Wello, Gonder, Gojam and the plateau of Shoa. According to Schaller (1972), gorges are found along the upper courses of the big rivers such as Tekeze and Abay. These areas are uninhabited by human beings due to excessive heat and the risk of malaria. In these massifs there are many mountain peaks above 4000 m, which are the result of volcanic activities. Mt. Ras Dejen or Dashen is found in this area. The south western highlands are found south west of the central massifs and comprise the highlands of Wellega, Illubabor, Kefa, Gamo and Gofa. The highlands in these areas are dissected by different river valleys. The general altitude of most mountains ranges from 3000 m to 4000 m. However, there are some mountains peaks above 4000 m, for instance Mt. Guge which is 4200 m above sea level.

b. The south eastern highlands- these areas are found east of the rift valley lakes region and North West of the eastern lowlands. The regions include the highlands of Sidamo, the Bale massifs and the highlands of Arsi and Harerghe. These highlands are separated by the rivers of Wabishebelle and Genale. In the highlands there are many extensive and little dissected plateaus with altitudes above 2000 m. These areas are favorable for settlements because of good climate which supports the growth of cash crops and food grains. Mt. Chilalo and Batu are the highest peaks which rise to 4139 m and 4307 m respectively. Though these highlands provide favorable climatic conditions for settlement, they affect the physical work performance, sleep, cardiovascular and neurological function of new comers, who are adapting themselves to the highlands.

The Lowlands

The lowlands of Ethiopia can be divided into three groups: the western lowlands, the eastern lowlands and the rift valley regions.

a. The western lowlands- these areas include the western margin of the western highlands and stretch from North West to South West of the country along the Ethio-Sudan border. The average elevation of these lowlands is about 1000 m to 1500 m. The Tekeze, the Abay and the Baro lowlands are parts of this region.

b.The south western lowlands- They are the most extensive lowlands that are found east of the rift valley lakes region. This area includes the lowlands of Borena, Bale and Ogaden. Besides, they extend up to the Somali lowlands, and the lowlands of Wabishebelle and Genale are also found in this area. The average altitude of this area is between 500 m to 1000 m.

c.The rift valley region- this area stretches from the Afar depression in the north to the Chew Bahir in the south. The Afar area, which is the northern part of the rift valley, is generally the lowest part of the country as well. It has an average altitude between 200 m and 500 m, and the lowest point of the country, i.e., Kobar sink is found in this part.

Because of unfavorable climatic condition, active volcano and the presence of various tropical diseases, this part of rift valley is occupied by nomadic pastoralists who frequently move from place to place. The rift valley lakes region, which is found in the southern part of the rift valley system, has relatively higher altitude than the Kobar sink (Dallol) depression. Accordingly, the area is hot and semi-arid in nature, and is characterized by a more tropical flora and fauna. Regarding diseases that threat the health of human beings, all four human *Plasmodium* parasites, sleeping sickness (*Trypanosomes)*, flariae, Rickettsia (*Rickettsia africae*), the Yellow fever virus and the *Leishmania* parasite are found (Kloos et al. 1988).

3.1.3 Drainage

Rivers

Ethiopia has rivers of considerable size and number, and most of which are international in nature. The direction of the flow of these rivers is guided by the general topography of the country and based on their flow of direction they can be divided in to three drainage systems:

A. The eastern drainage system- this includes rivers which drain the south eastern highlands and associated lowlands. The two major rivers of this system are the Genale and Wabeshebelle. The former enters in to the Indian Ocean, whereas the latter, which is the longest river of the country, fails to reach the Indian Ocean and remains in the Somali desert.

B. The western drainage system- it drains the western highlands and associated lowlands. The major rivers are Abay, Tekezze, Baro and Omo. Except river Omo which flows to Lake Rudolf, they flow towards the Mediterranean Sea after they joined the White Nile which starts from Lake Victoria.

C. The rift valley drainage system- it has rivers and lakes which remain within the rift valley. River Awash is the largest river that empties into lake Abbe after having lost much of its water through evaporation and seepage. Most of the Ethiopian lakes are found in this region and Lake Awassa is one of them.

Related to health and disease, these rivers have important feature, for instance, seasonal fluctuation. As a result of seasonal variation in rainfall, the rivers and lakes of Ethiopia have seasonal characteristics. During the rainy season both the rivers and lakes are full and some times they flow over their banks and these lead to flooding. During the dry season their volume is decreased and they create different pockets of water body that is favorable ground for the breeding of different disease vectors such as mosquito.
Most Lakes of Ethiopia are found in the rift valley. These lakes are only eight in number and they vary in size and depth. Due to high temperature which is favorable for the breeding of different disease vectors and pathogens, the habitats of the Lakes region are highly affected by vector born diseases especially by malaria. Moreover, Lake Tana, the largest lake in Ethiopia, provides conductive environment for the spread of different infectious diseases. Among others, its location in warm (kolla) zone of the country is an important factor (Schaller 1972) for the presence of different germs. Unlike the other it is located outside the rift valley regions.

3.1.4 Climate

In Ethiopia the three elements of climate i.e. temperature, rainfall and humidity are strongly associated with altitude and relief. Moreover, the location contributes to seasonal variation of rainfall and temperature in the country. Based on altitude, traditionally the country is divided in five agro-ecological climatic zones (Table 3.1).

Table 3.1 Traditional Agro-ecological Climatic zones (Biru, A. 2007, Pers.com)

agro-ecological climatic zone	Elevation (m)	Mean Temperature (°C)	Mean annual rainfall (mm)
Woorch/kur	Above 3500	Below 0	-
Dega	2500-3500	7-15	1000-1600
Woyna Dega	1500-2500	16-20	400-2400
Kolla	500-1500	20-30	100-900
Haroor/Bereha	Below 500	25-48	-

In the hottest places of the low lands there is a problem of heatstroke where as in the cool highlands hypothermia is the health problem of the community (Kloos et al. 1988). The pattern of rainfall in the country is seasonal and comes during summer. As a result of this the transmission of malaria, tryponosomiasis, leishmaniasis and other water-related diseases is seasonal (Kloos et al. 1988). Moreover, Ethiopia is among the most affected countries by malaria epidemic, mainly due to its topographical and climatic features. Distinct from the "normal" seasonal increase in many areas, major periodic epidemics have occurred in the country from time to time. In 1958, an epidemic resulted in an estimated three million cases out of which 150,000 people died (Fontaine et al. 1961).

3.2 Socio-economic Environment

3.2.1 Population and settlement

Ethiopia is a living ethnological museum due to its complex combination of different ethnic groups (Schaller 1972). Like many other African societies, Ethiopia is a multi-ethnic state embracing various ethnic groups with many divers' languages together. The population groups are broken into four main groups, i.e. Semitic, Cushitic, Omotic and Nilo-Saharan; and more than 83 languages with 200 dialects are spoken in the country (Kello 1972, Zewde 2002).

With an estimated growth rate of 3 % per annum, the total population of Ethiopia is estimated to be more than 71 million in 2004 (http://www.ethemb.se/ee_eth.html). The distribution pattern of the population is highly governed by the physical environment. According to statistics office (2005), more than 77 % of the population lives in areas above 1800 m. This constitutes only 37 % of the total area of Ethiopia.

The population density in rural areas is the highest in the south central and southern part of the country. Enset *(Ensete ventricosum*) cultivation is dominating the economic activity. The lowest densities are recorded in those areas where the inhabitants depend on non-market oriented stock rearing.

3.2.2 Healthcare systems

A. Traditional Medicine

Traditional medicine has been practiced in different parts of the country for centuries. In the country the traditional medicine practitioner are mainly divided into: traditional birth attendants (Yelemd awalaj), bone setters (Wogesha), spiritual healers, and herbalists (Kitel betash). The knowledge of these practitioners is handed over from father to son. Some of the diseases that are treated by the traditional practitioners are- treatment of wounds as well as extraction of teeth, treatment of venereal diseases, tuberculosis, worm infestations and delivery during child birth (Schaller 1972, Ethiopian Mapping Authority 1988). For example, traditional herbalists treat malaria using garlic and different kinds of grains and herbs.

B. Modern Health Services

The history of modern medicine in Ethiopia can be traced back to the sixteenth century. However, until the establishment of the Russian Red Cross Hospital in 1896, it had only been serving the Royal families. It was in 1910 that the first government hospital, i.e., Menelik II Hospital was inaugurated in the capital city by king Menelik (Ethiopian Mapping Authority 1988, Zein and Kloos 1988). Though the modern health care started its work during 1896, public health was not run by organized ministry until 1908.

The ministry of public health was established in 1948 as a separate government body. After its establishment, different centralized vertical health services were organized. These are: the control of malaria, the anti-epidemics service, tuberculosis, the trachoma, venereal diseases, the leprosy and child nutrition (Schaller 1972). However, these centralized services have been integrated step by step in to the existing general health services system after the 1974 socialist revolution (Ethiopian Mapping Authority 1988).

Basic Health Services

The lowest level of health care system is Health Post, which combines a community Health Agent and a Traditional Birth Attendant per 1000 people approximately. Next to this, there are Health stations. They function as out-stations of the health centers. The Health Centers are above health stations, which provide better curative and preventive services than the health stations. The Rural Hospitals are the fourth stage of the health service units. The Regional Hospitals, which are the fifth stage of the health service unit, provide full range services. Finally, the Central Hospitals including the University Hospitals are the last stage of the system. In addition to the above basic health services, which are controlled by Ministry of Health, there are also other healthcare facilities that are owned by different organizations. They can be divided into institutional and private health care facilities and health care facilities run by different missionaries (NGOs).

The Institutional health care facilities include different health care facilities ranging from health stations to hospitals and owned by different government organizations other than Ministry of Health. These are Ministry of Defense, Police, State farms, Ministry of Education etc. The Private health facilities had been limited in number during the socialist regime. However, after Ethiopian People's Revolutionary Democratic Font (EPRDF) took power, private investment has been encouraged and number of health institution has been increasing. This includes healthcare facilities such as pharmacies, drugstores, clinics and hospitals. The NGOs healthcare facilities are run by different missionaries. Their services range from health stations to rural hospitals.

3.3 Factors affecting malaria in Ethiopia

There are so many responsible physical and human factors for the occurrence of epidemic malaria in large parts of the country (Schaller 1972, Gbre-Mariam et al. 1988, Tulu 1993). The factors mentioned below are the most important ones.

3.3.1 Human factors

A. *Development projects*

In Ethiopia large irrigation schemes have been established along different rivers and their tributaries, especially in semi-arid areas of the country where temperature is high and humidity is low. If water is available these lowland areas have fertile soils, which are potentially productive. Major agricultural irrigation schemes are found in the valleys of Didessa, Awash, Gode, Beles and Wabi-shebele. All of them are found in malaria areas of the country and the nature of the malaria transmission is perennial because of the presence of permanent standing water bodies throughout the year. In these areas there are 16 major agro-industrial development schemes with over 25000 people (Tulu 1993). The majority of the residents are migrant labourers. Their families are from the highland areas of the country where land is degraded, and population pressure is high. As a result, the area has been affected by periodic drought. These laborers and their families are more vulnerable to malaria than the indigenous population due to lack of immunity to malaria. Furthermore, due to the seasonal nature of the agricultural activities in the project areas most of the workers are seasonal workers. During periods without job, they return to their area of origin. They loose their immunity that they have developed while they have stayed in malarious areas.

In addition to the above, there are other factors that aggravate the malaria problem. Such as low status of the health facilities, low economic status of the workers, poor house qualities, and large number of people living together in small areas. Lack of coordination among different government sectors during the preparation of the projects are also another factor. Micro dams have been built in different parts of the country where there has been drought and sever famine for a long period of time, due to unreliable rainfall. The aim of these dam constructions is to utilize effectively the available water that comes during the rainy season in the dry seasons and to lead the peasants to sustainable agricultural output.

However, the dams have changed the ecology of the area and created favorable breeding sites for the *Anopheles* vectors and for the development of *Plasmodium*. As a result of this the epidemiology of these areas is changed and malaria has become a great health problem which threatens the life of the human population and affects the peasant economy.

B. Population movement

The spread of malaria in Ethiopia is aggravated by the introduction of the disease from the kolla to the woyna dega zone. It spreads with seasonal migrant laborers that are employed in different plantation areas, mobile troops, and pastoral nomads. Besides, people from lowlands who visit markets in the neighboring highland areas can spread the disease. In addition to this, famine victims and other people that are displaced from their original places due to war and other factors and migrates toward highlands spread the malaria. Due to these migrant people, epidemics occur when there is appropriate vector during the rainy season (Tulu 1993).

For example, when the Awash valley agricultural scheme was established in the 1950s, due to the absence of a local labor force, the sugar cane farms recruited farm labors from the highlands of Ethiopia where population density is high. Besides, the cotton farms recruited seasonal workers from the central and northern highlands. Due to this, out of 250,000 people, half of them were migrant workers and other government officials. All of them were from the highlands of the country (Kloos et al.1988).

C. Urban areas and Rapid urbanization

Rapid urbanization plays a great role in transmission of malaria in Ethiopia. This is mainly due to the result of expansion of urban areas into malaria breeding areas. The establishment of new urban centers in malaria prone areas, and rapid population growth is another factor. Most urban centers of Ethiopia, which are found in malarious areas, have grown recently. For example, Awassa town formerly known as Tabor was established in the beginning of 1970s and had only 5,000 people (Schaller 1972). However, recently this town has become the regional capital city of the Southern Nation Nationalities with estimated population of 250,000 people (SMCF Ethiopia Children's Fund 2007). Bahir Dar which is the capital of the Amhara National Regional state was established in the 1950s near to Lake Tana (Covell 1957). Today it has more than 153,000 people and malaria is endemic.

D. Resettlement and Villagization

The resettlement programs which have taken place in the country in the past years have strongly contributed to the spread of malaria. This is because of two main reasons. First the settlement areas are located in areas where malaria has been moderately to highly endemic. The second reason is that most of the displaced people are highlanders and they have no immunity to the disease.

The history of voluntary and planned settlement in Ethiopia dates back to 1958. Since then different resettlement programs have been planned and implemented by the former Feudal and the Derg regimes. They had given different justifications for their resettlement programs. These are: to accommodate peasants, to use virgin arable lands of the country for agricultural production and to use water resources efficiently. It is also to provide employment to the urban unemployed, and to reduce pressure on land in the densely settled highland regions (Institute of Development Research (IDR) 1990, Kello 1992).

The Derg regime was accelerating the settlement programs for a long period of time. Immediately after the 1974 revolution, in 1975/76, eighty-eight settlement centers were established accommodating 38,818 householders. In 1982 120,000 people were settled into 112 planned resettlement areas. During the 1984/85 drought the government announced to settle 1.2 to 2 million people from the drought affected highland areas of the country to the lowlands. However, by the end of 1987 the government had resettled about 600,000 people in three settlement areas in the western lowlands.

Almost all resettlers originated from the highland areas and they were settled in the lowland areas. More than 250,000 were settled in Wollega, 150,000 in Gambella, 100,000 in Metekel and more than 78,000 went to Keffa, Shoa and Western Gonder. These areas are infected with malaria, trypanosomiasis, onchocerciasis and other tropical diseases which are not common in the highlands. In addition to these diseases the settlers suffered with malnutrition, which is a major predisposing factor to bad health conditions, including malaria (IDR 1990). For instance, in 1985 and 1986 more than 75,000 were settled in the Tana Beles resettlement area, which is found in the Metekel lowland. Among these settlers malaria had been totally unknown until they settled in the lowland areas (D' Arca et al. 1992). Since the environment of the settlement area is completely different from their place of origin they were immediately exposed to malaria. For instance, the average temperatures of the settlement area is about 25 ^{o}C and annual rainfall is 1100 mm which are favorable for the breeding of mosquito and the development of *Plasmodium*. In addition to this the area is located near to the Beles river and its tributaries.

E. Tourism

Most of the Ethiopian tourist attraction areas are found in malaria epidemic areas of the rift valley regions (Fig. 3.1). The following sites are major tourist sites that attract both domestic and foreign tourists.

National Parks- The main wildlife populations occur in the southwestern half of the country where malaria is epidemic. For instance, the Omo river basin and the Mago valley in the south are notable for the wealth of their wildlife. The Omo National park is said to have the largest concentration of wildlife in Africa. The rift valley lake regions are also famous for their wealth of different birds, some of which are endemic to Ethiopia. Furthermore, Lake Shala and Lake Abijata are in the migration route of birds from the northern hemisphere during the winter season. Thus, a substantial volume of tourist traffic is recorded in these areas. In addition to this, Nechesar and Awash National parks are also tourist attraction areas which are found in the malaria prone areas of the country (Ethiopian Mapping Authority 1988).

Hot springs and lakes- Ethiopia has natural hot springs in the rift valley regions. For example, Wondo Genet and Sodere, which are found within a distance of 250 km from the capital city, can be mentioned as important areas where both domestic and foreign tourists go visiting. Thus, domestic tourists who have little or no exposure-related immunity to malaria, travel from highland area to these areas and can easily be infected with malaria.

Figure 3.1 Tourist locations in Ethiopia (Source: Lonely Planet web page)

3.2.2 Physical factors

A. Climate

For the breeding of *Anopheles* mosquito and the development of the *Plasmodium* parasite in the mosquito, the country provides favorable temperature and moisture conditions. These elements of climate are mainly the result of the country's location and topography. As Ethiopia is located in the tropical region, most parts of the country have high temperature throughout the year. High amount of seasonal rainfall in most parts of the country and perennial rainfall in some areas are also the result of the location of the country. The seasonal rainfall with high temperature is responsible for the occurrence of unstable, seasonal malaria transmission after the onset of the rainfall in most part of the country.

Most of the lowland areas of the country have very high temperature throughout the year. However, the occurrence of malaria in these areas is not perennial except in some areas where there are permanent water bodies. Furthermore, the rift valley region is also another lowland area in the interior of the country that provides optimum climate for the breeding of the mosquito vector and the *Plasmodium* to be carried by the mosquito.

B. Drainage

The existence of permanent water bodies such as rivers, lakes and streams creates favorable environment for the breeding of the mosquito and the transmission of malaria in Ethiopia. Due to the high temperature and the seasonal nature of rainfall in the lowland areas, the volume of the rivers decreases and the water collects in the lower course of the rivers. These pockets of water are the important breeding places for the mosquito. Furthermore, the malaria parasite can easily be developed and carried by the mosquito and causes immense human morbidity and mortality. Most lakes of Ethiopia are found in the rift valley region where the temperature is high throughout the year. These regions are occupied by both rural and urban populations, and high numbers of people are vulnerable to the disease.

3.4. The Epidemiology of Malaria in Ethiopia

3.4.1 Spatial Distribution

The existence of malaria in Ethiopia is unquestionable due to its tropical location. Besides, 75 % of the area that lies below 2000 m and accommodates two-third of the population of the country provides favourable natural environment for the occurrence of malaria and hence it is malarious.

As it is stated above, the spatial variation of malaria in the country is largely governed by the topography of the country which affects the climate of the particular area (Tulu 1993, FDROEMOH 1997). In the cold zone (dega), since the temperature doesn't support the breeding of *Anopheles* mosquito and the development of the malaria parasite in the *Anopheles*, there is no malaria at all.

In the *weyna dega* zone, where the major portion of the country lies, due to temperature variation malaria occurs most often in areas below 2000 m. However, in isolated pockets a few indigenous malaria cases have been seen during extensive epidemics up to 2500 m altitude. This is due to the climate and local physical characteristics that are conductive to the breeding and survival of the vector. Generally speaking, when malaria occurs in this zone it leads to high morbidity and mortality due to the absence of immunity in the highland population. The risk of epidemics is high and all age groups are equally vulnerable to infection.

In the *kolla* zone malaria is moderately to highly endemic. High malarious areas of Metema, Metekel, Settit Humera and Gambella are found in the western lowlands of Ethiopia. Due to low rainfall, high evapotranspiration and absence of standing water bodies some of the warm zones of the country are characterized by short lived transmission. In the Danakil depression where elevation is 116 m below sea level and in the Ogaden lowland, malaria hardly occurs far away from rivers, lakes and swampy areas.

3.4.2. Temporal Pattern

Seasonal pattern

Seasonal transmission – in most parts of the country's *weyna dega* and *kola* zones malaria transmission is highly seasonal. Two transmission seasons are identified in the country following the periods of both light rains in February to April and heavy summer rains from June to August.

In these areas the peak malaria transmission period is from September to November. However, there are some exceptional areas where peak transmission occurs after autumn and spring rainfall seasons. These areas are found in the south and south eastern parts of the country along the Somali and Kenya borders. In some areas of Afar transmission also occurs during these seasons.

Perennial transmission – malaria transmission is perennial in areas where there are permanent warm bodies and graded as meso and hyper-endemic in areas below 1600 m and 2150 m respectively. These areas include the Lake Tana region, rift valley lake regions, swampy areas and areas near to irrigation schemes. They also include large rivers particularly the Awash, Baro, Blue Nile, Tekezze, Wabe shebele, Didessa and Omo river (Tulu 1993, Yohannes 1996, FDROEMOH 1997; 2004).

Yearly variation

The prevalence and incidence of malaria has greatly increased since the mid of 1980s because of different physical, social, economic and political factors. The sharp increase of reported cases after 1982/83 appears to have been a result of primarily the return of normal rainfalls after the 1982-1985 droughts. According to FDROEMOH (1997, 2004), the number of malaria cases is not complete due to irregular reporting of the regional health offices. However, the number of malaria cases in the country may reach 1.5 to 2 million in recent years. This number is very much larger than that of malaria reported cases in 1989/90.

4. MALARIA IN ETHIOPIA

4.1 The History and Epidemics of Malaria in Ethiopia

Different indigenous names for malaria in different languages exists in Ethiopia, for instance *busa* in Oromigna and *nidad* in Amharic, shows that malaria has been endemic in many parts of the country for centuries. Besides, malaria has not occurred for long period of time in the central highlands, where population is concentrated. The lowland areas were occupied mainly by scattered nomadic people. This partly indicates that the history of malaria is linked with the history of settlement in the country (Tulu 1993).

Most epidemiological studies were carried out for the first time during the Italian invasion between 1936 and 1941 (Covell 1957, Wang 1966, Tulu 1993). The problem of malaria in Ethiopia have been described by different explorers since the middle of the nineteenth century. Wang (1966) translated what Ferret Galiner wrote in Italian about *fever* disease in his *voyage en Abyssinia*: “Toward the end of the rainy season, the humid atmosphere and the soil, which is soaked and productive of a *Pernicious miasma*, turn the country into a fatal region.” From this translation it is evident that in most parts of the country, malaria occurred during the onset of the main rainy season, i.e., summer.

In the first Egyptian congress of medicine in 1902, Parissis reported malaria from different parts of Ethiopia. Specially, in the swampy sparsely populated areas of the Tekeze valley, Tigray, Amahara, and south east Ethiopia, there had been malaria which he called *Fiever paludeennes*. In these areas at that time there were 300,000 soldiers and Parissis found that many of them died of malaria (Wang 1966).

The Italians were the first to carry out detailed investigations and studies on malaria. They made different investigations and did some epidemiological studies after they invaded the country in the 1930s. They also conducted systematic surveys on the regional distribution of *Plasmodium* in Ethiopia. The first malariologist team investigated malaria free areas in 1936. The main purpose of this investigation was to survey areas which could be good for settlements and then to establish settlements for large groups of small farmers. The investigation team which comprised three malariologists, i.e., Canalis, Raffaele and Lega, made the survey in large parts of the country along the Addis Ababa-Asmara road, the Addis Ababa-Dire Dawa railway line and parts of Italian Somaliland.

In 1937 Mariani conducted a research along Ethio-Somali border and identified 5 % *Plasmodium malariae*, 30 % *Plasmodium vivax* and 65 % *Plasmodium falciparum*. From 1936-1939 the leadership of the research center, Corridetti who personally travelled to the north and north east of Ethiopia, described the epidemiological conditions of malaria in Diredawa and Wollo. He published papers on the female *Anopheles* mosquito in Ethiopia (Covell 1957, Wang 1966).

In 1942 for the first time four malaria cases were identified by Martin at average altitude of 2040 meter above sea level close to Addis Ababa (Covell 1957, Wang1966). Fifteen years later, in 1955 the female *Anopheles* mosquito had been recorded by Ovazza and Neri around Addis Ababa (Covell 1957).

In autumn 1955, Gorden Covell (1957) made a malaria survey in different parts of the country. During the survey, he examined only children from two to ten years of age since children are the most rapid groups of measuring malaria epidemicity. In his investigation he stressed that the major public health problem of Ethiopia during that time were "those relating to malaria, tuberculosis, venereal diseases, typhus fever, relapsing fever and intestinal infections" (Covell 1957). In addition to these diseases, he mentioned other infectious diseases like leprosy, trachoma, and skin infections as wide-spread diseases. Besides, he also identified other water related infectious diseases like schistosomiasis, leishmaniasis, brucellosis and onchocereiasis. These were found in limited areas and occurred frequently. His extensive investigations covered the whole country. He identified that in most years malaria had not been a serious problem in the plateaus surrounding the lake and it occurred only during October and November after the main rain season. Because of this, the people in the area had little immunity to the disease. Clearly from his explanation, it is evident that there has been an environmental change in the area which created a conductive environment for the breeding and longevity of *Anopheles* mosquito.

When Sir Covell visited southern parts of the country, he identified high degree malaria epidemicity in the rift valley lake regions and very little local transmission in the Omo valley, the southern parts of the rift valley region. Based on his investigations and recommendations, WHO/ UNICEF have carried out a pilot project in the upper Awash valley (Covell 1957, Wang 1966), which served as a spring board for the establishment of Malaria Eradication Service of Ethiopia in 1959.

In the year 1958 a devastating malaria epidemic broke out in many parts of the country, mainly in the highlands. This epidemic "appears to have been the most disastrous one in the country" (Tulu 1993). Out of estimated 3 million malaria cases 150,000 people died during this epidemic (Wang 1966, Bamazai 1969, Tulu 1993, FDROEMOH 2004). The population of Ethiopia was estimated to be 11 to 12 millions in 1957 (Covell 1957). Thus it attacked one person out of four. This epidemic was extremely serious and devastating.

According to Wang (1966) some of the factors behind the outbreak of the epidemic were: high rainfall, abnormal high atmospheric temperature and relative humidity. The pattern of rainfall distribution favored for the vector breeding together with low level of immunity in the highland population. However, he did not mention any other social, economic and political factors which might contribute to this devastating epidemic.

In 1958 there was a great famine in the northern part of Ethiopia. The Tigray famine of the same year was also "a very devastating famine" (Wolde-Mariam 1966). Based on this mortality rate, among the population of Tigray (1,961,000 in 1958) about 397,000 people died (Wolde-Mariam 1966).This famine might have some relationship with the malaria epidemic which occurred in the same year, since Tigray was among those parts of the country where the epidemic occurred. World Food and Agriculture Organization (FAO), argues that malaria is a cause of famine (Knell 1991). When the agricultural communities are attacked by epidemics, a large part of the work force will be off from their work because of illness. A majority of the family members of the farmers will also be ill or busy with helping sick individuals. Even the farmers after recovering from the disease they lost their strength so that they could not be active in the production process. Chand (1957) described reductions in the agricultural crops, which is induced by shortage of labour, due to malaria, as follows:

Malaria being a predominantly rural disease, agricultural economy is therefore primarily affected by it. As sowing, planting, and harvesting are particular seasonal activities only, illness during this period will certainly adversely affect the yield from the land, as is the case in this country. The peak incidence of morbidity coincides with the harvest. There are vast areas of arable lands available in this country but malaria is an important cause of abstainism and labor shortage.

There have also been malaria epidemics in the country after the establishment of Malaria Eradication Services in Ethiopia. According to the Federal Democratic Republic of Ethiopia Ministry of Health (2004), these epidemics occurred at intervals of approximately 5 to 8 years. However, particularly, in recent years, it is evident that major malaria epidemics in Ethiopia have occurred within two and even one year intervals.

Some of the major epidemics that occurred since the establishment of the Malaria Eradication Program in 1960s could be mentioned. In 1964, there were malaria epidemics in Gonder. Mengistu (1979) stated that in this epidemic there were 100,000 malaria cases out of which 5,000 to 7,000 died. In 1992 malaria epidemic was limited to the Rift valley part of the Southern Ethiopia region. In 7 localities, out of a total population of 13,000, the number mortality reported was 759. At that time, 70,000 people were at risk in the whole region (WHO 1997).

The 1994 epidemic, which was mainly dominated by *falciparum* infection, occurred together with drought and famine. The epidemic attacked about half a million people in different parts of the country in different seasons. In Southern Ethiopia it occurred from February through June. The main reason for the occurrence of the epidemic was "*abnormally extended dry season which created favorable mosquito breeding places in river beds*" (FDROEMOH 1997). But in other parts of the country, particularly in the Tigray and the Amhara -National Regional states, and in the central part of the Rift valley, the epidemics occurred during the main malaria transmission season, i.e., just after the summer rainfall season between September and November.

In 1995, after the small rain season of January and February, epidemics occurred in Bahirdar and Jimma towns. In Bahidar, out of 11,588 febrile patients examined, 5,944 were malaria cases. At the same time, as a result of abnormal high rainfall which prevailed during the rainy season, large-scale epidemics occurred in Oromia, Amhara and Southern Ethiopia region (FDROEMOH 1997).

According to The FDROEMOH, a large-scale and severe malaria epidemic occurred in most highlands as well as lowland areas in the country in 1998. In 2002, severe and widespread outbreaks of malaria occurred in Amhara and SNNPR states which ended up in large-scale epidemics in 2003. In 2003, widespread epidemic malaria, which was similar to the 1958 and 1998, unusually occurred in highland and highland fringe areas (up to 2500 m) between the months of April and December.

4.2 Vector and Plasmodium species

4.2.1 Vector species and their distribution

In Ethiopia, the identification of the *Anopheles* species and their distribution was carried out for the first time in a few accessible areas by the Italian and British malariologists in the 1930s and 1940s. Among others, Corradetti, Gasperini, Brambilla, Giaquinto-Mira, and Mara studied the most important vectors of malaria and described new species. The National Malaria Control Program supported their findings by collecting data from large parts of the country, from which the previous malariologists had not carried out investigations (Schaller 1972, Gebre-Mariam et al. 1988).

There are many species of *Anopheles* fauna found in Ethiopia. According to Gebre-Mariam et al. (1988) there are 42 species of *Anopheles*, however, "small proportion of them are important as vectors" (FDROEMOH 1997). These are *Anopheles arabiensis*, *Anopheles funestus, Anopheles pharoensis* and *Anopheles nili.* In addition to this, *Anopheles coustaini, Anopheles pauraludis*, *Anopheles ziemanni* and *Anopheles d` thalia* have been recorded to possess vector capacity (Gebre-Mariam et al.1988, Tulu 1993, FDROEMOH 1997).

1. Anopheles arabiensis (Anopheles gambiae)

This is considered as a major malaria vector and is widely distributed. It breeds in small, temporary, sunlight pools and become abundant at the beginning and end of the big rainfalls. It is found in both lowland areas as well as in the highland areas up to 2000 m above sea level. It is found in all parts of Ethiopia.

Between 1984 and 1988 outdoor and indoor resting collections were made in different parts of Ethiopia and 19,352 specimens were collected and out of which 75.5 % was *A. gambiae*. Accordingly, the feeding and resting habit of this specimen indicates that 72 % feeds outdoors and 80.3 % rests indoors.

2. Anopheles pharoensis

It is the second most frequent and widely distributed vector of malaria in Ethiopia. It breeds in large, permanent and shaded water bodies with emergent vegetation. Lake shores and irrigation canals are also favourable breeding places. The 1984-88 study shows that 18.9 % of the collected specimens were *A. pharoensis* and of which 65.1 % feed outdoors and 88.5 % rest indoors. It is found along river Baro and Awash, in Lake Tana and in the rift valley lake regions.

3. Anopheles funestus

It is the third most common vector of malaria comprising 3.2 % of all the specimens collected during the period 1984-88. It dominates in areas where malaria is endemic especially along rivers, around lakes and shaded swamps in the lowlands where altitude is between 1000 m and 1500 m. 76.2 % of the specimens collected feed outdoor and 63.5 % of them rest outdoors. This vector is found along river Baro, Lake Tana and the lake regions of Shoa and Sidamo.

4. Anopheles nili

It is the least common and more localized species and is not adequately studied except in Gambella. It is found in the south western, western and north western parts of Ethiopia along river Bilate, the Segan river valley and the Baro River.

4.2.2 Plasmodium species

All four human malaria species are found in the country.

1. Plasmodium falciparum

It is a dominant species with relative frequency of 60 % of the total malaria cases causing the most frequent and fatal episodes of malaria (FDROEMOH 1999a; 2004). It is the reason for severe and complicated malaria. The fatality rate of this species is about 10 % in hospitalized adults and around 33 % in children less than 12 years.

Although chloroquine-resistant malaria was reported earlier in Sudan and Kenya, it was in 1972 that the first chloroquine-resistance in Ethiopia was identified (Tulu 1993). During the malaria surveys made in kobo-chercher in October 1958, about 62 % of the cases were due to *P. falciparum* (Gebre-Mariam et al. 1997).

2. Plasmodium vivax

It is the second dominant species in Ethiopia accounting 40 % of the total *Plasmodium* species (FDROEMOH 1999). It is often more common than *P. falciparum,* specially during the wet seasons of March, April and May; and it is an important cause of morbidity in the country. Due to the absence of Duffy antigen in Nilotic Ethiopians, they have been found more resistant to this species than Semantic and Cushic speaking people who arrived recently to the lowlands of western Ethiopia (Gebre-Mariam et al. 1988, Tulu 1993).

3. Plasmodium malariae and Plasmodium ovale

Plasmodium malariae accounts less than 1 % of the total cases, and *Plasmodium ovale* is hardly reported. However, there is spatial variation of occurrence of the species in the country (FDROEMOH 1999). In studies conducted in 1960s by the Malaria Eradication Service, 15 % of the cases were *P. malariae* (Schaller 1972). This shows that there has been a great reduction in the occurrence of this species. Accordingly, *P. falciparum* and *P. malariae* accounted for 60 % and 15 % respectively, and *P. ovale* was not reported.

4.3 Anti-Malaria programs

4.3.1 WHO'S Anti-Malaria Programs

A. From control to eradication

In large parts of the world where malaria was occurring, the anti-malaria program was aimed at controlling the *Anopheles* mosquito rather than eradicating it. It was done by killing the mosquito's larva in their aquatic stage; it is called larva control. In addition to this, it was done by insecticide spraying in the air of bedroom and cleaning drainage facilities around settlements. However, controlling methods were economically feasible only in towns and other settlement areas with marked economic values like mining and industrial areas, and in military barracks and camps. Malaria has mainly been a rural disease, which has affected large numbers of population residing in developing countries of Latin America, Asia and Africa. The program was extremely difficult and it couldn't achieve its goal (Pampana 1969).

Muller demonstrated for the first time in 1939 how DDT was a powerful insecticide to kill mosquitoes. He showed that it killed insects without being ingested, but only being touched by the insects' limbs. In addition to this, he demonstrated that it could be lethal to insects for several months after it is sprayed on a surface. It does not cause any serious harm to human beings and other domestic animals, unless it is ingested by them (Pampana 1969).

Anopheles mosquitoes rest on the wall of houses after sucking blood from human beings. It was believed that it would be effective to use DDT or other residual insecticides like chlordane, dieldrin, hexachlorocyclohexane (HCH), on the wall of the houses. In doing so, the mosquitoes could easily absorb the insecticide within their body and die immediately. The transmission of malaria would not continue and there would be no new infection of the disease and eradication could be possible (Pampana 1969).

As a result of this discovery in the early 1950s, different malariologists believed that it would be possible to stop transmission and eradicate malaria from the world without eradicating the *Anopheles* mosquitoes. Eradicating mosquitoes is absolutely impossible and extremely difficult and costly. Moreover, if it is possible to eradicate the vectors from one country, there could be the possibility of reintroducing them from abroad.

In addition to this discovery, there were some justifications which were contributed to the substitution of malaria control programs by eradication program (Pampana 1969). The first justification was that, the main aim of the malaria control program was to reduce the disease to a status of prevalence where it would be no longer a major public health problem in a country. Those who justified the importance of eradication argued that instead of having a few malaria cases in a country it would be better to have no malaria cases at all in the world. For that reason, there should be a campaign to eradicate malaria from the whole world.

The second justification of the support for the eradication program was that because of the very efficacy of the insecticides, the control program might show great reduction of morbidity and mortality in a given country. However, since the disease would be no longer a major public threat in that particular country, the government would decide to reduce the expenses for the program. Due to this, the disease would re-emerge again and cause immense morbidity and mortality in the form of epidemics.

The third justification was if malaria had become no major health problem in the community then it would be less important to them. For this reason the population might not be interested in having their houses sprayed. This opposition of the population would interfere with the program and create problem to control the disease. Furthermore, they argued that while being exposed to insecticides year after year, the vector species might become insecticides-resistant and this would lead to new transmission of the disease among the population.

Finally, in 1954 the feasibility of eradicating malaria from the world was accepted on the 14th Pan-American Sanitary Conference and in 1955 it was confirmed by the 8th World Health Assembly in Mexico. Then the anti-malaria policy of WHO changed from control to eradication of the disease from the world (Pampana 1969).

B. From eradication to control

The WHO’S malaria eradication program, which had been launched between 1955 and 1969, was implemented by the spraying of the inside of homes with residual insecticides. After its implementation in different parts of the world, it was shown that there had been success and failures in the eradication of the disease. The program was successful in large areas of North America, Southern Europe, Australia, the former USSR and Latin America.

For instance, without eradicating the *Anopheles* mosquito, eradication of malaria had been achieved in the USA and Puerto Rico. In Egypt malaria has been endemic since ancient history. The country seems successful in reducing the problem of malaria after implementing the malaria eradication campaign. In 1942 there was a sever epidemic of *P. falciparum* malaria in the southern part due to the invasion of *Anopheles gambiae*. But because of strong eradication program, *Anopheles gambiae* was declared eradicated from the country. During 1952-1962, the prevalence of malaria was about 20 % per year. In 1970 out of one million examined samples, the prevalence rate was only 1 % (WHO 1998).

India launched its National malaria Eradication program in 1953. Before this program malaria was the single most important disease resulting in 75 million cases and 800,000 deaths per year. When epidemic occurred, these numbers increased too much higher numbers. The malaria control program was redesigned in 1958. It was possible to reduce the number of malaria cases to 100,000 per year in 1960 and this number reduced to 8,000 in 1964 (Gish 1992, WHO 1998).

In spite of these successes in different parts of the world, in Africa south of Sahara no progress was reported at all due to insufficient efforts made to eradicate the disease. Despite its achievements in other parts of the world, there has also been re-emergence of the disease due to many factors. For instance, in India the number of malaria cases reported was 6.8 million in 1976 (WHO 1998). Even in some countries during the eradication campaign in the 1960s, there had been an absolute increase in the number of reported cases. For example, according to WHO's statement there were still 150 million cases of malaria in the world (Stamp 1964).

The failure was due to different reasons. These include vector resistance to insecticides, parasite resistance to chloroquine, and inadequate application of eradication techniques (Gish 1992). Shortage of experienced professional and field personnel, loss of "will" and related decline of financial support by donor agencies. Because of all these factors the eradication program failed and WHO's World Health Assembly decided to change the global malaria eradication program into control program in 1969.

4.3.2 Malaria Eradication Program & Malaria Control Service in Ethiopia

Based on the pilot malaria projects, which were undertaken by the USAID during 1956, 1957 and 1958 at Dembia piain (Gonder), Gambella, and Kobo chercher (Wollo) respectively, the following conclusions were made. The peak transmission of malaria was during September through December. It could be possible to interrupt malaria transmission using residual indoor insecticide spraying (Chand 1965, Bamazai 1969).

Malaria endemicity was directly proportional to the proximity of villages to the *Anopheles* mosquito breeding area. The country was vulnerable to regional epidemics of malaria time to time. As a result of this, Malaria Eradication Training Centre was established at Nazareth (90 km from Addis Ababa) to train sub-professional staff (Chand 1965, Bamazai 1969). Under the plan of this eradication program "malaria was eradicated from Ethiopia by 1980" (Gish 1992).

When the program started financial, material and technical assistance was provided by the USAID, and this support continued until 1963. Then the Ethiopian government covered all costs. However, the USAID continued providing advisory personnel oversee commodities through direct grant assistance until 1967. Then from 1967, onward 94 % had become loans, and only 6 % remained grants. WHO also participated in the program by supplying materials and advisory training staff and fellowships (Bamazai 1969, Gish 1992).

At the beginning of 1960s, Ethiopia was the only African country that had formally started malaria eradication program at the national level. Instead of the African Regional Office (AFRO), Ethiopia was the member of the Eastern Mediterranean Regional Office (EMRO). While EMRO joined the WHO's malaria eradication program, AFRO did not. The program was planned to launch by dividing the country into 4 areas (Bamazi 1969). The areas were (Fig. 4.1):

1. Area A- Tigray, Gonder, Eastern Wollo, Northern Harar, Eastern Shoa, and Northern Arsi.
2. Area B- Gojam, Western Wollo, Western Shoa, Northern Wellega, Northern Keffa and Eastern Illubabor.
3. Area C- South western Wellega, Western Illubabor, Southern Keffa, Gamu-Gofa and Western Sidamo.
4. Area D- Southern Harar, Southern Arsi, Bale and Eastern Sidamo.

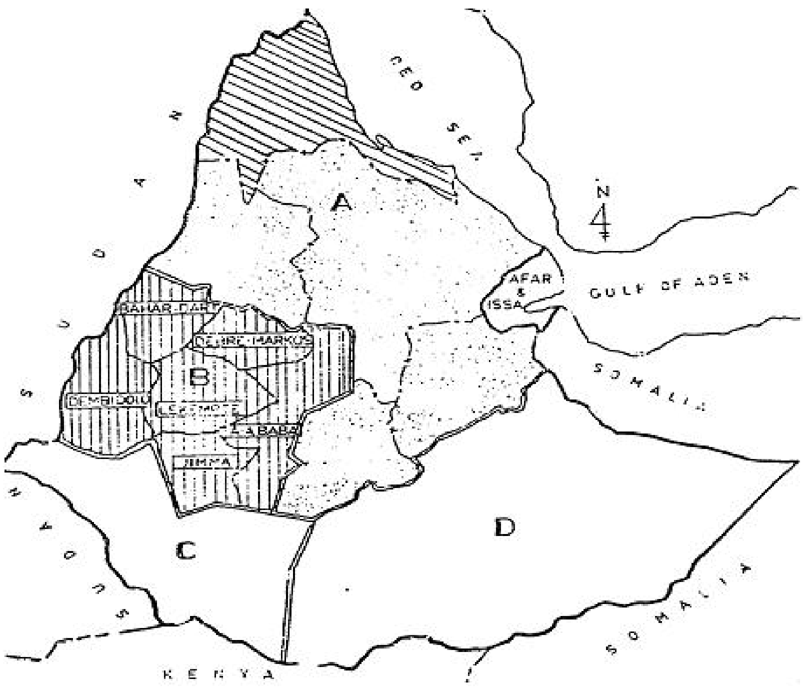

Figure 4.1 Plan of malaria eradication program (source: Mekuria and Girma 1970)

1.The preparatory phase- according to the plan it would take two years. In 1959, this phase was started in area A and continued until 1965. In area B it was in 1967 that the first major action to launch a full-scale attack on malaria was taken by initiating this phase. However, in area C it began in late 1968 and until 1971 it had not been started in area D.

2. The attack phase- the phase was supposed to take four years. This was a period during which spraying of insecticide at regular intervals would be carried out on each structure used by *Anopheles* as a resting place. In area A it began in March 1966.

3. The consolidation phase- it was supposed to follow the attack phase. During this phase there was plan to continue the spraying campaign and to make every effort to detect transmission and to eliminate it. Preventing action against re-importation of malaria and verification as whether eradication had been achieved were major measures included in this phase.

4. The maintenance phase- this phase had no time limit. During this phase responsibility for the detection of new transmission and cases of malaria would be transferred to the Public Health Services. The target date for attaining the maintenance phase in area A was 1973. According to the program this phase should have been reached by 1973 for the whole country and malaria was to be eradicated from Ethiopia by 1980. However, without achieving its goal the anti-malaria program of Ethiopia changed from malaria eradication program to malaria control service in 1971. Even after the control program started, the situation had not been changed in the country.

In 1976, after sixteen years of the implementation of the program, the EMRO/WHO Regional Malaria Advisor and the Regional Entomologists stated that, “the anti-malaria program has not brought about definite improvement in the pre-operational epidemiological situation” (Gish 1992). Inspite of this fact, the Ministry of Public Health announced that, following the introduction of the anti-malaria program good progress was made towards the reduction of malaria. The anti-malaria program had a profound positive impact on the health of the population, and on the economic development of the country.

However, Gish (1972) criticized both the anti-malaria programs, i.e., the Malaria Eradication and Control programs. According to him until 1976, the programs could not fulfil their objectives. The basic justifications for the campaign were not fulfilled. Interruption of transmission was not accomplished, and there was little evidence that the campaign had successfully facilitated the opening of new lands. Despite the failures of the program, the EMRO/WHO experts recommended the continuation of separate anti-malaria organization in the country.

However, the malaria review team of WHO clearly expressed in 1977 that, the separate anti-malaria program should not be continued. Besides, they recommended the integration of the program into the general health system. The integration would not be successful unless the budgetary, staff, and administration of the malaria eradication service would merge with the general health system. Hence, in 1977 not only the malaria eradication service but also other specialized health programs were integrated into the general health system (Gish 1992).

Currently the malaria eradication service of Ethiopia is organized vertically under the Ministry of Health. Since July 1993, i.e., after the Derg regime was replaced by the EPDRF, it has been decentralized following International Monetory Fund (IMF) prescription of decentralization. Hence, recently the regional malaria control office is not accountable to the Ministry of Health but the Regional Health Offices (FDROEMOH 1997).

5. RESEARCH METHODOLOGY

This study was done in Ethiopia in Awassa and Hossana area between June 15 and August 15, 2006, and between January 15 and June 15, 2007. The selected areas have been chosen for the study because of both human and physical environment that they have; moreover, both areas are malaria endemic.

5.1 Method of Data Collection

The collection method consisted of sampling methods for both quantitative and qualitative data. Random sampling was employed to select the samples from the population. The base for selection of the samples was settlement pattern. In Awassa randomly five households were selected from each of the fourteen villages (N = 70) and in Hossana randomly ten households were chosen from each of the seven villages (N = 70). The selection method was done from the list of the households that are found in each village. This helped to select different individuals that have different birthplace, educational background, occupation, income and ethnic group. Then, the same questionnaire was administered to the household heads in both places (Annexes).

The data collected during the fieldwork consisted of both primary and secondary sources.
The primary data- consisted of information from questionnaires, interview, discussion with selected groups of individuals, photographs and field observations.
The secondary data- consisted of library materials, published and unpublished thesis, hospital reports, and different internet sources.

A questionnaire (Annex es) was prepared for households with two different sections. The first section deals with the socio-economic and demographic background of the household heads and the family members. This has cross-sectional data regarding the household heads such as age, sex, place of birth, educational level, occupation, place of work, income, etc. The second section deals with malaria and environment. This includes the number of malaria-infected individuals in the household, major physical, economic and social factors that are responsible for the occurrence of malaria in both Awassa and

Hossana.

The second type of questionnaire was prepared for health personnel. This questionnaire includes question related to the situation of malaria in Awassa and Hossana, and different problems encountered to control malaria in both places. This questionnaire was administered to different health assistants, nurses, health officers and doctors in both places.

To administer the questionnaire to the households, two enumerators were involved during the data collection, in addition to myself. Both have good educational background with matured personality. The first one is a BSc graduate from Addis Ababa University faculty of science, and the second one is my lovely wife who graduates from Adama University faculty of Technology (BEd). The enumerators took both practical and theoretical training from the researcher to administer the questionnaire.

I conducted unstructured and structured interview with both Awassa and Hossana Public Health department heads, malaria experts from the Federal Ministry of Health, and the World Health Organization of Ethiopia.

5.2 Data Processing and Statistical Analysis

The collected primary and secondary data were entered into Analyse-it for Microsoft Excel software program and different statistical methods were used. Before using the statistical tests, the following points were considered (O'Brien 1992):
The research question – depending on the research question different statistical methods were used for prediction, measuring association and comparing differences.
The nature of the data – statistical tests were selected depending upon whether the data was interval, ordinal or nominal[θ]. In addition to this, depending upon the number of

[θ] Regarding nominal data, their information could not be manipulated mathematically, the only possible thing that could be done is equivalence comparison (O'Brien 1992).

independent variables, bivariate and multivariate statistics were used. To assess the presence and/or the strength of association the following statistical tests were used:

I. The Pearson Product Moment Correlation Coefficient (r) – It is a parametric[Ψ] measure of association between two continuous variables. The formula used is:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})}\sqrt{\sum(y-\bar{y})}} \tag{5.1}$$

Where,

r = the correlation coefficient

X = the individual observed values of X variables

$\bar{X}$ = mean value of X

Y= the individual observed values of Y variables

$\bar{Y}$ = mean value of Y

The value of r ranges from -1 to 1, which indicates a perfect negative and perfect positive relationship. Zero indicates that the two variables are not linearly associated.
In this research, r is calculated to see the correlation between family size in the households and number of malaria infected individuals, and income of the households and number of malaria-infected individuals.

II. An ***F-test***- is any statistical test in which the test statistic has an F-distribution if the null hypothesis is true. The name was coined by George W. Snedecor, in honour of Sir Ronald A. Fisher (Bryman and Cramer 1996).

[Ψ] Parametric techniques may only be used with continuous scale (O'Brien 1992).

III. Chi-square (χ^2) – it is a non-parametric* measure of association between qualitative variables. It is mainly used to describe relationships in contingency tables of two or more categorical variables. It allows ascertaining the probability that the observed relationship between two variables may have arisen by chance or not (Bryman and Cramer 1996). To compute chi-square test, the expected and the observed values should be prepared based on the null hypothesis (H_o) of independence. If the two variables are independent, then the observed and expected patterns should be similar, i.e., chi-square is equal to zero; otherwise they are dependent. When there is a perfect relationship, the computed chi-square value would be maximum (Mark 1996). The formula for chi-square test is:

$$X^2 = \sum \frac{(O - E)2}{E} \qquad (5.2)$$

Where,

X^2 = the calculated value of chi-square

O = the observed data value

E = the expected value under the hypothesis of independence

Unlike F test, the degrees of freedom for chi-square are not dependent on the number of observations, they are rather dependent on the number of rows and columns in the cross break and it is computed as (Mark 1996):

$$DF = (r - 1)(c - 1) \qquad (5.3)$$

Where, r = the number of rows, and c = number of columns.

However, the chi-square test is not always suitable as a measure of association, because it is affected by the total frequency. Therefore, it could be impossible to use it when 20% of the expected cell frequencies are less than 5. In this case Phi Coefficient Correlation and Cramer's Coefficient Correlation are used (O'Brien 1992, Bryman and Cramer 1996). Chi-square is computed to see whether there is association between the following variables or not. These are: educational level of the householders and insecticide use;

* Non Parametric- techniques may be used regardless of scale (O'Brien 1992).

educational level of the householders and toilet use; educational level of the workers and malaria infection (of the workers); and place of work and educational level of the workers.

IV. Phi Coefficient Correlation – This is used to measure strength of association between 2 x 2 contingency (each variable with two categories) and when it is difficult to compute chi-square. The formula is:

$$\Phi = \sqrt{\frac{X^2}{N}} \qquad (5.4)$$

Where,

Φ = the value of phi coefficient correlation,

N = number of cases, and

X^2 = the calculated value of chi-square

It is used to compute association between place of work and malaria infected workers.

5.2.1 Measure of prediction

Simple Linear Regression – is used for modeling dependency relationship between a continuous response variable and one or more explanatory variables (O'Brien 1992). The formula is:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots \beta_n X_n + \varepsilon \qquad (5.6)$$

Where,

α = the intercept with y- axis

Y = the dependent variables

X = independent variables

β = the rate at which changes in values of X affect the value of Y

n = the number of independent variables

ε = the residual or error

In this equation the square of coefficient correlation (r^2) indicates how well the model

implied by the regression equation fits the data (Bryman and Cramer 1996).
The square of *r* is conventionally used as a measure of the association between *X* and *Y*. For example, if the coefficient is 0.90, then 81% of the variance of *Y* can be "accounted for" by changes in *X* and the linear relationship between *X* and *Y*. In this research, this equation is used to predict monthly malaria cases in Awassa and Hossana. Independent variables used are average temperature, mean monthly rainfall, mean monthly evaporation, relative humidity and population. Extreme values (outliners) from the dependent and independent variables are removed.

5.2.2 Comparing Differences

I. Independent samples t-test – it is used to ascertain the significant of difference between two means. The null hypothesis is: there is no significance difference between the means of the two samples.

The formula for t-test is:

$$t = \frac{\overline{X_1} - \overline{X_2}}{SE} \qquad (5.7)$$

Where,

$\overline{X_1}$ and $\overline{X_2}$ are the sample means of the two groups

SE = standard error

The result is given together with the 95% confidence interval of the difference for both equal variances assumed and equal variance not assumed situations. To select which situation should be used, it is necessary to determine the homogeneity of variance from the *Levene's Test for Equality of Variances*. Provided the test is not significant ($p > 0.05$), the variances can be assumed to be homogenous and the equal variances line of values for the t-test can be used. Otherwise, the homogeneity of variance assumption has been violated and the t-test based on equal variance should be replaced by equal variance not assumed estimates (Kinnear and Gray 1999). The degrees of freedom of the distribution depend upon the size of the samples.

This test is employed to the difference in the mean number of malaria infected individuals in the households that use toilet and those households that use the forest for defecation. It is also used to see the difference in the mean number of malaria infected individuals in the households with drainage and without drainage.

II. Analysis of Variance (ANOVA) - one-way ANOVA is a more powerful technique than the Pearson's chi-square (Walford 1995). Like the t-test, it tests the H_o hypothesis of no difference between the mean value of three or more samples (Kinnear and Gray 1999). The F test is computed by the following formula (Mark 1996):

$$F = MS_{bg}/MS_{wg} \quad (5.8)$$

Where,

MS_{bg} = Variance between-groups

MS_{wg} = Variance within-groups.

A large F test statistics, i.e., statistically significant difference, occurs when the between-groups differences are larger relative to the within-groups differences. Therefore, there is statistically significant difference if the differences between means are large and the variance within each group is small.

In this research paper, to test the mean differences between three categories of a variable, one way ANOVA is employed. Besides, the post hoc test is given to make *pair wise multiple comparisons* and determine which means differ. These testes are employed for educational level of the householders, and mean number of malaria infected individuals. It is also employed for educational level of the householders and family size, educational level of the householders and mean income of the household, village and mean number of malaria infected individuals, family size and mean number of malaria infected individuals; and village and mean number of family size.

5.3 Main Variables in the Statistical Analysis

To employ the above statistical methods that are applicable for categorical data, all variables are coded as categorical. However, some continuous data, for example number of malaria infected individuals and family size are treated as they are (O'Brien 1992). The following variables are used.

● *Village/Town/* (Nominal scale) – Village is categorized into number of kebeles[♦]. These villages are different in terms of the quality of houses, their relative distance from the open water surface area, and the status of individuals that live in the houses. In all kebeles the qualities of houses are mixed, i.e., from high to low quality and different people with different educational background (higher class, middle class and lower class people) live in the houses. The houses occupied by higher class people labeled as variable 0. The houses occupied by middle class labeled as 1, and those occupied by lower class is labeled as 2.

● *Education* (The type of data is ordinal) – Information gathered from the study area shows that there was variation in educational level of the householders. It is categorized into three levels. The first level is low level of education that includes those illiterate individuals, those who can read and write and those individuals that attended elementary education. This level is labeled as 1. Those householders that graduated from secondary schools are categorized under the middle level and number 2 is assigned. The high level of education includes those individuals that have attended higher education in different colleges and universities, and number 3 is assigned for it.

● *Place of work* (nominal) – The workers in Awassa and Hossana are involved in indoors and outdoors work. A variable 0 is given for indoor workers and outdoors workers are labeled as 1.

● *Yearly income* (categorical) – It is categorized into five categories. These are those

[♦] A kebele is the smallest administrative unit of Ethiopia similar to ward, a neighbourhood or a localized and delimited group of people (http://en.wikipedia.org/wiki/Kebele retrieved on 31, October 2007).

household that have annual income below $466, from $467 to $975, from $976 to $1266, from $1267 to $2868 and above $2868[†].These are labeled as 1, 2, 3, 4 and 5 respectively.

● *Family size* (continuous) – Number of individuals in the household.

● *Place of birth of the workers* (Nominal) – A variable 1is given for those workers who were borne in both Awassa and Hossana, and 0 is given for migrant workers.

● *Previous address* (Nominal) – The workers were asked whether they had been living in some other places than Awassa and Hossana . A variable 1 is assigned for those who have only been living in Awassa and Hossana, and 0 is given for workers who had been out of Awassa and Hossana.

● *The use of spray* (Nominal) – A variable 1 is given for households that use insecticide spray, otherwise 0.

● *Availability of drainage* (Nominal) – A variable 1 is given for households that have drainage, otherwise 0.

● *Are you infected with malaria*? (Nominal) – The household heads were asked whether they were infected with malaria or not. A variable 1 is given for infected workers and 0 is given for workers that have never been infected with malaria.

● *Does malaria recurs frequently*? (Nominal) – The workers were also asked whether malaria frequently recurs or not. A variable 1 is given for those workers responded yes and 0 for no.

● *How frequently does it recur*? (Continuous) – The workers were asked about the frequency of recurrence per year.

● *Number of infected individuals* (Continuous) – Number of infected individuals in the household.

● Do you use net? (Nominal) – A variable 1 is given for households that use net, otherwise 0.

5.4 Methodological Problems

5.4.1 During Data collection

[†] During the field work. $1 was equivalent to 8.7 Ethiopian Birr.

The following are the major problems which were encountered during the fieldwork. First and for most, offices are not cooperative to give all needed information. Besides, during the first few days of the fieldwork I myself was sick. Therefore, the remaining working days were very challenging and it was very difficult to manage the data collection process within all that condition.

Different bureaucratic processes were source of challenge to get permission to receive information that I needed during the fieldwork. In some places, due to different reasons individuals that were in charge of some offices were not willing to give me information. In addition to this, it was very difficult to get malaria experts in both places. This is because the malaria control office was not organized properly. The existing statistical data were also not organized in desired manner. Because of suspicion, some respondents were reluctant or afraid to give the information we needed. Others were very tired of responding to different items of the questionnaires. Despite their reluctance, an attempt was made to collect the required information. I also faced a great problem to take my camera with me to the field site. Let alone taking photographs, it was strictly prohibited for strangers to take a camera with them. Even if, after I got permission, it was difficult to take it with me while I was administering the questionnaire and the interview. Accordingly, the chance of taking photographs of interesting events related to the study was lost. However, some of the photographs are included.

5.4.2 During the Analysis

The attempt to predict the number of individuals in the household using multivariate linear regression model has not been successful because of mixture of measurements of scale in the independent variables. For example, income and family size are continuous data, village is a nominal data; and education is ordinal data. Therefore, prediction at the household level is ignored in this research paper and instead I, the researcher, sticks to using the other statistical methods mentioned above.

6. The Geography of the Study Areas

6.1 Physical Geography

Awassa is located in the rift valley regions between 4^0 and 7^0 North latitudes and between 7^0 04' and 38^0 31' East Longitude (Awassa city government 2007). It is found in the Rift valley region in SNNPRS (Fig. 6.1). The town of Awassa, the regional capital of the Southern Regional State, is located right on the eastern shore of the Lake Awassa. Oromia borders it to the north, Sidamo villages to the west and south. It is about 275 km far from Addis Ababa, the capital city of Ethiopia. One of the most popular towns of the country, i.e. Shashemene is found 25 km east of it. The total area of Awassa is about 1628.04 km^2 (Awassa city government 2007).

About 99 % of the total area is flat. The average elevation of Awassa is about 1750 m above sea level. Based on the traditional agro ecological zone, it is classified under the warm plateaus and plains/ temperate zone (woyna dega). Recently the weather condition is changing due to different regional human activities; like, deforestation, movement of people from rural area to the city, and cutting trees for different constructional purpose (Biru, A. 2007, Per. com)

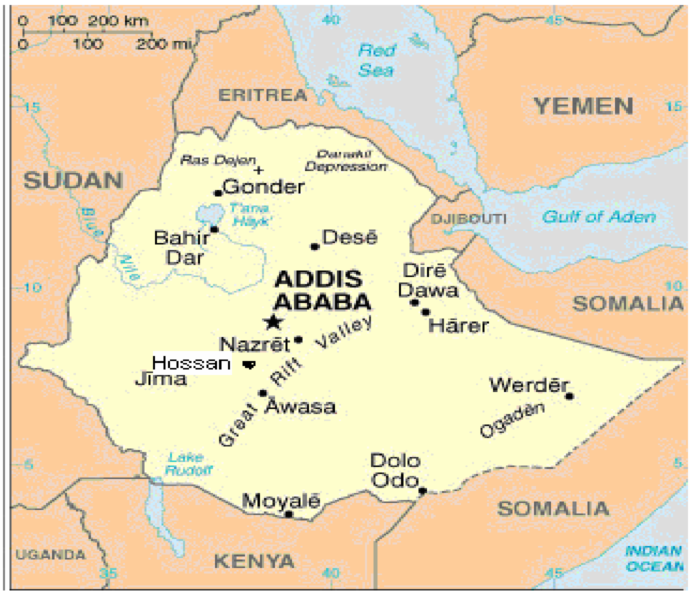

Figure 6.1 Awassa and Hossana town (Source: Remodified from World Fact book)

It was difficult to get the temperature data for a period of time during the field study. But according to US Department of Energy weather data 2006, yearly average temperature was about 20 ^{o}C. The highest temperature is recorded in September (32.2 ^{0}C), and the lowest in December (2.8 ^{o}C). The maximum mean daily temperature is 21.4 ^{0}C and the minimum mean temperature is about 18.6 ^{0}C (US Department of Energy 2006). Based on figures from 1972 – 2001, the total annual rainfall is about 1558 mm (Belehu 2003). Like most central parts of the country, the largest rainfall comes during the main summer rainfall season. There are also small rainfalls that come between March and April. The area is drained by Awassa Lake, and river of Black Water (Tikur wuha). Sandy brown soil dominates the Awassa area.

Hossana is located in the SNNPRS, which is capital of former Kembata and Haddiya Awraja. Now it is the capital of Haddiya zone as well as Lemo woreda. It is located 232 km Southwest of Addis Ababa via Alemgena- Butajira – Sodo road (Fig. 6.2). The town is located at 7^{0} 33' north latitudes and 37^{0} 51' 06.67'' east longitude (Fig. 6.1).

Peasant associations namely Ambicho and Kalisha bound Hossana in the north, Lereba, Jewe and Hyse in the south, Ambicho again in the east and Gora, Bobicho and Allela in the west. The total area of Hossana is about 23 km^2 of which the built up area is about 6.25 km^2 (Hossana municipality 1998). The average elevation of Hossana is about 2276 m above sea level. In terms of traditional classification based on altitude and temperature, Hossana town is found in the warm plateaus and plains/ temperate zone (Woyna Dega).

Climate has a great influence on human activities and life in many ways. Therefore, it is probably the most important factor in socio-economic development. Based on the data collected for the last 28 years at Hossana weather station (1972 to 2000), the mean maximum annual temperature of Hossana was 22.54 ^{0}C. The mean minimum annual temperature was 10.35 ^{0}C. Hossana received seasonal rainfall ranging between 469.98

and 156.66 mm in summer season from June to August (Yansiso 2003)[⁎]. Hossana gets its maximum rainfall in summer as most Ethiopian high land areas. There are also small rainfalls during March and September. June, July and August being the rainiest months, where as November, December, January and February are the driest months.

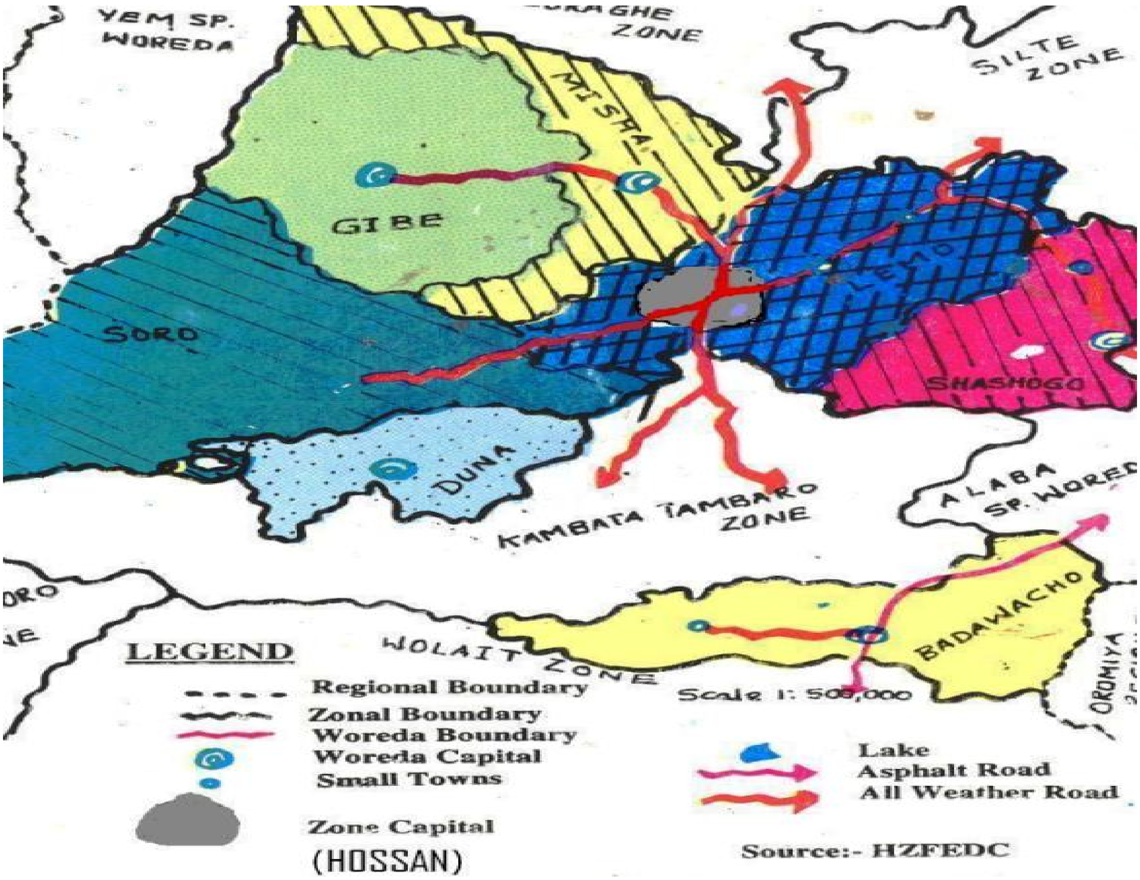

Figure 6.2 Hossana town (source: Haddiya zone finance and economic development coordination department (HZFEDCD) 2006).

Hossana is drained by one perennial river called Batena that flows from the north to the south-eastern part of the town. Intermittent streams are Ashenda, which flows around the old market area, Abera wonz in the central east, Giorgis and Ajo river in the

⁎ The author puts too precise values.

west and Shilansha in the north. There are also water wells such as Mariam wuha, Elol Dejamach, Debritu, Keabaminch, Likeleshmichael wuha etc. Batena river was the source of drinking water for Hossana until the construction of modern pipeline water source in 1975 (Hossana municipality 1998). According to Hossana municipality (1998) report there is relatively small drainage problems in the town except for low laying new market area which faces water logging problem during rainy season.

The soils in Hossana are derived from weathered volcanic rocks. According to municipality of Hossana (1998), types of soil are closely related to altitude. The most widely distributed soil types that cover large areas in the zone are eutric nitosols and chromic luvisols (Table 6.1). They are characterized by high amount of clay. These soils are well drained. The study by the regional authority of SNNPRS together with Ministry of Agriculture, and Ethel (1994) sited in WoldeMichael (2002) indicated that luvisols, camisoles, nitosols and vertisoles are types of soils found in most of the highland areas of the SNNPRS. Regosols and camisole are mainly found in degraded areas (HZFEDCD 2006).

Table 6.1 Distribution of soil units (Source: Rewritten from Hossana municipality 1998).

Soil units	Square kilometre (Km^2)	%
Eutric nitosols	15.11	61
Chromic luvisols	5.95	23
Camisoles	2.94	11
Eutric regosols	0.70	5
Total	24.70	100

6.2 Human Geography

According to the 2005 population and housing census, the total population of Awassa was 515,898. Of this 262,991 were males and 252,907 females (Central Statistical Agency of Ethiopia 2005). Social activities and services take place in social environment.

The environment in which human being lives is divided in to two: the cultural and natural environments. Cultural environments are more or less dominated and bounded by human activities and man's culture. Therefore, these cultural traits get upper hand over natural relief. Cultural environment includes social environment in which social services and activities take place. In the social environment, health, education and other social services are categorized.

The availability of clean, plentiful and easily accessible water supply is something we all take for granted. Therefore, it is hard to imagine life when every drop of water had to be carted or carried to each household. As far water quality is concerned, generally, the groundwater is of good quality for drinking but high concentration of fluoride is observed in the groundwater of Awassa. According to Awassa children's project (retrieved on September 19, 2007), "at this time it is not safe for travellers to drink the water in Awassa".

The Awassa (Sidama zone) economy is based primarily on subsistence agriculture characterized by archaic production techniques. However, a substantial proportion of the Sidama land produces coffee *(Coffee arabica)* which is the major cash crop in the area. Other major crops produced in Sidama include enset *(Ensete ventricosum)*, wheat *(Triticum aestivum)*, oats *(Avena ludoviciana)*, maize *(Zea mays indentata)*, barley *(Hordeum vulgare subsp. Vulgare)*, sorghum *(Sorghum bicolor)*, pearl millets *(Pennisetum glaucum)*, sugar cane *(Sacchrum officiarum)*, sweet potatoes *(Impomoea batatas)*, and other cereal crops and vegetables (Megalommatis 2007). Enset is the main source of food. Apart from being the main source of food, parts of the enset tree can be used as inputs in other economic activities like construction of houses, production of containers like sacks, and for handling food items during and after preparation of food. Thus, the pattern of enset and coffee production and consumption over the years has substantially shaped the nature of the Sidama culture.

According to the 2006 population and housing census, the total population of Hossana was 54,231. Of this 26,676 were males and 27,555 females (HZFEDCD 2006) (Table 6.2). Regarding the composition of population in the town there are different ethnic groups such as Haddiya, Kembata, Guraghe, Amhara and others, of which Haddiya is the majority.

Table 6.2 Population size of Hossana in different years (Source: Centeral Statistical Agency of Ethiopia 2006)

Year	1983	1994	2000	2003	2005	2006
Male	4,980	5,410	21,164	23,072	25,246	26,676
Female	4,650	4,870	21,817	23,828	26,081	27,555
Total	9,630	10,280	42,981	46,900	51,327	54,231

Education – In Hossana there are twenty-one private kindergartens, thirty three elementary schools of which eight of them are private owned. There are nine junior schools, two senior secondary schools, one teachers training college and one technical college. In addition to these, there are four nursing schools of which three of them are private owned.

Health service – Health creates a good ground for a nation to grow economically as well as progress in culture and science. To control spread of different diseases caused by insects, impure water and poor hygiene and sanitation in the town measures are being taking place through educating and training community. This has been done through educating and training community how to take environmental sanitation by health personnel’s those can reach up to rural population. To enable the community to protect itself from diseases caused by lack of pure water and environmental sanitation, health posts are constructed in different kebeles. The staffs from these health posts educate the rural community on how to keep the environment clean and free from diseases causing insects, like malaria.

Health facilities – In Hossana there are one health station, six clinics, and one hospital. These facilities have very important roles especially in disease management, epidemic detection and control, as well as health education to clinic attendants. In particular, the health stations have higher coverage in rural areas than the other health service units.

Health Personnel – According to the 2005 Haddiya zone health desk, there were fifteen physicians, five health officers, one hundred sixty-seven nurses, thirty-seven health assistants, twenty one pharmacists, thirty sanitarians, twenty seven laboratory technicians, and four X–Ray technicians.

In Hossana the use of pipe water supply was unknown until 1975. A study was conducted on general conditions of water supply to alleviate the problems of shortage of drinking water supply in Hossana. As a result, the water supply project of Hossana was established in cooperation with the government of the federal republic of Germany (HZFEDCD 2006). By this project, a small dam was constructed in the town of Hossana in 1975 expected to be functional for about 10 years. However, both the quality and quantity of the pipe water in the studied areas have shown major problems up to now. The water supply did not solve the problem of scarcity of drinking water in the town due to the following reasons:

1. The poor quality of water as well as the small amounts of water,
2. Shortage of chemicals like aluminium sulphated lime, chlorine, hydrated lime (Calcium hypo chloride) is another problem that hinders good water quality,
3. Seasonal fluctuating water supply, and
4. Population increase.

Most of the crops in Hossana (Haddiya zone) are produced in subsistence basis for domestic consumption. About 69 % of the total land area is cultivated and used for growing different crops. Major groups produced in Hossana are serial crops. Some of the most important serial crops in agricultural field coverage and amount of yield per unit area are wheat, teff *(Eragrostis)*, enset, maize, sorghum, barley, peas *(Pisum sativum)*, beans *(Phaseolus lunatus)* etc. In addition to this serial crops, root crops, such as potato, sweat potato, oil seeds, and the pulses such as lentils *(Lens culinaris)*, soya beans *(Glycine max)* and vegetables, ethiopian cabbage (*Brassica carinata)*, red pepper and green pepper *(Ampelopsis arborea)* are produced in large amounts. Even though, the surplus product is merely for local use, coffee is produced almost in all districts (woredas) both for home use and sale (Personal observation 2006).

7. RESULTS AND DISCUSSIONS

7.1 Species of Plasmodium and Anopheles

With regard to species of *Plasmodium*, the hospital's documents reveal that *falciparum* malaria accounted for more than 75 % of total malaria cases in the last ten years, followed by *vivax* malaria. The other two species have rarely been recorded in Hossana malaria control station. *Anopheles gambiae* is the dominant vector in the areas and *Anopheles pharoensis* is recorded as the secondary vector. Another vector, which is rarely found and epidemiologically unimportant, is *Anopheles funestus*. In Awassa chloroquine resistance *falciparum* malaria is known, where as in Hossana, chloroquine resistant *falciparum* malaria and the level of the *Anopheles* susceptibility to the insecticide are not well known.

7.2 Age and Sex

It is difficult to get malaria cases data by specific age and sex group though children and pregnant women are the most vulnerable group to malaria. However, according to Health personnel in Awassa and Hossana (2007), the majority of malaria patients from 1994-1998 were in the age group between 15 and 44 and predominated by male population. This might have been associated with the place of work and the nature of work that the working age groups are involved in.

7.3 The yearly trend of malaria in Awassa and Hossana

According to Awassa malaria control and prevention office and Hossana hospital administrator (2007), the total number of malaria cases in both places have increased compared to 10-15 years ago. However, the number of malaria cases in the early 1990s was small. Nevertheless, starting at the end of 1990s, it has been increasing and has reached climax in recent years (Fig. 7.1). The main reason for the low number of malaria cases during the early 90s was, “during these times the general situation of the towns were excellent and continuous DDT spray was done throughout the year by the malaria eradication/control program” (Gish 1992). These activities combined with early diagnosis and treatment might have contributed for such small number of malaria cases in the early 90s. After 2002, the malaria cases decreased all over the country, especially in 2005/2006 due to the following reasons (Dr. Florence, F. 2007, pers.com):

- ♦Small amount of rainfall because of weather change,
- ♦Proper use of an insecticide treated net, and
- ♦Increase of health coverage in the country.

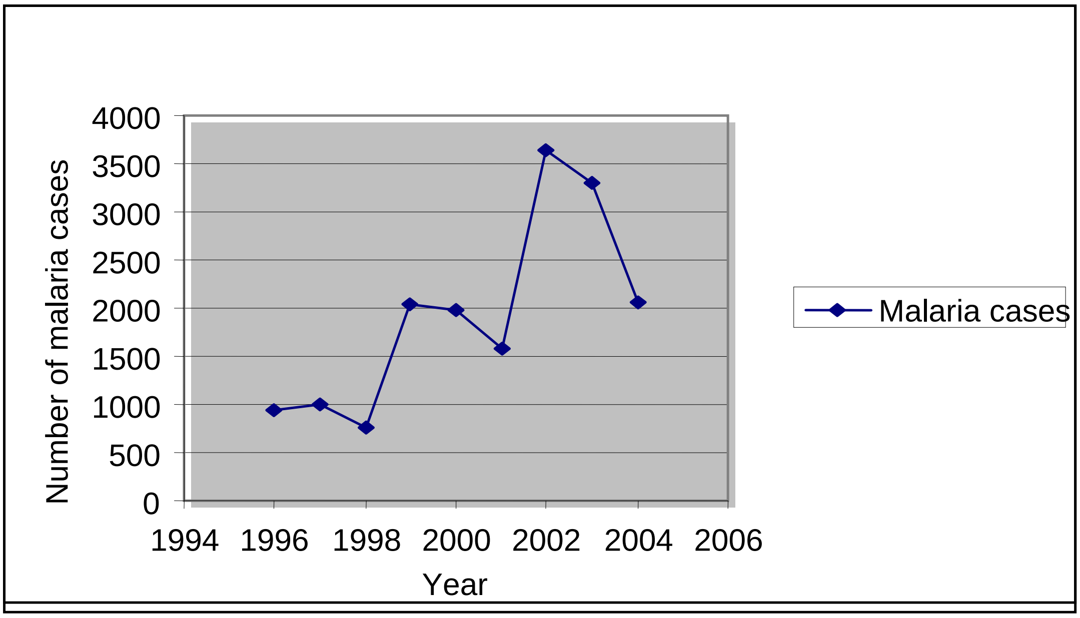

Figure 7.1 Reported malaria cases in Hossana from 1996 to 2004 (Source: Hossana Health station 2006 Pers.com)

Though the report said nothing about the main reasons to the present resurgence of the disease, some of the residents in the areas supported the above stated reason. The residents believed that the general situation of the town has been deteriorating from time to time. In addition to this, some other additional factors might have contributed for the present severe problem of malaria. According to some respondents during the fieldwork, the growth of population, the development of drug resistant strains of the parasite and the development of insecticide resistant *Anopheles* mosquitoes are major reasons.

Poverty is another contributing factor for the present malaria problem. The amount of the salary that the workers get is not enough to lead a healthy life. Besides, these workers have large families. Almost all of the family members are dependent on the amount of income that the household heads get. The information gathered during fieldwork shows that the average yearly income of the 70 households is $50,000. That means on average one member of the household gets $122 per year.

Moreover, the majority of the family members are young aged children (< 12 years) Except 12 households (17 %), all householders have at least one child. One householder, for instance has 10 children and 27 % of the householders have more than three children (Table 7.1).

Table 7.1 Total numbers of children (< 12 years) in the sampled households in Hossana 2006/2007

Number of children (< 12 years)	Number of householders	% of number of householders	Total number of children
0	12	17.1	0
1	10	14.3	10
2	14	20	28
3	15	21.4	45
4	4	5.7	16
5	5	7.1	25
6	3	4.3	18
7	2	2.9	14
8	2	2.9	16
9	2	2.9	18
10	1	1.4	10
Total	70	100	200

In Ethiopian culture, having extended family is common. Forty householders (57 %) have 69 extended families (Table 7.2). That means 40 household heads should support 69 additional individuals other than their wives and children. The household heads complain that the cost of living in Awassa and Hossana is always increasing at a fast rate. However, the growth of their salary relative to the fast growing cost of living is insignificant. Let alone to use different malaria preventive methods, they could not properly feed their family. They believe that they are mostly attacked by malaria because they and their family are malnourished. Besides, the type of work they are involved in is very tedious.

Table 7.2 Number of extended families in the sampled households in Hossana 2006/2007

Number of extended family in the household	Number of householders	% of number of householders	Total number of people in extended family
0	30	42.9	0
1	18	25.7	18
2	15	21.4	30
3	7	10	21
Total	70	100	69

Poverty is also expressed in terms of the dressing conditions of the household members. Though the culture and the physical environment affect dressing style, especially by climate, poverty also contributes to a certain extent. It was common to see children that wore shorts during the fieldwork. Most of the time, these children spend their time in mosquito breeding areas by exposing themselves to mosquitoes. The main reason for this, according to their parents, is that there are no properly protected playing grounds for their children. As I observed, children were playing different games in places where refuses were disposed and water was collected. It could even be seen that the dressing style of the householders themselves did not protect them from mosquito. The fieldwork information also suggested that deteriorating environmental sanitation is another factor that is responsible for the increasing number of malaria cases in the study area. Most of the existing sanitary facilities were not working properly.

Culture is another important factor, which contributes to the spread of malaria in Awassa as well as Hossana. Social gathering for different purposes in a crowded condition is a cultural factor that exposes individuals to malaria. In Ethiopian culture when some one dies, the mourning ceremony takes at least three days. After tents are laid outside the main house, the neighbours gather and spend three days and nights with the families, that have lost their member or relative.

According to the *Ider's*[α] rule, if not possible to spend the nights, members are supposed to spend at least three evenings in the mourning place. This gathering exposes a great deal of individuals to *Anopheles* mosquitoes, in areas where the environment is conductive for the breeding of mosquitoes. The transmission of the parasite from infected to uninfected individuals could be easy since different people are crowded in a small area.

Another cultural practice that exposes people to mosquitoes is wedding ceremony. Though its purpose is different from the mourning, the gathering takes place in the same way. Eating, drinking and singing outside the main house for more than three days depending on local conditions. It could be in the tents or simple temporary shelters that are made of sticks and leaves.

Gathering for religious purposes and outdoor night entertainment are some cultural practices that contribute to malaria. Lack of special training on malaria for medical personnel is also another cause for the spread of malaria. According to the public health department of Hossana health station, there was no special training on malaria for health personnel.

7.4 Seasonal Pattern of Malaria in Awassa and Hossana

In Awassa and Hossana, due to the presence of permanent water from Awassa Lake (Tikur Woha), and Abera wonz respectively, malaria transmission is perennial. Based on their altitude, the transmission is graded as meso and hyperdemic, since they are found in temperate zone (woyna-dega zone), i.e., 1500-2500 m above sea level. Moreover, there are some main reasons for perennial transmission of malaria. These are swampy areas

[α] Idir is a community based traditional association. It is formed by interested group of individuals and its main task is organizing funeral ceremony when death occurs and mourning the family that lost its relative. Idir is common culture in the whole Ethiopia.

and multiple pockets of water created during the rainy season.

Additionally, there are mosquito-breeding areas, which are created from leaking water taps. According to SNNPRS malaria control office, the peak transmission season in the areas occur in the months of September, October, November and December. It is also observed that high rainfall comes during June, July and August, whereas the highest malaria cases are recorded in the lowest rainfall months of November, December and January. Because of high temperature throughout the year, if water is available for breeding, then malaria can occur throughout the year.

Atmospheric humidity is also high throughout the year because of availability of permanent water bodies and high temperature, which are important factors for high evaporation. The relationship between malaria cases and evaporation shows relatively inverse relation. High evaporation occurs during high temperature period, i.e., in March, April, May and June. However, malaria cases dramatically decreases in April and May because of the reduction of surface water as the result of high evaporation. Nevertheless, in June when evaporation starts decreasing, malaria again starts increasing because of the oncoming rainfall that provides surface water for mosquito breeding. Though it starts rising in June, malaria does not reach climax until October because of high runoff that hinders the mosquitoes' egg and larva from getting matured (reach adult stage).

7.5 Malaria at Household Level

7.5.1. Education and Malaria Infection

Mead et al. (2006) assert that education is an important element of behavior that affects the health of individuals. The educational status of individuals involves their exposure to a disease and their experience that could influence in a way that improves their health status by reducing their exposure to disease causing pathogens. In addition to this, education increases protective buffering and it also induces alteration of physical environment that in turn affects the ecology of diseases.

For successful health programs education is a basic criterion; mainly health education is needed to achieve better health status of the community (Hurskainen 1994). However, in developing countries health education is not so expanded into the community that the intended goal regarding better health could be achieved. The main reason for this is that, the infrastructures for communication are insufficiently developed.

Due to the difference in the traditional conceptions of health and disease from the modern one, the conception of health education varies depending on who gives it. Because of this the majority of the population in developing countries is far from education in general and health education in particular. Therefore, those infectious diseases that could easily be controlled by simple preventive mechanisms are widely spread and kill so many people. Accordingly, the negative impact of low level of education in spread of malaria might be large in countries like Ethiopia.

The educational level of the householders has association with the occurrence of malaria in the household (Table 7.3). From the 25 households that have low level educated householders, 56 (47.8 %) members of the family were infected with malaria. The 22 households that have middle level of educational background householders had 32 (27.4 %) malaria infected individuals. However, from 23 households that have higher-level educated householders, the number of individuals who were infected with malaria was 29 (24.8 %).

Table 7.3 Educational level of the householders and number of malaria infected and non-infected individuals in Awassa 2006/2007

Level of Education	Total number of households		Number of malaria infected individuals		Number of non-infected individuals	
	No	%	No	%	No	%
Low	25	35.7	56	47.8	97	33.2
Medium	22	31.4	32	27.4	86	29.5
High	23	32.9	29	24.8	109	37.3
Total	70	100	117	100	292	100

The Chi-Square test is computed using Analyse-it for Microsoft Excel software to see if there is association between educational level and number of infected individuals (Table 7.4). Thus, there is significant association between educational level and number of infected individuals ($\chi^2 = 8.81$, $P = 0.0122$)

Table 7.4 Summary of Pearson Chi-Square test of educational level of the householders and number of malaria infected and non-infected individuals in Awassa 2006/2007 (DF = Degree of Freedom, P = Significance level)

Educational Level **of householders**	Infected ind.	Non infected individuals	Total
Low	56	97	153
	(43,8)	(109,2)	
Medium	32	86	118
	(33,8)	(84,2)	
High	29	109	138
	(39,5)	(98,5)	
Total	117	292	409
Pearson's X^2 statistic	8,81		
DF	2		
p	0,0122		

This variation in the occurrence of malaria in different educational categories could occur in countries like Ethiopia, where the male householders because of cultural, social and economic influences dominate the family. The educational level of the householders plays a great role in the health of the family members by protecting or exposing them from different diseases.

Education could play a special role in malaria transmission in the study area directly or indirectly. For example by influencing the behaviour of individuals related to malaria in different ways or by influencing the income of the householders. The following factors that could affect the transmission of malaria are influenced by education directly or indirectly.

I. General Information about Malaria

The level of education of individuals may influence their consciousness about malaria and other diseases. Those individuals with high level of education could have enough information from different sources about environmental health hazards in general and malaria in particular. However, those individuals with low level of education might have limited knowledge about malaria and other diseases mainly based on traditional knowledge. Otherwise, their information from modern sources is limited. The information gathered during the survey also reveals this fact.

II. Education and Family Size

There is positive association between number of individuals in households and number of malaria-infected individuals (section 7.5.3). This information is reflected in educational categories, too. The low-level educational category had high number of malaria-infected individuals and of big family size. Therefore, it is possible to conclude that households with low-level educational background have higher number of family size than the other two categories. In addition to this, higher proportion of their family members were infected with malaria compared to the medium and high-level education categories (Table 7.5).

Table 7.5 Educational level of the householders and family size in Awassa 2006/2007

Educational level	*Number of householder*	*Mean number of family size*	*Total number of family size*	*Mean number of infected individuals*
Low	25	6.12	153	2.24
Medium	22	5.36	118	1.45
High	23	6.00	138	1.26
Total	70	5.84	409	1.67

III. Method of Malaria Control

According to gathered information during fieldwork, personal protection from malaria is highly education dependent. Most householders that had low level of education explained that they usually used traditional methods. According to one respondent, “I have never gone to work without eating my breakfast, because malaria usually attacks those individuals that are weak because of hunger”. These people believe that though the mosquito that carries the parasite of malaria could bite them, the parasite would not be developed in their body and it would not cause malaria.

Householders with low level of education are protecting themselves from being bitten by mosquitoes. They try to protect themselves from mosquitoes using different mosquito repelling leaves and smokes of different plants. The most commonly used traditional mosquito repellent smoke in the study areas are olive tree. In the night, they smoke the leaves and steam of this tree to repel or to kill indoor mosquitoes. The smoke of eucalyptus tree is also used as mosquito repellent. In most parts of Ethiopia it is used as firewood, smoke from it helps to avoid mosquitoes. The problem with using smoke is that mosquitoes can continue entering the house as the smoke gradually vanishes. Most *Anopheles* species are very active in the morning when there is no smoke in the house. Therefore, the uses of smoke as a preventive method probably have not been effective in the study areas.

The householders with high level of education, even though they sometimes use smoke as malaria prevention in addition to other methods, most of them believed that it is not an effective controlling mechanism. Hence, they use other preventive measures as main controlling mechanism and consider smoke as a supplementary method of control. Out of 70, 10 people (52.6 %) with high level of education used insecticide spraying other than DDT (Table 7.6). The medium level educated headed householders only 13.6 % of the total had used different insecticides as main malaria prevention methods. Only 17.2 % of the houses with low-level educated headed households used insecticide spray.

Table 7.6 Educational levels and Use of Insecticide Spraying (other than DDT) in Awassa 2006/2007

Educational level	Without spray		Spray other than DDT		Total	
	No of people	%	No of People	%	No of People	%
Low	24	82.8	5	17.2	29	100
Medium	19	86.4	3	13.6	22	100
High	9	47.4	10	52.6	19	100

The Chi-Square test is computed using Analyse-it for Microsoft Excel software to see if there is association between educational level and use of spray (other than DDT) (Table 7.7). Thus, there is significant association between educational level and use of spray ($\chi^2 = 9.98$, P = 0.0068).

Table 7.7 Summary of Pearson Chi-Square test of educational level and use of spray in Awassa 2006/2007 (DF = Degree of Freedom, P = Significance level)

Educational Level	Spray other than DDT	Without spray	Total
LOW	5	24	29
	(7,5)	(21,5)	
Medium	3	19	22
	(5,7)	(16,3)	
High	10	9	19
	(4,9)	(14,1)	
Total	18	52	70
Pearson's X^2 statistic	9,98		
DF	2		
p	0,0068		

In general, the use of net in the study areas was extremely limited. Only eight out of the total 70 householders (11.4 %) used impregnated bed net. However, the information collected prevails that most of the householders with bed net were found in householders with high-level education category. The use of net even in the medium level educated category is insignificant. Only two householders (10 %) had used impregnated bed net (Table 7.8). This difference in the use of bed net is statistically significant (χ^2 = 7.17, P = 0.0277) (Table 7.9).

Table 7.8 Educational levels and the use of net in Awassa 2006/2007

Educational level	Without net		With net		Total	
	No of People	%	No of People	%	No of People	%
Low	25	100	0	0	25	100
Medium	18	90	2	10	20	100
High	19	76	6	24	25	100

Table 7.9 summary of Chi-Square test of educational levels and the use of net in Awassa 2006/2007 (DF = Degree of Freedom, P = Significance level)

Education Level	With net	Without net	Total
Low	0	25	25
	(2,9)	(22,1)	
Medium	2	18	20
	(2,3)	(17,7)	
High	6	19	25
	(2,9)	(22,1)	
Total	8	62	70
Pearson's X^2 statistic	7,17		
DF	2		
p	0,0277		

IV. Education and Income

Albeit the association between income and malaria infection is very weak in the study areas, the educational level of the household heads has strong positive association with their income. 66.7 % of high-level educated householders had yearly average income above $2868 (Table 7.10). From this category, no household had income less than $976. Ten households (40 %) headed by low educational level had very low income, i.e., less than $466. Eleven householders (44 %) from this category had income between $467 and $975. Eight householders from the medium level educated headed households had income below $466, and five between $467 and $975(Table 7.10).

It is well known that different factors that play great role in malaria transmission are income dependent. For example, to use different mosquito preventive methods, the income of the household is a determining factor in addition to awareness. For those many poor workers who should feed many household members, buying insecticide spraying or impregnated net is a luxury. Therefore, the existed income difference in the different educational categories contributes to the variation of mean number of malaria-infected individuals in different educational categories.

Table 7.10 Educational level of the householders and average income of the households in Awassa 2006/2007

Educational level	Yearly average income											
	Below $466		$467 to $975		$976 to $1266		$1267 to $2868		above $2868		Total	
Low	10	(40)	11	(44)	4	(16)	0	(0)	0	(0)	25	(100)
Medium	8	(53.3)	5	(33.3)	0	(0)	2	(13.3)	0	(0)	15	(100)
High	0	(0)	0	(0)	4	(13.3)	6	(20)	20	(66.7)	30	(100)

7.5.2 Malaria and Income

Income is one of the most important variables that can explain the social status of the population. It affects the life style of the people in different ways. Health of the individuals is one aspect of life that is influenced by their income. It is normal to expect poor health condition in households that have low income and better health condition in households with high income. However, income variation does not show any significant influence on malaria infection in both Awassa and Hossana. This is because all could be equally vulnerable to the disease since the houses are crowded (Figure 7.2). Besides, most households have large number of family size and it is easy to transmit the disease.

Figure 7.2 The crowded houses in the leasehold area of Awassa are contributing for the increasing number of malaria infection 2006/07 (Photo…Ashenafi)

7.5.3 Family Size and Malaria Infection

The mean number of malaria-infected individuals in the households varies with family size (Table 7.11). The average number of malaria-infected individuals was high (0.37) in the householders that had family size above six. Householders that had less than four individuals had 0.11 infected individuals in average. However, householders that had 4 to 6 and above six family members had 0.38 and 0.37 average number of infected individuals, respectively. These mean differences are statistically significant (Table 7.11).

Table 7.11 Family size and number of malaria-infected individuals in Awassa 2006/2007

Family size	Number of individuals	Mean number of infected individuals	Number of infected individuals
1 – 3	153	0.11	17
4 – 6	138	0.38	52
Above 6	118	0.37	44
Total	409	0.28∗	113

∗ Number of infected individuals per total number of households

The Chi-Square test shows a significant association between family size and number of infected individuals ($\chi^2 = 20.7$, P = 0.0001) (Table 7.12).

Table 7.12 Summary of Pearson Chi-Square test of family size and infected individuals in Awassa 2006/2007 (DF = degree of freedom, P = significance level)

Family size	Number of people	Number of infected individuals
1 to 3	153 (133,2)	17 (36,8)
4 to 6	138 (148,9)	52 (41,1)
above 6	118 (126,9)	44 (35,1)
Total	409	113
Pearson's X^2 statistic	20,17	
DF	2	
p	0.0001	

This might be associated with high density of the population in the households, which increases the risk of high malaria infection. This is because several family members have high chance of being bitten by the same mosquito that carries *Plasmodium*. Particularly *Anopheles gambiae*, which is the most efficient vector of the malaria parasite, can attack them easily since it feeds on man frequently (Taylor-Robinson 2002). Besides its frequent feeding habit, its indoor resting habit increases the risk of all members of the family to be infected by it until it dies or leaves the room. *Anopheles* mosquito could have the meals that it needs without travelling long distances. If it bites a member of the family who has already been infected with *Plasmodium*, then it can easily transmit the parasite to other members that have not yet been infected.

7.5.4 Malaria and Environmental Sanitation

The level of sanitation plays a crucial role for the spread of waterborne, water washed and various vector borne diseases (Figure 7.3). Hence, the provision of improved sanitation and/or sewerage facilities is an important precondition for environmental health (Silfverberg 1994). In developing countries, the majority of the population does not have access to these facilities. The absence or low provision of sanitation facilities is one of the main problems in these countries. This problem is caused by poor economic performance of the people. Low use of existing sanitation facilities is another problem.

Educational level of individuals and the culture in which individuals are brought up are important factors that determine the individuals' behaviour regarding the use of the facilities. Because of lack of awareness, some people do not use the facilities properly and this provides good ground for the breeding of vectors and the transmission of other pathogens. Accordingly, all these conditions contribute to low environmental health of developing countries like Ethiopia.

Figure 7.3 Important breeding sites for *Anopheles* mosquitoes near the leasehold area in Awassa 2006/07 (Photo…Ashenafi)

7.5.4.1 Drainage and Malaria Infection

Due to low sewerage facilities in large parts of developing countries, wastewater treatment is very weak. Hence, after different household uses wastewater is removed improperly (Figure 7.4). The treatment of rainwater is also a great problem in these countries. Due to this, different infectious diseases, particularly water related diseases are common. To avoid this problem, in some areas individuals themselves prepare surface water drainage. Nevertheless, the problem is that because of unwise management of the existing drainage systems, they expose themselves to water-related diseases among which vector borne diseases are common. In Awassa and Hossana too, this problem seems common. During the fieldwork, it was common to see collected water in the unprotected drainage area that was dug to remove rainwater, and wastewater from the houses (Figure 7.5). This condition in association with the favourable temperature helps the breeding of *Anopheles* mosquitoes to increase the risk of malaria in the households.

Figure 7.4 Collected water, which is a favourable place for breeding of vector borne diseases in Hossana 2006/2007 (Photo…Ashenafi)

Figure 7.5 Due to poor treatment of rainwater and wastewater, malaria-breeding areas are created everywhere in the study area of Awassa 2006/2007
(Photo…Ashenafi)

The result of the fieldwork shows that among 70 households, 30 (42.9 %) did not have properly managed drainage system. The remaining 40 households (57.1 %) had well protected drainage. This allows continuous flows of wastewater and the breeding of mosquitoes could not be possible since the larva could be washed away easily. The numbers of malaria-infected individuals in these two different sample groups show significant differences. In those households that did not have proper drainage system, the total number of malaria infected individuals was 59 (mean number of infected individuals was 1.97). The number of infected individuals in those households with proper drainage systems was 54 (mean number of infected individuals was 1.35) (Table 7.13).

Table 7.13 Availability of drainage and malaria infected individuals in Awassa 2006/2007

Availability of drainage	Households		Malaria infected individuals		Mean number of malaria infected individuals
	Number	%	Number	%	
No	30	42.9	59	52.2	1.97
Yes	40	57.1	54	47.8	1.35
Total	70	100	113	100	1.61

Unpaired t test is computed to see if there is statistical significance between availability of drainage and malaria infection in Awassa using online calculators for scientists (http://www.graphpad.com/quickcalcs/index.cfm). It could be concluded that drainage facility plays a significant role in the spread of malaria in the study areas ($t = 21.77$, $p = 0.0021$).

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7.6 Malaria and Working Environment

7.6.1 Place of Birth and Malaria Infection

About 53 % of the people were not borne in Awassa (Table 7.14). They have migrated from other parts of the country. Out of the 37 migrant workers, 22 (59.5 %) migrated from the south central highlands of the country. Here the population density is high because of fertile soil and favourable climatic conditions, i.e., from Welayta and Kembata which are free from malaria (Awassa city government 2007).

Table 7.14 Place of birth of the workers and malaria infection in Awassa 2006/2007

Place of birth	Non – infected people		Infected People		Total people	
	Number	%	Number	%	Number	%
Not Awassa	7	100	30	47.6	37	53
Awassa	0	0	33	52.4	33	47
Total	7	100	63	100	70	100

Out of 37 migrant workers 30 (81.1 %) were infected with malaria, whereas all 33 workers that were born in Awassa were infected with malaria. This clearly indicates that those workers who were borne in Awassa did not have passive immunity or they might have lost their immunity. Out of the 30 infected migrant workers, the number of individuals who were infected with malaria in Awassa was 25 (83.3 % of the total). The rest of the workers were infected in some other places.

Usually the highland population has lower immunity to malaria than the lowland population. The main reason is that after repeated exposure to the parasite, the lowlanders develop the so-called acquired immunity. However, since most of the highland workers stayed in Awassa for a long period, they could also develop immunity after repeated exposure to the parasite. To see whether there is difference with regard to acquired immunity between the migrant and the indigenous workers in the study area, the infected individuals were asked whether malaria recurs repeatedly or not. Out of 34 workers who migrated from other places and were infected with malaria in Awassa, 20 workers said that malaria recurs frequently. This number accounts for 80 % of the total workers that said malaria recurs frequently. However, out of 17 infected individuals that were borne in Awassa, it was only 5 (29.4 %) workers that had frequent malaria recur. This accounted for 20 % of the total workers who had frequent malaria recurrence (Table 7.15).

Table 7.15 Place of birth and malaria recurrence in Awassa 2006/2007

Place of birth	Not recur		Frequently recurs		Total	
	No of people	%	No of people	%	No of people	%
Not Awassa	14	53.8	20	80	34	66.7
Awassa	12	46.2	5	20	17	33.3
Total	26	100	25	100	51	100

The workers were also asked how frequently they were attacked by malaria per year. 40 % of the workers who migrated from other places said that malaria recurred one or two times per year. The rest, 60 %, said that they were attacked by malaria three or four times per year. It is possible to see that all workers that were frequently attacked by malaria (three or four times per year) were migrant workers. However, all workers who were borne in Awassa were attacked by malaria less frequently than the immigrants (60 % of them once a year and 40 % twice a year) (Table 7.16).

Table 7.16 Place of birth and frequency of malaria recurrence per year in Awassa 2006/2007

Place of birth	1 times		2 times		3 times		4 times		Total	
	No	%	No	%	No	%	No	%	No	%
Not Awassa	2	10	6	30	4	20	8	40	20	100
Awassa	3	60	2	40	0	0	0	0	5	100
Total	5	20	8	32	4	16	8	32	25	100

7.6.2 Place of Work and Malaria Infection

Among different factors that expose individuals to mosquitoes, the most important one is their place of work. Both in Awassa and Hossana there are two quite different working places. One place of work is indoor activities where different office activities take place. The second work place is outdoor activities, i.e., most agricultural activities take place. Only 5.3 % of the outdoor workers were free from malaria, whereas 20 % of the indoor workers were free from malaria (Table 7.17).

Table 7.17 Place of work and malaria infection of the workers in Awassa 2006/2007

Place of work	Not infected individuals		Infected individuals		Total individuals	
Outdoor	2	(5.3)	36	(94.7)	38	(100)
Indoor	6	(20)	24	(80)	30	(100)
Total	8	(11.8)	60	(88.2)	68	(100)

The computed phi coefficient correlation shows statistically little or no association between working place and malaria infection ($\Phi = 0.227$, $P = 0.0611$). The main reasons seem to be that all of the people are equally vulnerable to the disease because of the spread of malaria everywhere.

8. RECOMMENDATION

To reduce the problem of malaria in the study areas, the researcher forwards the following recommendations based on the above findings:

1. The awareness of the people regarding the diseases should be developed. Since education is an important means of vehicle to transform ideas, health education should be explained in the community through formal education in the school curriculum, different media, and community based organizations.
2. The existing health care systems should be strengthened by providing manpower, equipment, drugs, capital and other necessary materials so that early diagnosis and

prompt treatment would be easy.

3. The existing sanitation facilities should be well developed. For instance:
   - the old water pipeline should be repaired or changed, so that it would be possible to avoid water leakage and in turn collection of water would not be possible;
   - those toilets that are not functional should be rehabilitated or replaced by new ones;
   - the sewerage system should be developed; and
   - rain water and waste water drainage should be cleaned.
4. The level of susceptibility of *Anopheles* mosquitoes to insecticide and *Plasmodium* to the existing drugs should be studied and then proper insecticides should be sprayed inside and outside residential houses. This also helps to identify and provide proper drugs for treatment.
5. Larvicide should be used in collected water bodies such as waste water and rain water drainage systems, and water reservoirs.
6. The use of personal protection, such as the use of impregnated bed nets should be introduced to the community. It should also be supplied to the community with prices that can be affordable to them.

REFERENCES

Books and Articles

American Public Health Association (APHA), 1995. Malaria, Control of Communicable Diseases Manual, 16th ed. An official report of the American Public Health Association, pp. 283-292

Bamazai, P. N. K. 1969. Focus on malaria eradication, The Ethiopian Herald, Addis Ababa, pp. 4

Belehu, T. 2003. Agronomical and Physiological factors affecting growth, Development and Yield of Sweet Potato in Ethiopia. Ph.D Thesis submitted to University of Pretoria

Bradley, M. 1993. Temperature is predictive of severe malaria years in Zimbabwe, Elsevier Science Ltd., Harare

Brian, M. 1989. Malaria. In Adams M. and Brian, M. eds. Clinical Tropical Diseases, 9th ed. Blackwell Scientific ed., London

Bryman, A. and Cramer, D. 1996. Quantitative Data Analysis for Social Scientists, 2nd Rev. ed. Routledge, London

Centeral Statistical Agency of Ethiopia, 1989. People and Housing Census of 1984, Addis Ababa, Ethiopia

Centeral Statistical Agency of Ethiopia, 2005. National Population and Housing Census of Ethiopia, Addis Ababa, Ethiopia

Chand, D. 1965. Malaria problem in Ethiopia, In Ethiopian Medical Journal, 4(1) pp. 27 – 39

Covell, G. 1957. Malaria in Ethiopia, In Tropical Medicine and Hygiene, 60 pp. 7 – 16

D'Arca, T., Alas Ali, A., Declich, S. and Scozzafava, G. 1992. Strategie di immunizzazione in area rurale. In: Branca, F. and D'Arca, R. eds. Salute per tutti? Esperienza da un'area rurale Africana, Franco Angeli, pp. 257-265

Desowitz, R. S. 1980. Recent Advances in Malarial Immunity, Annual Review of Medicine

Ethiopian Mapping Authority, 1988, National Atlas of Ethiopia, Addis Ababa, Ethiopia

Federal Democratic Republic of Ethiopia Ministry of Health, 1997. Malaria and Other Vector borne Diseases Control Unit, Epidemiology and AIDS Department: Guidelines and plan for epidemic forecasting, prevention, detection and control in Ethiopia, Addis Ababa

Federal Democratic Republic of Ethiopia Ministry of Health 1999. Malaria and Other Vector-borne Diseases Prevention and Control Unit: Guidelines for Malaria Epidemic Prevention and Control in Ethiopia. Disease Prevention and Control Department, Addis Ababa

Federal Democratic Republic of Ethiopia Ministry of Health, 2004. Malaria and Other Vector-borne Disease Control Unit, Epidemiology and AIDS Department: Guidelines and plan for epidemic forecasting, prevention, detection and control in Ethiopia, Addis Ababa

Fontaine, R. E., Najjar, A. E. and Prince, J. S. 1961. The 1958 malaria epidemic in Ethiopia, American Journal of Tropical Medicine and Hygiene, 10: 795-803

Gebre-Mariam N., Abdulahi, Y. and Mebrate, A. 1988. Malaria. In: Zein Z. A. and Kloos H. eds. The ecology of health and disease in Ethiopia, 1st ed. Ministry of Health, Addis Ababa, pp.136-150

Gish, O. 1992. Malaria eradication and the selective approach to health care: some lessons from Ethiopia. International Journal of Health Services, 22: 179–192

Guinovart, C., Navia, M. M., Tanner, M. and Alonso, P. L. 2006. Malaria: Burden of Disease, Bentham Science Publishers, USA

Haddiya zone finance and economic development coordination main department, 2006. Haddiya zone socio-economic profile, Hossana

Hossana municipality, (Unpublished). Regional Population Information of 1998

Hunter, J. M., Ray, L., Chu, K.Y. and Adekoi-John, E. O. 1993. Parasitic diseases in water resources development, The Need For Intersectoral negotiation, WHO, Rome, Italy

Hurskainen, A. 1994. The Neglected Education. In: Lankinen K. S., Bergström, S., Mäkelä, P. H. and Peltomaa, M. eds. Health and Disease in Developing Countries. The Macmillan Press Limited, London, U.K. pp. 59-66

Institute of Development Research (IDR), 1990. Inter Sectorial Collaboration to Improve the Health Status of Resettlers in Keffa Resettlement farms. Addis Ababa

Kello, A. B. 1992. Effect of malaria on peasant production: A case study of two Ethiopian villages. Thesis, submitted to the University of Keel in fulfilment of the requirement of the degree of Doctor of philosophy in the centre for Health Planning and Management

Kimbi, H. K., Awah, N. W., Ndamukong, K. N. J. and Mbuh, J. V. 2005. Malaria infection and its consequences in school children, East African Medical Journal, 82 (2)

Kinnear, P. R. and Gray, C. D. 1999. SPSS for window made simple, 3rd ed. University of Aberden

Kloos, H., Adugna, A. and Sahlu, E. 1988. The Physical, Biotic and Human Environment in Ethiopia; The perspective of Medical Geography: The Ecology of Health and Disease in Ethiopia, Ministry of Health, Addis Ababa

Knell, A. J. 1991. Malaria, A publication of the tropical program of the welcome trust, Oxford University Press, Oxford, New York, Tokyo

Lindsay, S. W. and Birley, M. H. 1996. Climate change and malaria transmission, Annual Tropical Medicine Parasitol, 90:573-588

Malakooti, M. A., Lindblade, K. A., Walke, E. D. R, Onapa, A. W., Katungu, J. and Wilson, M. L. 2000. Land use change alters malaria transmission parameters by modifying temperature in a highland area of Uganda, Tropical Medicine & International Health, 5(4)

Mark, R. 1996. Research made simple, A handbook for social workers, Saga Publications, London, New Delhi

McGregor, I. A. 1989. Epidemiology and Control of malaria. In: Robinson, D., Epidemiology and the community control of disease in warm climate Countries, 2nd ed. New York, pp. 413-430

Mead, P., Maclin, A., Morsi, R., Turnquest, S. and Wallace, S. 2006. Health Education and Behavior, Society for Public Health Education, San Diego, California

Megalommatis, M. S. 2007. The Independence Struggle for the Sidama Land, Awassa city government, Awassa

Mengistu, M., Maru, M. and Ahmed, Z. 1979. Malaria in Gonder, Ethiopia, 1975-1978: A review of 435 Cases with special emphasis on cerebral malaria, Ethiopian medical Journal, 17 (3): 57-62

O'Brien, P. C. 1992. Tests and Measures in the Social Sciences and Medicine, USA

Pampana, E.1969. A Textbook of Malaria Eradication 2nd ed. Oxford University Press, London

Patz, J. A., Epstein, P. R. and Burke, T. A. 1996. Global climate change and emerging infectious diseases, American medical Journal, 275 (3)

Phillips, R. S. 1983. Malaria, Studies in Biology, Edward Arnold Limited, 41 Bedford Square, London, no. 152

Pålsson, K. 1999. Ecology and control of *Anopheles* mosquitoes and human malaria in Guinea Bissau, West Africa, Uppsala universitet, Sweden

Schaller, K. F. 1972. Ethiopia: Geomedical Monograph Series, Regional studies in Geographical Medicine, Berlin, Heidelberg, New York

Shibeshi, W. 2001, Junoir Atlas for Ethiopia, Ethiopia

Silfverberg, P. 1994. Environmental Health Hazards, In: Lankinen K. S., Bergström, S., Mäkelä, P. H. and Peltomaa, M. eds. Health and Disease in Developing countries, The Macmillan Press limited, London, pp. 67-78

SMCF Ethiopia Children's Fund 2007. The population of Awassa, Awassa

Stamp, L. D. 1964. Some aspects of Medical Geography, London, Oxford University Press, New York, Toronto

Taylor-Robinson, A. W. 2002. A model of development of acquired immunity to malaria in humans living under endemic conditions, University of Leeds, UK

Teklehaimanot, A. 1986. Chloroquine-resistant *Plasmodium falciparum* malaria in Ethiopia: The Lancet, 2: 127 – 131

Tropical Diseases and Progress in International Research (TDR) 1989. Special program for Research and Training in Tropical Diseases: 1987-1988 Geneva

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

Walford, N. 1995. Geographical Data Analysis, John Wiley and Sons Ltd. New York

Wang, L. 1966. Malaria in Ethiopia, In SATACA Review, 11(2)

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

Wold-Mariam, M. 1966. "Cultural Problems of Development", A paper prepared for seminar of Ethiopian studies, Addis Ababa University, Addis Ababa

World Health Organization 1993a. A global strategy for malaria control, WHO, Geneva

World Health Organization 1993b. The Urban Crisis, Strategies for health for all in the face of rapid urbanization, Report of the technical discussions at the forty-fourth world

World Health Organization 1996a. The World Health Report 1996, Fighting Disease- Fostering Development, WHO, Geneva

World Health Organization 1996b. Controlling infectious diseases remains a global challenge, why? WHO, Geneva

World Health Organization 1997. World malaria situation in 1994, Weekly Epidemiological Record, 72: 269-276

World Health Organization 1998. World Health Report: Fifty Facts of Health. WHO, Geneva

Yansiso, Y. 2003. The Effects of Population Pressure on land utility in Sonda Peasants' Association, Soro Woreda, Hadiya zone

Yohannes, M. 1996. Characterization of the epidemiology of Urban malaria in Nazareth, Ethiopia: parasitological studies. Ethiopian Medical Journal, 34: 83-96

Zein, A. Z. and Kloos, H. 1988. The Ecology of Health and Disease in Ethiopia Ministry of Health, Addis Ababa, pp. 18-42

Zewde, B. 2002. A history of modern Ethiopia: 1855-1991, Addis Ababa, Ethiopia

Web pages

Awassa city government, 2007. Investing in Awassa. Accessed September 8, 2007. http://www.awassacity.gov.et/inve/index.htm

Awassa Children's Project, 2007. Frequently asked questions. Accessed September 19, 2007. http://www.awassachildrensproject.org/volunteer_services.asp

Belehu, T. 2003. Weather data of Awassa. Accessed September 15, 2007, http://upetd.up. ac.za/thesis/available/etd-07262004-141704/unrestricted/ 10back.pdf

Embassy of Federal Democratic Republic of Ethiopia in Sweden, 2007. Quick facts about Ethiopia. Accessed November 15, 2007, http://www.ethemb.se/ee_eth.html

Graphpad Software, 2007. Quick Calcs online calculators for scientists. Accessed December 12, 2007. http://www.graphpad.com/quickcalcs/index.cfm

Teklehaimanot, H. D., Lipsitch, M., Teklehaimanot**,** A and Schwartz, J. 2004. Weather-based prediction of *Plasmodium falciparum* malaria in epidemic-prone regions of Ethiopia I. Patterns of lagged weather effects reflect biological mechanisms, Accessed June 11, 2007 http://www.malariajournal.com/content/3/1/41

US Department of Energy, 2006. Weather Data. Accessed September 15, 2007 http://www.eere.energy.gov/buildings/energyplus/cfm/weather_data3. cfm/region=1_africa_wmo_region_1/country=ETH/name=Ethiopia

World Fact Book, 2007. Map of Ethiopia, Accessed September 8, 2007 https://www.cia.gov/library/publications/the-world-factbook/geos/et.html

World Health Organization/ CTD, 1998. Malaria prevention and control. Accessed August 25, 2007. http://www.who.int/ctd/html/malaria/html

ANNEX I

QUESTIONNAIRE FOR RESIDENTS

I. General Household Information

1. Age_______
2. Sex ☐ Male ☐ Female
3. Educational background
    - Reading and writting ☐
    - Elementary ☐
    - Secondary ☐
    - College and above ☐
4. Occupation______________________ Place of work________________________
5. Status of employment a) permanent b) seasonal
6. Monthly Average Income_______________
7. Marital status Married ☐ Single. ☐ Divorce ☐ Widow ☐ Separated ☐
8. Do you have children? Yes ☐ No ☐
9. If yes

Age	Sex		Total
	Male	Female	
Under 1			
1 to 5			
6 to 15			
16 and above			
Total			

10.Other members of the family

Age	Sex	Relation with the householder

11. Place of birth_______________
12. If your place of birth is not Awassa,
    a. Where is your previous address _____________________
    b. Why did you come to Awassa?________________________
    c. How long have you stayed in Awassa? □Less than 4 years □4 to 8 years □ 8 to 15 years □above 15 years □ the whole

II. About environment and malaria

13. Is there malaria in your previous address? Yes □ No □
14. Have you infected with malaria? Yes □ No □
15. If your answer for question no. 14 is yes
    a. Where? _________________________
    b. When? (month and year) ____________________
    c. Does it recur frequently? Yes □ No □
    d. If your answer is yes, how frequently per year?

    ____

e. Did you receive medication? Yes ☐ No ☐

f. If your answer is yes, where?

☐ From modern medical centers ☐ From traditional practitioners

g. What do you think that the main reason for your infection with Malria?

____

____

____

h. Do you think that your job contribute for malaria infection?

Yes ☐ No ☐

i. If your answer is yes, how?

____

____

____

16. Is there any member of your family who has contracted Malaria? Yes ☐ No ☐

17. If your answer is yes, how many members of your family?

Age	Sex

18. Is there any member of your family who died of malaria?

Yes □ No □

19. What measures do you take to prevent/control malaria?

- Drug □ What kind of drug?

  ____

- Unimpregnated Mosquito nets □
- Insecticide treated Mosquito nets □
- Insecticide spraying □

  Type:____

- Others □ Mention:

  ____

- None □

20. How is your method of prevention effective?

Method	Effective	Ineffective
Drug		
Unimpregnated Mosquito nets		
Insecticide treated Mosquito nets		
Insecticide spraying		
Other		

21. From which material is your house made of?

a. Wall

I. Wood □ II. Wood and mud □ □ III. Stone □

IV. Cement □ V. Bricks □ VI. Others □

b. Roof

I. Corrugated Asbestho □

II. Corrugated iron sheet □

III. others □

____

22. Does your house has

♦ Sewerage Yes □ No □

♦ Drainage Yes □ No □

23. From where do you get water? Pipe line □ River □

Pond □ Lake □ Well □

24. What are the major environmental factors for the spread of Malaria in Awassa

I. Physical environments

a.____

b. ____

c. ____

d. ____

e. ____

II. Social environments

a. ____

b. ____

c. ____

d. ____

III. Economic environments

a.____

25. Is Awassa Lake contributes for the spread of Malaria?

Yes ☐ No ☐

26 If yes how?

a. Directly

____

____

____

b. Indirectly

____

____

____

27. How do socio- economic environments affect the spread of Malaria in Awassa?

a.____

____

____

b.____

____

____

28. What measures have you noticed which have been taken to eradicate Malaria?

a. By the government

____

____

____

b. By the community

____

____

____

29. How are these measures effective to control Malaria?

____

____

____

30. In your opinion what are the main problems related to Malaria eradication?____________________________________

31. What measures should be taken to eradicate Malaria?

____

____

____

____

ANNEX II

QUESTIONAIRE FOR HEALTH PEROFESSIONAL

1. Age________
2. Sex M F
3. Place of birth______________________________
4. Qualification....a) Health assistant b) Nurse c) Health officer d) Medical Doctor
5. Position in the medical center ____
6. How long have you stayed in this area? __________________
7. Is this Health facility A) Hospital B) Health station C) Health center D) Health post

8. How do you see the problem of Malaria in this area?
   - ♦ Very serious □
   - ♦ Moderate □
   - ♦ Weak □

9. Which are the top diseases that are prevalent in this area? _______________________

10. Which species of mosquitoes are found in this area?

    ____

    ____

    ____

    Which one is dominant? ___________________________

11. Which species of plasmodium are found in this area?

    ____

    ____

    ____

    Which one is dominant? ___________________________

12. What are the main environmental factors for the problem of Malaria?
    A) Physical
    B) Social
    C) Economic

13. What impact have you noticed in the environment of Awassa in relation to Awassa Lake?

    ____

    ____

14. How do you see the trend of Malaria in Awassa because of Awassa Lake? _______________________________________

ANNEX III

INTERVIEW GUIDE FOR AWASSA HOSPITAL AUTHORITIES

1. What is your position in the hospital?

   ____

2. What is your qualification?

   ____

3. How long have you stayed in Awassa?

   ____

4. Which diseases are the most top 5 diseases that prevail in this area?

   ____

   ____

5. Which species of Mosquitoes are found in Awassa?

   ____

   ____

6. Which species of plasmodium are dominant?

   ____

7. How is the trend of Malaria in Awassa in relation to Awassa Lake?

   ____

8. What environmental changes have you noticed in Awassa because of the lake?

   ____

9. Have these changes affected the situation of Malaria in Awassa?_______

   How?____

10. What are the main environmental factors that are responsible for the occurrence of Malaria?

____

____

11. During which months (season) do you attend high number of Malaria patients?____________________________

____

12. During which months do you attend the lowest number of Malaria patients?______________________________

____

13. Do Malaria patients immediately come to your health center to get early diagnosis and treatment? __________

14. Which age groups are affected by Malaria?

____

15. Do you have enough manpower and equipment to prevent and treat Malaria?____________________________

16. Do the medical personnel in this area receive special training on Malaria?______________________________

17. What special measures do you take during peak Malaria transmission seasons?

____

____

18. What general preventive methods do you take to control Malaria? ____________________________________

____

19. What problems do your hospital has in relation to Malaria prevention and control?

____

____

____

20. When was Malaria registered in Ethiopia for the first time in? ____

21. When was Malaria registered in Awassa for the first time?

∗ N. B. - The same questionnaires were administered in Hossana also.