ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF BIOLOGY

IRRIGATION AND SOCIO-ECONOMIC FACTORS RELATED TO MALARIA TRANSMISSION IN ZIWAY, EASTERN OROMIA ZONE.

By
Yihenew Alemu

In partial fulfillment of the requirements for the degree of Master of Science in Biology (Biomedical Sciences)

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May, 2007

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ACT	Artemisin-based Combination Therapy
CDC	Centers for Disease Control and Prevention
ILRI	International Livestock Research Institute
IPT	Intermittent Prevention Treatment
IRS	Indoor Residual Spraying
ITN	Insecticide Treated Nets
IWMI	International Water Management Institute
MFI	Malaria Foundation International
MoH	Ministry of Health
MoWR	Ministry of Water Resource
NIH	National Institute of Health and Medicinal Services
NMA	National Meteorological Agency
RBM	Roll Back Malaria
SP	Sulfadoxine Pyrimethamine
UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund
WHO	World Health Organization
WMR	World Malaria Report
WRBU	Walter Reed Biosystematics Unit
X^2	Chi square tests

ABSTRACT

Ziway is one of the regions in central Ethiopia where unreliable rainfall frequently affects agricultural production. To deal with this problem the government of Ethiopia has initiated the introduction of small-scale irrigation schemes. However, without proper planning such schemes are known to worsen vector-borne disease endemicity. This necessitates health impact assessment of irrigation systems to prevent water related diseases. The objective of the study was to assess the effect of small-scale irrigation schemes on malaria transmission in irrigated areas around Ziway. Blood smear samples were examined at the end of the main rainy season and the dry season of 2005/2006. The socio-economic condition of the irrigated and non-irrigated farming communities was assessed by using interviews based on questionnaires with household heads and agricultural and health workers. Overall irrigated areas had significantly higher (19.2%) ($p<0.05$) malaria infection prevalence rate as compared to the non-irrigated study sites (16%). In irrigated areas all age categories in the dry season showed higher malaria infection prevalence as compared to the rainy season. However, the difference was significantly ($P<0.05$) higher in the age category greater than 15 years old. In irrigated areas, households producing by irrigation had larger farm size and higher income but with higher malaria infection prevalence, indicating higher risk of malaria transmission. In non-irrigated areas, households with larger farm size and higher income were with lower malaria infection prevalence, indicating some protection provided by the limited anti-malaria measures in the area. Households living in grass top houses were with higher malaria infection prevalence rate as compared to those living in corrugated iron sheet roofs. In order to see the association of individual parameters in malaria infection, analysis was done by using the logit model. Accordingly, farmers with irrigated farms had higher income and yet did not use malaria protection measures such as bed nets, drugs, etc. Therefore, control interventions through integrated malaria control approaches that include education about its importance, source reduction and combined effort by agricultural and health workers during establishment of small-scale irrigation schemes are recommended.

Key words: Agriculture, *Anopheles pharoensis*, Ethiopia, Irrigation, Malaria, *Plasmodium falciparum*, *P. vivax*, Socio-economy, Ziway.

1. INTRODUCTION

1.1 Historical overview

Malaria has been around since ancient times. The early Egyptians wrote about it on papyrus, and the famous Greek physician Hippocrates described it in detail (N.I.H, 2002). It is assumed that the evolutionary history of mammalian *Plasmodium* started with the adaptation of Coccidian of the intestinal epithelium to some tissues of the internal organs and then to the invasion of free cells in the blood .The next step was the possibility of transmission of the parasite from one animal to another by blood sucking arthropod vector. Over 100 species similar to those of humans are found in a wide range of vertebrates from reptiles to birds and to higher apes. None of the parasites, except for those found in some monkeys, can be transmitted to humans. This high host-specificity indicates a long association between the human species and the four particular species of plasmodia that infect humans (Gilles and Warrell, 1993). It is probable that the disease originated in Africa, which was believed as the cradle of human beings (Gilles and Warrell, 1993). Studies have shown that, *P. falciparum,* the most serious malaria parasite, was thought to emerge in Africa in the past 6000 years (Deirdre *et al.*, 2003).

The main breakthrough in the long history of malaria was connected with the first real therapeutic advance. At the beginning of the 17th century came the discovery of the value of the Peruvian bark. Quinine was extracted from the same bark (Gilles and Warrell, 1993). Towards the end of the 19th century, an army surgeon called, Laveran, first saw and described malaria parasite in the red blood cells of human beings. Sir Ronald Ross, a British military physician, demonstrated in 1897 that mosquitoes were the carriers of malaria (Daniel, 1999).

During the twentieth century, much research was devoted to malaria control. Larvicides in the form of oil or Paris green were introduced to prevent the breeding of mosquitoes in different types of water (Gilles and Warrell, 1993; ICMR, 2002). Another major discovery was to revolutionize the techniques of malaria control by spraying insecticides against the vectors (Gilles and Warrell, 1993), soon after DDT and other residual insecticides like Hexachlorohexines (HCH) and Dieldrin were introduced (Gilles and Warrell, 1993; ICMR, 2002).

The possibility of global extension of malaria control activities to bring about the final eradication of the disease was contemplated in the 1950s when the result of the application of DDT showed great promise. Between 1955 and 1969, WHO launched a series of campaigns to eradicate malaria by spraying homes with insecticide (Gilles and Warrell, 1993; Daniel, 1999). The results over the next fifteen years were excellent in Europe, North America, the former USSR, Australia and some parts of Asia. But in Latin America and most Asian countries, results varied and the disease persisted (Gilles and Warrell, 1993; Daniel, 1999). The WHO goal was never achieved for verities of reasons. First, the mosquitoes that transmit malaria rapidly developed resistance to main insecticides used like (DDT). Secondly, resistance to Chloroquine by strains of *P. falciparum* was observed after its continuous use (Gilles and Warrell, 1993; Daniel, 1999).

In 1969 WHO revised the strategy of malaria eradication by stressing the need for greater involvement of the general health services, extension of research to new insecticides, improved surveillance, development of new anti malarial drugs and alternative methods of malaria control (Gilles and Warrell, 1993). In tropical Africa, the malaria situation has deteriorated. Severe outbreaks have occurred in several countries, with high mortality and a shift of morbidity to older age groups. Uncontrolled and rapid urbanization has created pockets of transmission in the cities, thus increasing the size of vulnerable group .In 1998, WHO launched a new global program in partnership with UNICEF, UNDP and the World Bank known as “Roll Back Malaria” (RBM). The program seeks to reduce substantially the human suffering and economic losses due to one of the world’s most costly disease .The RBM initiative is different from previous efforts because it uses new tools to control the disease and strengthen health services . RBM seeks to cut disease from malaria in half by the year 2010.The plan aims to reduce malaria incidence by controlling transmission, using community health workers to help diagnose and treat the disease (Daniel, 1999).

1.2 The Parasites

The malaria parasites, the microorganisms causing malaria, are categorized in the family Plasmodiidae within the order Coccidiida, sub-order Haemosporidiidea, which comprises varies parasites found in the blood of reptiles, birds and mammals (Gilles and Warrell, 1993). Only four species of *Plasmodium* can infect humans under natural conditions -*P. falciparum*, *P. vivax*, *P. ovale* and *P. malariae.* Of these only *P. malariae* may naturally infect non-human primates (Gilles and Warrell, 1993). The first two species cause the most infections worldwide.

P. falciparum is generally confined to tropical and subtropical regions because the development of the parasite in the mosquito is greatly retarded when the temperature falls below 20^{O}C. At this temperature, 3 weeks are required for maturation of sporozoites. *P. falciparum* is the chief infection in areas of endemic malaria in Africa, and is also responsible for the great regional epidemics, which were a feature of malaria in North West India and Sri Lanka (Gilles and Warrell, 1993). It is the only species that can cause severe malaria because it multiples rapidly in the blood, and can thus cause severe blood loss (anemia). In addition, the infected parasites can clog small blood vessels (CDC, 2006). When this occurs in the brain, cerebral malaria results as a complication that can be fatal.

It is estimated that every year 700,000 to 2.7 million people are killed by *P. falciparum*, especially in Africa where this species predominates (CDC, 2006). The young ring forms of *P. falciparum*, as usually seen in the peripheral blood, are very small. In many of the ring forms there may be two chromatin granules, and marginal forms are fairly common. The succeeding developmental stages of asexual erythrocytic stage do not generally occur in the blood, except in sever ‘pernicious’ cases. Although erythrocytic schizogony in *P. falciparum* is completed in 48 hours and periodicity of development is therefore of typically tertian type, there frequently occurs in this species two or more broods of parasites, the segmentation of which is not synchronized, so that the periodicity of symptoms in the patient tend to be irregular (CDC, 2006).

P. vivax occurs in most of the temperate zones and also in large areas of the tropics (Gilles and Warrell, 1993). It is found mostly in Asia, Latin America, and in some parts of Africa (CDC, 2004). Because of the high human population densities, especially in Asia, it is probably the most prevalent human malaria parasite. While *P. vivax* only exceptionally causes death (most often due to rupture of an enlarged spleen), it can cause symptoms that are incapacitating. Thus, *P. vivax* contributes substantially to the disease burden (morbidity) of malaria, with a resulting social and economic impact. The mean duration of the pre-erythrocytic stage of the early tissue schizonts is 8 days. During the erythrocytic development of *P. vivax*, all blood forms can be found in the circulation and most stages are larger than in the other species of human plasmodia. Generally, the entire asexual erythrocytic cycles are repeated approximately every 48 hours. It has a striking effect on the invaded red blood cell, which gradually enlarges and becomes decolorized. Gametocytes may appear in the blood within 3 days after the first appearance of asexual parasites. The sexual cycle, in mosquito, takes 16 days at 20^{O}C. Below 15^{O}C, the completion of the sporogonic life cycle is unlikely (Gilles and Warrell, 1993).

The two other species are less frequently encountered. *P. ovale* is found mostly in Africa (especially West Africa) and the islands of the western Pacific. It is biologically and morphologically very similar to *P. vivax*. However, differs from *P. vivax* as it can infect individuals who are negative for the Duffy blood group, which is the case for many residents of sub Saharan Africa. This explains the greater prevalence of *P. ovale* (rather than *P. vivax*) in most of Africa (CDC, 2004).

P. malariae is found worldwide and causes a long lasting, chronic infection that in some cases can last a lifetime. In some patients, *P. malariae* can cause serious complications (CDC, 2004).

1.3 The vectors

There are nearly 400 species of *Anopheles,* of which some 60 are proven vectors of human malaria. However, in each geographical area there are usually not more than three or four anopheline species that can be regarded as important vectors. To be an effective vector a species must be present in adequate numbers in or near human habitats (Gilles and Warrell, 1993).

The *An. gambiae* complex is the most important malaria vector in Africa. The species complex comprises six named species, one unnamed species and several incipient species. It includes two of the most effective vectors of malaria parasites in Africa viz*. An. gambiae* s.s and *An. arabiensis* (White, 1974; Cotzee *et al*., 2002). *An. arabiensis* is slightly less efficient vector than *An. gambiae* s.s (Gillies and DeMeillon, 1968; Hunt *et al*, 1998; Lindsay and Boyoh, 2004). Cotzee and his colleagues (Cotzee *et al.*, 2002) have reviewed the current knowledge on the distribution of members of the *Anopheles gambiae* complex.

An. arabiensis is a principal vector of malaria under many circumstances, particularly in arid or mountain areas prone to seasonal outbreaks (White, 1974; Fontenille *et a*l., 1997). Plenty of circumstantial evidence indicates that *An. arabiensis* somehow manages to endure droughts (White, 1974). It may multiply prolifically in residual pools, such as remain in the beds of drying streams prior to onset of fresh rains (White, 1974; Fontenille and Lochouarn, 1999). *An. arabiensis* was identified as a major malaria vector in irrigation schemes in Kenya with sporozoite rate of 1.24% during the long rainy season (Ijumba, 1990).

An. pharoensis is primarily a species of large vegetated swamps, also found along lakeshores and among floating plants (Gillies and DeMeillon, 1968). It is found distributed in Africa; including Ethiopia (WRBU, 2005). *Anopheles* species composition and behavioral pattern study from Gambela region, south west Ethiopia, showed that *An. pharoensis* was an important vector in the area next to *Anopheles gambiae* s.s (Negatu *et al.*, 1994). Abose *et al*. (1998) and Seyoum *et al.* (2002) reported it as a secondary malaria vectors in Ziway, Ethiopia. In 1984 and 1985, it contributed to the epidemiology of *P. falciparum* malaria with sporozoite rates of 1.3% by ELISA and 0.68% by dissection in the Mwea irrigation area in Kenya (Mukiama and Mwangi, 1989). According to Carrara *et al.* (1990), *An. pharoensis* was the main malaria vector for intensive *P. falciparum* transmission in Senegal.

Anopheles funestus, like *Anopheles gambiae s.s* and *Anopheles arabiensis*, is one of the principal vectors of malaria in Africa (Gillies and DeMeillon, 1968). It breeds characteristically in bodies of clear water that are either large and more or less permanent, e.g. swamps , weedy sides of streams, rivers, furrows or ditches, protected portions of lake shore, ponds, etc (WRBU, 2005). It was identified with sporozoite rates of 1.7% by ELISA and 1.25% by dissection in the Mwea irrigation area in Kenya (Mukiama and Mwangi, 1989). Despite its importance, until recently little attention has been paid to the genetics of this species (Garros *et al*., 2005).

1.4 Global malaria distribution and burden

Malaria has been recorded as far North 64^0 N latitude and as far South 32^0 S latitude and in altitude ranges of 400m below sea level up to 2800m above sea level. Within these limits of latitude and altitude, there are large areas free of malaria (figure: 1), which is essentially a focal disease, since the transmission of malaria depends greatly on local environment and other conditions (Gilles and Warrell, 1993). The World Health Organization estimates that 300 to 500 million people are diagnosed with malaria annually, causing 1.1 to 2.7 million deaths (WHO, 2000; WHO, 2003).

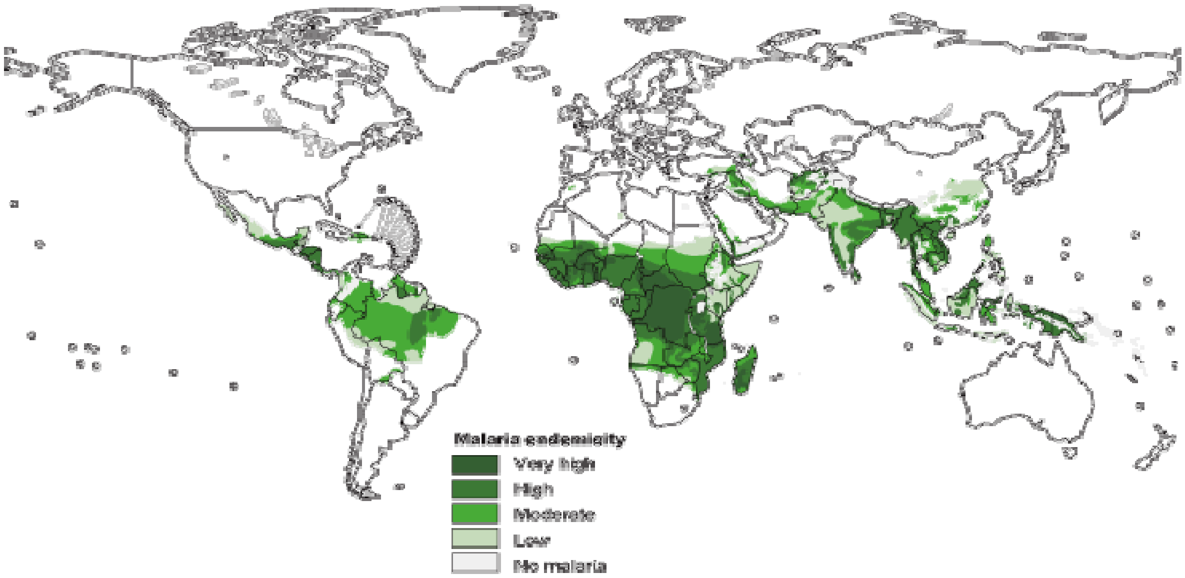


Figure 1: Global distribution of malaria transmission, 2003. Source: (WHO, 2005)

Malaria has a major place among the endemic tropical diseases (Gilles and Warrell, 1993). Reports as for 2004 indicate that 107 countries and territories have reported as areas at risk of transmission. This number is considered less than the 1950s report where 140 endemic countries and territories were accounted, but still in these 107 countries there are 3.2 billion people at risk of infection (WMR, 2005). Around 60 % of the cases of clinical malaria and over 80% of deaths occur in Africa, south of the Sahara. In addition to acute disease episode and deaths in Africa, malaria also contributes significantly to anemia in children and pregnant women, adverse birth outcome and overall child mortality. Financially, it is estimated to be responsible for 3% in average annual reduction of economic growth in countries with high disease burden (WMR, 2005).

Malaria extracts an enormous toll in lives, medical costs, and days of labor lost. Educational systems also suffer as large numbers of children miss several weeks of school each year in endemic regions (MFI, 1997). In addition to the direct economic cost of malaria such as costs related to transportation to health service facility, consultation fee, laboratory test fee, and more importantly, drug cost, malaria mortality and morbidity sluggish economic growth by reducing the capacity, and efficiency of the labor force. The economic loss due to malaria is very high, with an annual loss of growth estimated at 1.3% and loss of approximately 12 billion US dollars every year in Africa (WHO, 2005).

The wide variation seen in the burden of malaria between different regions of the world is driven by several factors (WMR, 2005). The presence of the most serious parasite, accompanied by the potent vector species and vulnerable human population (Parasite-vector-human transmission dynamics) is the one amongst the factors that favor or limit the transmission of malaria and the associated risk of disease and death (Gilles and Warrell, 1993; Konradsen *et al.,* 1990; cited by Joshi *et al.,* 2005). The severe malaria parasite *P. falciparum* and the most efficient malaria vector mosquitoes *Anopheles gambiae* occur exclusively in tropical and sub tropical part of the world, especially in Africa (Gilles and Warrell, 1993; WMR, 2005). Tropical areas of the world have the best combination of adequate rainfall, temperature and human host allowing for breeding and survival of malaria vector mosquitoes (WMR, 2005).

The other major factor contributing to regional and local variability in malaria burden is differences in level of socio-economic development. Determinants include general poverty, quality of housing and access to health care and health education, as well as existence of active malaria control programmes providing access to malaria prevention and treatment measures (Gilles and Warrell, 1993; WMR, 2005). The poorest nations generally have the least resource for adequate control efforts (WMR, 2005). The combination of all these factors put down a heavy toll on malaria burden in Africa. In fact, the population groups at risk of malaria also differ between regions. The majority of death in tropical Africa occurs in areas of stable transmission of *falciparum* malaria (WMR, 2005). In these areas the two groups at high risk are the very young children, who have not yet acquired clinical immunity (Gilles and Warrell, 1993), and pregnant women, whose immunity to malaria is temporarily impaired (WMR, 2005). Whereas in areas of unstable or highly seasonal *falciparum* malaria transmission, which is mostly common outside Africa, the lack of frequent exposure to malaria infection early in life delay the acquisition of clinical immunity, and thus older age groups remain at relatively higher risk for malaria disease when exposed (WMR, 2005).

More recently, there is evidence that compared with the 1980's, the burden of malaria increased during the 1990s in several areas in terms of population at risk, the severity of infection and the number of deaths (WMR, 2005). Malaria re-emerged in several countries of central Asia with an increased frequency of epidemics and with the re-establishment of stable endemic transmission. Factors contributing to the increase in malaria include (i) resistance of parasite to commonly used anti-malaria drugs; (ii) breakdown of control programs; (iii) complex emergencies; (iv) collapse of local primary health services; (v) resistance of mosquito vectors to insecticides (WMR, 2005). In addition, there are other variables that expand malaria endemicity such as, deforestation, introduction of different irrigation schemes, swamp drainage and specific crop intensification (Patz and Lindsay, 1999; Boelee *et al*, 2002; ICMR, 2002; Kebede *et al*, 2005). Within the same period, however, malaria was well controlled in the five northern African countries and elimination or a very low level of transmission was maintained in some of the islands of the cost of Africa. Throughout the decades, malaria was generally less intense in central and South America than in Africa and south East Asia (WMR, 2005).

From the available information, it is not yet possible to determine with sufficient confidence whether the global burden of malaria has changed substantially, for better or worse, since 2000 when Roll Back Malaria (RBM) implementation began in many countries. In some areas, fluctuations in malaria transmission from year to year potentially confound evaluation of broader trends. Therefore, a final conclusion typically requires analysis of epidemiological data over multiple years. For the high burden in Africa, reliable data will only become available after a time lag of several years. Nevertheless, for some countries and areas throughout the world, there is evidence that successful control has got an impact on malaria disease burden (WMR, 2005).

1.5 Current world malaria control policies and strategies

Appropriate malaria control strategies vary with local malaria endemicity. The key control strategy by the Roll Back Malaria is the national control policy of malarious countries for their different epidemiological settings (WMR, 2005). Countries with stable endemic malaria use strategy of prevention by ITN (insecticide treated nets), IRS (indoor residual spraying). In addition, IPM (intermittent preventive treatment) especially for malaria prevention and treatment in pregnant women, and control strategy and treatment by early and effective case management are also strategies of prevention in endemic countries. Countries with unstable malaria use prevention by IRS, ITNs, larviciding, environmental management, and treatment by early and effective case management. Countries with regions considered as free of malaria use control strategy of prevention for travelers going to malarious areas. These include chemoprophylaxis and personal protective measures against mosquitoes and treatment by early and effective management in suspected cases and diagnosis to confirm cases, if possible before treatment (WMR, 2005).

1.6 Malaria in Ethiopia

Malaria is a major public health problem in Ethiopia (Abose *et al.*, 1998). Its occurrence in most parts of the country is unstable mainly due to the country's topographical and climatic features (Abose *et al.*, 2003). Although the two epidemiologically important malaria parasite species in the country are *P. falciparum* and *P. vivax*, the other two species, *P. malariae* and *P. ovale*, are also reported to occur. *Anopheles arabiensis* is the major malaria vector; *An. pharoensis, An. funestus a*nd *An. nili* are deemed as secondary vectors (Abose *et al.*, 1998).

Approximately 4-5 million cases of malaria are reported annually in Ethiopia (in a normal transmission year) (WHO, 2005). Malaria is found in about 75% of the total area of the country, and 40-50 million (>65%) of the total population is at risk of infection (Tulu, 1993; WHO, 2005). Malaria accounts for seven per cent of outpatient visits and represents the largest single cause of morbidity. It is estimated that only 20 per cent of children less than five years of age that contract malaria are treated at existing health facilities. Large-scale epidemics occur every 5-8 years in certain areas due to climatic fluctuations and drought-related nutritional emergencies. There are also areas of stable transmission in some low-lying western regions of the country (WHO, 2005).

Transmission usually occurs at altitudes <2000 meters above sea level. The two main seasons for transmissions of malaria in Ethiopia are September–December, after the heavy summer rains, and March–May, after the light rains. *P. falciparum* and *P. vivax* are the dominant human malaria parasites, which account for about 60% and 40% of cases, respectively (Tulu, 1993). Malaria epidemics are frequent and widespread in the country. Most of the areas affected by epidemics are highland or highland fringe areas (mainly areas 1000–2000m above sea level), in which the population lacks immunity to malaria (Tulu, 1993). Occasionally, transmission of malaria occurs in areas previously free of malaria, including areas >2000m above sea level, in which the microclimate and weather conditions are favorable for malaria. According to Negash *et al.* (2005) true explosive epidemic malaria was recorded at exceptionally high altitude (around 2500 m above sea level). Resulting from human activities, aggravated transmission in the country was also observed (Negatu *et al*., 1992).

1.7 Malaria and irrigation

Today, malaria occurs mostly in tropical and sub-tropical countries, particularly in Africa south of the Sahara, Southeast Asia and in the forest fringe zones in South America. The ecology of these areas is closely associated with the availability of water bodies (WHO, 2005) for which irrigation is playing its own roll. The abundance of water in irrigated areas is due to seepage, silting, and stagnation, creating innumerable sites for malaria vector mosquitoes (Maihotro and Srivastave, 2005) and if these mosquitoes can live longer they can transmit malaria efficiently.

According to Boelee (2003), the agro-ecological changes formed as a result of irrigation development in various parts of Africa may have tremendous effect on the level of malaria and other water-borne and vector related diseases transmission. Usually, water-borne (diseases encountered by drinking contaminated water), water-washed (diseases that can be avoided by washing), water-based (diseases where the intermediate host resides in water) and water-related insect-borne diseases (the life cycle of the intermediate insect needs water) transmission could alter with irrigation development. Among these, water-related insect borne diseases are most widely reported as disease problems associated with irrigation development (Cairncross and Feachem, 1993; cited by Boelee, 2003). Water-washed diseases, such as louse-borne infections and infectious eye and skin diseases may be reduced dramatically with the development of water resources. These are diseases that we can avoid by washing and keeping our personal hygiene using irrigation water even if, its quality is questionable. This effect is especially widespread in arid and semi-arid regions, where irrigation systems may be the main source of water for all purposes (Van der Hoek *et al.*, 2002). Whereas, water-related diseases (diseases transmitted by water-related insect vectors) sometimes increase with irrigation development. Irrigation canals, pools and drainage lines, if not properly managed, can create ideal sites for vector breeding and enhance transmission of vector-borne diseases like malaria and schistosomiasis (Boelee, 2003).

The agro-ecology of an area changes with the introduction of irrigation. The type of crop, the system of planting, the method of cultivation, by and large the flora and the fauna and the entire human environment are often changing with irrigation (Boelee, 2003). The mechanisms of disease development and the way of its transmission in the irrigated area will be changed. Overall the impacts of irrigation on humans are diverse. It could be positive by improving income, better nutrition and generally good health conditions. It has also negative impacts by aggravating some water-based and water-related diseases, as more water is available in irrigated areas as compared to non-irrigated areas that can be used as breeding sites for intermediate hosts and vectors (Ijumba and Lindsay, 2001; Boelee *et al.*, 2002).

Irrigation development and transmission of water related diseases have different linkages especially in rice fields. Water related diseases particularly malaria transmission may increase, decrease, or remain largely unchanged as related to irrigation development (Ijumba and Lindsay, 2001).

Irrigation often facilitates double or even triple cropping of crops; here the irrigation system might lead to continuous availability of surface water where vectors can breed without restraint. In the irrigated fields mosquito abundance will increase and if these mosquitoes have enough food source in the breeding sites, the resulting adults may live longer and allow malaria parasites to complete their developmental cycle so that they can be passed on to another host. This allows year round transmission of disease (Bradley, 1995; cited by Boelee, 2003). This is contrary to the report from some parts of West Africa where rice cultivation by irrigation did not increase malaria transmission (Ijumba and Lindsay, 2001). Different reasons can be cited for this effect. It is clear that in rice fields with continuous availability of water for vector breeding, there could be high population density of larvae, competition among these larvae increases and in the absence of adequate nutrition, the produced adults might not live longer and hence fewer mosquitoes might be found infected. People with access to irrigation development might get better income so that they can afford bed nets. Moreover, it is indicated by different authors that the introduction of crop irrigation has little impact on malaria transmission in malaria stable areas. The explanation for this finding is still unresolved, but in some cases can be attributed to displacement of the most endophilic and antropophilic malaria vectors by the lower vectoral capacity vector (Ijumba and Lindsay, 2001). Other reason could be in areas of stable endemicity repeated exposure to the parasite leads to acquisition of species specific immunity in adults causing mild febrile illness (Gilles and Warrell, 1993).

Irrigation projects in Ethiopia are identified as large-scale irrigation (> 300 ha.), medium-scale irrigation (200-300 ha.), and small-scale irrigation (< 200ha.) (Awlachew *et al.,* 2005). Traditionally farmers have built small scale-schemes on their own initiatives, sometimes with government technical and material support. They manage them through their own water users association or committees (MoWR, 2002). The farm size (household farm size) varies between 0.25 ha and 0.5 ha (Awlachew *et al.,* 2005). The Federal or Regional government normally constructs small-scale modern schemes. Such schemes were expanded after the catastrophic drought in 1973/74 to achieve food security and better peasants' livelihoods by producing cash crops. Such schemes involve dams and diversions of streams and rivers (Awlachew *et al.,* 2005).

Irrigation schemes in some parts of the country were found to increase malaria transmission (Birrie *et al.,* 1997; Ghebreyesus et *al.,* 1999). These Irrigation schemes had been introduced to reduce dependence of local agriculture on irregular rainfall following the famines in 1974 and 1984. However, while the schemes has had a positive impact on agriculture, the effect on health has been worrying, with an increased incidence of malaria. The findings in the country raise fears that, unless properly thought out schemes to improve the environment are in place, irrigation could do as much harm as good (Ghebreyesus *et al.,* 1999). Therefore, it is vital to gain a better understanding of the influence that irrigation and agricultural activities have on the spread of malaria especially as developing countries extend their irrigated areas to feed rapidly growing populations (IWMI, 2004). Faced with this trend, there is a real danger that the incidence of malaria and other water related vector-borne diseases will increase unless the management of many agro ecosystems is improved.

1.8 Ecological control of malaria mosquitoes in irrigated areas

Insecticide-resistant vectors and drug resistance hampered many established malaria control methods (WHO, 2000; ICMR, 2002; Keiser *et al.,* 2005). For instance in Ethiopia, malaria control was seriously hindered by drug and insecticide resistance (Tulu, 1993; Abose *et al.,* 1998). Therefore, as part of integrated disease control, finding water management-based interventions is becoming an increasingly important alternative for malaria control (IWMI, 2004) and needs to be underlined as irrigated agricultural production systems are increasing. In areas of low intensity transmission ecological control measures involving community-led larval control may be a cheap and effective method of controlling malaria (Yohannes *et al.,* 2005).

Environmental changes through irrigation development could affect factors that affect public health, and hence there is now increased interest to avoid the adverse impacts of irrigation to human health (Amerasinghe and Boelee, 2004) by using ecological control measures. Malaria control measures built around environmental management are non-toxic, cost-effective, and sustainable (Keiser *et al.,* 2005). Bziava and Kruashvili (2002) have elucidated different ecological control measures of hydrological mode where engineers played a significant role to control malaria in irrigated areas. The measures were, Periodic watering of agricultural crops combined with obligatory complete drying of soil after irrigation, intermittent irrigation of rice fields and other crops using artificial water supply, changing the water table in reservoir, periodic dawn of water in current and destruction of vector breeding areas (Bziava and Kruashvili, 2002; Konradsen *et al.,* 2002).

The current economic policy in Ethiopia is geared towards ensuring food self-sufficiency. However, sustainable food production could only be guaranteed through core problem identification and generation of usable appropriate technologies. Ethiopia's agriculture, which is highly dependent on seasonal rainfall, results on tragic drought and famine-prone decades since 1970's with climatic and environmental variability. This shifted the attention of concerned policy makers and researchers towards a common goal to look for long-term solutions to the country's food security needs by using irrigated agriculture. However, planning of irrigation systems in various parts of the country do not consider its impact on health by aggravating water related diseases (Birrie *et al.,* 1997; Ghebreyesus *et al.,* 1999;

Ashenafi, 2003). The effect of irrigation on malaria transmission in Ziway is not clearly known. In this study it was hypothesized that irrigation has resulted in increased malaria transmission and burden of disease in Ziway.

2. Objectives of the study

2.1 General objective

- To generate information for an effective and economically viable integrated management strategy that describes health and irrigation factors, to create effective malaria prevention in irrigated area.

2.2 Specific objectives

1. To determine malaria transmission as related to irrigation development at the study sites; by determining the prevalence of the *Plasmodium* species in irrigated and non-irrigated areas at different villages around Ziway in the middle course of the Ethiopian Rift Valley.

2. To portray the socio-economic aspects of farmers in irrigated and non-irrigated areas of the study, and its relation to malaria transmission.

3. To identify options and give recommendations and directions for creative malaria control if it is found increased with irrigation.

3. Materials and Methods

3.1 Study Area

The study was conducted in 2005/06 in two farming communities, Abine Germamo and Weshgule (Control), representing the irrigated and non-irrigated areas, respectively, in Ziway area located in the Great Rift Valley. Ziway is found in Oromia Regional state, East Showa Zone, Adamitulu Judo Kombolcha Woreda (figure: 2). It is 163 Km south of Addis Ababa alongside of Lake Ziway. The rainfall pattern is similar to other Ethiopian regions with the main rainy season starting in June and extends up to August/September while the short rainy season begins in March and extends to April/May but usually it is very erratic. The area has a fairly warm climate with mean annual temperature of 20^{O}C and annual maximum and minimum temperature of $27.5\,^{O}$C and 13.9^{O}C respectively .The mean annual rain fall of the Ziway area is 13.7 mm (Figure: 3) .The area is characterized by lowland marks with sparsely distributed *Acacia* trees and thorny bushes. Lake Ziway and river Bulbula, originating from Lake Ziway and flowing to the south, are the two main water sources.

At the beginning of the study, relevant socio-demographic information was sought from the agricultural and health office experts of the area through a structured interview. The information gathered include: total number of kebeles in the woreda, the irrigated kebeles of the Woreda, total area in the Woreda under small scale irrigation schemes, the time of establishment of the irrigation schemes, the method of irrigation, the source of irrigation water, the type of crops cultivated through irrigation, population censes for the different Kebeles in the Woreda, malaria transmission data by kebeles, the predominated malaria parasites in the area, malaria vectors and parasites control program, time of vector control, and the type of drugs used for the different malaria parasites. This was followed by selection of specific sites/villages and conduct of two cross sectional survey at the end of the rainy and during the dry season. The rainy season data was colleted in September/October, which is the period with the highest malaria transmission almost every year in Ziway (Abose *et al.*, 1998; Seyoum *et al.*, 2002).The dry season study was conducted in February/March before the beginning of the short rainy season and before the second round indoor insecticide spray begins.

In the study area, there were four major types of houses wherein farmers lived. According to the information obtained from the agricultural office the type of the wall of the houses mainly depends on the availability of materials for construction at the specific sites. Most of the houses in irrigated areas were made of mud walls reinforced with wood, except for a few that were made of mud brick wall. In the non-irrigated areas the walls of houses were usually made from mud brick though in some cases there were houses made of mud reinforced with wood. On the other hand, the roofs or the top of the houses in both areas could be made from grass top or corrugated sheets of iron. It was confirmed during the study that those houses having corrugated sheets of iron roof, had their walls usually made of mud brick or have mud walls reinforced with wood and were well plastered. Most farmers in irrigated and non-irrigated areas kept cattle, goats and sheep which were corralled close to their houses, but there were also mixed dwellings where both cattle and people lived (Seyoum *et al.*, 2002). Both the irrigated and non-irrigated areas were sprayed with DDT in September 2005.

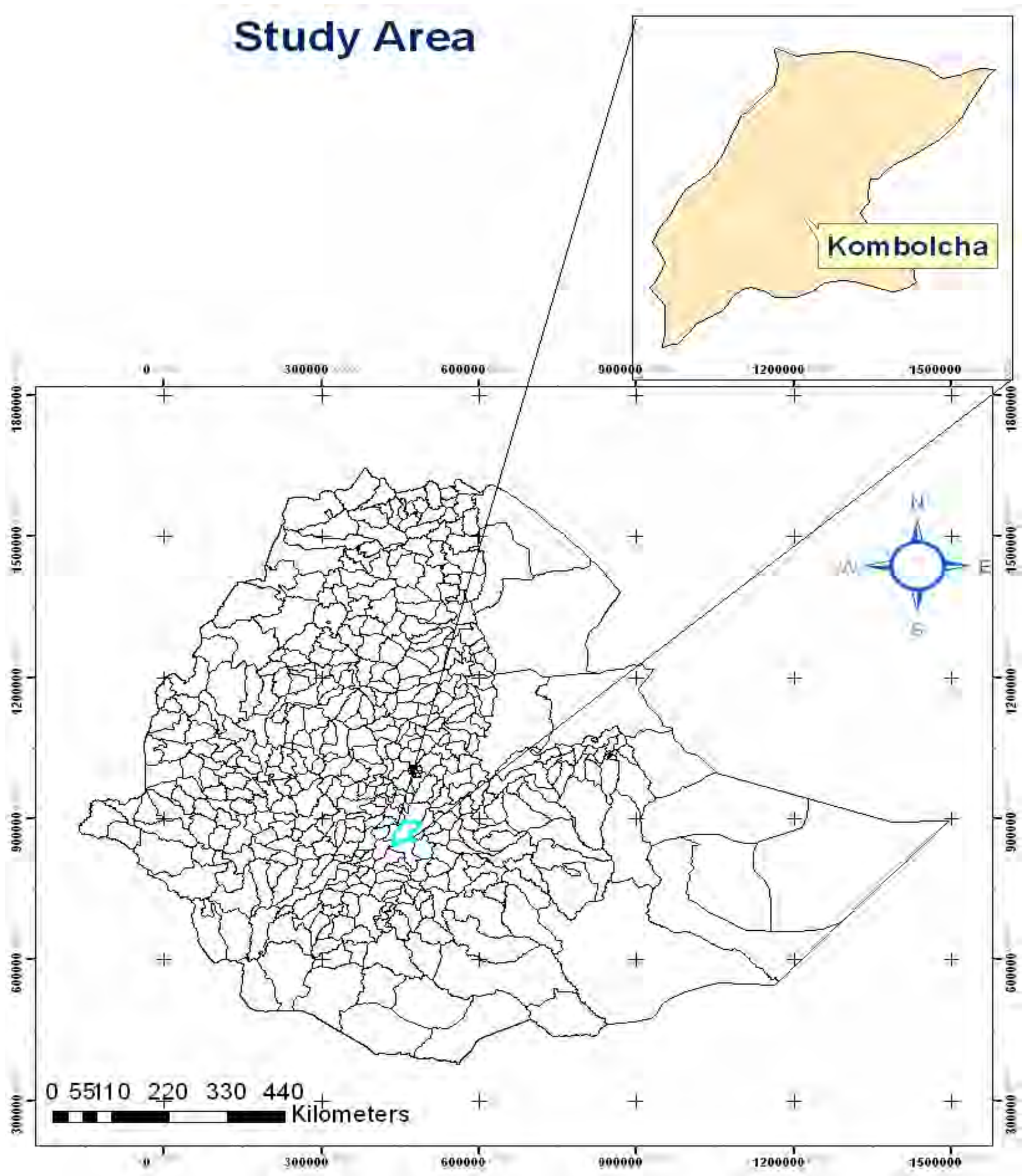


Figure 2: Map of Ethiopia showing location of the study site

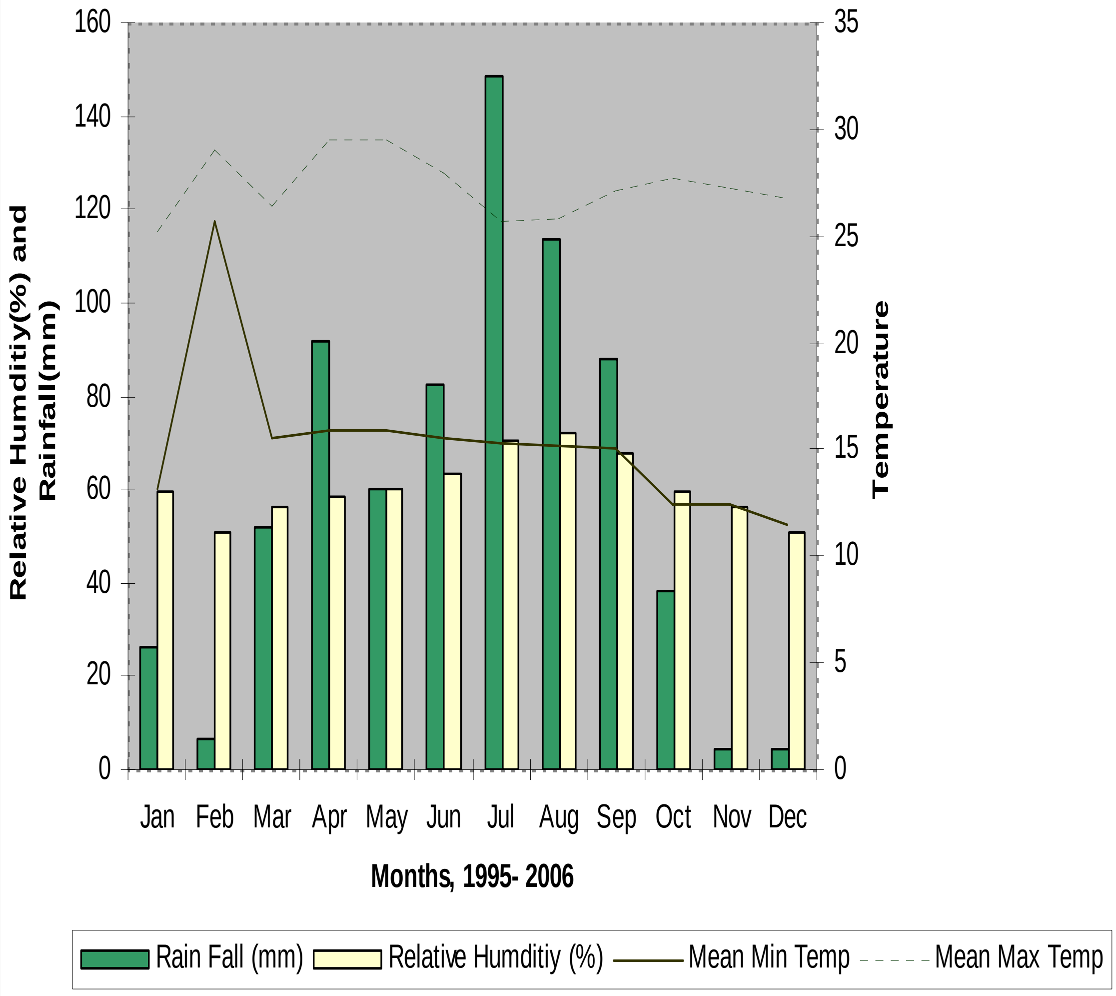


Figure 3. Monthly rainfall (mm), mean relative humidity, mean maximum and minimum monthly air temperatures (°C) of Ziway area, 1995-2006.

Source: National Meteorological Agency (NMA)

Irrigated site

According to the information obtained from the Woreda agricultural office, total area in the Woreda under irrigation in 2004/2005 was about 1873 hectars. This figure comprises irrigation fields by estate farm (Gerbi estate farm), private investors (like Ethico, Meskel flower etc…) and small-scale irrigation fields by farmers.

Selection of the irrigated area was done based on pre-defined criteria 1) the irrigation site should be far from the main source of irrigation water in order to avoid the effect of vectors that breed in natural habitats; 2) the irrigation fields should be away from the control site based on the likely appetitive flight distance of female mosquitoes, greater than one km., (Ghebreyesus et *al.*, 1999; Klinkenberg *et al.*, 2005 ; Yohannes *et al.*, 2005); 3) farmers should live in close proximity to the irrigation fields but away from the source of irrigation water; 4) the irrigated and the non-irrigated (control) areas should be with the same topographical position, comparable agricultural production systems and other important features (Ghebreyesus et *al.*, 1999; Klinkenberg *et al.*, 2005; Yohannes *et al.*, 2005); 5) the sites should be accessible and close to the Woreda health center for easy of sample transport and examination . Abine Germamo was found to be the area, which best fitted to the selection criteria. It is found more than 5 km away from the source of irrigation water (the lake) and non- irrigated area.

In our categorization an irrigation area encompasses more than one village /Gote/. In the new kebele classification of villages, two and some times three kebeles are now merged in to one and given a new name. Here we will follow the new name given to the kebeles. Surface irrigation is the method of irrigation used in the area.

Abine Germamo is found at the northern outskirts of Ziway town by the side of the road coming from Addis Ababa. It includes previous kebeles Hizbawi Betele, Abine Gijota and Abine Germamo. It is located at 1647 meters above sea level. According to the information obtained from the agricultural office, the number of households in this kebele reaches up to 934. However, beneficiaries (those undertaking irrigation) of the irrigation activity in 2004/2005 production time were only 75 households. Lake Ziway is the source of irrigation water. Both the eastern (the field between the lake and the road) and the western side of the main road are irrigated but almost all the farmers are living on the western side of the road. Pumps are used in order to propel water then the water is delivered over a long distance through pipe and surface canals, when it reaches to uplifted mass of soil it would be diverted down to all irrigation fields by surface irrigation with the help of the force of gravity. The houses of the farmers are found in close proximity to the irrigation fields. All the inhabitants of the area, those benefited from irrigation (irrigators) and those who are not using irrigation (non-irrigators) are almost found in close proximity with the irrigation field (Figure 4& 5).

Figure: 4 Irrigated onion farm at Abine Germamo, Ziway February - March 2006.

Figure: 5 Irrigated onions, cabbage and maize farm with the irrigation canal at Abine Germamo, Ziway February - March 2006.

Figure: 6 Household heads with their children at Abine-Germamo while collecting blood smear samples, Ziway February - March 2006.

Non-Irrigated site

The main criteria for selecting the non-irrigated area were: (1) it should be at a distance beyond the reach of mosquitoes from the irrigated area (Ghebreyesus et *al.,* 1999; Klinkenberg *et al.,* 2005 ; Yohannes *et al.,* 2005); (2) with the same topographical position, comparable agricultural production system and other important features except irrigation with the irrigated areas (Ghebreyesus et *al.*, 1999; Klinkenberg *et al.,* 2005 ; Yohannes *et al.,* 2005) (3) accessibility .Three areas were taken into consideration for the selection of the non-irrigated area but Weshgule was found to be the area, which fitted to the selection criteria. Weshgule is found at the southern outskirts of Ziway town at 1654 meters above sea level.

Figure: 7 Female household head with her child at Weshgule while collecting blood smear samples, Ziway February - March 2006.

3.2 Sample selection

We assessed malaria parasite prevalence, a direct indicator of the impact of malaria, in communities with and without irrigation (Klinkenberg *et al*., 2005). Six year data of malaria prevalence in the study areas from the Health office at Ziway was taken for the determination of sample size. Average of positive cases 1999/2000 - 2004/2005 of the irrigation area divided by the population of 2003/04 of the area was taken as average annual prevalence in irrigated area and average of positive cases of 1999/2000 - 2004/2005 of the non-irrigated areas divided by the population of 2003/04 of the area was used to estimate the prevalence in the non-irrigated area. Using Win Episcope 2.0 (developed by facultad de veternaria Zara goza, Wagningen University and University of Edinburgh) computer soft-ware the sample size was determined. It was estimated by using the difference between proportions with 95% level of confidence interval and value of 80% for the power with the formula (for the sample size) for a two-tailed test:

$$n = \left[\frac{Z(a) + Z(b)}{p_1 - p_2} \right]^2 * \left[(p_1 * q_1) + (p_2 * q_2) \right]$$

Where Z (a) and Z (b) are the value of student's t at specified confidence level and at the specified power ,respectively, and p_1 and p_2 are proportion in population one and two respectively and $p_1.q_1$ and $p_2.q_2$ are the variance of the proportion in population one and two; finally it was calculated to be 700. Meanwhile, parasitological survey conducted at Ziway (Eddo Gojola) irrigation area, obtained during later literature review, indicates that monthly point prevalence of malaria during the six months (July-December 1994) ranged from 3.5% to 12.6% (average 6.8%) (Abose *et al.*, 1998). With this prevalence rate the sample size was found to be 280.Then by taking the average of these two cases the sample size was finally determined to be approximately 500 samples (individuals) each from the irrigated and non-irrigated areas.

Our sampling method was probability sampling; where each member of the population has a known non-zero probability of being selected. Systematic sampling was used in the study. The list of households for the selected areas, knowing that the list does not contain any hidden order, was obtained from the kebele leaders and it was used as a sampling frame. After the required sample size had been calculated every n^{th} record, calculated by dividing the sample size by the average family size of the area, selected from a list of population members. Every head of the household found at home during sample collection was informed about the study and the consent form was read to them, when they agreed to participate in the study blood smear samples were collected from all family members. In case a household did not want to participate in the study or if the head of the household not found at home, then the next house was taken as a replacement.

3.3 Parasitological surveys

Blood Sample Collection

Blood samples from the specified number of people, based on the sample size, from irrigated and non-irrigated areas were colleted by skin pricking of the finger onto glass slides at the end of the rainy season and during the dry season of the study. Specialized laboratory technicians of the Woreda malaria control laboratory did house to house survey for blood sample collection from the selected households (Figure 6 &7). The thick and thin blood smears were prepared on the same slide side by side, properly labeled, air dried and then the thin blood smears were fixed with methanol at the sites. The samples carefully transported to the Woreda malaria control laboratory where parasitological test by microscopic examination was performed.

Handling and Transportation of the Samples

The thick and the fixed thin blood film slides from each samples of the first season (rainy season) were cautiously transported to Ziway Woreda health office laboratory. Specialized laboratory technicians did the staining and parasitological test by microscopic examination. The samples were put into slide boxes and transported to Addis Ababa and further examination of all the positive samples and 10% of the negative samples (Ghebreyesus *et al*.,. 1999) was also done in AAU Biomedical Science laboratory. The thick and the fixed thin blood film slides of the second season (dry season) samples were properly stained and examined at Ziway Woreda health office laboratory. They were also put into slide boxes and transported to the Ethiopian Health and Nutrition Research Institute (EHNRI) Laboratory, Addis Ababa, where further conformational examination was done by technicians of the institute.

Staining and Microscopy

The quality of the Giemsa staining solution was checked before using directly to the samples. A fresh 10% Giemsa solution in tap water was prepared and the air-dried slides were immersed into a staining jar for 10 minutes. The stained slides were rinsed by tap water and put in upright position to dry (Schilchtherle *et al.,* 2000). The stained thick and thin films were observed under 100x oil immersion objective light microscope. First, the thick blood smear samples were observed in order to know whether the sample is positive or negative. When a sample is found positive then the thin blood smear was used to identify the species.

3.4 Socioeconomic survey

The socio-economic study was undertaken by enumerators specifically recruited and trained, both at Woreda health office and on site. It was done mainly based on the data collected during the second season of the study , as it was the time where best estimate of annual household income of the year would be obtained, using a structured questionnaire. The most important study attributes included: study of population profile, family size, composition of households (age and sex), resource ownership of farmers, livestock ownership and housing condition (Klinkenberg *et al.,* 2003). Corrugated sheet iron roof and mud wall reinforced with wood, corrugated sheet iron roof and mud bricks made wall, grass top and mud wall reinforced with wood and grass top and mud bricks made wall are the four different type of houses in the area (Figure 12). Though cattle keeping conditions of households in Ziway is known to have impact on malaria infection prevalence (Seyoum *et al.,* 2002), randomizing the sample was considered to remove the impact on the study. Study of farmers' total annual income was made. It was an estimate from the total annual crop production of farmers, from irrigation or rain fed or from both rain-fed and irrigation, and was the gross annual income calculated by using data from the questionnaire. Individual interviews were made using the pre-tested questionnaire (Appendix A).

A total of 220 households, from which blood smear samples were taken from all consenting residents were surveyed. 114 (51.8%) were from the irrigated areas and 106 (48.2%) were from the non-irrigated areas. Heads of the household found at home during the time of survey were interviewed for the socio-economic study. A household was recorded as positive at least when one of its family members was found positive for malaria infection during microscopic examination of blood smear. On the other hand, when all the family members of a household were found negative then the household was recorded as negative for malaria infection prevalence.

3.5 Data Management, Interpretation, and Analysis

All raw data generated from this study was entered into Microsoft Excel database system and referenced with location. This included data on socio-economic indicators: Education status of head of household, occupation of household head, production type, land holding in Kart (one fourth of a hectare), type of crops produced, production by rain-fed in quintals, production by irrigation in quintals, yearly income from rain fed, yearly income from irrigation, total annual income, livestock ownership, type of house, malaria history, knowledge about malaria transmission, malaria protection measure, bed net use, malaria medication and others.

Chi-square test (X^2) was used to determine the variation in malaria prevalence in irrigated and non-irrigated areas, season, age and sex. Malaria prevalence data was analyzed using descriptive statistics and cross tabulations using SPSS 13.0, a computer-based statistical package for Windows.

In order to identify factors that determine prevalence of malaria in the households, logistic regression model was employed. Before undertaking the model, co-linear analysis was done and the result of analysis was less than 10, confirming that one attribute used in the model do not explain the other.

The logit model with the functional form presented below was fit to the field data and analysis was done using LIMDEP 7 software (Greene, 1998).

$$\Pr ob(Y = 1) = \frac{1}{1 + e^{-\left(\beta' X\right)}}$$

The expression $\beta' X$ is defined as follows:

$$\beta' X = \beta_0 + \beta_1 X_1 + \beta_2 X_2 ... + \beta_n X_n + \varepsilon$$

Where, β_0 is the constant, $\beta_1, \beta_2 \ldots \beta_n$ are coefficients to be estimated,

X_1, $X_{2\ldots}X_n$ are independent variables and

ε is the error term with zero mean and constant variance

3.6 Ethical considerations

Ethical considerations were addressed by treating positive malaria cases by using the standard drug regimen. Informed consent was obtained from adult study subjects and from parents and guardians in case of children before sampling. The project obtained ethical approval from the ethical committees of School of Graduate Studies of Addis Ababa University .The project was also discussed with concerned bodies in the study areas and their agreement was obtained. Those individuals with positive results were treated with the required treatment and dose free of charge. The treatment was given in collaboration with the Woreda health office according to the guidelines of Ethiopian Ministry of Health. In this study, no invasive procedure other than the finger pricking, which is used for routine diagnosis, was used. Experienced laboratory technicians performed finger-pricking in order to avoid unnecessary pain and bleeding. For finger pricking, single disposable sterile lancet was used per person to avoid possible transmission of infection.

4. Results

4.1. Malaria infection prevalence

Blood smear samples were examined from a total of 2435 study participants. Of these 1060 were males and 1375 females. A total of 427 parasite positive slides were found in both study sites, 232 (19.2%) in irrigated villages and 195 (16%) in non-irrigated areas. Out of 198 (18.6%) infected males 10.3 % were in irrigated areas and 8.3% were in non-irrigated areas. Out of 229 (16.6%) infected females 8.9% were in irrigated areas and 7.7% in non-irrigated areas. Overall malaria infection prevalence in irrigated areas (19.2%) was significantly ($P<0.05$) higher than the prevalence in non-irrigated areas (16%).Moreover, the result revealed that there was no significant ($P>0.05$) difference in malaria infection prevalence between the two sexes (Table 1).

Table 1. Overall malaria infection prevalence in the irrigated and non-irrigated areas, Ziway (2005/06).

	No. of study participants	Malaria positive cases (%)	
		Irrigated	Non-irrigated
Male	1060	110 (10.3)	88 (8.3)
Female	1375	122 (8.9)	107 (7.7)
Total	2435	232 (19.2)*	195(16.0)

* Significant difference at (X^2, $P<0.05$)

The rainy season malaria prevalence in irrigated area was (16.0%) and the figure for the same in the dry season was (22.7%) (Table 2) .The finding showed that malaria transmission in irrigated areas during the dry season was significantly ($P<0.05$) higher than during the rainy season. For the non-irrigated areas, the rainy and the dry season malaria infection prevalence was (19.6%) and (11.5%), respectively. The rainy season infection prevalence of non-irrigated areas was significantly ($P<0.05$) higher than the prevalence in the dry season (Table 2). Moreover, additional analysis by season revealed that malaria infection prevalence during the dry season was significantly ($p<0.01$) higher in irrigated areas (22.7%) as compared to non-irrigated areas (11.5%). Nevertheless, during the rainy season, malaria infection prevalence in irrigated areas (16.0%) was significantly ($p<0.05$) lower than non-irrigated areas (19.6%) (Table 2).

Table 2. Overall malaria infection prevalence in irrigated and non-irrigated areas during the rainy season and the dry season, Ziway (2005/06).

Study areas	Season	Malaria positive cases (%)
Irrigated areas	Rainy (n=699)	112 (16%)
	Dry (n=528)	120 (22.7%)*
Non-irrigated areas	Rainy (n=692)	136 (19.6%)*
	Dry (n=516)	59 (11.5%)

* Significant difference at (X^2, $P<0.05$)

Comparison of infection prevalence of malaria in different age categories in irrigated and non-irrigated areas during the rainy and the dry seasons of the study is shown in table 3. In irrigated areas all age categories in the dry season showed higher malaria infection prevalence as compared to their infection prevalence in the rainy season. However, the difference was significantly ($P<0.05$) higher in age category greater than 15 years. In non-irrigated areas higher infection prevalence was depicted in all age categories during the rainy season as compared to the prevalence during the dry season. However, the difference was insignificant for all age categories. Overall, there was a decreasing trend in infection prevalence of malaria with increasing age categories within a season. However, the difference was not significant.

Table 3. Age-specific malaria infection prevalence in the irrigated and non-irrigated areas during the rainy and the dry season, Ziway (2005/06).

Area	Age	Season			
		Dry		Rainy	
		No. Examined	% Positive	No. Examined	%Positive
Irrigated	<5	156	26.9	212	21.7
	5 to 9	112	21.4	168	16.2
	10 to 14	58	20.8	70	15.7
	>15	202	20.3*	249	11.2
Non- irrigated	<5	153	17.5	189	24.7
	5 to 9	125	13.2	165	20.4
	10 to 14	46	10.1	82	17.3
	>15	192	7.1	256	14.4

* Significant at (X^2, P<0.05)

Analysis of infection prevalence of the *Plasmodium* parasite species was done in irrigated and non-irrigated areas during the rainy and the dry seasons of the study. In the irrigated areas infection prevalence of *P. falciparum* in the dry season was significantly (P<0.05) higher than its prevalence in the rainy season, whereas infection prevalence of *P. vivax* in the rainy season was significantly (P<0.05) higher than its prevalence in the dry season. For the non-irrigated areas, rainy season infection prevalence of *P. falciparum* was significantly higher (P<0.05) than the dry season infection prevalence and the same scenario was observed for *P. vivax* (P<0.05) (Table 4).

Table 4. Species-specific infection prevalence of malaria parasites in the study population during the rainy and dry seasons in the irrigated and non-irrigated areas, Ziway (2005/2006).

Area	Season	No. Examined	% Species	
			% *P. falciparum*	% *P. vivax*
Irrigated	Rainy	699	9	7*
	Dry	528	21*	1.7
Non-irrigated	Rainy	692	12.6*	7.1*
	Dry	516	10.7	0.8

* Significant difference at (X^2, $P<0.05$)

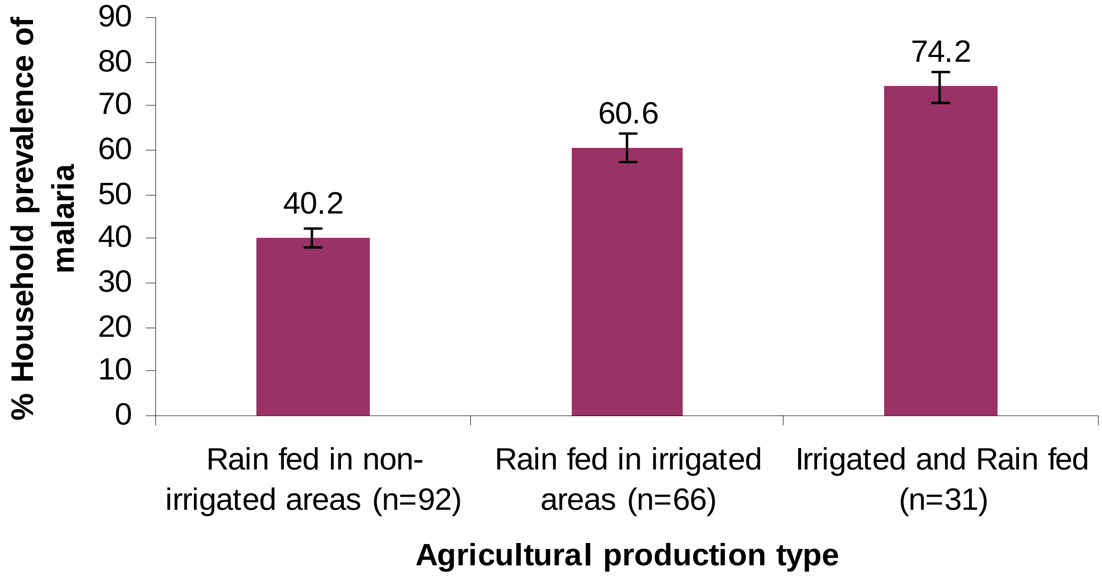
4.2 Prevalence of malaria and Socio-economic factors

4.2.1 Influence of mode of agricultural production on malaria infection prevalence

From the total of 220 households surveyed during the second season of the study, 206 were farmers, 5 were government employees and the rest (9) did not have specific job. 158 (76.7%) farmer households were producing crops only by rain-fed agricultural production system, 4 (1.94%) farmer households were producing crops by using only irrigation, 31 (15%) farmer households were producing crops by combining rain-fed and irrigation agricultural production systems and 13 (6.3%) farmer households did not clearly respond to the questions and were recorded as ‘not available for production type’. By considering the number of households surveyed in each category of production type, comparison of attributes was done for rain-fed only and rain-fed and irrigation producers.

From the 92 farmer households surveyed in non-irrigated areas producing crop by rain-fed agricultural production system, 37 (40.2%) were reported to have at least one of their family members positive for malaria infection. From the 66 farmer households surveyed in irrigated areas producing crop by rain-fed, 40 (60.6%) were found to have at least one of their family members positive for malaria infection. Moreover, from the 31 farmer households producing crops both by rain-fed and irrigation systems (all from irrigated areas) 23 (74.2%) were found to have at least one of their family members positive for malaria infection. The result indicated households using both irrigation and rain-fed agriculture to have significantly (P<0.05) higher infection prevalence as compared to households using only rain-fed. Rain-fed producers in irrigated areas were found with significantly (P<0.05) higher malaria infection prevalence as compared to rain-fed producers in non-irrigate areas of the study, which is the result of higher malaria infection prevalence in irrigated areas. (Figure 8).

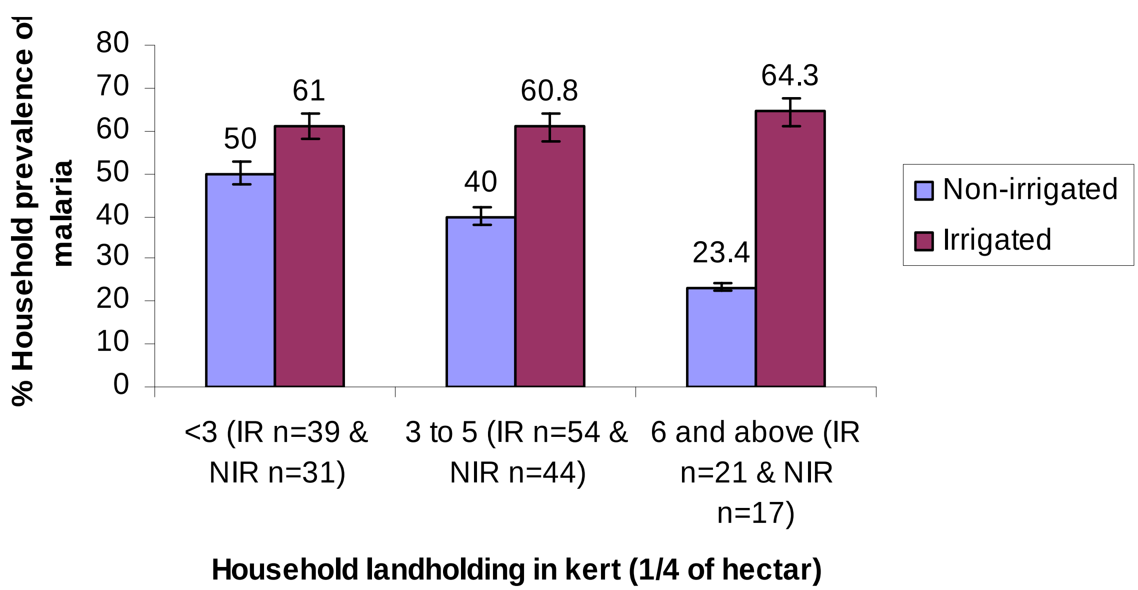
Figure 8. Comparison of infection prevalence of malaria in at least one family member of households surveyed with production types during the dry season in Ziway, February-March 2006.



4.2.2 Influence of resource ownership on malaria infection prevalence

Households' land was categorized in every two kart (half hectar), considering half hector as the minimum land holding of households. Then comparison of infection prevalence of malaria in at least one family member of households in each category of landholding was computed for irrigated and non-irrigated areas. The result revealed that in irrigated areas as farm size increased infection prevalence of malaria showed insignificant variation (P>0.05). On the contrary, in non-irrigated areas as farm size increased infection prevalence of malaria significantly (P<0.05) decreased (Figure 9).

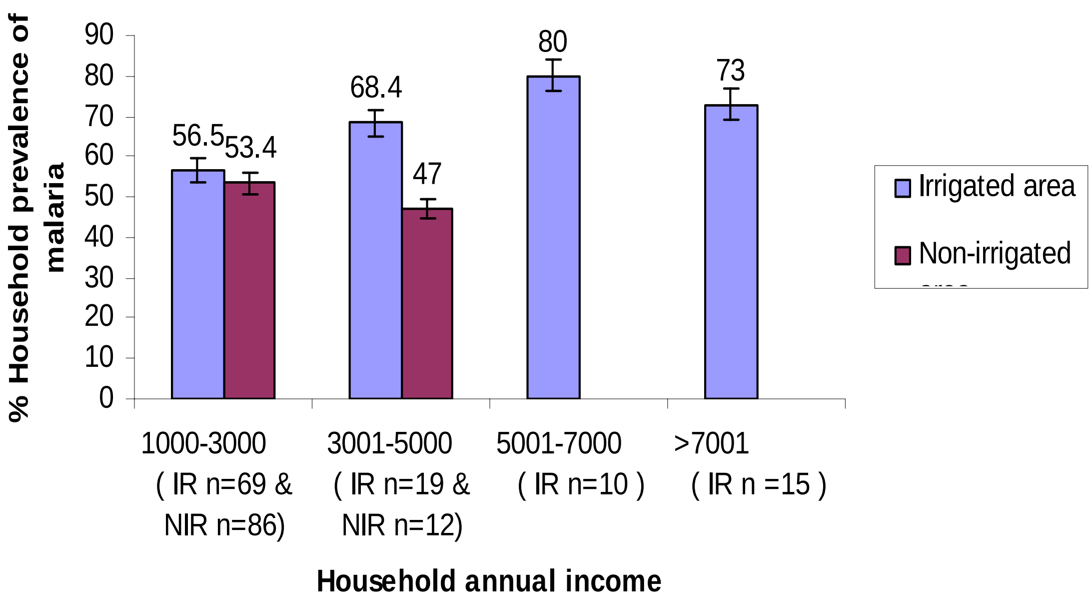
Figure 9. Comparison of infection prevalence of malaria in at least one family member of households in irrigated and non-irrigated areas in different farm size categories during the dry season in Ziway, February-March 2006.



The total annual income of households who were producing crops by rain-fed agricultural production system only, either in the irrigated or non-irrigated areas, and total annual income of farmers producing crop by irrigation only ranged from Eth. Birr 1020 to 9740 and from Eth. Birr 4175 to 5550, respectively. Total annual income of farmers producing crop by combining irrigation and rain-fed agricultural production system ranged from Eth. Birr 3320 to 26,025. Average income of farmers producing by rain-fed only was Eth. Birr 2084.8 and average income of farmers producing by combining irrigated and rain-fed agricultural production systems was Eth. Birr 7799.24. Income per person per day by rain-fed producers was 1.08 while income per person per day by irrigated and rain-fed producers was 3.9.

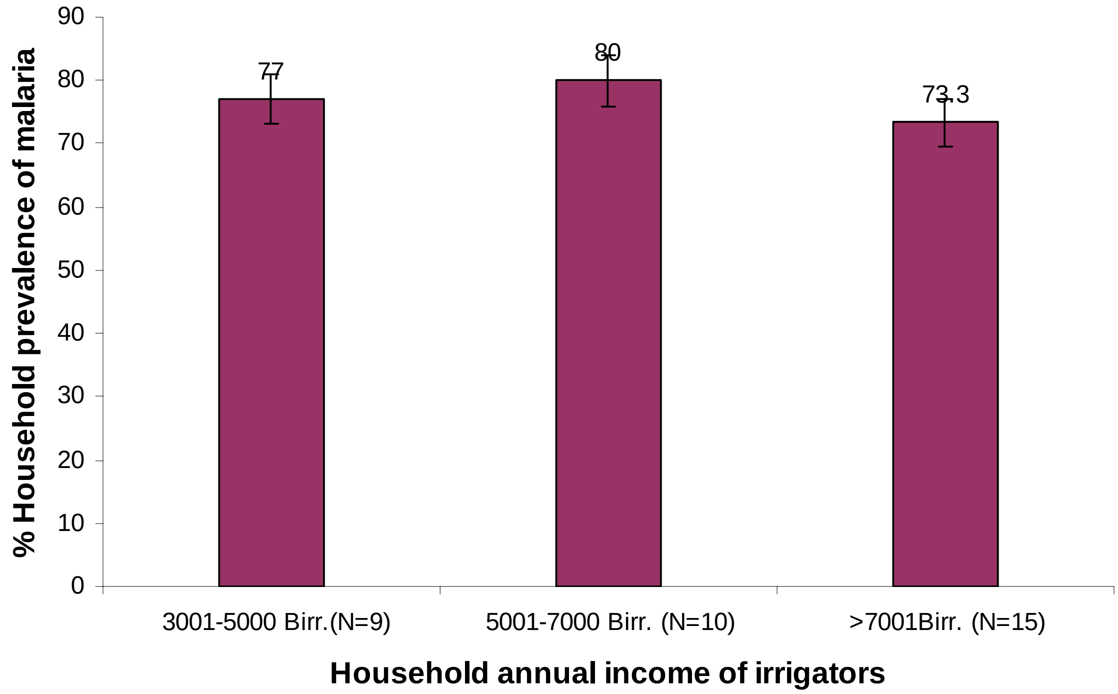
The total annual income of households in Birr were categorized in every 2000 Eth. Birr increase and comparison of households with at least one family member positive for malaria infection in different income categories in irrigated and non-irrigated areas of the study was made (Figure 10). The result revealed that as the household income in irrigated areas increased malaria infection prevalence increased significantly ($P < 0.05$). Whereas, in non-irrigated areas as the household income increased infection prevalence of malaria showed a decreasing trend.

Figure 10. Infection prevalence of malaria in at least one family member of households in irrigated and non-irrigated areas in different annual income (Birr) categories in Ziway, February-March 2006.



Further comparison of household income categories of irrigators with at least one of the family member positive for malaria infection prevalence was made (Figure 11). As the total annual income of irrigators increased infection prevalence of malaria has also increased but was not significant ($P>0.05$).

Figure 11. Infection prevalence of malaria in at least one family member of households of irrigators (excluding sole rain-fed producers in irrigated areas) in different annual income categories in Ziway, February-March 2006.



4.2.3 Influence of housing type on malaria infection prevalence.

A) Grass top and mud wall reinforced with wood.

B) Corrugated sheet iron top and mud brick wall.

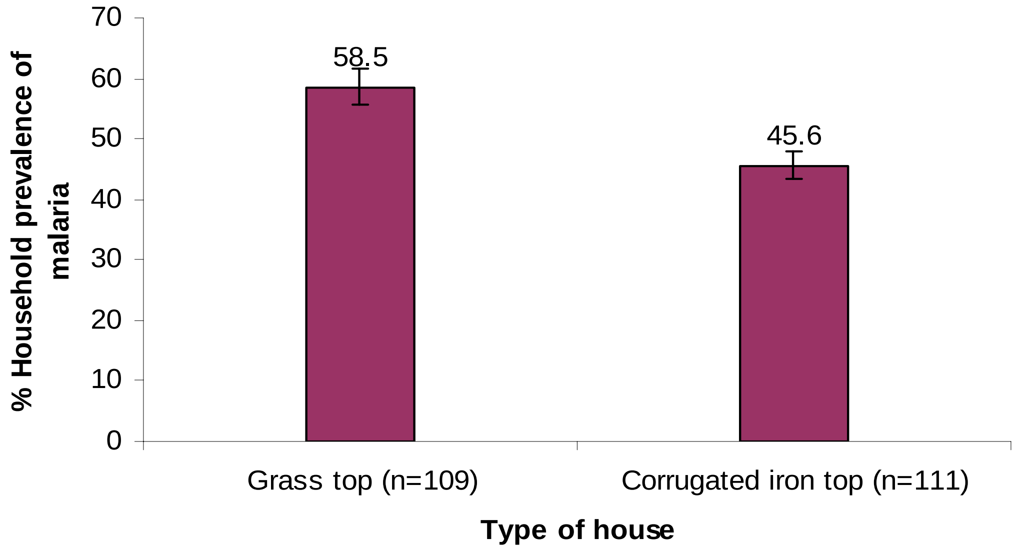
C) Corrugated sheet iron top and mud wall reinforced with wood

D) Grass top and mud brick wall

Figure 12. The four major types of houses found in the study site, Ziway February-March 2006.

Infection prevalence of malaria in relation to the type of houses in which the family members lived was compared. 105 houses made of grass top and mud wall reinforced with wood, 4 houses made of grass top and mud brick wall, 26 houses made of corrugated sheet iron roof and mud wall reinforced with wood and 85 houses made of corrugated sheet iron roof and mud brick wall were surveyed for malaria infection of household members. Infection prevalence of malaria at least in one family member of households that lived in grass top houses was significantly ($P<0.05$) higher than infection prevalence of malaria at least in one family member of households that lived in corrugated iron roof (Figure 13).

Figure 13. Comparison of infection prevalence of malaria in at least one family member of households surveyed in irrigated and non-irrigated areas and their house type in Ziway, February-March 2006.



In order to identify factors that determine the prevalence of malaria at household level, a logit model was fit. The hypothesized determinants were described and the result of the model is indicated in table 5.

The Logistic regression (logit) model indicated that a change in house type from grass top to corrugated sheet iron roof showed 0.5660 unit probability decrease in malaria infection prevalence. On the contrary, an increase in the total annual income of farmers showed 0.0002 unit probability increase in malaria infection prevalence and an increase in household malaria history also showed 0.4509 unit probability increase in malaria infection prevalence (Table:5).

Table 5. Logistic regression analysis of factors affecting the probability of malaria prevalence in at least one family member of households in Ziway, February-March 2006.

Explanatory variables	Coefficient	t-ratio
Sex	0.1228	0.347
Educational Status	-0.3692	-0.901
Occupation	-0.3763	-1.071
Total annual income	0.0002	2.537***
Livestock ownership	0.0523	1.036
Type of house	-0.5660	-2.535***
Malaria History	0.4509	1.879*
Bed net use	0.3172	1.273
Distance from health center	-0.1525	-1.088
No of observations (Households)	220	

*** and * show significance at 1%, and 10%, respectively

Figure 14. Possible *Anopheles* spp. breeding sites (seepages) created by irrigation, Ziway Feb-March 2006.

Figure 15. Possible *Anopheles* spp. breeding sites (canal seepages) formed by leakage of water at broken main canal line, Ziway Feb-March 2006.

Figure 16. Vegetation produced by irrigation where adult *Anopheles* vectors can rest, Ziway Feb-March 2006.

5. Discussion

It is to be expected that irrigation structures would offer ideal habitats for the proliferation of anopheline mosquitoes, including vectors of malaria. A study conducted in Tigray (Northern Ethiopia) for instance, indicated an overall increase in prevalence of malaria in the villages close to dams as compared with the control villages (Ghebreyesus *et al*., 1999). Another study in South eastern Ethiopia had shown malaria due to *P. falciparum* and *P. vivax* to be the main health problems in irrigation schemes along the Genale River (Birrie *et al.,* 1997). A study in Arba-minch also showed irrigation activity to have created a year round breeding habitat for the anopheline mosquitoes (Ashenafi, 2003). The present study looked into the situation in Ziway where small-scale irrigation has been in practice for decades but the extent of its linkage with malaria has not been studied. The study findings are in agreement with the earlier reports that assessed the impact of construction of small irrigation dams on the incidence of malaria in Tigray (Ghebreyesus *et al*., 1999) and that of Klinkenberg *et al.* (2005) in the irrigated areas in Ghana.

The difference in malaria prevalence between irrigated and non-irrigated sites was more pronounced during the dry season. This is because the irrigation structures in the area would provide suitable breeding sites for malaria vector mosquitoes during the dry season. Since mosquito-breeding sites would be equally available both in the irrigated and non-irrigated areas during the rainy season, such increase in malaria prevalence was not observed with irrigation. The humid environment during the small rains (March, April and May) which was at the same level of humidity following the big rains (October) (National Meteorological Agency, NMA) and the humid environment, which also is created through irrigation during the dry season, would enhance vector longevity. Moreover, Robert (2004) observed, the increase in the density of foliage of plants will provide more shelter for adult mosquitoes, extending their longevity. Likewise, when the residual soil moisture increases with irrigation, it will extend the range of sheltered habitats for mosquitoes. This would explain the higher adult density of *An. pharoensis* in irrigated areas during the dry season (Abose *et al*., 1998).

An. pharoensis is the second important vector, next to *An. arabiensis*, implicated in malaria transmission in Ziway (Abose *et al*., 1998; Seyoum *et al.,* 2002). This species mostly rests outdoors on vegetation. The irrigated farming in the area where vegetables (onion, cabbage, tomato, cucumber etc…) and cereal crops, mainly maize, were grown and other trees planted for fencing irrigation fields would provide ideal sites for resting and enhancing longevity of this vector species. The relevance of enhancement of longevity of vector mosquitoes to malaria transmission has been shown by the findings of Mukiama and Mwangi (1989) where higher adult population of sporozoite-infected *An. pharoensi*s was more abundant in irrigation schemes in Kenya. Moreover, the higher minimum temperature of the dry season in the irrigated areas would contribute to completion of parasite life cycle inside vectors.

Furthermore, according to Carrara *et al.* (1990), *An. pharoensis* was the main malaria vector for intensive *P. falciparum* transmission in Senegal River delta where all examined *An. gambiae* Giles *sensu lato* were *P. falciparum* sporozoite negative. Besides the report from Senegal, the role of *An. Pharoensis* in *P. falciparum*-dominated malaria transmission in Ziway study area during the dry season is supported by the entomological survey concomitantly conducted in the area (Solomon Kibret, Personal communication).

The higher dry season malaria transmission, related to availability of water bodies, was similar to what was reported by John *et al.* (2004) that water lodged pits created during brick-making supported the development of malaria vectors and thus enhanced dry season malaria transmission in western Kenya.

On the other hand, the higher prevalence of malaria in the non-irrigated areas during the rainy season might be due to "drown dawn" phenomenon in the irrigated areas whereby the over-flooding of the irrigation structures would disturb the vector breeding sites and lead to decreased transmission. Bziava and Kruashvili (2002) had shown that periodic "drown dawn" of irrigation canals can be used as an ecological measure for malaria control.

In irrigated areas older age group inhabitants will be at work during early evenings where the prominent vector of the dry season, *An. pharoensis*, will be active and hence will have a higher risk of infection. Higher malaria prevalence in older age groups in Ethiopia was also reported by Yohannes and Petros (1996) by observing the absence of apparent decrease in prevalence with increasing age in Nazareth, Ethiopia. Although Abose *et al.* (1998) reported that men in the area were affected more than women, considering that men (especially adult men) are more likely to spend the evening hours outdoors working in their plantations and might receive more mosquito bites than women, the present study revealed no significant difference in malaria infection prevalence between the two sexes. This suggests lack of difference in the outdoor stay behavior of the two sexes and is consistent with the findings of Himeidan *et al.* (2005) in an irrigated area in Eastern Sudan.

It is generally known that *P. falciparum* is dominant during the peak malaria transmission season in September and October, while *P. vivax* tends to dominate during the dry season in Ethiopia (Tulu, 1993). The present findings from the non-irrigated areas confirm the above generalization for *P. falciparum*. Decreases in *P. falciparum* prevalence have been shown to allow the patency of other parasite species (Smith *et al.,* 2001).This will explain the lower infection prevalence of *P. vivax* in non-irrigated areas during the dry season. The lower infection prevalence of *P. vivax* in irrigated areas during the dry season could be due to the fact that *P. vivax* is most prevalent in unstable transmission conditions (Gilles and Warrell, 1993) and hence its rate of transmission may not be influenced by irrigation.

Irrigation has created enhanced conditions for endemicity of *falciparum* malaria by changing its seasonal patterns. In irrigated areas, stable malaria transmission favors *P. falciparum*, whereas transmission of *P. vivax* was much lower as its transmission would be suppressed by *P. falciparum* (Smith *et al.,* 2001). An irrigation-associated increase of *P. falciparum* infection prevalence during the dry season was also reported from India, where extensive irrigation had triggered *P. falciparum* dominated malaria in the virgin levees of Thar Desert in India (Tyagi, 2004).

Although all factors that contribute to malaria risk are not fully understood (Robert *et al.*,2003), seasonality features, which could be altered in time through irrigation availability of surface water, humidity and temperature are factors which affect vector abundance, longevity and parasite development inside vectors (Woyessa *et al.*, 2004; Teklehaimanot *et al*., 2004) .

The study site (Ziway) has an average temperature of 20.7^0C with the higher temperature occurring during dry season (Figure 4) (Teklehaimanot *et al*., 2004). At 20^0C, 3 weeks are needed for *P. falciparum* development inside mosquitoes while *P .vivax* can develop in 16 days (Gilles and Warrell, 1993; CDC, 2004). As the temperature increases, for instance at 22^0C, mosquito's life cycle and *P. falciparum* development inside mosquitoes will be completed in 18 and 7.9 days, respectively (Teklehaimanot *et al*.,2004), and hence *P. falciparum* would be favored and could suppress other human *Plasmodium* species (Smith *et al.*, 2001).

Persistence in *P. falciparum* malaria may also be due to other more direct human activities (Singh *et al.,* 2004). For example, due to resistance developed by *P. falciparum* in most parts of Ethiopia (Worku *et al.,* 2005), Coartem (Artemisin-based Combination Therapy, ACT) is substituting sulfadoxine pyrimethamine (SP). However, the population in Ziway is still using SP (personal communication with health worker), as it is available on market, and such patients are most likely to serve as reservoirs of the parasite and may lead to enhanced *P. falciparum* transmission in the dry season.

The higher infection prevalence of malaria in irrigated areas is the result of favorable conditions created by irrigation for malaria transmission. This finding is similar to the report of Hunter *et al.* (1993) from Kenya. The higher infection prevalence observed among the farmers who were using irrigated farming can also be explained by the fact that the farmers using irrigation spend most of the early evening outdoors, doing irrigation activities and this is the time of the night when *An. pharoensis* is known to be most active (Gillies and DeMeillon, 1968). The higher infection prevalence of malaria in irrigated area in older age group (>15years old) during the dry season compared to rainy season also supports the above statement since it is older persons who work in the farms.

The finding in the irrigated areas that as farm size increased infection prevalence of malaria also increased, may be explained by the fact that, although farmers that have larger farm sizes and who use irrigation had more income, the population was not investing on protection against malaria.

According to the World Bank poverty analysis at global level, people living under poverty line (consumption or income level that falls below some minimum level necessary to meet basic needs) have less than 1USD per person per day (World Bank, 2006). A rough calculation of the increase in income by irrigators, which was from 1.08 Eth. Birr per person per day (by rain fed producers) to 3.9 Eth. Birr per person per day (by irrigators), was much lower than $1 (8.7 Eth. Birr). Therefore, the increase in income due to irrigated farming was not adequate to extricate poverty so as to allow the population to invest on malaria prevention measures.

The finding that in non-irrigated areas, as farm size and income increased, infection prevalence of malaria decreased, is an indication that the limited anti-malaria measures that may be in place (DDT spraying, etc…) in the non-irrigated areas provide some protection in view of the fact that there was no increase in the intensity of transmission as a result of irrigation.

The fact that the type of houses would have impact in malaria infection prevalence was substantiated by the comparison of malaria prevalence in the four different types of houses found in the study area. A decrease in malaria prevalence was observed as the type of houses improved from grass top to corrugated iron roof and plastering the wall of houses is known to prevent mosquito entrance into the houses. The contribution of improvement of housing to malaria control has also been reported from other studies (Ghebreyesus *et al*.,. 1999; Gilles and Warrell, 1993; Konradsen *et al.,* 2003). Further evidence to this was provided by the logistic regression model, which indicated that a unit increase in the quality of house wherein farmers lived, from grass top to corrugated sheet iron roof, revealed a significant decrease in malaria infection prevalence.

The significant increase in malaria infection prevalence for a single increase in previous malaria history in at least one family member of a household could be explained by possible clustering of mosquitoes to specific houses within villages as demonstrated elsewhere (Ghebreyesus *et al*.,. 1999; Ribeiro *et al.,* 1996; Keating, *et al.,* 2005).

Although they had a relatively higher total annual income, the households in irrigated areas were at a higher malaria risk population. The logistic regression analysis of the data revealing a low educational status of the study population is suggestive of the possibility that with an improvement in the income of farmers, a minimum effort like educating farmers about malaria protection could minimize the negative impact of irrigation on malaria transmission around Ziway. Ijumba and Lindsay (2001) had reported malaria control effort benefiting from the greater wealth created by irrigation schemes. This can be achieved by having increased use of bed nets thus receiving fewer infective bites and better access to improved health care as compared with those outside irrigation development schemes.

6. Conclusions

The following conclusions can be drown from the present study on the impact of small scale irrigation on malaria transmission in Ziway:

1. Significantly higher prevalence of malaria was observed in irrigated areas as compared to the non-irrigated in Ziway. This suggests that the irrigated areas around Ziway are more favorable for breeding and activity of malaria vector mosquitoes, which enhances their longevity and facilitates completion of parasite life cycle for most months of the year. This finding provides evidence that special measures for malaria control must be instituted while undertaking development efforts such as expansion of irrigated agriculture, especially in epidemic-prone areas.

2. Malaria infection prevalence significantly increased at irrigated sites during the dry season when compared with the parallel scenario during the rainy season. This was exhibited in all age groups but, older age groups (greater than 15 years old) in irrigated areas had significantly higher infection prevalence during the dry season as compared to the same age group in the rainy season.

3. In irrigated areas an increase in land holding and increase in total annual income has not shown a decrease in infection prevalence of malaria.

4. Change in the type of residential houses from grass top to corrugated iron roof sheet showed decrease in malaria infection prevalence.

7. Recommendations

1. Despite advantages of increased agricultural productivity, development of water resources may have negative impact on health .Therefore, to counter the increased malaria risk near developed water resources, there is need for special attention to health issues in the implementation of ecological and environmental development programs.

2. Integration of the activities of agriculturalists, health professionals, and communities is essential to reduce the existing impact of malaria in small-scale irrigation schemes and to prevent future escalation. Awareness creation educational interventions must be undertaken so that the use of ecological control measures, mainly focusing on eliminating breeding sites and personal protection through the use of ITN are effectively practiced.

3. In depth study, including different agro-ecological zones, is needed to assess the overall importance of irrigation-related epidemiology of malaria in Ethiopia.

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Appendix: A

<u>Questionnaire</u>

Malaria prevalence in irrigated and non-irrigated areas around Ziway

1. Household Identification

Woreda: ________________________

Kebele: ________________________

Household number: ________________________

2. Household head characteristics

Age of household head________________ Years

Sex: 1 = Male 2 = Female

Religion: 1= Orthodox 2 = Muslim 3 = Protestant 4=other____

Educational status: 1=Illiterate 2 = Read and write only,

3 = _____ Years of formal education 4 = others (Specify) _________

3. Family size and composition

No	Family members	Age	Sex 1=Male 2=Female	Slide No	Result 1= Positive 2 =Negative	Species 1=*P.falciparum* 2=*P .vivax* 3=*P. malaria*
1						
2						
3						
4						
5						
6						
7						
8						
9						

4. Occupation of household head

1= Farmer 2= Merchant

3= Government employee 4 = others (specify)…………………

5. If the answer for No.4 is farmer, what is the production system?

1 = Under rain fed 2= Under irrigation

3 = Under both rain fed and irrigation

6. Resource ownership

Farm size: ______ ha of land

Type of crop produced:

Crop	Area cultivated in kert by		yield (qt/kert)		Price (birr/qt)	
	Rain	Irrigation	Rain	Irrigation	Rain	Irrigation
Sorghum						
Maize						
Haricot bean						
Teff						
Wheat						
Barely						
Onion						
Other Vegetables						
Others						

Livestock ownership:

# of cattle _____ # sold / year ___ # of small ruminants _____# sold/year___

# of Donkeys and Mules _____# sold/year___ # of Horses_________# sold /year __

Type of house owned: (1=well plastered, 2= not)

1 = thatched top, mud wall reinforced by wood 2= thatched top, mud bricks made wall

3= corrugated tin top, mud wall reinforced by wood

4= corrugated tin top, mud bricks made wall

7. Do you face malaria problem?

1 = Yes   2 = No

8. If yes, how do you prevent and control malaria?

*By using modern prevention method

1= Use impregnated net   2= Medication

*By using conventional prevention methods like

3=Clearing water, dirty and marshy   4=Smoking some incense woods

5= both 3 and 4   6= other (specify) ________________

9. If you use impregnated net, who in the family use it?

1 = All the family members   2= only father and mother

10. If you do not use impregnated net, what is the reason?

1 = Lack of knowledge about the importance of the net

2 =The net is expensive   3= Other (specify) ________________

11. Do you know how malaria transmits from one person to another?

1 = by insect vector bite   2 =other (specify)……………………

12. Is there any health center for malaria treatment?

1 = Yes   2 = No

13. If yes,   1= Woreda health center   2= private health Center   3= both

Distance to the nearest health center ________Km

14. Since when did you face malaria problem ______E.C?

Appendix: B

<u>CONSENT FORM</u> (English Version)

PIN ----------------------

Name of study participant ---------------------------------- Age---------- Sex-----------

Lab. technician Name-------------------------------- Site /Health center -------------------------

I have been informed about a study that plans to investigate the '**Irrigation and socio-economic factors related to malaria transmission in ziway, eastern oromiya zone',** which will help assess the difference of malaria transmission pattern between irrigated and non-irrigated areas and if difference in transmission due to irrigation is observed to use appropriate control measures that can minimize the transmission of the first top disease of 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 priker (lancet). I have been informed that if positive result is observed treatment will be given for free 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 cooperated 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: C

<u>የጥናት ተሰናተፊ የስምምነት ቅጽ </u>(Amharic Version)

መለያ ቁጥር------------------

የተሳታፊው ስም -- እድሜ------------------ፆታ------
የህክምና ባለሙያው ስም ------------------------------------ ቦታ -----------------------------

እኔ --- የተባልኩት የአዳሚቱሉ ጂዶ ኮምቦልቻ (የዝዋይ አካባቢ) ወረዳ ነዋሪ በአካባቢያችን ውስጥ በየወቅቱ በሚከሠተው የወባ በሽታ ጥናት ውስጥ እንድሳተፍ ፈቃደኛ መሆኔንና አለመሆኔን ተጠይቄአለሁ:: ይህ በሽታ መስኖ በሚጠቀሙና በማይጠቀሙ መንደሮች ያለውን ልዩነት ለማጥናትና በርግጥ በመንደሮቹ መሀከል የወባ ስርጭት መጠኑ የተለያየ ሆኖ ከተገኘ አስፈላጊውን ጥንቃቄ በመውሰድ ለመቀነስ የሚረዳ መሆኑ በቅድሚያ ተነግሮኛል::

ለዚህ ጥናት ያገለግል ዘንድ በፈቃደኝነት ላይ የተመሠረተ የወባ ምርመራ እኔና በስሬ የሚተዳደሩ ልጆቼ እንድናደርግ ተጠይቄአለሁ:: በደማችን ውስጥም የወባ አምጭ ተህዋስ የተገኘ እንደሆነ አስፈላጊው መድሀኒት በነፃ እንደሚሠጠን ተነግሮኛል:: ጠብታ ደም ከጣት በሚወሰድበት ወቅት ደም አወሳሰዱ ልምድ ባለው የጤና ባለሙያና የህክምና ደንብ በሚፈቅደው የንፅህና አጠባበቅ ደረጃ እንደሚከናወን ተገልፆልኛል:: በዚህም መሠረት እኔም ሆንኩ በስሬ የሚተዳደሩ ቤተሠቦቼ ምርመራውን ለማድረግ ከጣታችን ጠብታ ደም ለመስጠት ተስማምቻለሁ:: ከፈለግሁ ማንኛውም ውጤት በሚስጢር እንደሚያዝ ተገግሮኛል::

በዚህ ጥናት ምንም አይነት የገንዘብ ጥቅም የማላገኝ መሆኔንና ከመፈረሜ በፊት እንዳስብበት በቂ ጊዜ ተሰጥቶኛ የተስማማሁ መሆኔን በፊርማዬ ለማረጋገጥ እወዳለሁ::

የተሳታፊው ስም ----------------------------- ፊርማ ----------------- ቀን -----------------
የአጥኚው ስም -------------------------------- ፊርማ ----------------- ቀን -----------------
የምስክር ስም --------------------------------- ፊርማ ------------------ ቀን -----------------

Declaration

I, the undersigned declare that this thesis is my work and that all sources of material used for the thesis have been correctly acknowledged.

Name: ________________________________

Signature: ____________________________

Date of submission: ____________________