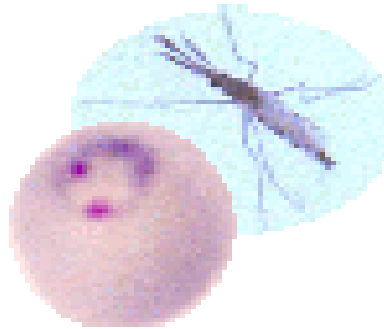




**Assessment of Malaria as a Public Health Problem
in Finchaa Sugar Factory based on
Clinical Records and Parasitological Surveys**



**A Thesis Presented to
the School of Graduate Studies
Addis Ababa University**

**In Partial Fulfillment of the Requirements for the Degree of
Master of Science in Biology (Biomedical Science)**

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**ADDIS ABABA UNIVERSITY
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1. Introduction

Health is defined as "a state of complete physical, mental and social well being and not merely the absence of disease or infirmity" (WHO, 1992). Studies showed that health problems or conditions become public health issues when four criteria are met. First, the disease burden must be high which can be experienced in terms of mortality and morbidity, quality of life, cost and hence is perceived as a threat by the public. Second, the problem is distributed unevenly affecting more certain segments of the population. Third, there must be evidence that upstream preventive strategies that target economic, political and environmental factors that affect a population's health could substantially reduce the burden of the disease; and fourth, evidence shows that such preventive strategies are not yet in place (Vinicor, 1994; Saaddine *et al.*, 2003).

Malaria is a major public health problem in the world whose transmission is influenced by several inter-linking factors like climate, environment and demography. Development projects like water resource projects and industrial undertakings in the tropics are fertile grounds for outbreaks of malaria (Gilles and Warrell, 1993). However, many water resource projects for irrigated semi-arid lands are implemented without any significant assessment of potential health impact (Alemayehu *et al.*, 1998; WHO, 2000c).

There is no documented report on the prevalence of malaria in Finchaa Sugar Factory (FSF) area, but according to local informants and records of health facilities of the area, there is a significant seasonal prevalence of malaria. For instance, in 2003 and 2004 FSF Health Center reported serious outbreaks with considerable morbidity in the area (Fig. 5). On the other hand, other studies like cross-sectional survey of helminth infections were conducted in the area with *Ascaris lumbricoides*, *Schistosoma mansoni* and hookworms being the most prevalent, reaching, on average 28%, 26% and 20%, respectively (Birrie *et al.*, 1997).

In spite of multiple external factors in FSF, such as environmental changes via agro-industrial activities and various constructions, huge population influx and other triggering

factors in addition to the existing favorable climate for the transmission, no study has so far been conducted on malaria in the area. In order to investigate the public health burden of malaria in FSF in relation to the expansion of irrigated agro-industrial sugar cane plantation, the increasing influx of migrant labor force to the area and the prevailing favorable topography and weather conditions for the transmission, this study was initiated.

1.1 The malaria parasite and vector mosquitoes

1.1.1 The malaria parasite

Malaria is a very old protozoal disease transmitted by female *Anopheles* mosquito, caused by minute parasitic protozoa of the genus *Plasmodium*, which infects human and insect hosts alternatively. In general, these plasmodia species infect reptiles, birds and mammals, several species of which have received considerable attention for their medical (e.g. *P. falciparum* and *P. vivax* in man) or veterinary (e.g. *P. gallinaceum* in chickens, *P. reichenowi* in chimpanzees, *P. knowlesi* in monkey, *P. berghie* in rodents and *P. relictum* in birds) importance (Paul *et al.*, 2003).

There are over 400 species, of which four of them occur in humans: *Plasmodium falciparum*, *P. vivax*, *P. ovale*, and *P. malariae*. Among these species of *Plasmodium*, the most damaging type of malaria is caused by *Plasmodium falciparum*, which represents a growing threat and burden to human health and welfare. *Plasmodium falciparum* is justifiably regarded as the greater menace because of the high levels of mortality with which it is associated, its widespread resistance to anti-malaria drugs, and its dominance in the world's most malarious continent, Africa (Deponete and Becker, 2004; Mayxay *et al.*, 2004).

While they all belong to the same genus, each species behaves quite differently in most aspects of their biology within the human and mosquito host. They also vary with respect

to geographic distribution. Because they require warm, humid environments for replication in the insect vector, malaria-generating species of *Plasmodium* are generally limited to tropical and sub-tropical locations. *Plasmodium falciparum* is found in most tropical regions throughout the world. Relapses cannot occur with this species. In contrast, relapses due to *P. vivax* can routinely occur due to a latency period, during which time the parasites in the infected hepatocytes remain dormant. The longevity of relapse is apparently dependent on the particular geographical region in which the organism is found. *Plasmodium vivax* is prevalent in many sub-tropical zones, but more prevalent in Asia, Oceania and Latin America than Africa. *Plasmodium ovale* is similar to *P. vivax* in its biology, but is found primarily in West Africa. *Plasmodium malariae* has a widespread distribution area but is fairly scattered within this area (Breman *et al.*, 2006).

All four species of *Plasmodium* are known to occur in Ethiopia (Krafsur and Armstrong, 1982). However, *Plasmodium falciparum* and *P. vivax* are the most dominant malaria parasites in the country, accounting for 60% and 40% of malaria cases respectively. *Plasmodium malariae* accounts for less than 1% and *P. ovale* is rarely reported (Tulu, 1993).

Warm and moist climatic conditions are conducive for the development of the parasite and breeding of vectors (Temu *et al.*, 1998; Sutherst, 2004). At 20-30 °C, malaria parasites develop optimally in the vector, however, the parasites cease to develop in the mosquito when the temperature falls below 16 °C. High humidity prolongs the life of the vector and transmission is extended under these conditions. In the human intermediate host, the parasite must function at 37 °C or higher, since the infection induces a significant rise in core temperature during the height of the infection (Sutherst, 2004). Thus, mosquito breeding and parasite life cycle inside the mosquito are highly dependent on air temperature and humidity (Zucker, 1996; Malakooti *et al.*, 1998).

While the four major species of *Plasmodium* differ in some ways from each other, they all share the same complex life cycle involving the insect (mosquito) vector and the human host (Fig. 1).

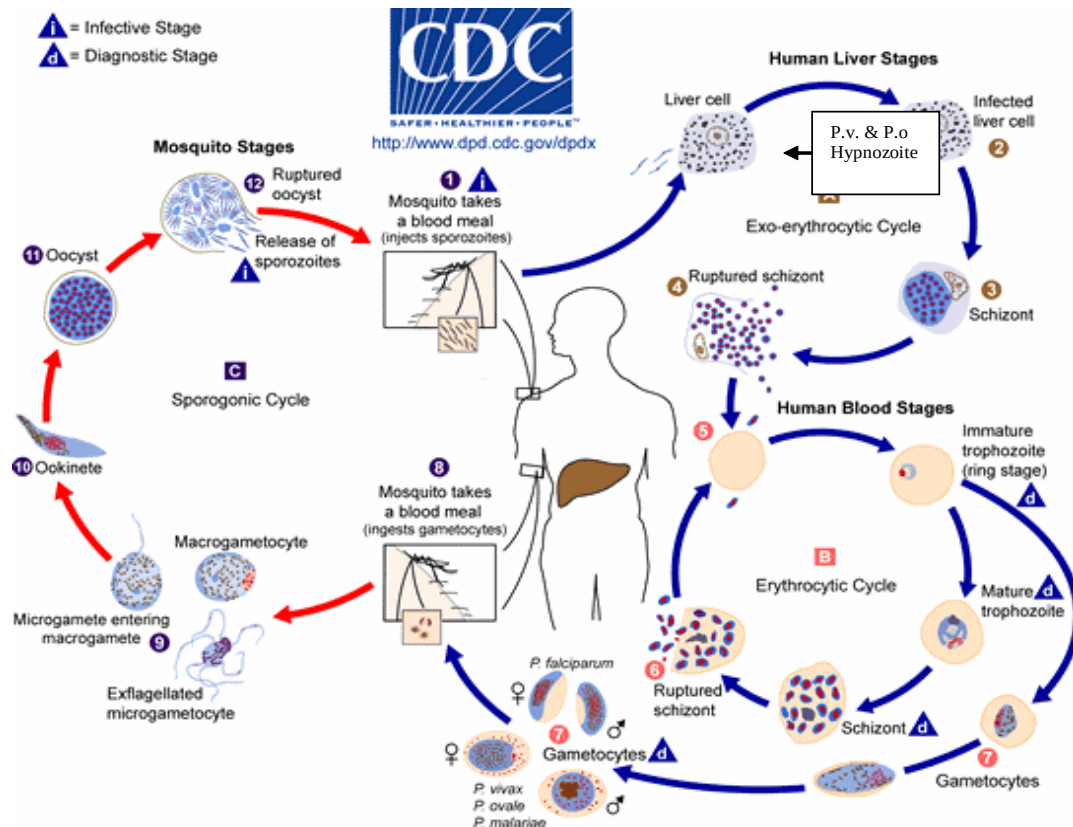


Fig. 1 Life cycle of *Plasmodium* species.

Source: CDC [http:// www.dpd.cdc.gov/dpdx/HTML/Malaria.htm](http://www.dpd.cdc.gov/dpdx/HTML/Malaria.htm).

When an infected *Anopheles* mosquito bites a human, sporozoites are injected with the saliva. After entering the circulatory system, the sporozoites make quick work of invading liver cells (hepatocytes) using the apical organelles (characteristic of all apicomplexans). After being introduced into the human intermediate host, it enters the bloodstream and is carried to the liver. There, it penetrates hepatocyte and undergoes growth and multiplication. In the case of *P. vivax* and *P. ovale*, some sporozoites transform to the dormant hypnozoite, remaining viable for up to 50 years (Krotoski *et al.*,

1982). This stage is responsible for relapses when it re-enters its developmental cycle. Inside the host's liver cell the *Plasmodium* cell undergoes asexual replication. After 9-16 days they return to the blood and penetrate the red cells, where they multiply again, progressively breaking down the red cells. This induces bouts of fever and anaemia in the infected individual. In cerebral malaria, the infected red cells obstruct the blood vessels in the brain. Other vital organs can also be damaged often leading to the death of the patient (Lambert, 2005).

1.1.2 The malaria vector mosquitoes

There are about 400 different species of *Anopheles* mosquitoes transmitting malaria, of which only about 70 species have been definitely incriminated as vectors of human malaria (Service, 2000). In Africa, members of *Anopheles gambiae* complex and *Anopheles funestus* are widely distributed and are responsible for the transmission of malaria in the region. *Anopheles gambiae* s.s is the most anthropophagic species in the complex and the most important, probably the world's most efficient malaria vector with characteristic indoor and outdoor resting. *Anopheles arabiensis* and *An. quadriannulatus* sp. B are among the species of the *An. gambiae* complex that are found in Ethiopia (Gebre-Mariam, 1984). *Anopheles arabiensis* occurs in most areas of tropical Africa and could be considered as a major target for control, as a major vector where malaria transmission is stable (Fortenille and Lochouran, 1999). It is the principal vector of epidemic malaria in all administrative regions of Ethiopia (Ameneshewa, 1995). Apart from the members of *An. gambiae* complex, *An. pharoensis* and *An. nili* are regarded as secondary vectors of malaria in Ethiopia (Gebre-Mariam *et al.*, 1988; Nigatu *et al.*, 1994; Abose *et al.*, 1997).

Even though entomological findings conducted so far indicated the presence of 42 anophelines in Ethiopia, only *An. arabiensis* is known to play a crucial role in malaria transmission in the country. Others such as *An. funestus* and *An. pharoensis* playing secondary role, while *An. nili* involves transmission in localized areas (Abose *et al.*, 1997).

1.2 The global malaria situation

Malaria is one of the leading causes of illness and death in the world. Nine out of ten of these deaths occur in Africa and the rest occur in Asia and Latin America. Being the world's most prevalent vector-borne disease, it is endemic in 92 countries, with pockets of transmission in an additional eight countries (Martens and Hall, 2000).

With respect to the endemic altitudinal range, the greatest altitude at which malaria occurs differs very much from place to place in the tropics, from nearly 2500m in Kenya to under 1000m in Sri-Lanka (Bruce-Chwatt, 1980; Gilles and Warrell, 1993). Throughout most of sub-Saharan Africa (SSA), malaria shows a high endemicity with average altitude of 1400m, but a low epidemic potential except in some areas (Gilles and Warrell, 1993).

On the other hand, within the endemic altitudinal range, the movement of infected people from malaria endemic to areas where the disease had been eradicated was reported for the resurgence of the disease (Martens and Hall, 2000). Such resurgence was observed in Armenia, Azerbaijan, Chechnya, Russia, Tajikistan, Turkey, Madagascar, South Africa, and Zanzibar where the disease was previously eradicated using effective control programs (Lambert, 2005).

It has been estimated in the 1950s that worldwide, the annual incidence of the disease was of the order of 250 million cases with 2.5 million people dying of malaria every year (Bruce-Chwatt, 1980). In 1990, 80% of cases were in Africa, with the remainder clustered in nine countries: India, Brazil, Afghanistan, Sri-Lanka, Thailand, Indonesia, Vietnam, Cambodia and China.

The disease remains one of the most important causes of human morbidity and mortality with enormous medical, economic and emotional impact in the world (WHO, 2005a). More than half of the world's population is at risk of acquiring malaria, and the

proportion increases each year because of deteriorating health systems, growing drug and insecticide resistance, climate change and natural disasters (WHO, 2000d).

Malaria has been estimated to account for 2.3% of global disease after pneumococcal acute respiratory infections (3.5%) and tuberculosis (TB) (2.8%); annually it kills one in 20 children less than 5 years of age (WHO, 1996). According to WHO estimates in 1998 up to 500 million clinical malaria cases occurred with nearly 3 million people dying of the disease (WHO, 2000a).

Currently, about 6-10% of the world population harbor malaria parasites in their bloodstream (Mayxay *et al.*, 2004). Almost 3% of disability adjusted life years (DALYs) are due to malaria mortality globally (Breman, 2001). Cerebral malaria is estimated to be responsible for a fatality rate of more than 20% of malaria cases even in urban areas (Warrell *et al.*, 1990).

Worldwide prevalence of the disease is estimated to be 300-500 million clinical cases each year (Breman, 2001). It used to be widely spread throughout the tropical belt, into the sub-tropical lands, and even to the edges of the temperate zones. Even at present, it is endemic in most of tropical and sub-tropical ecosystems worldwide and exhibits great geographic diversity. This diversity is expressed in ecological and epidemiological characteristics, in addition to the extensive polymorphism in the genes encoding antigenic proteins (Escalante *et al.*, 2002).

The vast majority of malarial cases occur in children under age of 5 years and pregnant women (Greenwood *et al.*, 2005). Other risk groups are non-immune travelers, refugees, displaced persons and laborers entering endemic areas (WHO, 2000d). Children, particularly under-fives, are at risk of developing severe malaria due to their relatively less developed immunity to malaria and the decline of passively acquired immunity (Alamirew, 1998).

According to Mayxay *et al.* (2004) despite over a century of attempts to control malaria, the disease continues to cause high morbidity and mortality and kills between one and five people every minute, most of them children. In the past decade, the incidence of the disease has been escalating at an alarming rate (Tanser *et al.*, 2003). Hay *et al.* (2004) stated that, if the prevalence of malaria stays on its present upwards course, the death rate could double in the next twenty years.

Although science still has no magic bullet for malaria, effective low-cost strategies are available for its treatment, prevention, and control. Roll back malaria began in 1998 to reduce the global burden associated with the disease (WHO, 2000a). The selective use of protection methods, including vector control, is proving to be more cost-effective and more sustainable (<http://www.rbm.who.int/>).

Currently, one of the promising interventions, using insecticide-treated nets (ITNs), can reduce malaria-specific death by over 20%. However, only about 15% of young children, in SSA, sleep under a bed net and only about 2% sleep under an impregnated bed net (WHO-UNICEF, 2003). Similarly, studies reported that proper use of ITNs combined with prompt treatment for malaria at community level can reduce malaria transmission by as much as 60% and the overall young child death rate by at least one fifth (WHO-UNICEF, 2003).

1.3 Malaria in Africa

Malaria is the largest single component of disease burden; epidemic malaria in particular, remains a major public health concern in tropical countries. In many developing countries, and especially in Africa, malaria exacts an enormous toll in lives, in medical costs, and in days of labor lost (Lambert, 2005). Especially, the physical consequences of infection with *P. falciparum* are the main causes of malaria morbidity and mortality in Africa (Snow *et al.*, 1999).

The epidemiological situation with respect to malaria has worsened in Africa over the last decade and the disease has occurred in areas previously free of malaria. Outbreaks have also been reported in some locations of Africa that had been previously thought to be at elevations too high for malaria transmission due to changes in climate (Lindsay and Martens, 1998) and human migration (Martens and Hall, 2000). On the other hand, compared to the malaria situation between the 1920s and 1950s, the current pattern of malaria in the highlands is characterized by increased frequencies, expanded geographic areas, and increased case-fatality rates (Zhou *et al.*, 2004).

It has been reported that about 18% of the people in Africa live in areas prone to epidemic malaria due to unstable and seasonal characteristics of malaria transmission (WHO, 1993). East African highland chains, from Ethiopia in the north to South Africa in the south are the most affected parts of Africa (Lindsay and Martens, 1998). In recent years, disastrous malaria epidemics were reported from Botswana, Mozambique, South Africa, Zambia, and Zimbabwe. Statistical assumptions suggest that about 110,000 people die every year, in sub-Saharan Africa, during malaria epidemics (RBM; Nchinda and WHO, 1998).

Brinkmann and Brinkmann (1991) suggested that approximately 60% of the population of SSA lives in areas of stable malaria transmission where protective immunity develops from about the age of five. 30% live in areas of seasonal transmission where protection is gained rather later (at age of 10); and 10% live in areas of unstable transmission where epidemics may occur with substantial consequences for adult morbidity and mortality.

Studies revealed that a recent upsurge of malaria in endemic areas with explosive epidemics in many parts of Africa is caused by several interacting factors, including rapid climatic changes, population movements and spreading resistance to anti-malaria drugs (Nchinda and WHO, 1998).

Climatological changes such as increased temperatures, humidity, and unusually prolonged heavy rainfall is considered to aggravate malaria, particularly at higher

altitudes (Gebre-Mariam *et al.*, 1988). In particular, it has been reported that increasing temperature could be part of the reason why malaria can now survive at higher altitudes although many other confounding factors exist (Patz *et al.*, 2000a).

Seasonal migration of workers has been associated with epidemics in Kenya (Bloland and Williams, 2003). A huge influx of such population groups can disturb the equilibrium in man-vector-parasite relationship and cause epidemics. Ultimately, population movement impacts on the extent of drug resistance via introducing the parasite strains into areas where resistance has not been acquired yet (Meade and Earickson, 2000).

Agricultural projects aggravating the malaria situation have been identified in many African countries (Howard, 1987). These development projects based on increasing surface water like irrigation schemes have a significant role in aggravating the magnitude and distribution of malaria and other vector-borne diseases in Africa (American Association for the Advancement of Science (AAAS, 1991).

In the same way, engineering and development projects like the construction of dams, highways and industrial centers may also increase the number of mosquito breeding habitats and lead to disease propagation in malaria-prone areas (Patz *et al.*, 2000b). Hence, the so-called ‘man-made malaria’ that refers to the creation of breeding places of malaria vectors as a result of human activities contributes considerably to spread of malaria (Martens and Hall, 2000).

The disease is directly responsible for one in five childhood deaths in Africa and indirectly contributes to illness and deaths from respiratory infections, diarrhoeal disease and malnutrition (World Health Report, 1999). In SSA alone, an estimated 0.9-2.3 million annual child deaths are attributed to malaria (Villamor *et al.*, 2003). About 1 million of those who die from malaria are children below five years of age. Every 30 seconds malaria kills an African child (RBM, 2006) and about 25% of the child mortality in SSA is due to malaria (WHO, 2000d; UNICEF, 2004).

Household surveys carried out in 28 SSA countries as reported by WHO-UNICEF (2003) suggested that only about 42% of children under 5 years of age receive anti-malaria medication when they needed it; about 80% of them receive Chloroquine alone. Children who survive the episode of severe malaria may suffer from learning impairment or brain damage (UNICEF, 2004).

Apart from the health impact, the disease is a major impediment to socio-economic development as the main transmission seasons coincide with peak agricultural harvesting times. There is a striking correlation between a country's per-capita gross domestic product (GDP) and malaria that demonstrates lower rates of economic growth of endemic countries. It impedes the development of a country's population in a complex manner, restricting population growth, reducing savings, economic investment and the productivity of the workforce (Sachs and Malaney, 2002; Greenwood *et al.*, 2005).

In addition to the impact on GDP, there is also significant cost to the health sector that in itself will impact on the macro-economics of individual countries (Sachs and Malaney, 2002). Likewise, Gallup and Sachs (2001) showed the impact of malaria on the economy of the endemic countries.

Sauerborn *et al.* (1995) provided a detailed specification of the wage rate method of assessing the time costs of illness as the sum of the opportunity cost of wages forgone by the sick individual due to illness, and the opportunity costs of healthy household members' time spent on treating or attending to the sick person or accompanying them for treatment.

According to the report of the Commission on Macroeconomics and Health, currently, a total US\$ 600 million is spent annually for malaria control. However, to meet the goals of Roll Back Malaria of halving malaria by 2010, up to US\$ 2 billion is needed. Overall, malaria accounts for 10% of Africa's disease burden and it is estimated that malaria costs the continent US\$ 10 to 12 billion in lost GDP growth (UNICEF, 2004).

1.4 Malaria in Ethiopia

1.4.1 Overall situation

In Ethiopia, malaria was reported to be endemic first and foremost by the Italian and British scientists from the mid 1930s to the late 1950s. In 1953, severe outbreaks that devastated the lives of 7000 people was reported to occur in Dembia plain near Lake Tana (Covell, 1957) and more than 1 million cases were recorded in the recent epidemic year of 1998 (WHO-UNICEF, 2003). In 2003 and 2004, there were serious malaria epidemics throughout the country, which affected 15 million persons in 3 federal regions (World Malaria Report, 2005).

According to Federal Democratic Republic of Ethiopia Ministry of Health (FMOH, 2004), in non-epidemic year, 5 to 6 million clinical malaria cases and over 600,000 confirmed cases were reported from health facilities. An estimated of more than 65% of the 70 million people has been reported to be exposed to the disease. Nevertheless, as the potential health service coverage is accessible to about 61% of the population and due to low service utilization rate (27%), the number of malaria cases reported by the health facilities is only a portion of the actual magnitude (FMOH, 2004).

The disease is one of the country's foremost health problem top ranking in the list of common communicable diseases (MOH, 2005). In 2002/03 the disease has been reported as the first cause of morbidity and mortality accounting for 15.5% outpatient consultations, 20.4% admissions and 27% in-patient deaths (FMOH, 2004). Even in 2004/05, it was reported to be the leading infectious disease followed by helminthiasis and tuberculosis (MOH, 2005).

Ethiopia has three geo-climatic zones that have characteristic malaria endemicities; the “Kolla” or the hot zone below 1500m, “Woina dega” or temperate zone between 1500m and 2500m altitude and the “Dega” or cold zone above 2500m altitude (WHO, 1991). It has been reported that areas above 1500m of the country are among the mostly affected

parts by seasonal malaria. This is because of the varying topographical and climatic features in which all age groups are affected due to lack of protective immunity (Tulu, 1993). Malaria distribution under normal condition depends largely upon topographic and climatic features and is endemic in warm and moist lowlands (Nega and Haile-Meskel, 1991).

The epidemiological pattern of malaria transmission is generally unstable and seasonal, the level of transmission varying from place to place because of altitude and rainfall patterns. Unstable malaria occurs in most parts of the country particularly in the highland fringes where climatic conditions are conducive for its transmission (Gebre-Mariam, 1984). The major transmission of malaria follows the June to September rains and occurs between September to December while the minor transmission season occurs between April to May following the February to March rains (MOH, 2000). Some localities also experience perennial malaria, because the environmental and climatological situations permit the continual breeding of vectors in permanent breeding sites (Gebre-Mariam *et al.*, 1988; Tulu, 1993; MOVBCU, 1999).

Altitude and climate (mainly rainfall and temperature) are the most important determinants of malaria transmission in the country although change in settlement patterns, drought and migrations could contribute a lot for the spread. Transmission usually occurs at altitudes below 2000m above sea level (Tulu, 1993). Likewise, it has been reported that although elevation is important, factors such as rainfall, temperature and humidity levels play an important role in determining its intensity (Malakooti *et al.*, 1998). Even, the relationship between malaria transmission and the rainfall is further complicated by temperature, humidity and the movement of people between lowland and highland areas (Malaria Control Program, 1983).

Evidence showed that rainfall, famines, and major malaria epidemics in Ethiopia are tightly temporally coupled. All of the unusually low rainfall periods since 1950 (1957, 1965, 1973, 1984) have been followed by major famine episodes (1958, 1965, 1973-1974, 1983-1985); mostly focused in the highland populations. Synchronous with these

events have also been a series of devastating malaria epidemics (1958, 1965, 1973, 1985-1987, 1998) with approximately 8-10 year periodicity, though sources rarely agree on the exact duration of this inter-epidemic period (Mengesha *et al.*, 1998).

Other studies from elsewhere have also shown that changes in weather conditions play a major role as the cause of severe epidemics of malaria (Abeku *et al.*, 2004; Thomas *et al.*, 2004). For instance, the sharp increase of reported cases after 1982-83 as described by Tulu (1993) appears to have been caused primarily by the return of the normal rains after the 1982-1985 drought, although deterioration of living conditions, changes in settlement patterns due to villagization programs and extensive population movements appear to have contributed to this trend.

Displacement of large numbers of people and their circulation favored malaria transmission in the country (Gebre-Mariam *et al.*, 1988). Similar studies suggested that, the migration of about 600,000 drought victims from northern to western Ethiopia as part of the 1984/85 resettlement programme exposed the settlers to some major vector-borne diseases for the first time (Kloos and Adugna, 1988). Likewise, the country's variation in landscape and complex human social forms created a wide range of macro- and micro-climatic conditions which result in spatially varied incidence and distribution of malaria (Gebre-Mariam *et al.*, 1988).

Another contributing factor for the rise of malaria is insecticide and drug resistance. Insecticide susceptibility studies in Gambella Region, south-western Ethiopia, for instance, showed the presence of DDT resistant *Anopheles gambiae s.l.* mosquitoes, showing below 80% susceptibility threshold with mortality values for one, two and four hours of exposure (Nigatu *et al.*, 1994).

Drug resistance of *P. falciparum* to Sulfadoxine-Pyrimethamine (SP) and Chloroquine (CQ) is frequent and intense in some areas of Ethiopia. Thus, spread of CQ resistance in falciparum malaria was thought to be another reason for the increase of malaria transmission in the lowland (Mengesha and Mekonnen, 1999). Recently, studies showed

an extraordinarily high frequency of drug-resistance mutations in both *P. falciparum* and *P. vivax* in southern Ethiopia. *Plasmodium falciparum* mutations conferring resistance to CQ and SP are abundant in southern Ethiopia as are mutations in *P. vivax* associated with SP resistance (Schunk *et al.*, 2006).

Since *Plasmodium falciparum* in Ethiopia is resistant to CQ and SP, this has triggered a shift to more effective anti-malarias, particularly Artemisinin Combination Therapy (ACT) since 1999; with the first line treatment for uncomplicated falciparum malaria in the country being Arthemeter Lumefantrine (AL). No ACT resistant *P. falciparum* has been detected (WHO, 2005c), *Plasmodium vivax* responds well to CQ and confirmed *P. vivax* cases are treated by CQ alone.

On the other hand, there were different epidemiological studies conducted on various aspects of malaria in the country. For instance, studies on some aspects of malaria prevalence in Gambella, southwestern Ethiopia, revealed a positivity rate of 4.1%(34) blood films out of a total 821 individuals examined from nine villages of the area (Nigatu *et al.*, 1994). Similarly, a prospective study among children with severe malaria admitted to Gambella hospital during the 1998-99 revealed a case fatality rate of 22% with most deaths within the first 24 hours (Gebre and Negash, 2002).

Today, malaria is also becoming an urban issue in some parts of the world, partly because of infrastructure failures such as inadequate drainage systems (Ijumba *et al.*, 2002). Parasitological studies conducted in Nazareth city, eastern Ethiopia revealed 2.8% (108) smear positive for malaria parasites from 3,890 blood slides collected during 4 cross-sectional surveys (Yohannes and Petros, 1996). In the same way, community-based malaria prevalence studies conducted in Akaki town had shown 3.7% smear positive from 2,136 examined blood films (Woyessa *et al.*, 2004).

In Ethiopia, aggravated malaria transmission was observed in 25 districts, 16 in Oromia region and 9 in SNNPR. True explosive epidemic malaria was recorded at exceptionally high altitude in at least one of the health facilities in seven districts (Negash *et al.*, 2005).

According to 1997 mid-term review of the accelerated implementation of malaria control program in Oromia and SNNP Regions, clinical malaria accounted for up to 40% of all outpatient consultations with corresponding proportional morbidity among under five children being up to 20%. The disease accounted for up to 26% of all inpatient admissions with proportional mortality rates of up to 35% in the various health facilities (Ethiopian Humanitarian Update, 2001).

Malaria is widely distributed in about 75% of the land surface of Oromia and threatens nearly 14.4 million (65.2%) of the population. Annually, about 1.5 million cases are reported from malaria control clinics and general health services; constituting an average of 20% of all diagnosis (Oromia Health Bureau, 2000).

The study on malaria admissions and deaths in Oromia region provides estimates of burden of the disease. Evidences from retrospective study of the magnitude of malaria admission and death review in Oromia revealed that out of total 302,035 admissions, 16,061 deaths were registered from 1995 to 2000. Accordingly, malaria accounted for 11.2% of all admissions and 14.26% of all deaths (Deressa *et al.*, 2004b).

In a similar fashion, retrospective record review of malaria cases in Oromia by Deressa *et al.* (2004a) showed that a total 6,214,132 malaria cases were diagnosed from 1995 to 2000. There was a steep increase from 816,114 in 1995/6 to 2,020,308 in 1998/9 and a decline to 729,176 in 1999/2000. On the other hand, from total outpatients registered at all health facilities malaria cases showed an increase trend from 10.6% in 1995/6 to 15% in 1998/9 (Deressa *et al.*, 2004a).

Other than health impact, the disease is a significant impediment to socio-economic development of the country. Fertile lowlands and major river valleys have not been fully inhabited and developed largely due to high malaria transmission in the areas. Due to fear of malaria in the lowlands the population are largely settled on the highlands which has caused over population, ecological degradation, reduced productivity and hence famine and poverty (Gebre-Mariam *et al.*, 1988).

In endemic areas, malaria strikes during planting and harvesting seasons, cutting down productive capacity at a time when there is the greatest need for agricultural work. The disease is thus, associated with loss of earnings, low school attendance, and high treatment cost (MOH, 2000).

The disease also impedes flow of trade, foreign investment and commerce. During epidemics, malaria generally cause panic in the general population and economic activities, particularly agricultural activities are paralyzed. Health facilities are also overwhelmed with patients and a lot of unnecessary resources are spent on dealing with the emergency situation accounting for 30% of the disease burden (DALYs) in all age groups (MOH, 2002).

It has been estimated that the economic burden due to malaria accounting for a 1.3% reduction in the annual economic growth rate of malaria endemic countries and that the long term impact of this is a reduction of GNP by more than half (TDR, 2002). Ethiopia is among the countries where malaria is endemic and disastrous epidemic occur frequently. It is now convincing that in some parts of the country, prevalence and incidence of malaria is increasing with ultimate cause of socio-economic impediment (Hodes, 1996). Currently there is real threat of the disease that the incidence of malaria and vector-borne diseases increase unless the management of many agro-ecosystems is improved.

1.4.2 Development projects and malaria in Ethiopia

Development projects like water resource projects and industrial undertakings in the tropics are fertile grounds for outbreaks of malaria (Gilles and Warrell, 1993). Service (1991) reported that the establishment and operation of water resource development like dams and irrigation schemes transform ecosystems thereby changing malaria risk. Canals and drains create ideal breeding sites for malaria mosquitoes, bringing both the vector and the disease closer to people. Breeding sites for *Anopheles* malaria mosquitoes are

found in clear surface water well available in irrigation systems and an increase in vector usually leads to an increase in malaria (Boelee, 2004).

Since planning of irrigation system in various part of Ethiopia does not consider its health impact (Alemayehu *et al.*, 1998), the construction of irrigation schemes, establishment of state farms and extensive migrant labor and resettlement population movements in the country have been the major factors influencing the prevalence, severity, and dissemination of malaria (Gebre-Mariam *et al.*, 1988).

Sprinkler irrigation system was reported to have influenced the actual microclimate of the area and thereby influencing the development of both the vector and the parasite. Studies from elsewhere showed that incidence of malaria as estimated from recorded new cases of the disease was much higher in sprinkler irrigation schemes than in surface irrigation schemes. Malaria risk factors were more prominent in sprinkler irrigation schemes, as opposed to risk factors for schistosomiasis (Chimbari *et al.*, 2004).

There are 16 major agro-industrial development schemes in Ethiopia that lie in the lowlands that are highly malarious with a population of migrant laborers who often go into these areas from the less malarious and malaria-free regions with little or no exposure-related immunity (Tulu, 1993). In the same way, the wide scale development in all major river basins and lowland fertile areas of the country during the mid-1980s, resettlement and villagization changed malaria and its severity (Kloos *et al.*, 1988; Gebre-Mariam *et al.*, 1988; Nega and Haile-Meskel, 1991).

Evidences showed that, the influence of human activities undertaken in Gambella (south-west Ethiopia) for the past 10 years have brought changes on the socio-economic situation and environmental factors which enhanced the prevalence of malaria and vectors in the area (Nigatu *et al.*, 1994). By the same analogous the importance of surface water management for malaria outbreak in Ethiopia has been pointed out by Ghebreyesus *et al.* (1999) in their investigation on the relationship between micro-dams and malaria transmission.

Reports obtained from the study on malaria incidence among children living near dams in Tigray (northern Ethiopia) revealed that construction of small dams led to increased spread of malaria, even at higher altitudes and children living near small dams had a 7 to 14 times higher risk of getting infected than children living further away. In such areas, seasonal transmission was changed to year-round transmission because of the continuous availability of surface water (Ghebreyesus *et al.*, 1999).

1.4.3 Past and present malaria control actions in Ethiopia

The health and general welfare of a large proportion of the Ethiopian population has undoubtedly been affected by malaria for centuries. The control of malaria in the country has a history of more than four decades, which initially began as pilot control projects in the 1950's and then launched a national eradication campaign in the 1960's followed by a control strategy in the 1970's. The long time economic interest in fertile lowland areas and the devastating malaria epidemic of 1958 were some of the ground reasons to launch eradication service (Gebre-Mariam, 1984).

The effort to achieve malaria eradication in the country was not successful partly due to some technical and financial constraints in countries and institutions that were supporting the eradication effort (MOH, 2000). However, since the development of the Global Malaria Control Strategy by the World Health Organization in 1992, emphasis in malaria control has shifted from vector eradication to increased case detection and treatment of malaria (Roberts *et al.*, 1997).

Since June 1993, under the general policy of decentralization and federalism in Ethiopia, malaria control became the responsibility of the regional health offices. At the central level, cores of professionals are now responsible for formulation of policies, provision of technical guidelines to regions, assistance in training, conducting operational research and support in anti-malaria drugs, insecticides and equipment (MOH, 1995; CSA, 2000).

Currently, the main components of malaria control strategies in Ethiopia included the early diagnosis and effective treatment of cases, the application of selective vector control measures like indoor residual insecticide spray (IRS) and environmental management, strengthening the information system to facilitate the prevention and early detection and control of epidemics (Tulu, 1993; Abose *et al.*, 1997). More recently, community education regarding the use of ITNs and its supply progressed as one major control strategy of malaria in the country. More than 1.4 million ITNs procured by UNICEF have been delivered within Ethiopia by the government's RBM team, but at least another six million nets are required to attain the Abuja target for malaria prevention of 60% of children aged under five years and 60% pregnant women sleeping under ITNs by 2005 (UNCT, 2004).

It has been recommended that reducing the impact of malaria epidemic largely depends on its early detection and timely targeting of appropriate and effective control measures (WHO, 1993). However, currently, there are no robust forecasting and early warning methods that can guide estimation on the likely occurrence of malaria to ensure preparedness. As a result, epidemics capture health facilities and communities almost unnoticed until the capacity of health facilities is overwhelmed (UNCT, 2004).

Despite efforts of nearly four decades to control the spread of malaria, now in tandem with HIV/AIDS, the disease still remains to be the leading challenge to the health and development of the people (MOH, 2002).

2. Objectives

2.1 General objective

- ♣ To investigate the public health burden of malaria in the community of Finchaa Sugar Factory based on clinical records and parasitological surveys.

2.2 Specific objectives

- ▶ To estimate the level of prevalence of malaria in the community.
- ▶ To investigate parasitological and socio-economic factors associated with or contributing to the transmission of human malaria in the area.
- ▶ To recommend possible control measures.

Hypothesis: Seasonal malaria prevalence will be high in Finchaa Sugar Factory area and hence can be a serious public health problem.

3. Materials and methods

3.1 Description of the study area

The study was carried out in Finchaa Sugar Factory areas, East Wellega Zone, west-central Ethiopia (Fig. 2) from November 2005 to May 2006. The factory is bounded by escarpments from east, west and south within the general boundaries of latitudes 9° 30'N to 10° 00'N and longitudes 37° 15' to 37° 30'E at an altitude between 1350m and 1600m above sea level at about 332km north-west of Addis Ababa. The area can be reached via the main highway from Addis Ababa to Gedo (192Km west of Addis Ababa) and thereafter by means of an all weather gravel road from Gedo to Finchaa Dam (95Km to the north-west of Gedo). Then at 47Km away from Finchaa town, following a gravel road running along the top of the escarpment before it descends very steeply ends to the factory area.

Finchaa Sugar Factory was among the well-known intensive Estate Farms of the country during the past years. The previous Estate Farm area is now entirely absorbed by the FSF project. Currently it is one of the many fertile lowland areas in the country where several hectares of sugar cane are cultivated for the ultimate purpose of sugar production. The Project area, lying in the Finchaa River Valley has been envisaged to cover about 20,000 ha of land to grow sugar cane using sprinkler irrigation system at a cost of over US\$ 300 Million (Tate and Lyle, 1986). Finchaa Sugar Factory together with Wonji/Shoa and Metahara cultivates a total of 24,000 hectares of land to grow sugar cane, each with 7000ha, 7000ha, and 10,000ha, respectively. But currently, Finchaa Sugar Factory is on progressive expansion of sugar cane plantation towards the East Bank of Finchaa River. These estates produce about 280,000 tons of white sugar per annum (Tafesse and Baissa, 2005). Wonji/Shoa and Metahara sugar factories use irrigation water abstracted from Awash River while Finchaa sugar factory from Finchaa River (Abejehu, 2005).

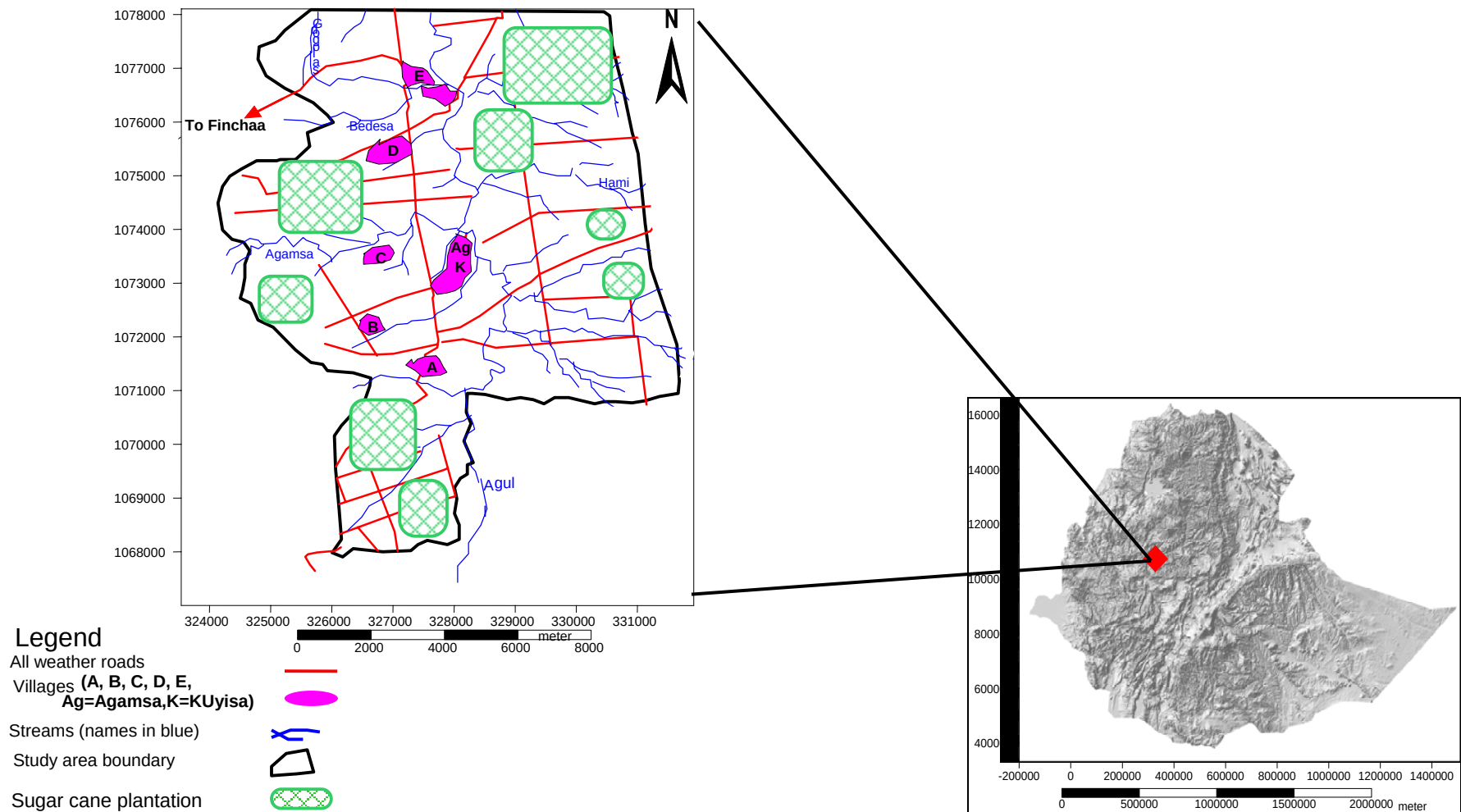


Fig. 2 Map of Finchaa Sugar Factory with its location site.

The valley is typically characterized by semi-arid climate with mean relative humidity of 62%. The mean annual precipitation received is 1485 mm while the mean maximum and mean minimum temperatures are 30.6 °C and 14.5 °C, respectively (Fig. 3 and Fig. 4). The area, like most parts of Ethiopia, has two periods of rainfall: the “big” and “small” rains of June to September and March to April, respectively. The topography of Finchaa Valley is undulating and a network of seasonal streams heavily dissects it. During the wet season, there are several temporary collections of surface waters of various sizes and durations.

Surrounding the factory, especially along the south, west and southeast perimeter, there are some streams and canal outlets of water including Finchaa River. River Agul, one of the tributaries of Abay River, separates two adjacent woredas, Guduru and Abay Choman. It is the major river formed as the extension of Finchaa River after generating hydroelectric power. All activities of sugar cane cultivation are entirely dependent upon this river. The other four rivers, Agamsa, Gogoldas, Badessa and Badessa Kala all flow toward Agul river crossing villages “A”, “B” and the main town (Agamsa and Kuyisa). Major soil types under sugar cane cultivation include Luvisols, Vertisols and Fluvisols (Damte and Abejehu, 2005). The area grows maize, millet, sesame, teff, etc. but is highly suitable for growing vegetables and fruits like onion, potatoes, sweet potatoes, papaya, avocado, lemon, mango, and the likes.

With respect to the ecosystem, it is naturally well provided by different species of plants being dominated by *Acacia* species, typical of semi-arid areas. Furthermore, the area is also characterized by varieties of wild animals. In the past, the existence of some mineral water was reported (Burayu, 1995).

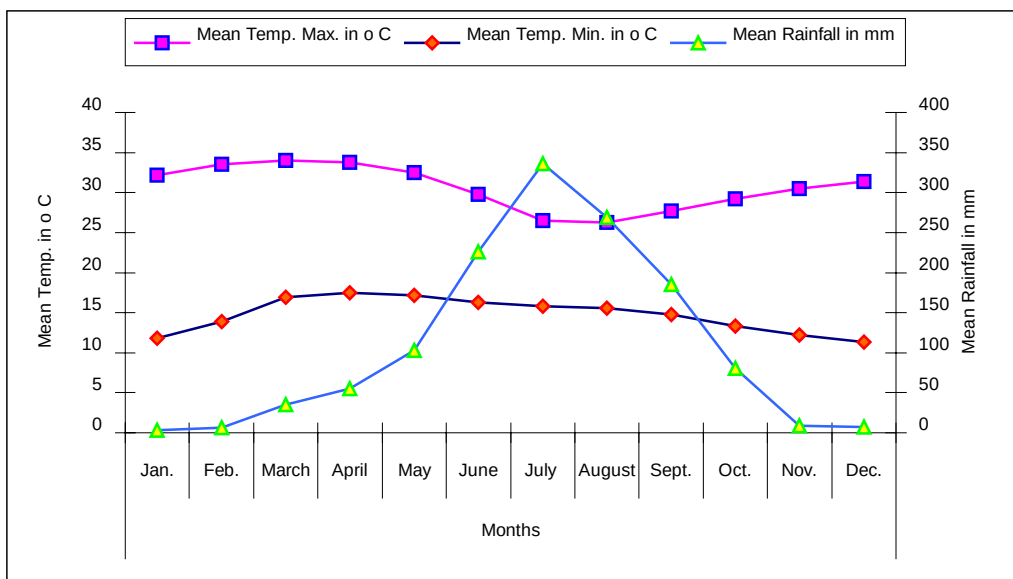


Fig. 3 Mean temperature maximum and minimum in °C versus mean rainfall in mm of 26/27 years in Finchaa Sugar Factory.

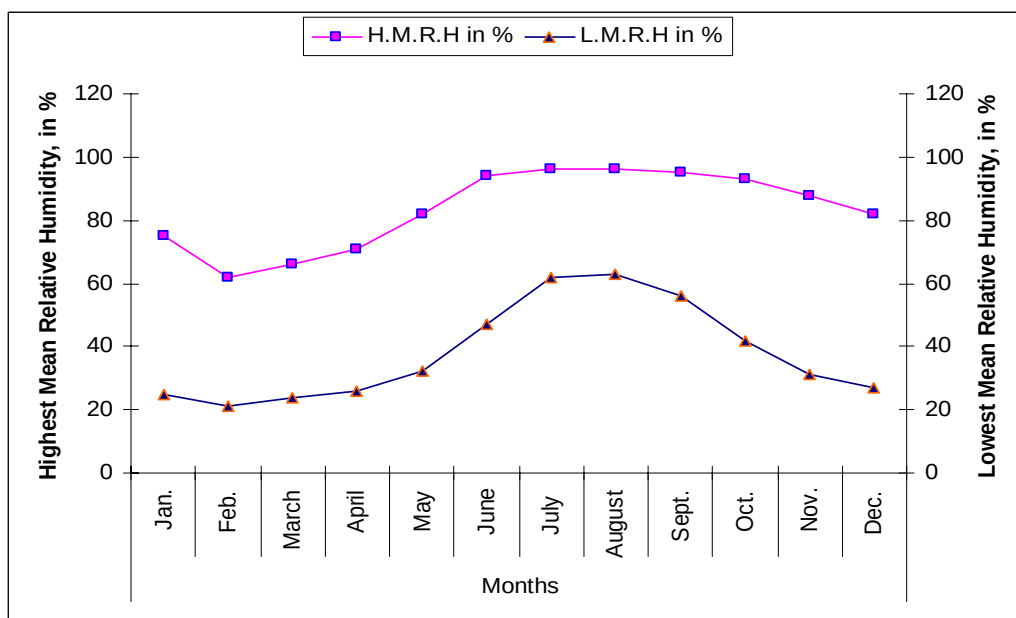


Fig. 4 Highest and lowest relative humidity (%) at 1.5m above ground level (15/16 years) in Finchaa Sugar Factory.

H.M.R.H – highest mean relative humidity; L.M.R.H - lowest mean relative humidity

Source: Institute of Agricultural Research Finchaa Sugar Factory Station.

According to Buta Damessa (personal communication, August 17, 2005) there were indigenous inhabitants in the valley before the establishment of Fetan farm. The Fetan farm was established in 1975 under the supervision of the Ministry of Agriculture. The farm was handed over to the Ministry of state farms in 1980. In the same year, the ex-Ethiopian Sugar Corporation has established some sugar cane research trials in the valley. The Finchaa Estate Farm and other not yet occupied land was exclusively taken by Finchaa Sugar project in 1992 (Burayu, 1995).

Inaugurated in April 1999, Finchaa Sugar Factory has reached full capacity production in the year 2004/05 after seven years of production that is more or less in line with project master plan. The factory was planned to operate for 177 days per annum and produce 85,000 tons of direct consumption sugar and 8 million liters of power alcohol of 99.5 °GL (grade level) to be blended with gasoline to be used as motor fuel for vehicles. Currently the capacity of sugar production grew to about 95,000 tons annually. The second phase will be to develop the East Bank of the Finchaa River to a maximum available irrigable area for which the feasibility is underway.

Regarding social aspects, Finchaa Sugar Factory, being among large-scale factories in the country, is characterized by diversity of several ethnic societies of different socio-economic background. The population comprises of workers of the previous state farm, their families and new arrivals in search of job opportunities. According to the 1996 Population Census, the total population of the area is estimated to be 18,360 out of which 9557 and 8803 were males and females, respectively. The sex ratio is approximately 1.1:1 (Raji Sufa, pers. communication, August 28, 2005).

The factory has created over 5,500 jobs for skilled, semi-skilled and permanent and seasonal labour at the present stage. Although seasonal fluctuation in the number of workers prevails, the factory supports 6,685 employees out of which 1,666 were permanent, 417 contract and 4,553 seasonal (Abdissa Merga, pers. communication, November 21, 2005). The factory area is broadly categorized into the so-called Main Town, comprising Agamsa and Kuyisa and five sparsely populated small villages namely villages A to E (Fig. 2). The Sugar Factory, the

various administrative offices, a secondary school and an elementary school, telecommunication offices and Health Center were located within the main town.

Almost all of the dwellings in the main town and the existing villages are rectangular, constructed of bricks or stones with corrugated iron roofs. All of the houses constructed by the factory have electricity, water, and a considerably varying quality of residence with bathroom and latrine. The so called “Kuyisa”, a village within the Main Town but not part of the Finchaa Sugar Project, had unique housing units. The houses in Kuyisa were completely different from the rest of the residential houses of study sites in their standard of sanitation and quality of construction. The walls of all housing units are composed of wood and mud partly with corrugated iron roofs and some with grass thatched-roof patterns.

There have been several malaria control measures in Finchaa Sugar Factory area. The principal control measures, at the time of the survey, included prompt treatment of cases, systematic DDT residual household spraying every year in August, periodic application of oil to larval habitats and environmental management (filling, drainage etc.).

3.2 Health services and malaria diagnosis in FSF health facilities

In FSF and the surrounding communities, all health services were provided by one Health Center and four small Clinics. All the villages A to E with the exception of village “C” had a Clinic. The Clinics provide basic health services entirely based on clinical symptoms within the respective villages. However, laboratory based medical treatment including malaria is provided only at the Health Center. The Health Center consisted of four laboratory technicians for microscopic examination of blood films for malaria diagnosis. *Plasmodium vivax* and *P. falciparum*, the two epidemiologically dominant species of the country, had exclusively been diagnosed at the health center. So far, there was no hospital in the area; Ambo, Nekemte and Addis Ababa Hospitals were commonly used for referral health services.

According to local informants and personal inquiry, partly due to distance between villages and the main town and partly due to economic reasons many febrile cases are treated by anti-malaria drugs based on clinical symptoms rather than by laboratory-based diagnosis in their respective villages. On the other hand, serious health cases including malaria from the villages are expected to go up to 12 Km to the health center for laboratory examination. In fact, for emergency health services such as delivery, severe malaria and other related problems, there are two Ambulances to provide transportation service back and forth the health center.

3.3 The study population

All household heads and all family members in the selected villages of FSF were the source of the study population for the interview questionnaire and parasitological blood film investigation, respectively. A pre-coded questionnaire was administered to all family heads living in the selected households in a face- to- face interview approach. In addition, blood smears were collected from a finger of all members in the selected households for smear test.

All household heads and family members who were available in the selected households during sample collection were eligible for interview and smear test respectively. However, relatives who came during the study period and family members who were not available in the home were excluded.

3.4 Study design and sampling techniques

A community based cross-sectional household survey was conducted during the two peak malaria transmission seasons, from November 16 to 22, 2005 (first survey) and from April 26 to May 4, 2006 (second survey). The study utilized a pre-coded questionnaire administered to the household head on some aspects of malaria in that specific area. The questionnaire that includes demographic information such as name, age, sex, place of residence, duration of

stay and previous residence, educational background, housing system etc. was filled by the head of the household.

Calculation of sample size (n) was done using the formula for estimating single proportion at 95% CI level ($Z_{\alpha/2}=1.96$). However, since there were no previous or pilot malaria studies conducted in the area and data from the clinic were studied only after the epidemiological study was done, 50%: 50% was assumed for prevalence (P). A minimum of 600 samples (n) was generated using 4% marginal error (d) as shown below.

$n = Z^2 P (1-P)/d^2$	Where	n = sample size,
$n = Z^2 \alpha/2 (50\%) (50\%) / d^2$		P = average prevalence
$n = (1.96) (1.96) (0.5) (0.5) / (0.04)^2$		$Z_{\alpha/2}$ =P- value at 95% CI from table,
n = 600		d= worst accepted value/marginal error

Therefore, once the minimum number of sample was obtained, by adding 16.5% contingency, a total of 700 study subjects were enrolled.

The survey was conducted in six geographically separated villages found in FSF namely, Village “A”, “B”, “C”, “D”, “E” and main town. In fact, within the main town, there were two distinct but geographically adjacent villages; Agamsa, a village consisting of residential house of the employees of the factory and Kuyisa, a village not constructed by the factory. Therefore, villages A to E, Agamsa, and Kuyisa were the specific study population. The average total number of households was 3,359 with 18,360 total estimated population as provided by the local Sugar Project authorities. Based on assumption of five average family sizes (Statistical Report of Population and Housing Census, 1995), from selected 140 households, 700 individuals were sampled (Table 1). Then, by using proportional stratified sampling, the share of households of each of the seven study sites was proportionally distributed. Thus, the households to be sampled from each village were systematically drawn, taking every 10th household from a random start and if the 10th household was inconvenient the households before or after the indicated one was assumed to be sampled.

Table 1. The description of the study population in FSF during November 2005 and April/May 2006 (N=1400), East Wellega, Ethiopia.

Village	Total	Sampled	Total	Sampled population	
	household	household	population	Male	Female
	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
A	211(6.3)	9(6.4)	1048(5.7)	44(6.7)	34(4.6)
B	176(5.3)	7(5)	880(4.8)	28(4.2)	40(5.4)
C	182(5.4)	8(5.7)	906(4.9)	26(3.9)	44(6.0)
D	168(5)	7(5)	840(4.6)	28(4.2)	36(4.9)
E	189(5.6)	8(5.7)	946(5.2)	42(6.3)	30(4.0)
Agamsa	1149(34.2)	48(34.3)	6594(35.9)	238(36.0)	264(35.8)
Kuyisa	1284(38.2)	53(37.9)	7146(38.9)	256(38.7)	290(39.3)
Total	3359(100.0)	140(4.2)	18360 (100.0)	662(3.6)	738(4.0)

3.5 Reagents and equipment

Compound microscope, surgical gloves, cotton, detergents (soap), sterile disposable blood lancet, glass slides, distilled water, staining jars, giemsa stain, glycerol, 70% ethyl alcohol, methyl alcohol, oil immersion, anti-malaria drugs, slide boxes, digital camera, sample storage and transportation boxes etc. were among the reagents and equipment that were used during the study.

3.6 Parasitological study and blood film collection

Peripheral smear examination of well-prepared and well-stained blood film is the gold standard in confirming the presence of malaria parasite (Payne, 1988). Thick and thin smears prepared from the peripheral blood are used for this purpose. The peripheral blood smear provides comprehensive information on the species, the stages and density of parasitemia with a sensitivity of 5 to 10 parasites per μL of blood for an experienced laboratory technician but under typical field conditions the limit of sensitivity is approximately 100 parasites per μL (WHO, 1988).

Two laboratory technicians, one nurse supervisor, three field technical assistants and one guide man for interviewing the household heads were involved. Before blood sample collection, slides were properly soaked in hot water, washed with distilled water, rinsed in denatured alcohol and cleaned with gauze. Before taking the blood sample the glass slides were labeled in the field in such a way that the slide code could match with the file of that particular individual. Then, the finger was cleansed with an alcohol-moistened swab, dried with a piece of dry cotton, punctured with a disposable blood lancet. Through wiping off the first drop of blood, thick and thin films were made on the same slide. After being air-dried in a horizontal position, the slides were placed in a slide box. Before staining, thin blood films were fixed in methanol for 30 sec. in FSF Health Center Laboratory Settings. Then smears were stained with 3% giemsa solution for 30 minutes. The staining techniques and blood film examination was conducted according to a standard of World Health Organization protocols (Cheesbrough, 1987; Garcia, 2001). Microscopic examination of thick films using high power magnification for the presence of parasites and parasite species identification using thin films under 1000x oil immersion objective was done. Then the slides were cleaned with xylene and get dried and kept in a slide box for second round confirmatory microscopic examination and parasite density determination conducted at AAUSF Biomedical Laboratory. The second round confirmatory microscopic examination followed similar procedure like that of the first conducted at FSF Health Center Laboratory.

During blood sample collection ethical consideration was taken into account to treat those individuals with positive results. Accordingly, all the positive study subjects were given anti-malaria drugs (Chloroquine and Arthemeter Lumefantrine) within a week after blood sample collection. The anti-malaria drug was provided by FSF Health Center free of charge.

3.7 Structured questionnaire

All the household heads were interviewed at their residence using a structured questionnaire. The questionnaire requested the individuals' socio-demographic information, experience to malaria infection, use of malaria preventive measures, place of residence, use of anti-malaria drugs and other malaria related issues.

A pre-tested structured Afan Oromo language questionnaire comprising 11 multiple-choice items of “yes” or “no” response with some reasoning answers was developed for the study. The questionnaire was originally developed in English (Appendix 2) and then translated into Afan Oromo. The Afan Oromo version was later translated back into English by the help of the concerned language professionals. The questionnaire included 8 items of socio-demographic parameters and 10 main item questions and 11 sub-items on awareness aspects of malaria. The questions consisted of issues like means of malaria transmission, exposure factors, nature of housing units, presence or absence of livestock and treatment practices. It has also dealt with issues of current malaria preventive techniques including use of chemoprophylaxis for preventive purpose, awareness towards insecticide treated mosquito nets (ITNs) and insecticide spray to their house.

3.8 Ethical consideration

The study was carried out after obtaining ethical clearance from ethical committee of the Faculty of Science, Addis Ababa University Department of Biology. An official letter was written from the Department of Biology to Oromia Regional Health Bureau and the Oromia Regional Health Bureau in turn wrote to Abay Choman Woreda Health Department from

which a letter of agreement and cooperation was written to FSF Health Center. Following a thorough discussion with head of FSF health department and coordinator of disease prevention and control unit, a brief letter of agreement and cooperation was written to each FSF village council. Then the study communities were asked for verbal consent after being introduced to the purpose of the study and informing about their right of answering or rejecting the questions.

In addition, written consent (Appendix 3) was obtained from all of the study participants including guardians for children in blood film collection. Positive cases for malaria were initiated to go to health services for appropriate treatment freely and health education in malaria prevention and control through local health care providers. Privacy was maintained during the interview.

3.9 Data analysis

A descriptive analysis of cases and interviewed individuals was conducted, followed by univariate and multivariate analyses of risk factors for malaria. Using SPSS version 12 statistical software packages, the association and frequency of variables was carried out. Stepwise multivariate analysis was carried out to determine the predictor variable affecting the malaria infection prevalence. Chi-square test was used to check the associations of different variables as well as to measure the significance and strength of associations between outcome variables and certain independent variables with 95% confidence interval. For this study, statistical significance was defined at probability level of 0.05. Results were presented in tables and graphs.

4. Results

4.1 Malaria case profile in outpatients at FSF Health Center (2001 - 2005)

The profile of malaria prevalence recorded at FSF Health Center from outpatients between 2001 and 2005 is shown in Fig. 5. Residential insecticide spraying took place every August in all years.

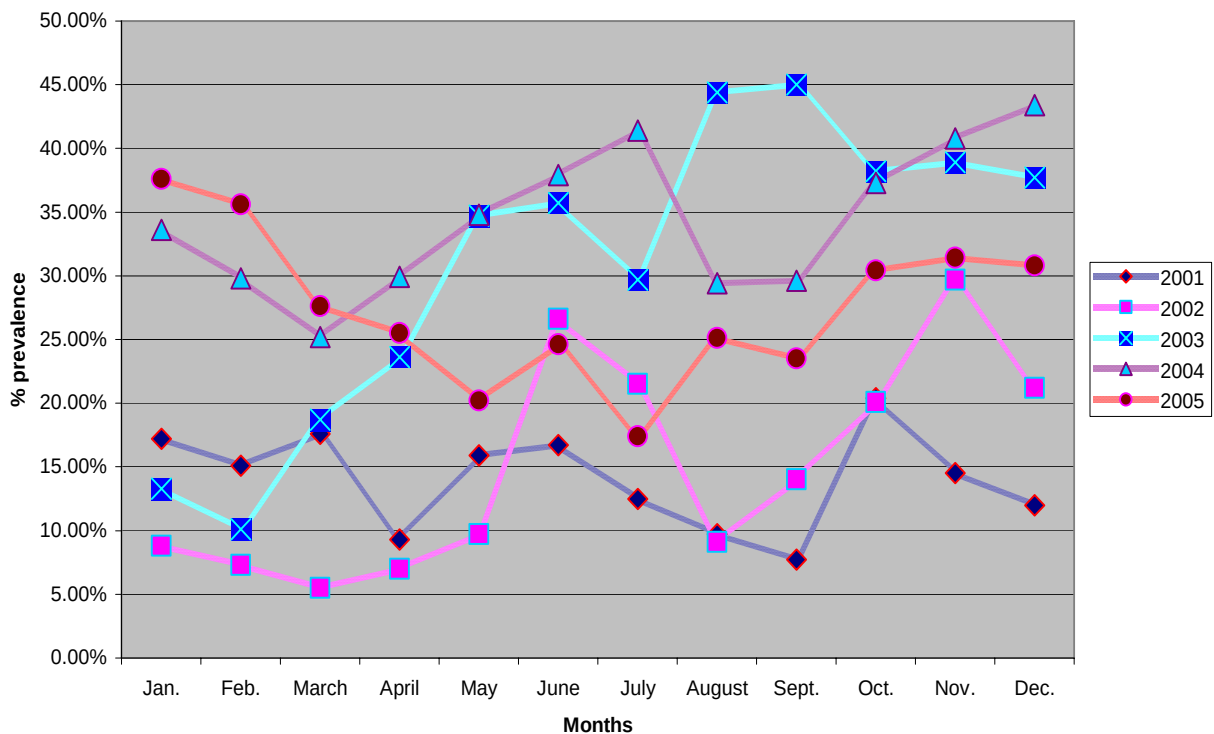


Fig. 5 Clinical record of malaria prevalence in outpatients at FSF Health Center from 2001 to 2005.

From FSF Health Center clinical records, a fluctuating trend of malaria prevalence through the years 2001 to 2005/06 was observed (Appendix 1a-1f). For instance, in 2001 and 2002 the average annual malaria prevalence was 14.1% and 17.1%, respectively. During these years, prevalence was observed below average (<30%) of the past half decade. The average prevalence of malaria in 2003 was 35.7%, which was the second highest next to 36.5% average annual prevalence recorded in 2004. The prevalence showed above average (>30%) from May to December 2003. The highest peak of malaria prevalence in 2003 was observed

from August to December. In 2004, the first high peak malaria prevalence was recorded from May to July; the second peak being from November to December. The average annual prevalence of malaria by 2005 was 29.5%. In this year, first peak malaria prevalence was recorded from January to February followed by the second peak from October to December.

From clinical records of FSF health facilities, the trend of malaria in relation to respiratory infections showed an increment between 2002 and 2003 and with a decline in 2005 (Fig. 6). Respiratory infections were the leading cause of morbidity followed by malaria and helminth infections in the area. During the years 2003 to 2005 malaria became second to respiratory infections in the outpatient admissions at the FSF Health Center.

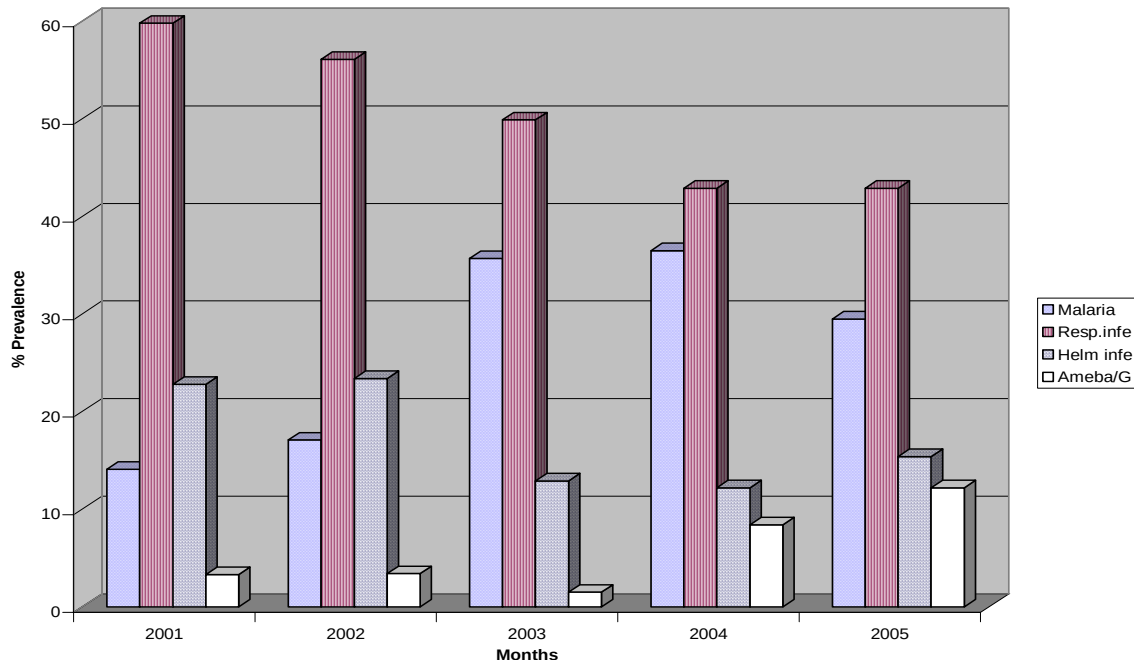


Fig. 6 Clinical record of malaria prevalence in relation to other infections in outpatients in FSF Health Center from 2001 to 2005.

During the years 2001 to 2005 of FSF Health Center clinical records as shown in Fig. 7, Fig. 8, Fig. 10 and Fig. 11 with the exception of 2003, a slight predominance of *Plasmodium vivax* over *P. falciparum* was observed in the dry season whereas the reverse was true for *P. falciparum* during major transmission period. By the year 2003 *P. falciparum* was found to be quite significantly diagnosed relative to *P. vivax* throughout the year as shown in Fig. 9.

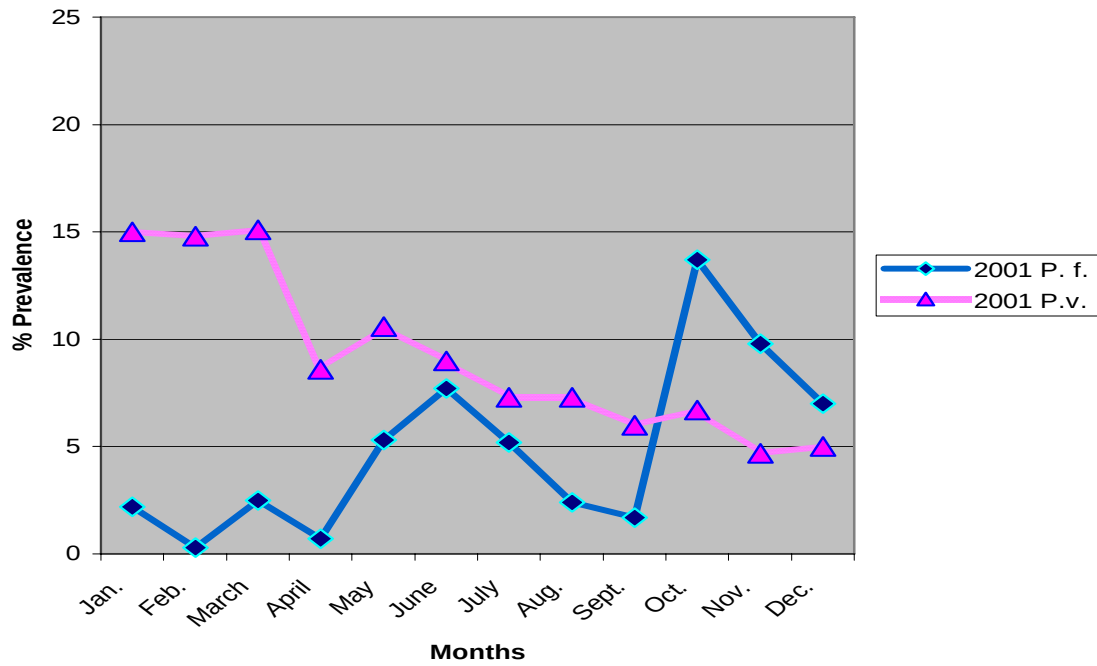


Fig. 7 Relative prevalence of *P. falciparum* and *P. vivax* from clinical records at FSF Health Center through the months of the year 2001.

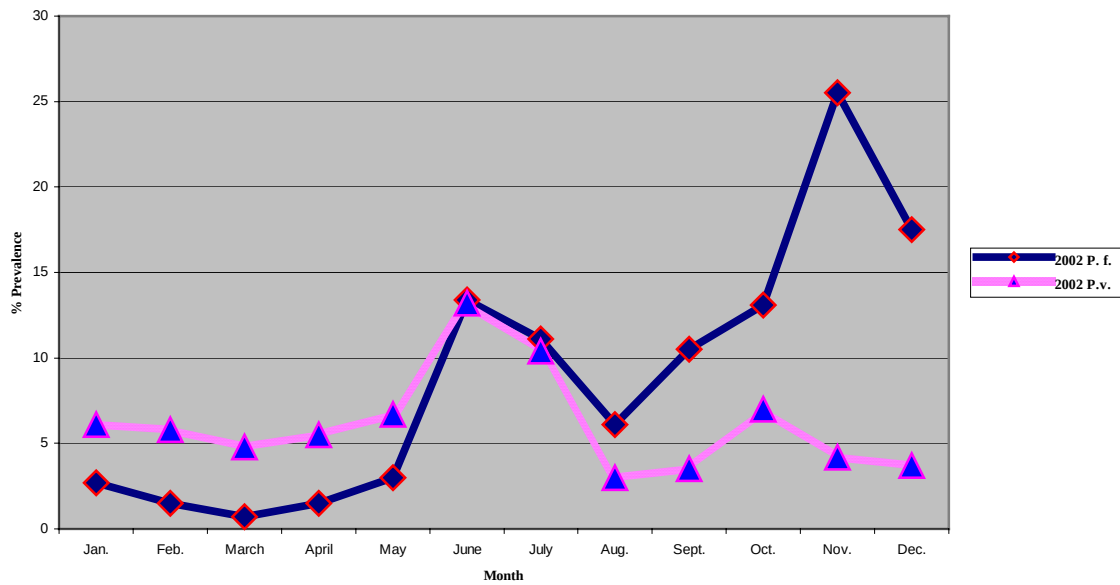


Fig. 8 Relative prevalence of *P. falciparum* and *P. vivax* from clinical records at FSF Health Center through the months of the year 2002.

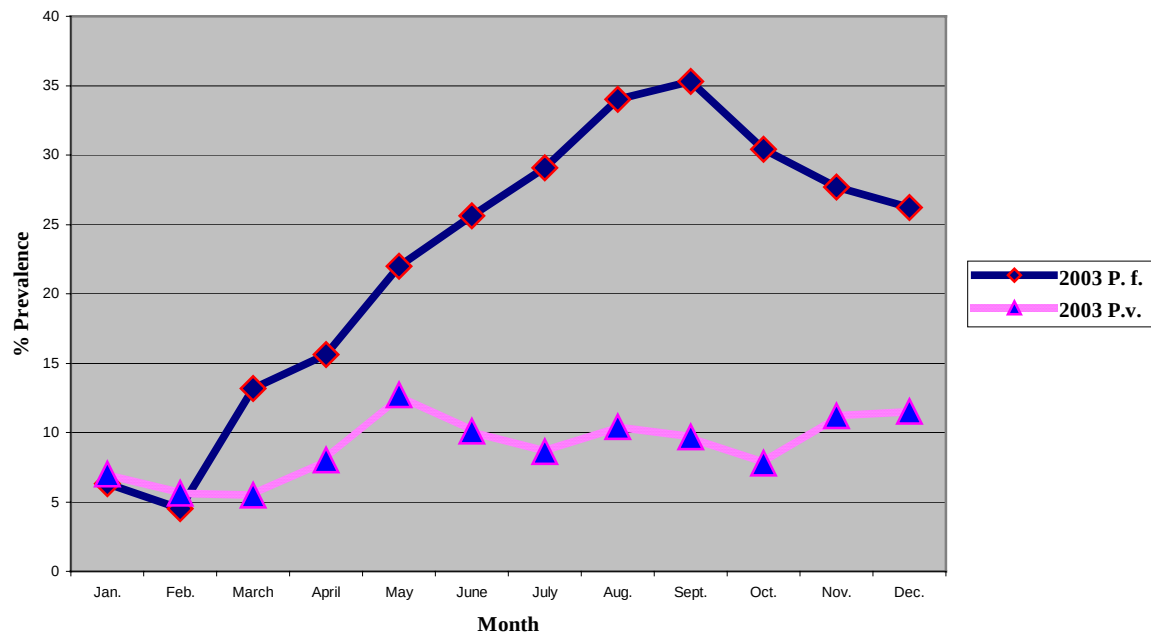


Fig. 9 Relative prevalence of *P. falciparum* and *P. vivax* from clinical records at FSF Health Center through the months of the year 2003.

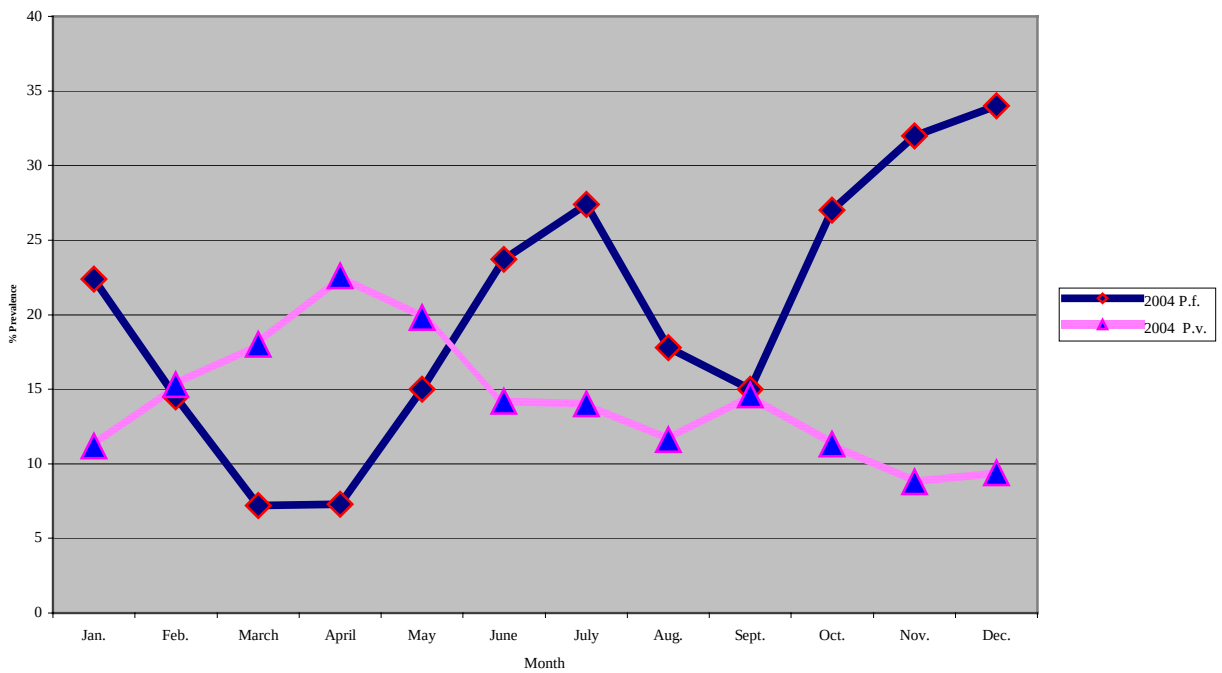


Fig. 10 Relative prevalence of *P. falciparum* and *P. vivax* from clinical records at FSF Health Center through the months of the year 2004.

The relative prevalence of the two *Plasmodium* species followed the normal pattern of *P. vivax* dominance in the dry season and that of *P. falciparum* following the heavy rains of June to August as shown in Fig. 11.

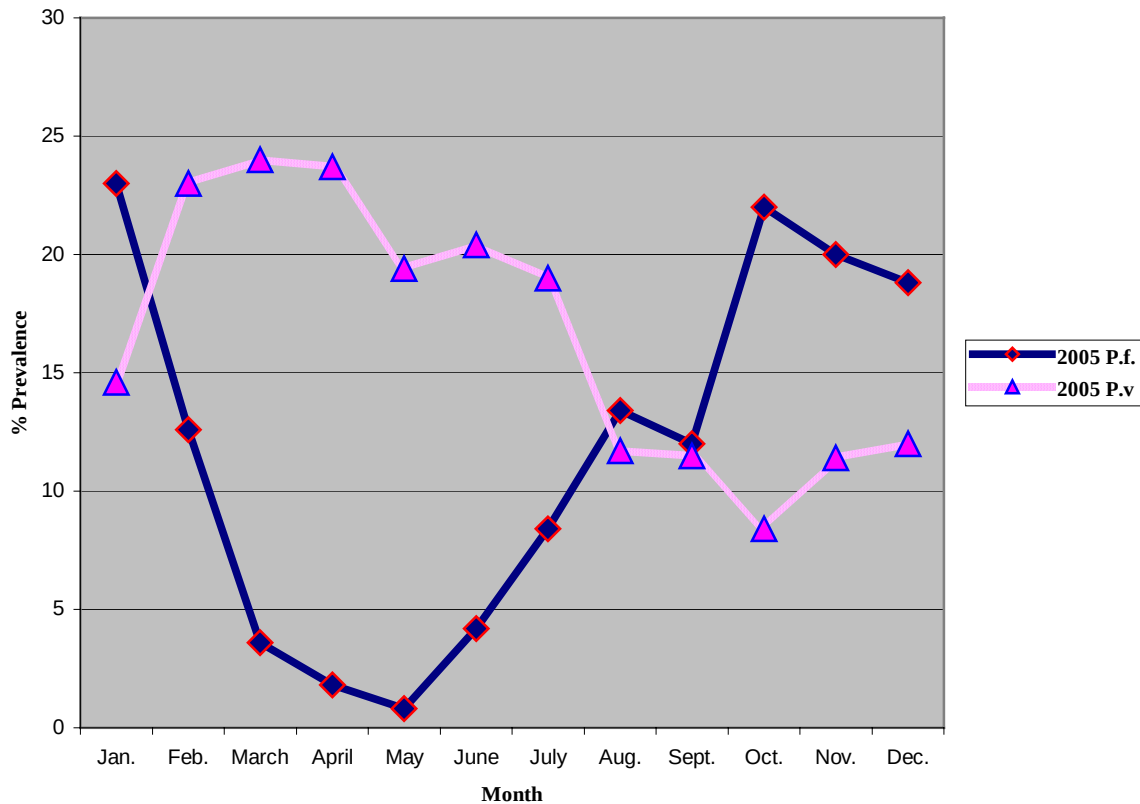


Fig. 11 Relative prevalence of *P. falciparum* and *P. vivax* from clinical records at FSF Health Center through the months of the year 2005.

During the last half decade, a total of 22,040 malaria cases were treated at FSF Health Center, with an average of 4,408(30%) cases each year and the distribution of *Plasmodium* species showed variation from year to year. For example, of the total malaria cases treated at FSF Health Center in 2004, 64.5% and 35.5% were due to *P. falciparum* and *P. vivax*, respectively. However, in 2005 out of 4,986 total malaria cases, 51.7% and 48.3% were due to *P. vivax* and *P. falciparum*, respectively. This shows that there was a dominance of *P. falciparum* over *P. vivax* in the year 2004 but in 2005 a slight dominance of *P. vivax* was seen.

The review of Finchaa Sugar Factory Health Center clinical records showed that malaria has been the major cause of morbidity and mortality with high burden on health services. For instance, clinical records from the health center showed that in the year 2003/04, out of 46,697 patient admissions, 13,954(29.8%) were malaria cases and out of 35 deaths, 17(48.5%) were due to malaria. Similarly, in the year 2004/05 out of 42,497 patient admissions, 12,612(29.6%) were malaria cases and out of 28 deaths, 7(25%) were due to malaria.

4.2 Parasitological survey of the population

A total of 1400 (approx. 3.8% of the total population) individuals were enrolled in the study from 140 households from the five separate villages (A, B, C, D and E) and the two geographically adjacent villages (Agamsa and Kuyisa) of FSF during the two peak malaria transmission seasons of the year 2005/06 (November 2005 and April/May 2006). The study population was composed of mainly persons above 15 years old (49.4%) followed by 5-14 age groups (32.7%) and 17.9% in 0-4 age groups. The mean age of the study population was 18 years. Of the total study population, 331(47.3%) were males and 369 (52.7%) were females with a sex ratio of 1:1.1.

A total of 1400 blood smears were collected from individuals residing in the seven study sites during the period November 16-22, 2005 (first survey) and April 26 to May 4, 2006 (second survey), comprising all age groups. Only 10 (1.43%) individuals were found to be malaria positive in the first survey and 27(3.86%) in the second survey. The parasite species diagnosed were *P. vivax* and *P. falciparum*. The majority (70.3%) of malaria cases were asymptomatic with only small proportion (29.7%) being febrile. Among the infected, 8.1% were pregnant women.

Of the total malaria infected subjects 24.3% were found to be *P. falciparum* gametocyte carriers. On the other hand, 54% of malaria cases were found to show early stages (ring and early trophozoite) of both malaria parasites and 21.7% of mature schizont stages of *P. vivax*.

4.3 Environmental survey

The environment of Finchaa Sugar Factory (FSF) consists of five separate villages (A to E) and two geographically inseparable villages (Agamsa and Kuyisa) (Fig. 2). There were differences among the dwellings constructed by the FSF and those found in Kuyisa in terms of infrastructure and their proximity to mosquito breeding sites. All FSF constructed dwellings were made of bricks or stones with corrugated iron roofs. These houses had electricity, potable water, telephone services etc. However, residences in Kuyisa had no hydroelectricity, potable water and telephone services.

Kuyisa is almost entirely inhabited by daily laborers with low-income. It is visited by so many seasonal daily laborers and job seekers. Most of the peripheral inhabitants of Kuyisa live in grass thatched-roof houses (Fig. 12). According to the information available from the FSF Health Center and local informants, the inhabitants residing at the peripheral location are seriously exposed to the risk of malaria since they are very close to Agamsa stream, one of the claimed permanent mosquito breeding sites in the area.



Fig. 12 The houses in Kuyisa, one of the survey sites very close to Agamsa stream.

Conducive climatic conditions, environmental modifications via expansion of sugar cane plantations, road and residence construction activities, the availability of year-round water from sprinkler irrigation, canals and permanent streams crossing the villages could be the factors that enhance malaria transmission in the area (Fig. 13 and Fig. 14).



Fig. 13 Sprinkler irrigation in Finchaa Sugar Factory sugar cane plantation.



Fig. 14 An irrigation canal for water distribution to different sugar cane plantation sites in FSF.

4.4 Survey determination of malaria prevalence in FSF

In the first survey, November 2005, 10 (1.43%) of the 700 individuals examined had malaria (Table 2). On the other hand, during the second round survey, April/May 2006, 27 (3.86%) of the individuals examined were positive (Table 2). A relatively high prevalence (3.86%) was determined in April/May than in November (1.43%). An overall parasite rate of 2.64% was obtained based on a total sample of 1400 individuals from the blood smear examination in the two surveys. The proportion of the two species of parasites was comparable-*P. vivax* 1.43% and *P. falciparum* 1.21% (Table 2). In both surveys the prevalence of *P. vivax* exceeded *P. falciparum* and *P. vivax* was the only species detected among children aged less than five years (Table 3 and 4). Out of the total 37 malaria positive individuals, 16 (43%) were males and 21 (57%) females. However, no statistically significant variation ($P=0.655$) of malaria infection was seen between sexes.

The study detected focal variation of malaria prevalence with 6.95% in Village “E”, 21(3.84%) in Kuyisa (non-FSF village), 3(3.84%) in Village “A”, 2(3.13%) in Village ”D”, 1(1.47%) in Village “B” and 1(1.43%) in Village “C”. The least malaria infection was detected in Agamsa with 4(0.8%) prevalence (Table 2). Statistically significant variation ($P=0.001$) in malaria prevalence among the study sites was observed during the first survey. On the other hand, unlike the first survey, no statistically significant variation in the prevalence of malaria infection was detected among the study sites during the second survey ($P=0.171$).

Table 2. Cumulative malaria parasite prevalence among the seven survey sites, Finchaa Sugar Factory in November 2005 and April/May 2006 (N=1400).

Village	Malaria prevalence					
	November 2005			April/May2006		
	<i>P. falciparum</i> No. (%)	<i>P. vivax</i> No. (%)	Total No. (%)	<i>P. falciparum</i> No. (%)	<i>P. vivax</i> No. (%)	Total No. (%)
A (n=78)	1(1.28)	2(2.56)	3(3.84)	0(0.0)	0(0.0)	0(0.0)
B (n=68)	1(1.47)	0(0.0)	1(1.47)	0(0.0)	0(0.0)	0(0.0)
C (n=70)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(1.43)	1(1.43)
D (n=64)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(3.13)	2(3.13)
E (n=72)	1(1.39)	1(1.39)	2(2.78)	1(1.39)	2(2.78)	3(4.17)
Agamsa (n=502)	0(0.0)	0(0.0)	0(0.0)	2(0.40)	2(0.40)	4(0.80)
Kuyisa (n=546)	1(0.18)	3(0.55)	4(0.73)	10(1.83)	7(1.28)	17(3.11)
Overall (N=1400)	4(0.57)	6(0.86)	10(1.43)	13(1.86)	14(2.0)	27(3.86)

In the first survey, although malaria infection was observed in all age groups, a relatively more malaria prevalence (2.1%) was detected in the age groups 15 years and above followed by 5-14 and 0-4 age groups with (1.1%) and (0.71%) infection prevalence, respectively (Table 3). On the other hand, in the second survey, more parasite rate (4.32%) was detected in the 5-14 age group followed by 4% in 15 years and above and 2.73% in the age group 0 to 4 (Table 4). These cases were all *P. vivax* and were entirely from Kuyisa. Overall malaria infection among different age groups was not statistically significant ($P=0.377$). Within Kuyisa, of 21 malaria cases detected more than 52% were from peripheral part close to mosquito breeding site (Agamsa stream).

Table 3. Age-specific malaria infection and *Plasmodium* species prevalence among the inhabitants of Finchaa Sugar Factory in November 2005 (N=700).

Age group (in years)	Total examined No. (%)	Malaria cases No. (%)	<i>Plasmodium</i> species prevalence	
			<i>P. falciparum</i>	<i>P. vivax</i>
			No. (%)	No. (%)
0-4	140(20.0)	1(0.71)	0(0.0)	1(0.71)
5-14	273(39.0)	3(1.1)	2(0.73)	1(0.4)
≥ 15	287(41.0)	6(2.1)	2(0.7)	4(1.4)
Total	700(100.0)	10(1.43)	4(0.57)	6(0.86)

Table 4. Age-specific malaria infection and *Plasmodium* species prevalence among the inhabitants of Finchaa Sugar Factory in April/May 2006 (N =700).

Age group (in years)	Total examined No. (%)	Malaria cases No. (%)	<i>Plasmodium</i> species prevalence	
			<i>P. falciparum</i>	<i>P. vivax</i>
			No. (%)	No. (%)
0-4	110(15.7)	3(2.73)	0(0.0)	3(2.73)
5-14	185(26.4)	8(4.32)	4(2.2)	4(2.2)
≥ 15	405(57.9)	16(4.0)	9(2.22)	7(1.73)
Total	700(100.0)	27(3.86)	13(1.86)	14(2.0)

The present study has revealed that both children and adult residents in the area experienced malaria infection of varied parasitemia. Parasite density ranged from very low (<1% average parasitemia) to relatively high (an average of 10% parasitemia). Among the malaria cases, 10.8% were observed to show higher parasite density (about 10% average parasitemia) whereas the rest 89.2% cases exhibited very low to moderate (less than 3% average parasitemia).

Comparison of malaria prevalence based on clinical records and survey findings for the same period in November 2005 and April/May 2006 showed many more cases in the clinical records for both periods. Both determinations revealed more cases in the age group more than 5 years than in 0 to 4 years old (Table 5).

Table 5. Comparison of malaria case rate between the age groups of survey participants and clinical records from FSF Health Center in November 2005 and April/May 2006.

Age groups	Malaria case rate							
	Survey participants		Clinical records		Survey participants		Clinical records	
	November 2005		November2005		April/May 2006		April/May 2006	
	P.f (%)	P.v (%)	P.f (%)	P.v (%)	P.f (%)	P. v (%)	P.f (%)	P.v (%)
0-4	0(0.0)	1(0.14)	48(2.2)	29(1.3)	0(0.0)	3(0.43)	10(1.1)	15(1.6)
≥ 5	4(0.57)	5(0.71)	384(17.9)	216(10.1)	13(1.86)	11(1.57)	115(12.5)	137(15.0)
Total	4(0.57)	6(0.86)	432(20.1)	245(11.4)	13(1.86)	14(2.0)	125(13.6)	152(16.6)

4.5 KAPs Survey

Of a total 140 household heads, 112(80%) interviewees were males and 28(20%) females. The mean age of the household heads eligible for interview was about 36 years. The family size of the population ranged from 2 to 11 with an average of 6. The educational status of the interviewees was 19% illiterate and the rest 81% were literate. Of the total literate, 14% could read and write only, 49% completed elementary school and 17.5% high school. Their occupation consisted of government employment, 41.4%, while 15.0% of interviewees were unemployed. There was a significant percentage (43.6%) of daily laborers. The monthly income of unemployed, like students and housewives, could not be determined although they

earn money on temporary basis. Table 6 shows the monthly income of the study population in relation to malaria infection prevalence.

Table 6. Malaria prevalence versus monthly income of heads of household among study participants in FSF, November 2005.

Monthly income categories (in Birr)	No. of household heads	
	Number	Malaria infection
	interviewed	
	No. (%)	No. (%)
Unemployed	21(15.0)	5(23.8)
Below 200	32(22.9)	2(6.3)
201-400	42(30.0)	2(4.8)
401-600	25(17.8)	1(4.0)
601-1000	13(9.3)	0(0.0)
1001+	7(5.0)	0(0.0)
Total	140(100.0)	10(100.0)

Of the total 140 household heads interviewed from the seven survey sites, 91% replied that they had experienced malaria and had used anti-malaria drugs (Table 7). When asked what brand of anti-malaria drugs they used, 55% replied Chloroquine (CQ) and Sulphadoxine-Pyrimethamine (Fansidar) whereas 26% indicated that they did not know. Furthermore, few respondents reported to have used the combination of two or more of the anti-malaria drugs.

Table 7. The proportion of household heads reported malaria infection and use of anti-malaria drugs from the seven study sites in FSF, November 2005.

Survey site	No. of household heads			
	Number Interviewed	Reported malaria infection	Anti-malaria drug use	
			paid	Free
A	8	8	2	6
B	7	7	2	5
C	8	8	1	7
D	7	5	-	5
E	8	8	2	6
Agamsa	46	37	6(16.2%)	31(83.8%)
Kuyisa	56	54	38(70.4%)	16(29.6%)
Total	140(100.0%)	127(91%)	51(40.2%)	76(59.8%)

As to the frequency of application of anti-mosquito residual spraying, all the respondents agreed that it was applied once a year in August. The majority of the heads of households (61%) in all study sites replied that they did not so far use ITNs. However, an insignificant proportion (5%), all from Agamsa, were using ITNs which, however, was only limited to fathers and mothers. A similar proportion (5%) of respondents had used in the past but not at the time of interview. On the other hand, 18% household heads indicated that they did not know about ITNs. Use and knowledge of anti-malaria drugs for preventive purpose was reported to be insignificant (5%). In general, the community exhibited low awareness on average (16.3%) regarding knowledge towards ITNs and anti-malaria drug types as well as use of anti-malarial drugs for preventive purpose.

More than three-fourth (78%) of the respondents reported that they did not travel to any malarious area within the last 14 days, while other 22% heads of the household replied to

have visited at least one malarious area in Ethiopia within that period of time. 57% of the respondents indicated that they normally sleep outdoors. Out of these 35.5% sleep outdoors due to the nature of their work and 18% to avoid the heat indoors. However, outdoor sleeping was not significantly associated with malaria infection rate ($P= 0.544$).

Looking at the quality of residential houses, of the total interviewed household heads, more than half (57%) had good quality housing units made up of brick walls and tin roofs. 33% had woody walls and tin roofs and 10% with woody walls and grass thatched roofs. The number of rooms in the dwellings was also different. The vast majority (72%) of interviewees indicated that their houses comprised only one room; 23% of the interviewees had two room houses and only 7% had three rooms.

It was observed that households with three rooms in their dwelling experienced low (5.4%) malaria infection rate whereas households with one room experienced more (62.2%) malaria infection rate. Households with two rooms experienced about 32.4% malaria infection rate. Number of rooms in the houses and malaria infection prevalence was significantly associated ($P<0.001$).

Other factors such as income source and occupation were also associated with malaria infection ($P=0.05$). More numbers of unemployed individuals (23.8%), the majority of them being daily laborers, were found infected and increase in income was negatively associated with malaria infection rate (Table 6).

Out of the few of the respondents that had livestock, more than 90% replied that they keep their livestock outside their residence. No significant association ($P=0.658$) was observed between malaria infection prevalence and the possession of livestock by a household. Similarly, other factors such as educational status and family size were not significantly associated with malaria infection.

5. Discussion

Finchaa Sugar Factory (FSF), located between 1,350m and 1,600m a.s.l. in a warm and moist lowland, falls within an area of malaria endemicity in Ethiopia. In addition to the conducive climatic factors, there exists extensive irrigation farming which could create favorable conditions for a year-round malaria transmission. The moderately high mean annual minimum temperature (14.5 °C) and mean annual maximum temperature (30.6 °C) together with the relatively moderate moisture (62%), in FSF, would favor the breeding of mosquito vectors and enhance parasite life cycle completion inside the mosquito, a process highly dependent on environmental temperature and humidity (Zucker, 1996; Malakooti *et al.*, 1998; Temu *et al.*, 1998; Sutherst, 2004). The presence of temporary and permanent streams in addition to the numerous sprinklers and irrigation canals are additional factors that may favor malaria transmission throughout the year in FSF.

It is well known that a strong association exists between water resource development projects, especially irrigation, and the transmission of malaria (Chimbari *et al.*, 2004). Consequently, irrigation development in the Awash River Valley and elsewhere has contributed to increased malaria transmission in settlement schemes in Ethiopia (Haile-Meskel and Kloos, 1989). Nevertheless, planning of irrigation systems in various parts of Ethiopia has not been adequately considering its health impact. As a result, populations living near irrigation areas have been reported to be exposed to higher risks of malaria (Alemayehu *et al.*, 1998) and the situation in FSF is not much different.

Most malaria cases recorded in FSF Health Center can be assumed to have been contracted autochthonously although the contribution to its prevalence by labor migrants from endemic areas might also be significant. This is obvious from the retrospective clinical data of the past half decade, which, on the whole, shows a year-round transmission of the disease. The low level year-round transmission may have been maintained by multiple factors like irrigated sugar cane plantation, various construction

activities relating to irrigation as well as construction of residential houses, labor force immigration, etc.

The 5 years retrospective data showed that malaria has been the most important cause of human morbidity and mortality and hence, puts pressure on the health services of FSF. The significant rise in malaria prevalence observed in September/October 2001 appeared to be associated with the weather condition, especially the increase in rainfall (113.43 mm) and relative humidity (63.47%). On the contrary, the significant decline in malaria prevalence in July/August of 2002 could perhaps be associated with the relatively higher maximum temperature (31.16 °C), the low average annual rainfall (99.54 mm) and the low relative humidity (59.65%) recorded during the year (Appendix 5).

The relative escalation of malaria throughout the years 2003 and 2004 was associated with the increase in rainfall from 99.54 mm to 107.25 mm and 105.19 mm, respectively (Appendix 5). During these years the population surrounding the FSF was reporting in large numbers at the health center of the factory seeking treatment for malaria (Bezu Chemed, personal communication, November 25, 2005). This is consistent with the reports from elsewhere that sharp changes in weather conditions play a major role in causing severe epidemics of malaria (Abeku *et al.*, 2004; Thomas *et al.*, 2004).

On the other hand, compared to 2003 and 2004, a slight decline in malaria prevalence was observed in 2005. This relative decline in the average prevalence may be explained by the improved attention given for malaria control following the experience of the 2003 and 2004 epidemic years. Excessive flooding due to heavy rains (140.07 mm) may have also impaired mosquito breeding. The subsequent rise in the prevalence beyond the month of September in 2005 was to be expected as heavy rains subside ideal mosquito breeding water bodies will be created.

In addition to the prevailing meteorological condition for malaria endemicity, irrigation farming which utilizes inadequate vector control measures coupled with the low awareness of the population on the use of ITNs and the poor accessibility of the ITNs

appear to be the reasons for continued malaria transmission (Bezu Chemed, personal communication November 25, 2005). This lack of attention to vector control methods such as the use of ITNs is unacceptable in view of the evidence that they can reduce malaria-specific death by over 20% (WHO-UNICEF, 2003).

Clinical records have shown a sharp escalation in malaria prevalence from 2001 to 2004 in comparison with other common infectious diseases such as respiratory infections, helminthiasis and amoebiasis and giardiasis in FSF. This increase may have been associated with inter-linking factors like the environment (increase in rainfall) and demography (labor immigration) that directly or indirectly influence the transmission of malaria.

Although retrospective clinical records from FSF Health Center over the past half decade showed 30% average annual malaria prevalence, the low average prevalence (2.64%) detected based on the community-based cross-sectional prevalence survey was to be expected since more positive cases would be expected from treatment-seeking patients than active case detection through a survey of a random sample of the population. The existence of discrepancy in malaria prevalence estimation between cross-sectional surveys and clinical records is a well known phenomenon. For example, a report from the community of Mekong Delta region (Vietnam) where clinical records of malaria prevalence on average showed 62% while survey-based parasite prevalence and seroprevalence were less than 2.4% for the same study period (Erhart *et al.*, 2004). Similarly, the overall falciparum malaria rate among children aged 0-9 years in Humera, northwestern Ethiopia, was 12% based on a prospective study whereas over 50% of clinical falciparum malaria cases were recorded from treatment-seeking out-patients (Seboxa and Snow, 1997). Furthermore, determinations based on microscopic method of diagnosis may not be a definite proof for the absence of malaria parasites as samples reported to be negative microscopically have been shown to be PCR-positive (Roper *et al.*, 1998; Babiker *et al.*, 1998). Therefore, false negative reports during microscopic examination of blood films would be expected to be more in cross-sectional studies, thus under-estimating the malaria prevalence.

The report of the majority of household heads in the KAP survey that they have been using anti-malaria drugs as self-treatment is typical of the situation in rural Africa (Foster, 1995) where self-treatment is the most common practice in malaria. Thus, since self-treatment is most often known to be associated with an improper use of anti-malaria drugs (Mwenesi, 1994), the danger of spread of Chloroquine-resistant malaria is eminent if not already established in FSF.

Seasonal variation in malaria transmission is a well established feature of unstable malaria. In Ethiopia, Kidane and Teklehaimanot (1988) had reported 2.6% in dry season (April/May) 1984/85 and 5.8% during wet season (September-November) in Metekel resettlement scheme (northern Ethiopia). Similarly, malaria prevalence surveys in Kassena-Nankana District of northern Ghana showed 22% parasite rate in May (dry-low transmission) and 61% in November (wet-high transmission) (Koram *et al.*, 2003).

However, the unexpectedly low malaria prevalence detected in the present study, in the month of November, which is a high transmission month compared to the relatively high prevalence in April/May, the low transmission, may be due to the suppressive effect of the household residual spray, which is routinely applied every year in August. On the other hand, since more than eight months elapsed between DDT spraying and the second survey in April/May, the potency of DDT, which has an average residual effect of six months on most residential house surfaces (WHO, 2005b), will have lost potency to suppress malaria transmission during the low transmission season. This suggests that the residual insecticide spray in August may have effect on suppressing malaria transmission in the peak season in the FSF proper, and hence the bulk of treatment-seeking patients that visited the FSF health center for malaria treatment may be coming from outside DDT spray areas.

It has been reported by Kitaw *et al.* (1998) and MOH (2000) that *P. falciparum* is the dominant species during peak malaria transmission season while *P. vivax* tends to dominate during the dry season in Ethiopia. However, in the present study, the prevalence

of *Plasmodium* species showed little variation between the two survey periods. This possibly is the effect of the August insecticide residual spray which may have reduced the peak transmission of *P. falciparum* during the first survey. This may have been true because anti-malaria measures are known to lead to changes in the distribution and dominance of malaria parasite species (Geber-Mariam, 1984).

The relatively high malaria cases detected in Village “E” may be accounted for by its peripheral location from the center of FSF, which receives most malaria control measures. In this village, significant numbers of temporary shelters where daily laborers reside are not amenable to residual insecticide vector control. Furthermore, temporary pools of water from damaged pipes and sprinkler irrigation, creating a favorable environment for mosquito breeding, were prominent in this village.

Next to Village “E”, more malaria cases were detected from Kuyisa and Village “A”. Kuyisa, is located very close to a stream, which is ideal for year-round mosquito breeding. Even within Kuyisa the majority of malaria cases were from the peripheral location adjacent to the stream. Such difference in prevalence among the villages indicates that malaria transmission can be influenced by focal micro-ecological conditions. This finding is in agreement with the report of Yohannes and Petros (1996), which showed a variation in malaria prevalence between central and peripheral locations in the city of Nazareth, eastern Ethiopia.

In addition to its proximity to breeding site, the poor quality of housing in Kuyisa would provide little protection against malaria vectors. Moreover, the inhabitants of this site are predominately daily laborers and are the least paid. Thus, unlike the permanent employees of the FSF, the inhabitants of Kuyisa as daily laborers do not get adequate free medication (only 30% reported free medication) and hence a relatively high malaria prevalence would be expected among them.

The other villages “D”, “B” and “C” exhibited a relatively low malaria prevalence compared to Villages “E”, “A” and Kuyisa. The low prevalence could be due to the

absence of streams and canal outlets that proximally cross them. Moreover, these villages are centrally located and are close to the health center where the residents can readily obtain free laboratory-based medication.

The very low (0.8%) malaria prevalence in Agamsa (residential quarters of permanent employees) could be attributed to the availability of personal mosquito protection methods like mosquito window screening, use of bed nets, etc, in addition to the existing vector control measures and free treatment services (84% of the residents received free drugs). Furthermore, as revealed by the KAP survey, households from Agamsa have relatively good awareness towards malaria transmission and its control techniques compared to the remaining study sites. For instance, all ITNs users identified by the survey were from Agamsa.

Statistically significant difference ($P=0.001$) in malaria prevalence among the study sites was observed during the first survey. Differences in the nature of housing units as observed from KAPs survey were among the major differentiating features whereby poor quality housing was associated with the relatively high malaria prevalence. In addition, there were also differences with respect to the presence or absence of transient or permanent mosquito breeding sites (streams or canals) around human habitations as discerned by observation. On the other hand, unlike the first survey, no statistically significant variation in the prevalence of malaria infection was detected among the study sites during the second survey ($P=0.171$). This implies that rainfall, which is the feature of the first survey period, on top of the water bodies created by irrigation, may be responsible for the variation of malaria prevalence among the study sites.

Although the presence of infection among infants and children between ages 0 and 4 in stable communities implies autochthonous malaria transmission, the finding in FSF where the highest prevalence was in the age group 5 years and above does not fit into the conventional characterization of the epidemiology of malaria based on age stratification. That is, conventionally in areas of high endemicity, prevalence of malaria infection is known to peak at an early age with an increase up to the age of 5 years; followed by a

sharp fall in age groups 10-15 years and continuing on a slow decline with increasing age (WHO, 2000b). This pattern of prevalence is a reflection of the age related state of anti-malaria immunity that is developed as a result of repeated malaria infections under an established malaria endemicity.

However, the FSF environment with irrigated agriculture and the influx of seasonal laborers from malarious and non-malarious localities of the country does not appear to be a typical malaria endemic locality as it shows an asymmetrical age-related epidemiological profile. Studies had shown that individuals living in areas of unstable and low intensity malaria transmission do not acquire significant immunity to the disease (Macdonald, 1957) and hence, malaria infections can be observed in all age groups (Giha *et al.*, 2000; Oesterholt *et al.*, 2006). Recent work on the age-specific risk for malaria in eastern Sudan showed that the prevalence of malaria was high up to the age of 19 years (Giha *et al.*, 2000). Similarly, studies conducted in areas of lower malaria endemicity, for example, in Riboque in Sao Tome, had shown little or no influence of age on infection complexity (Muller *et al.*, 2001). Thus, the epidemiological condition prevailing in the FSF from a prospective parasitological survey point of view suggests that the area is characteristic of an unstable, low level of malaria endemicity. However, health center case rates up to the time of the present study showed significant malaria case detection.

Since its inauguration in 1999, the FSF has experienced tremendous demographic changes as a result of the huge influx of people coming in search of job. This mass movement of labor force including people from malaria endemic regions may have exasperated the malaria situation in the area. In addition to sugar cane cultivation, there was also extensive sesame cultivation by private investors outside the territory of FSF that also employ sizeable labor force. The labor force of both FSF and private investors seem to share every social, environmental and health episodes (including malaria) as they occupy the same environment under the same geographical boundary.

The frequent in-and-out migrant labor force could in particular account for the prevailing malariologic phenomenon since FSF is visited by an ever-increasing influx of population

from different areas of the country, including malaria endemic ones. The movement of labor force for harvesting sugar cane and other activities is more prominent during the operational period of the factory, that is, October to June. This coincides with the two peak transmission seasons of malaria and the potential for an epidemic situation is high. Bloland and Williams (2003) have reported that seasonal migration of workers was associated with malaria epidemics in Kenya. As a result, these populations returning from the malaria-endemic lowlands may transport malaria parasites as asymptomatic or symptomatic infections (Shanks *et al.*, 2005). This has been explained by the fact that equilibrium in man-vector-parasite relationship can be disturbed by the huge influx of population and would result in epidemics.

As far as the past half-decade is concerned, regular systematic antimosquito spraying were conducted every year after the cessation of heavy rains in August. Other than residual household spraying, periodic application of oil to larval habitats and environmental management (filling, drainage etc.) have been among the control measures practiced during sample collection. However, those control techniques involving environmental modification did not cover all the areas. Despite these control measures, the transmission of malaria continues to be a serious public health problem year after year (Bezu Chemeda, pers. communication November 25, 2005).

Although indoor residual spray of households has been practiced yearly in August, the effect of the spray in stopping transmission of malaria in the area was not successful. This could be an indication of either insecticide resistance of mosquito vectors or a reflection of the inefficiency of the control measures, including human interference with the indoor residual sprays and insufficient coverage of the spray. Other factors like drug resistance may also have contributed to the lack of impact of the intervention on the transmission.

Malaria costs in life and money and where the disease thrives economies suffer. A short-run economic consequence of malaria on households is known to be far reaching. For example, an assessment in Matale, a malaria-endemic district of Sri Lanka, showed that on average a household incurred a total cost of US\$ 7 per patient who fully recovered

from malaria. Out of this, 24% was direct cost while the 44% was an indirect cost for the patient and 32% an indirect cost for the household (Attanayake *et al.*, 2000). Figures for Ethiopia could be very different as here treatment is provided free of charge.

The reports from FSF health facilities also suggested that malaria has been reducing the work output of FSF permanent and seasonal employees and causing loss in school attendance among students, thus deserving a priority public health attention. Malaria is thought to slow annual economic growth by 1.3% in African countries with high prevalence (Gallup and Sachs, 2001) owing to an estimated economic cost of \$12 billion every year (Sachs, 2002). More recently, studies showed that the impacts of malaria on household economic status unfold slowly over time, influencing household ability to withstand the disease and other contingencies in future (Chuma *et al.*, 2006). Similarly, high loss in school attendance has been reported from Kenya whereby a loss of 11% out of 186 school days in a year was due to malaria (Leighton and Foster, 1993).

6. Conclusions and recommendations

The present study was an initial step to the understanding of the epidemiology of malaria in FSF area. Based on information from clinical records and the survey data, the following conclusions may be drawn about the malaria situation in FSF:

1. Malaria due to *P. vivax* and *P. falciparum* is among the major causes of morbidity and puts pressure on the health services of FSF;
2. As a result of DDT spray every August, there is suppression during the November peak transmission period, however, more positive cases detected in April/May may be accounted for by the diminishing potency of the residual insecticidal spray.
3. The majority of the population has been using anti-malaria drugs in low doses as self-treatment and hence, the danger of introducing drug resistance is eminent;
4. The asymmetrical age-related malaria prevalence profile in the population appears to be an indication of unstable epidemiological situation in the area, which is suggestive of an epidemic potential.

On the basis of the results obtained from the study, the following recommendations may be suggested:

1. Since FSF has been attracting a large number of seasonal workers from different malaria endemic parts of the country, the extent of imported malaria must be determined. On the basis of such determination, screening seasonal laborers for malaria and treating them prior to employment could possibly contribute to the overall malaria control by minimizing imported malaria into the area.
2. A study of insecticide resistance of mosquito vectors and drug resistance of malaria parasites is essential to design appropriate malaria control measures in FSF area.
3. Malaria control efforts in the area should focus more on management of seasonal and year-round streams, springs and canals that cross the villages. Efficient drainage systems and well-maintained canals should be in place.

4. Residual insecticide spray of the residential houses must be applied twice a year – one before the major transmission peak (August) and another one before the minor peak (March) transmission season. This must include communities adjacent to the FSF to prevent potential introduction of imported malaria.
5. Methods such as mosquito-window screening and use of impregnated bed nets must be promoted by the FSF with a special attention to the inhabitants that reside in the peripheral villages and economically disadvantaged households like those in Kuyisa.
6. Since poor awareness about the modes of malaria transmission and control measures characterizes the FSF community, health education targeting the population at risk will be necessary.
7. Entomological surveys coupled with parasitological study should be initiated to further characterize the epidemiological profile of malaria and better estimate level of prevalence in the area so as to design appropriate control measures.

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Appendix

Appendix 1. Annual malaria prevalence data obtained from clinical records of outpatients at FSF Health Center from 2001-2005/06.

1-a. Annual malaria prevalence data obtained from clinical records of outpatients at FSF Health Center, 2001.

Month	<i>P. falciparum</i> No. (%)	<i>P. vivax</i> No. (%)	Total examined
Jan.	9(2.2)	60(15)	401
Feb.	1(0.3)	49(14.8)	331
March	8(2.5)	49(15.1)	324
April	3(0.7)	36(8.6)	417
May	32(5.3)	64(10.6)	602
June	44(7.7)	51(9)	569
July	35(5.2)	49(7.3)	674
Aug.	15(2.4)	45(7.3)	613
Sept.	8(1.7)	27(6)	453
Oct.	94(13.7)	46(6.7)	687
November	77(9.8)	37(4.7)	789
Dec.	42(7)	30(5)	608
Total	368(5.7)	543(8.4)	6468

1-b. Annual malaria prevalence data obtained from clinical records of outpatients at FSF Health Center, 2002.

Month	<i>P. falciparum</i> No. (%)	<i>P. vivax</i> No. (%)	Total examined
Jan.	13(2.7)	29(6.1)	472
Feb.	5(1.5)	20(5.8)	344
March	3(0.7)	20(4.8)	416
April	6(1.5)	22(5.5)	405
May	11(3)	24(6.7)	360
June	50(13.4)	49(13.2)	372
July	100(11.1)	93(10.4)	897
Aug.	60(6.1)	30(3)	983
Sept.	48(10.5)	16(3.5)	456
Oct.	79(13.1)	42(7)	603
November	285(25.5)	47(4.2)	1119
Dec.	187(17.5)	39(3.7)	1066
Total	847(11.3)	431(5.8)	7493

1-c. Annual malaria prevalence data with age and *Plasmodium* species distribution obtained from clinical records of outpatients at FSF Health Center, 2003.

Month	Age groups				Total examined
	0-4		≥5		
	<i>P. vivax</i> No. (%)	<i>P. falciparum</i> No. (%)	<i>P. vivax</i> No. (%)	<i>P. falciparum</i> No. (%)	
*Jan.	-	-	-	-	-
*Feb.	-	-	-	-	-
March	16(2.3)	10(1.5)	75(11.0)	28(4.1)	688
April	19(2.7)	16(2.3)	106(15.0)	35(5.0)	706
May	32(2.1)	24(1.6)	179(11.7)	295(19.3)	1530
June	20(2.0)	39(4.0)	99(10.0)	198(19.8)	998
July	31(2.6)	83(6.8)	112(9.2)	232(19.1)	1215
August	35(2.4)	68(4.7)	216(15.0)	324(22.4)	1446
Sept.	27(1.7)	62(3.8)	216(13.3)	424(26.2)	1618
Oct.	66(2.8)	90(4.0)	314(13.5)	418(18.0)	2321
Novem ber	60(2.2)	86(3.2)	327(12.2)	573(21.3)	2692
Dec.	40(2.0)	49(2.4)	261(13.0)	405(20.2)	2006

NB. *There was no data for January and February 2003.

1-d. Annual malaria prevalence data with age and *Plasmodium* species distribution obtained from clinical records of outpatients at FSF Health Center, 2004.

Month	Age groups				Total examined
	0-4		≥ 5		
	<i>P. vivax</i>	<i>P. falciparum</i>	<i>P. vivax</i>	<i>P. falciparum</i>	
	No. (%)	No. (%)	No. (%)	No. (%)	
Jan.	55(3.2)	82(4.8)	238(14.1)	195(11.5)	1695
Feb.	37(3.1)	34(3.0)	225(21.6)	55(4.7)	1179
March	30(2.7)	0(0.0)	215(19.5)	32(3.0)	1104
April	22(2.1)	1(0.1)	292(27.3)	5(0.5)	1069
May	70(3.9)	72(4.0)	341(18.8)	146(8.1)	1812
June	75(3.4)	97(4.4)	376(17.1)	284(13.0)	2195
July	80(3.7)	96(4.5)	345(16.1)	364(17.0)	2137
August	23(1.4)	69(4.0)	197(11.5)	214(12.5)	1709
Sept.	27(1.6)	20(1.2)	189(11.3)	256(15.3)	1669
Oct.	66(2.3)	114(4.0)	465(16.3)	447(15.7)	2849
Novem ber	105(2.6)	161(4.0)	576(14.3)	799(19.8)	4034
Dec.	141(4.3)	103(3.1)	507(15.3)	687(20.8)	3309

1-e. Annual malaria prevalence data with age and *Plasmodium* species distribution obtained from clinical records of outpatients at FSF Health Center, 2005.

Month	Age groups				Total examined
	0-4		≥5		
	<i>P. vivax</i> No. (%)	<i>P. falciparum</i> No. (%)	<i>P. vivax</i> No. (%)	<i>P. falciparum</i> No. (%)	
Jan.	22(1.0)	105(5.0)	313(14.5)	371(17.1)	2165
Feb.	37(3.0)	5(0.4)	290(23.6)	104(8.5)	1227
March	30(2.8)	0(0.0)	218(20.3)	51(4.7)	1076
April	19(2.3)	1(0.1)	187(22.1)	8(1.0)	845
May	26(2.7)	2(0.2)	153(16.0)	14(1.5)	964
June	11(1.3)	1(0.1)	124(14.2)	79(9.0)	874
July	16(1.7)	7(0.8)	128(13.8)	103(11.1)	930
August	18(1.7)	7(0.7)	125(11.6)	121(11.2)	1081
Sept.	13(0.9)	12(0.9)	102(7.3)	163(11.6)	1403
Oct.	15(1.1)	24(1.7)	144(10.3)	245(17.5)	1400
*Nove mber	34(1.6)	43(2.0)	153(7.1)	447(20.8)	2150
Dec.	17(0.6)	17(0.6)	464(16.7)	357(13.0)	2776

* Shows the month during which first survey was conducted

1-f. Malaria prev. data obtained from clinical record at FSF Health Center from Jan. to June 2006.

Month	<i>P. falciparum</i> No. (%)	<i>P. vivax</i> No. (%)	Total examined
Jan.	130(7.4)	205(11.6)	1765
Feb.	53(5.2)	175(17.2)	1021
March	15(1.7)	134(15.0)	896
*April	131(15.0)	149(17.1)	871
*May	119(12.3)	156(16.2)	964
June	76(9.0)	133(15.8)	844

* Shows the months during which second survey was conducted

Appendix 2. Questionnaire

I. Area identification

1. Village_____ 2. Household No. _____

II. Particulars of the study subjects

1. Name_____ 2. Sex____ 3. Age ____ 4. Occupation_____

5. Average monthly income_____ 6. Educ. status (Illiterate, read & write only, elementary school, high school, higher institutions) (underline)

6.1 Are you currently attending school? Yes/No (underline)

6.1.1 Have you ever been absent from school? Yes/No (underline)

6.1.2 If yes reason for absence_____

7. Have you ever experienced malaria or fever? Yes/No (underline)

7.1 If yes did you use medicine? Yes/No (underline)

7.1.1 If yes how did you obtain the medicine you used? Free/with payment

7.1.2 What was the brand of medicine you used? (Chloroquine, Fansidar, Quinine, Primaquine, Others specify) (underline)

8. Have you ever been to malarious area? Yes/No (underline)

8.1 If yes when and where was it?_____

9. Have you used medicine for preventive against malaria? Yes/No (underline)

9.1 If yes how did you obtain it? Free/with payment (underline)

10. Is there chemical spraying to control mosquitoes? Yes/No (underline)

10.1 If yes how frequent? Once in a year/twice and more in a year (underline)

11. Do you use impregnated mosquito net? Yes/No (underline)

11.1 If yes a) all family members b) only father and mother c) only children

12. Do you have livestock? Yes/No (underline)

12.1 If yes where do you keep the livestock at night? _____

13. Do you sleep outdoors? Yes/No (underline)

13.1 If yes why? _____

III. Information on housing unit

1. What is the type of housing unit? a) Conventional (thatched roof, mud, bamboo, other)

b) Improved (blocket, bricks,) c) others (specify)_____

2. What is the number of rooms in the housing unit?_____

Appendix 3. Consent form

PIN -----
Name of study participant ----- Age----- Sex-----
Physician Name----- Site /Health center -----

I have been informed about a study that plans to investigate the malaria transmission pattern in Finchaa Sugar Factory entitled “**Assessment of Malaria as a Public Health Problem in Finchaa Sugar Factory based on Clinical Records and Parasitological Surveys**” which will help in investigating the extent to which malaria is a public health problem in the area. This study could contribute to in recommending the use of appropriate control measures that can minimize the transmission of the disease in the area.

For the study I have been requested to give a drop of blood from my finger and children under my guardian. They told me that experienced health professionals according to the established aseptic procedure would do the blood collection on to glass slide by finger pricker (lancet). I have been informed that if positive result is observed treatment will be given to children and me by using the standard drug regimen. Based on this, I have agreed to continue the examination with my children and me too. The investigator also informed me that if I want all the laboratory results would be kept confidential.

I have been given enough time to think over before I signed this informed consent. It is therefore, with full understanding of the situation that I gave my informed consent and cooperates at my will in the course of the conduct of the study.

Name (participant) -----Signature -----Date -----
Name (investigator) -----Signature -----Date -----
Name (Witness) -----Signature -----Date -----

Appendix 4. Malaria parasite distribution among the study subjects by sex, age, village and stage of parasite Finchaa Sugar Factory, 2005/06 (N=1400).

No.	Slide No.	Sex	Age	Village	Parasite type	Stages
1	2.1	F	15	A	<i>P.vivax</i>	Trophozoite
2	4.2	M	22	A	<i>P.vivax</i>	Trophozoite
3	5.4	M	25	A	<i>P. falciparum</i>	Gametocyte
4	13.4*	M	22	B	<i>P. falciparum</i>	Ring
5	30.2	M	20	E	<i>P.vivax</i>	Trophozoite
6	34.3	M	6	E	<i>P. falciparum</i>	Ring
7	65.01•	F	28	Kuyisa	<i>P.vivax</i>	Trophozoite
8	90.4	F	6	Kuyisa	<i>P. falciparum</i>	Gametocyte
9	106.2	M	5	Kuyisa	<i>P.vivax</i>	Schizont
10	118.1*•	M	4	Kuyisa	<i>P.vivax</i>	Ring
11	2.6	F	9	Kuyisa	<i>P. falciparum</i>	Ring
12	5.01+	F	25	Kuyisa	<i>P. vivax</i>	Ring, Schizont
13	5.2•	M	20	Kuyisa	<i>P. falciparum</i>	Gametocyte
14	35.4	F	10	C	<i>P. vivax</i>	Schizont
15	40.3	F	10	E	<i>P. vivax</i>	Ring, Schizont
16	41	M	22	E	<i>P. falciparum</i>	Gametocyte
17	44	M	18	E	<i>P. vivax</i>	Ring, Schizont
18	48.3	F	27	D	<i>P. vivax</i>	Schizont
19	49.3	M	45	D	<i>P. vivax</i>	Schizont
20	56.3•	F	6	Kuyisa	<i>P. falciparum</i>	Gametocyte
21	57.01*	F	70	Kuyisa	<i>P. falciparum</i>	Ring
22	58.4•	F	27	Kuyisa	<i>P. falciparum</i>	Gametocyte
23	58.7*	F	3	Kuyisa	<i>P. vivax</i>	Schizont
24	60.3+	F	18	Kuyisa	<i>P. vivax</i>	Schizont
25	61.4•	F	4	Kuyisa	<i>P. vivax</i>	Schizont
26	64.1	F	20	Kuyisa	<i>P. falciparum</i>	Gametocyte
27	64.3•	F	7	Kuyisa	<i>P. falciparum</i>	Ring
28	66.01+•	F	35	Kuyisa	<i>P. falciparum</i>	Gametocyte
29	69.2*	M	12	Kuyisa	<i>P. falciparum</i>	Ring
30	71.4•	F	20	Kuyisa	<i>P. falciparum</i>	Gametocyte
31	75.9	F	1	Kuyisa	<i>P. vivax</i>	Ring, Schizont
32	80.2•	M	10	Kuyisa	<i>P. vivax</i>	Schizont
33	82.1•	M	7	Kuyisa	<i>P. vivax</i>	Trophozoite
34	87.01*	F	35	Agamsa	<i>P. falciparum</i>	Ring
35	88	M	38	Agamsa	<i>P.vivax</i>	Ring
36	98.01*	F	27	Agamsa	<i>P. vivax</i>	Ring, Schizont
37	108*	M	48	Agamsa	<i>P. falciparum</i>	Ring

* febrile (high av. parasitemia), + febrile (preg. woman), • peripheral residents in Kuyisa

Appendix 5. Meteorological conditions prevailing in Finchaa Sugar Factory area, East Wellega, Ethiopia, 1979-2005.

Years	Rainfall (mm)	Max. Temp.	Min. Temp.	Mean Temp. (°C)	RH (%)
1979	114.09	30.13	14.36	22.24	_____
1980	115.9	30.51	14.56	22.54	_____
1981	110.47	29.82	14.09	21.96	_____
1982	99.68	30.09	15.21	22.65	_____
1983	117.3	30.34	15.1	22.72	_____
1984	106.1	30.6	14.45	22.52	_____
1985	122.66	29.8	13.78	21.79	_____
1986	88.94	30.34	14.47	22.4	_____
1987	106.61	30.97	15.32	23.15	_____
1988	127.05	30.34	15.29	22.81	_____
1989	120.47	30.18	14.32	22.25	_____
1990	124.7	30.84	14.9	22.87	61.45
1991	125.9	30.9	14.87	22.89	60.72
1992	122.65	30.1	15.25	22.67	63.2
1993	153.85	30.07	14.77	22.42	64.63
1994	123.16	30.74	14.88	22.81	61.04
1995	121.01	30.89	14.76	22.82	61.09
1996	117.87	30.41	13.94	22.17	63.75
1997	111.82	30.56	13.85	22.21	63.06
1998	130.97	30.45	14.68	22.57	62.25
1999	138.43	29.88	14.74	22.31	61.79
2000	145.34	29.9	15.27	22.59	63.18
2001	113.43	29.89	15.62	22.75	63.47
2002	99.54	31.16	15.94	23.55	59.65
2003	107.25	30.93	15.87	23.4	59.43
2004	105.19	30.51	15.82	23.17	61.45
2005	140.07	30.53	15.37	22.95	61.84

RH- relative humidity, Max Temp- maximum temperature, Min Temp- minimum temperature

Source: Agricultural Research Institute Finchaa Research Station

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Abbreviations

AAUMF	Addis Ababa University Medical Faculty
AAUSF	Addis Ababa University Science Faculty
ACT	Artemisinin-based Combination Therapy
AL	Arthemeter Lumefantrine
CDC	Center for Diseases Control
CQ	Chloroquine
DALYs	Disability Adjusted Life Years
DDT	Dichlorodiphenyltrichloroethane
ENHRI	Ethiopian Nutrition and Health Research Institute
FDRE	Federal Democratic Republic of Ethiopia
FMOH	Federal Ministry of Health
FSF	Finchaa Sugar Factory
GDP	Gross Domestic Product
GNP	Gross National Product
IRS	Indoor Residual Spraying
ITNs	Insecticide Treated Nets
P.f.	<i>Plasmodium falciparum</i>
P.v.	<i>Plasmodium vivax</i>
RBM	Roll Back Malaria
SNNP	Southern Nations and Nationalities People
SP	Sulphadoxine-Pyrimethamine
SPSS	Statistical Package for Social Science
SSA	Sub-Saharan- Africa
TDR	Tropical Diseases Research
UN	United Nations
UNICEF	United Nations Children's Fund
WHO	World Health Organization

Abstract

An assessment of malaria as a public health problem was conducted during the two peak malaria seasons of 2005/06 among the residents of Finchaa Sugar Factory (FSF), in eastern Wellega, western Ethiopia. The study was based on a cross-sectional survey for malaria prevalence and the use of retrospective clinical records from FSF Health Center. The study included determination of parasite rate, environmental and socio-economic factors associated with or contributing to the transmission of malaria. Retrospective clinical reports of FSF Health Center during the past five years showed that malaria was among the major infectious diseases constituting significant public health problem, accounting for over 30% average annual prevalence in the area. On the other hand, examination of thick and thin blood films from a random sample of 700 individuals from 7 villages of FSF revealed an infection prevalence of 1.43% in November 2005 and 3.86% in April/May 2006, which suggests that malaria prevalence in the area was moderate. Of the total 37 malaria positives on microscopy, 59.5% were age 15 years and above. The study detected focal variation of malaria prevalence with 6.95% in Village "E"; 3.84% in Kuyisa (non-FSF village) and Village "A"; 3.13% in Village "D"; 1.47% in Village "B"; 1.43% in Village "C" and 0.8% in Agamsa (a residential quarter for permanent employees). The result from the KAPs survey revealed low awareness (16.3%) in the community towards malaria infection and its control techniques. Multiple factors such as favorable climate and topography, availability of year-round water via irrigation, environmental modifications for irrigated sugar cane plantation, huge influx of labor force from malaria endemic adjacent regions and lack of continued attention to malaria control measures appeared to be responsible for the continuous transmission of the disease in the area. Hence, vector control measures, by instituting a second round of residual insecticide application in the period March/April and other vector control measures such as the use of ITNs, must be instituted. Prevention of imported malaria and disease management via administration of free anti-malaria therapy to the seasonal laborers must be given adequate attention.

Key words: Ethiopia, Finchaa Sugar Factory, Irrigation, Malaria, *Plasmodium falciparum*, *Plasmodium vivax*, Public health

Declaration

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

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