



**Addis Ababa University
Collage of natural science
School of earth and planetary science**

**Spatial Risk Prediction and Mapping of *Schistosoma mansoni* in Finchaa Sugar
Estate Farm, East wollega zone,, Ethiopia**

**Thesis submitted for Partial Fulfillment of the Requirements for the
Award of the Degree of
Master of Science**

In Remote Sensing and Geographical Information System (GIS)

By

Abenet Solomon

**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES**

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DECLARATION

I hereby declare that the dissertation entitled “*Spatial Risk Prediction and Mapping of Schistosoma mansoni in Finchaa Sugar Estate Farm, East wollega zone, Ethiopia*” has been carried out by me under the supervision of Dr.K.V. Suryabhagavan, school of Earth Sciences, Addis Ababa University, Addis Ababa during the year 2012-2013 as a part of Master of Science programme in Remote Sensing and GIS. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma.

Place: Addis Ababa

Date: June, 2013

Abenet Solomon

C E R T I F I C A T E

This is certified that the dissertation entitled “Spatial Risk Prediction and Mapping of Schistosoma mansoni in Finchaa Sugar Estate Farm, East wollega zone, Ethiopia” is a thesis work carried out by Abenet Solomon under my guidance and supervision. This is the actual work done by Abenet Solomon for the partial fulfillment of the award of the Degree of Master of Science in Remote Sensing and GIS from Addis Ababa University. Addis Ababa.

Dr. K.V Suryabhagavan

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Schistosomiasis is one of the world health organizations (WHO), great neglected disease. It is the second most prevalent tropical disease with 200 million people infected and 500 million at risk. The disease spread by cercaria infested water using fresh water snail as intermediate host. Intestinal schistosomiasis caused by Schistosoma mansoni infection is a widely distributed disease in several localities of Ethiopia. Now there are about 4 million people reported to be infected and 30 million at risk of schistosomiasis in the country. The major risk factors for increase prevalence of the parasite are population movement and water development schemes.

The aims of this research is the assessment of schistosomiasis mansoni risk areas in relation with environmental factors and tries to analyze Schistosomiasis mansoni incidence with some of the natural and socio-economic factors using Remote sensing and GIS techniques using risk model developed by shook.

It is indicated that 4020.5 ha high, 4462.5 ha moderate and 17 ha Low level of schistosomiasis mansoni vulnerability, hence 47.3 percent, 52.5 percent and 2 percent of the study area respectively are subject to high moderate and low level of schistosomiasis mansoni susceptibility.

KEYWORDS: *Schistosomiasis mansoni, remote sensing and GIS*

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AHP: Analytical Hierarchy Process
CDC: Center for Disease Control
CSA: Central Statistical Agency
DEM: Digital Elevation Model
EHNRI: Ethiopian Health and Nutrition Research Institution
EMA: Ethiopian Mapping Agency
FSF: Finchaa Sugar Factory
FSFHC: Finchaa Sugar Factory Health Center
GIS: Geographic Information System
GPS: Global Position System
IDW: Inverse Distance Weight
MOH :Minister of Health
MCE: Multi-Criteria Evaluation
SCHI: Intestinal Schistosomiasis
SCHu: Urinary Schistosomiasis
SNNPR: South Nation Nationality People Region
RS: Remote Sensing

1. Background

Schistosomiasis or bilharzia, coined after the discoverer Theodore Bilharz, is an “age old water born parasitic disease” in Ethiopia with a significant public health importance ranked 2nd to malaria. (Assefa *et al*, 2012) These trematodes affect approximately 200 million people and pose a threat to 700 million peoples worldwide. Largely its distribution shows majority in tropics and subtropics reflects the geographical distribution of their intermediate host fresh water snail species.

Infection is caused by four types of blood flukes of the genus *schistosoma*. Humans are infected by the *cercarial* stage of the parasite released from freshwater snail in ponds, canals, lake edges and stream. Penetration of intact skin occurs rapidly, and the schistosomes migrate into the portal system to mate and then to a part of the venous system to lay eggs.

Parasitic worms of the genus *schistosoma*, trematode species that transmits the disease are *schistosoma mansoni*, *schistosoma haematobium*, *schistosoma japonicum*, and *schistosoma mekongi*, also *schistosoma intercalatum* a parasite of cattle in West Africa occasionally causes the disease in human. Except for *schistosoma haematobium* that produces urinary tract disease, human Schistosomiasis primarily affects the intestine and liver. Chronic Schistosomiasis also causes physical growth and cognitive delay in children. (Despommier *et al*, 2006)

High infection rates persist among both the rural and urban poor. Rural living, poor housing water supplies and low educational level are major factors in *schistosomiasis* occurrence among agricultural population. The infection is most common in places with poor sanitation. School-age children who live in these areas, farmer who practice irrigated agriculture such as rice farm, fisherman's who fish in fresh water lakes, reservoirs and poor rural community which have lack access to clean water are often most at risk because they tend to spend time swimming, bathing and drinking in water containing infectious *cercaria*. Community or people who live in, or travel to, areas where *schistosomiasis* is found and are exposed to contaminated freshwater, are more likely at risk of infection because of worms are transmitted via contact with contaminated water.

In encroachment into natural system like, constricting irrigation canals and dams have resulted in regional increase in *Schistosomiasis*.

Schistosoma mansoni is found throughout most of sub-Saharan Africa. Egypt and Sudan. *Schistosoma haematium* is prevalent in most of Africa. *Schistosomiasis japonicum* occurs in China, Malaysia, the Philippines and Indonesia. *Schisto mekongi* a closely related species is found in Mekongi in Southeast Asia. <http://www.cdc.gov/parasites/schistosomiasis/epi.html>

Previous studies state that, *Schistosomiasis* due to *mansoni* is widely distributed within an altitude of 800m-2200m above msl and *haematobium* is found in lowlands bellows 800m in Ethiopia (Kloss *et al*, 1988). Two species of the genus *biomphalaria*, *bilinus sudenic* and *bulinus pfeifferi*, are known to transmit *schistosomiasis mansoni* in Ethiopia (Erko *et al*, 2006). *Bulinus abyssinieas* and *bulinus africanus* are the only bulinid species found naturally transmitting *schistosomiasis haematobium*.

Generally, three main ecological setting (irrigation, stream and lake ecology), where transmitted of *Schistosomiasis* occur are recognized in Ethiopia (Birrie *et al*, 1993a). Since stream create more favorable habitats for the breeding of the snail intermediate host, it constitutes the major transition ecology. Besides, it's evident that the majority of *schistosomiasis mansoni* endemic area occurs in agricultural community's resideing along stream (Birrie *et al*, 1993a). Growing evidence also suggest that irrigation ecologies are becoming molacologically suitable areas and these are sites of intense transmission for *schistosomiasis mansoni* (kloos *et al*, 1988).

1.1. Statement of the Problem

Schistosomiasis is reported to cause between 1.7 and 4.5 million deaths each year (Steinmann *et al*, 2006). Furthermore, 2011 fast fact 0f CDC, 700 million people are at-risk of acquiring *schistosomiasis* in the world and 207 million people suffer from *schistosomiasis*. Approximately 90% of those infected with *schistosomiasis* live in Africa out of these 85 % of them are concentrated in sub-Sahara Africa (Worner *et al*, 2007).

Finchaa sugar factory valley kebele is geographically located in the range of Altitude 1104-2420 m.s.l which is identified as *schistosomiasis* prone area in Ethiopia (Kloas *et al*, 1988). Such type of *schistosomiasis* transmission risk mapping were not held before in the kebele, except there was a study carried out by Getnet Melaku in 2009, the objective of the study was to assess the impact of *schistosomiasis* control on the prevalence and intensity of the disease in Finchaa and Wonji-Shoa sugar estates.

1.2 Objective of the Study

1.2.1. General Objective

It's important to create a method of separating area of high risk from area of low risk for control and address the problem in accordance. The general objective of this study is to map and identify high risk *Schistosomiasis mansoni* areas within Finchaa sugar estate valley kebele villages, which help the national disease control center and concerning bodies to give appropriate and on time response to epidemiology like *Schistosomiasis mansoni* and enable the officials to easily identify area of transmissions and incidence.

1.2.2. Specific Objective

- ✓ To prepare *schistosomiasis mansoni* hazard and risk map of the Study area using different Remote sensing and GIS techniques
- ✓ To identify climatic, environmental and geographical factors that contributes to *schistosomiasis mansoni* transmission.
- ✓ To indicate techniques of Remote sensing and GIS for *schistosomiasis mansoni* risk mapping.

1.3 Significance of the study

This study is expected to strength the control and eradication effort against *schistosomiasis mansoni* in Finchaa sugar estate valley by different stakeholders in the field of public health. Further, the outcome of the study essential for appropriate use and to ensure that the scarce resource implemented to the most high risk areas can support the eradications and prevention tasks.

1.4 Limitation of the Study

The limitation of the study includes lack of satellite images taken at different seasons which can help to map seasonal variation of climatic variables in relation with *schistosomiasis* epidemics. There was also lack of the necessary climate data (soil moisture, water body temperature). Lack of well documented monthly *schistosomiasis* case data at Kebele as well as at village level over extended years, and lack of a spatial population distribution data of

the study area were also encountered, which made analysis of risk map with *schistosomiasis mansoni* case at village levels difficult.

1.5 Organization of the Research

The thesis is organized in six chapters. Chapter one provides research background, problem definition, objectives and significant of the research. Chapter two provides a literature review, on basic concept of *schistosomiasis*, global distribution of *schistosomiasis*, *schistosomiasis* in African and Ethiopia, factor of transmission of *schistosomiasis*, application of Remote sensing and GIS in schistosomiasis study. Chapter three provides description and background of the study area. Chapter four describes the methodology and analysis. Results and discussion are contained in Chapter five, and finally Chapter six is about conclusion and recommendations

2. Literature Review

2.1 Concepts of Schistosomiasis

Schistosomiasis is a clinical term applied to complex water-borne disease of medical, social, behavioral and ecological significance, it is caused by parasites (genus *Schistosoma*) that enter humans body by attaching to the skin when came in contact with infested water body , penetrating it and then migrating through the venous system to the portal veins where the parasites produce eggs and eventually the symptoms of acute or chronic disease , fever, abdominal discomfort, blood in stools experienced by individual cases. (Edward *et al*, 2002).

Schistosoma parasites can penetrate the skin of persons who come in contact with contaminated freshwater, typically when wading, swimming, bathing, or washing. There are five *schistosoma* species producing schistosomiasis in humans include *Schistosomiasis mansoni*, *Schistosomiasis haematobium*, *Schistosomiasis intercalatum*, *Schistosomiasis japonicum*, and *Schistosoma mekongi* based on geographical distribution of the intermediate host. (Akullian , 2007)

2.2. Life cycle and transmission

The life-span of adult aquatic snail hosts does not normally exceed 12-15 months. Their reproductive cycles and population cycles depend on rainfall, water levels and temperature (Larsson, 1994).

Figure 2.1 shows that, eggs (1) of the human-dwelling parasite are emitted in the faeces into the water by infected person, the ripe *miracidium* hatches out of the egg (2). The *miracidium* searches for a suitable fresh water snail (3) to act as an intermediate host and penetrates it. Following this, the parasite develops via a so-called mother-sporocyst and daughter-sporocyst (4) generation to the cercaria (5). (<http://www.cdc.gov/parasites/schistosomiasis/biology.html>)

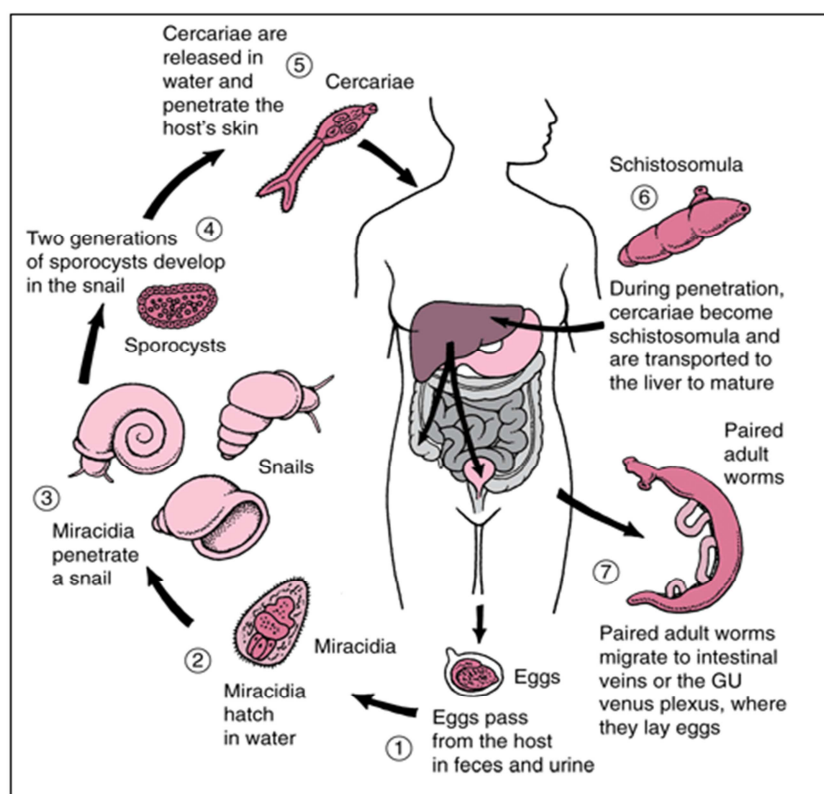


Figure.2.1. Life cycle and transmission of schistosomiasis

The purpose of the growth in the snail is the numerical multiplication of the parasite. From a single miracidium results a few thousand cercaria, every one of which is capable of infecting man. The cercarias propel themselves in water with the aid of their bifurcated tail and actively seek out their final host. When they recognize human skin, they penetrate it within a very short time and followed by migration through the body within the bloodstream. (<http://martin.parasitology.mcgill.ca/jimspage/biol/schisto.htm>)

After approximately 2 days, the *schistosomulae* migrate through the blood stream to the capillaries of the lung, then from the lungs via the blood stream to the liver, where they mature to adult worms(6). It's in a liver where the parasite to live out long, and prosperous life inside the new host (7). (McNally, 2001)

2.3 History, Burden and Distribution of Schistosomiasis in the World

Schistosomiasis is considered second only to malaria in socio-economic and public health importance in tropical and sub-tropical areas .The disease is found mainly in developing countries in Africa, Asia, South America, the Middle East, and the Caribbean.

2.3.1 History

Schistosomiasis was quite prevalent throughout the lower Nile River Valley more than 3,000 years ago, by evidence of autopsies of mummies and microscopic examination. (Despommier *et al*, 2006)

The earliest proof of *Schistosoma japonicum* infection in china goes back to Han dynasty. schistosoma eggs has been checked in female corpse excavated from Ma Wang dui tomb in Chang Sha city and male corpse excavated from Jiang Ling in Hu Bei province were evidence of the early prevalence in china. (Tong *et al*, 2006)

In 1851 the Germanys chief of surgery at the Kasr-el-Aini Medical School of Cairo, Egypt, Theodor Bilharz, who delectated his life for investigating the diseases ,wrote a letter to his friend between 1851 and 1853 ,described human causes of schistosomiasis heamtobium, a parasite of the venous plexus of the bladder and whose egg possessed a terminal spine. (Arden, 2008) The first case of schistosomiasis was reported in south America at piraja de silvain ,provines of brazil in 1908. (Despommier *et al*, 2006)

2.3.2 Burden

Schistosomiasis is both an environmental disease and a disease of poverty. It is environmental because anthropogenic and natural parameters shape the distribution of disease in aquatic systems by defining the ecological niches where the snail intermediate host can survive. Schistosomiasis is a disease of poverty because its geographic distribution reflects population lack access to safe water, sanitation infrastructure, socio-economic status, and access to secondary treatment. (Akullian, 2007)

Regarding to the global burden of schistosomiasis, various estimates and researches have been made. The results of several independent studies by (Steinmann *et al*, 2006), suggests that 779 million people are at risk of schistosomiasis and 207 million people are infected worldwide. According to estimate made by imperial collage of London , annual loss of peoples related to schistosomiasis is 280,000.(Assefa *et al* ,2012).Although, infection with schistosoma parasite is mostly associated with morbidity, it also has considerable mortality effect resulting in death (King *et al*, 2005). It is probably responsible for hundreds of

thousands of deaths annually (Bergquist, 2001). As of 1976, Japanese announced the eradication of *Schistosoma japonicum* from all of their islands as of yet to return to that country thanks to good control and monitoring program, they are relieved from the burden of the disease. <http://www.medicalecology.org/water/schistosomiasis/schistosomiasis.htm#sect3>

2.3.3. Global Distribution

Globally, Approximately 90% of those infected with schistosomiasis live in Africa out of these 85 % of them are concentrated in sub-Sahara Africa (Worner *et al*, 2007).The remaining percent live in Asia, South America, Middle East and Caribbean. From 2006 to 2009, the number of people treated for schistosomiasis in Africa doubled. However, less than 7% of the affected population was treated. According to WHO publication, Over 230 million people require treatment for schistosomiasis yearly and the number of people treated for schistosomiasis rose from 12.4 million in 2006 to 33.5 million in 2010.([www.who.int/schistosomiasis /fast fact/.com](http://www.who.int/schistosomiasis/fastfact/)) Water resources development projects such as, irrigation, streams, lakes and reservoirs may make schistosomiasis worse, and that there are serious public health consequences in many cases. (Birrie *et al*, 1993a).Specifically, WHO stated that in areas endemic for schistosomiasis, water resources development projects should have schistosomiasis prevention and control built into programs design and implementation.

Schistosomiasis mansoni and schistosomiasis haematobium is widely distributed most of Africa countries and schistosomiasis mansoni is found thought Sudan and Somalia (Figure 2.2.) schistosomiasis haematobium is distributed in Middle East ,Algeria , Mauritania. Mali, Cameron and Cote d' Ivoire (figure 2.2).In Brazil schistosomiasis mansoni dominate were as the rest of the world is free from schistosomiasis except a few islands in Caribbean.

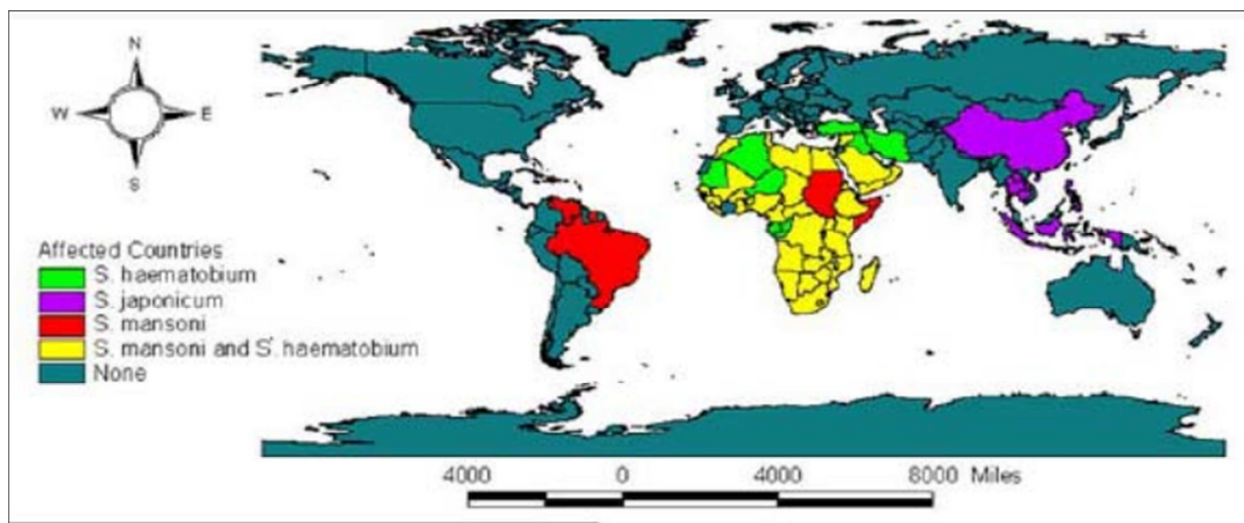


Figure 2.2 Global distribution of schistosomiasis

Source: Ethiopian Health and Nutrition Research Institution (EHNRI)

The severity of the disease is related to inflammatory and fibrotic response in the host to the eggs in the liver, lungs, intestine and urinary bladder. In urinary schistosomiasis (due to *Schistosomiasis haematobium*), damage to the urinary tract is revealed by blood in the urine. Urination becomes painful and there is progressive damage to the bladder and ureters and then to the kidneys. Bladder cancer is quite common in advanced cases. Intestinal Schistosomiasis (due to *Schistosomiasis mansoni*) is slower to develop. There is progressive enlargement of the liver and spleen as well as damage to the intestine, due to fibrotic lesions around the *Schistosoma* eggs lodged in these tissues and hypertension of the abdominal blood vessels. Repeated bleeding from these vessels leads to blood in the stools, and can be fatal (<http://www.cdc.gov/parasites/schistosomiasis/disease.html>).

2.4 Schistosomiasis Distribution in Africa

In Africa, almost 600 million population are at risk of infected with the disease. *Schistosomiasis mansoni* or intestinal schistosomiasis is endemic in the Nile River valley and the Upper Sudan and Egypt, and occurs along the East African coast from Eritrea through Kenya, Tanzania and Malawi to the Zambezi River and Zimbabwe inland through Zambia and Tanzania to the Congo River, with some cases reported from South Africa. (www.who/schistomiais/fastfact/.com). *Schistosomiasis haematobium* distributed throughout

Africa: There is risk of infection in freshwater in southern and sub-Saharan Africa—including the great lakes and rivers as well as smaller bodies of water. Transmission also occurs in the Nile River valley in Egypt and the Maghreb region of North Africa. *Schistosomiasis intercalatum* were found in parts of Central and West Africa. <http://www.cdc.gov/parasites/schistosomiasis/epi.html>

2.5 History and the Situation of Schistosomiasis in Ethiopia

The disease was first described by Italian physicians in the northern part of the country as early as early as 1930's (Agad *et al*, 1956). From this classically endemic and occasionally isolated area, the disease has progressively spread to newer and more southern part of the country following the establishment of water resource development projects and migration of people from endemic areas to previously non endemic ones (Kloos *et al* ,1988, Erko 1996, Birrie , 1996) hence the disease is now rapidly becoming an important public health threat. When in 1950, schistosomiasis was reported to be endemic in Ethiopia, the reported case were, four intestinal and one urinary schistosomiasis (Assefa *et al*, 2012).

In Ethiopia, intestinal schistosomiasis caused by *Schistosomiasis mansoni* and urinary schistosomiasis caused by *Schistosomiasis haematobium* have been known to be endemic. *Schistosomiasis mansoni* is widely distributed in the country while *schistosomiasis haematobium* has so far been reported only from three lowland areas, including the Awash and Wabe Shebele valleys and an intermittently flowing stream in Kurmuk at the Ethio-Sudan border (Kloss *et al*, 1988). The main determinants for the distribution, transmission and spreading of the schistosomiasis in Ethiopia include water temperature, local absence or presence of snail intermediate host, human population movement and water impoundment for irrigation and power . (Mitiku *et al*, 2010)

2.6. Schistosomiasis Transmission in Ethiopia

In the country, it is generally established that *Schistosomiasis mansoni* is largely confined within an altitude limits of 800m-2200m above sea level. *Schistosomiasis haematobium* is

found in lowlands below 800m because the intermediate host the *Bulinus*. In Ethiopia, *Bulinus* favors warm water temperatures (Kloos *et al*, 1988). Two species of the genus *Schistosoma*, *biomphalaria*, *bilinus sudanic* and *bilinus pfeifferi*, are known to transmit *Schistosomiasis mansoni* in Ethiopia (Ali *et al*, 2006). Unlike *bilinus pfeifferi*, which is known to have wide geographical distribution, *bilinus sudanic* has very limited distribution in Ethiopia. (Kloos *et al*, 1988) Its presence has so far been reported from only three areas in rift valley, Ziway and Abaya lakes and interface between Tigris River and Awassa Lake (Birrie *et al*, 1995). It seems that *Bulinus ptefifferi* has ubiquitous distribution, while *bulinus sudancia* is limited in its distribution. *Bulinus abyssinieas* and *bulinus africanus* are the only bulinid species found naturally transmitting *Schistosomiasis haematobium* in Ethiopia, even though about 10 bilinus species are expected to occur from the previous studies it is established that *bilinus abyssinicas* is the intermediate host for *Schistosomiasis haematobium* in Awash valley, whereas *bilinus africanus* transmits the diseases in Kurmuk border of Sudan (Mamo *et al*, 1989). Figure 2.3 shows current distribution of urinary and intestinal schistosomiasis and also new area identified as schistosomiasis prone area in regional states of Ethiopia.

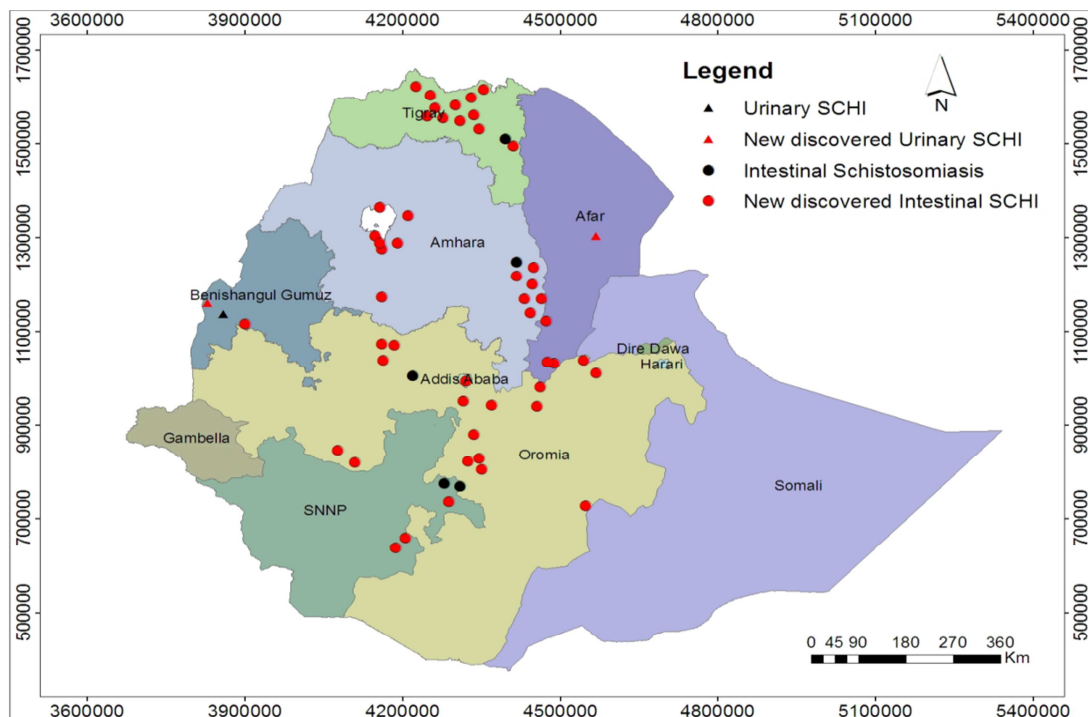


Figure 2.3 Schistosomiasis endemic foci in Ethiopia

(Source: www.aau.edu.et/news/inag/Berhanu_Erko_synopsis.doc)

Generally, three main ecological setting, irrigation ecology, stream ecology and lake ecology, where transmission of Schistosomiasis is recognized in Ethiopia (Birrie *et al*, 1993a). Since stream create more favorable habitats for the breeding of the snail intermediate host, it constitutes the major transition ecology. Besides, it's evident that the majority of *Schistosomiasis mansoni* endemic area occurs in agricultural communities resides along stream (Birrie *et al*, 1993a). Growing evidence also suggests that irrigation ecologies are becoming molacologically suitable areas and these are sites of intense transmission for *Schistosomiasis mansoni* (kloos *et al*, 1988). Now there are about 4 million people reported to be infected and 30 million at risk of schistosomiasis in Ethiopia. Figure 2.4 shows prevalence of *schistosomiasis mansoni* infection by age group and sex among school children in endemic foci, Ethiopia and the intensity of infection by egg per gram. (Assefa *et al*, 2012)

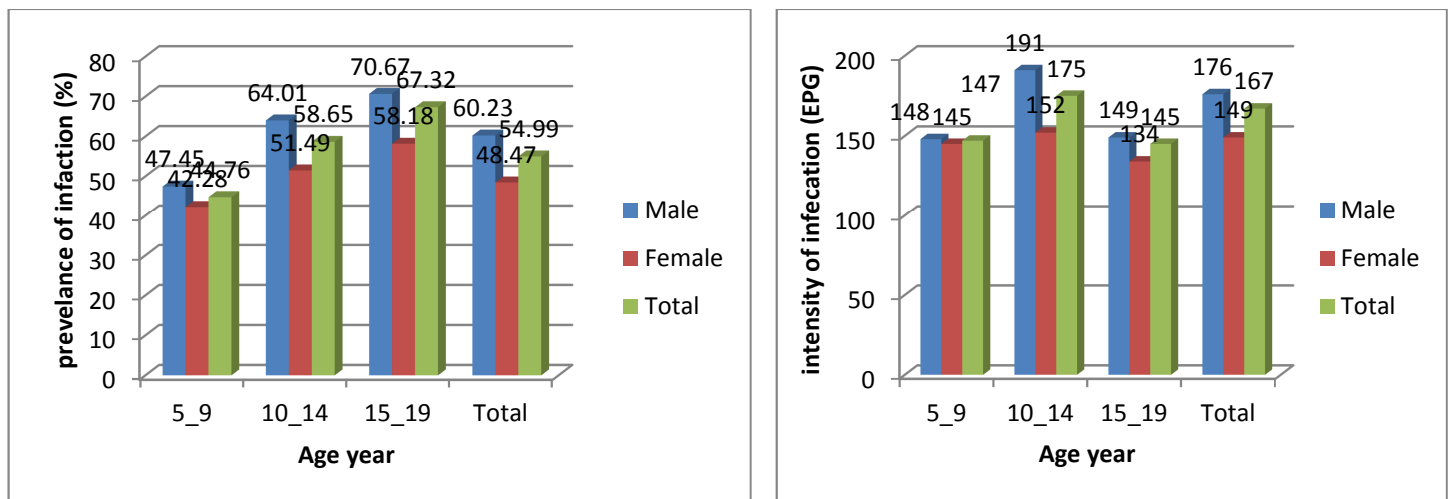


Figure 2.4. Intensity and Prevalence of Infection

According to ministry of health report of 2012, a total of 12175 population ages from 0-15 were diagnosed with Schistosomiasis national wide reported from varies hospital, clinics and health office. Amhara, Oromiya and SNNPR region is the most prevalent to the disease while Addis Ababa city and Dire dawa administration were the list area of incidence refer to figure 2.4. The figure 2.5, describes distribution of Schistosomiasis case with age variation in the administration regions.

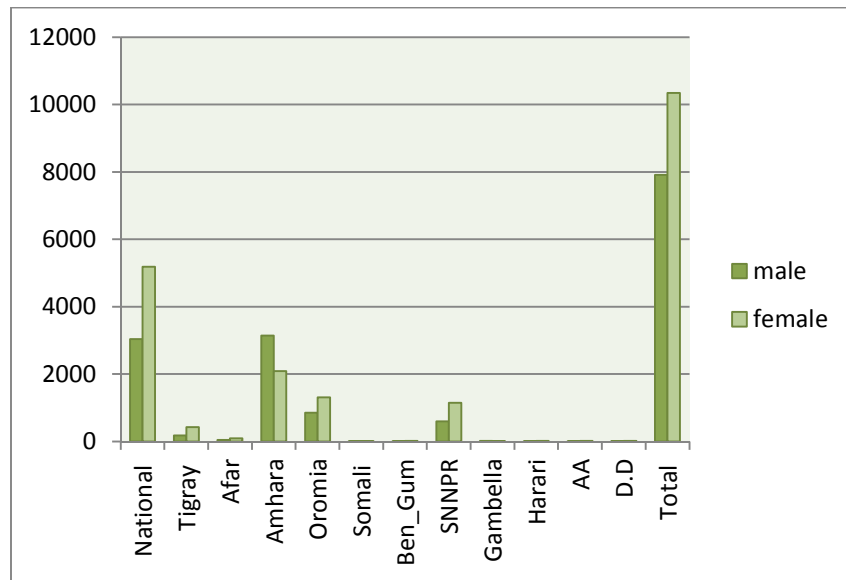


Figure 2.5 Incidence of schistosomiasis in Ethiopia

2.7. Factors of Schistosomiasis in Ethiopia

The burden of *schistosomiasis* in the world is so huge and Ethiopia is one of the countries in Africa that are most affected. The current development activities in Ethiopia, such as large and small scale irrigation schemes, large and small dams of agriculture and electricity are some of the risk factors.

Low quality drinking water supply and latrine coverage in Ethiopia makes schistosomiasis infection the second causes of outpatient morbidity. (Alemu *et al*,2011). There is a scarcity of information on the prevalence of Schistosomiasis in Ethiopia. The predominate causes of the infection water contact activities as swimming, bathing, playing, and cutting grass, drawing water, performing religious rites such as Wudu by Muslims, washing clothes and horses.

2.7.1 Environmental Factors

The ecology of schistosomiasis includes tropical lotic (lakes and reservoirs) and lentic environments (rivers), and the behavior of people and their domestic animals that live near

these aquatic environments. The recent surge in construction of large impoundments throughout many parts of the tropics and China has dramatically increased the health risks associated with acquiring schistosomiasis, and represents a growing concern among public health professionals in those regions.

<http://www.medicalecology.org/water/schistosomiasis/schistosomiasis.htm#sect3>

In sub-Saharan Africa, schistosomiasis has a complicated distribution owing to the complex interplay of biotic and abiotic factors, but it is significant blight upon the especially in places where people, snails and parasites are brought together on a regular basis. (Werf *et al*, 2003) In such locations, schistosomiasis can be almost universal and contributes to the daily entrapment of those often already in poverty and marginalization. Disentangling macro-epidemiological and micro-epidemiological determinants of the disease is particularly challenging, as an intriguing feature. Predictive epidemiological models have struggled to encapsulate this feature precisely but can, at least, identify environments unfavorable for transmission and therefore exclude areas quite confidently. (Stothard, 2009)

2.7.1.1 Temperature

The intermediate host snails that transmit schistosomiasis generally prefer to move slowly in water, and with stand high degree of variation in the temperature of their habitat. In general, the optimum temperature that is tolerated by snails is between 22°C and 26°C, but they can withstand extreme temperatures for a considerable period of time. In addition, the snails can be found alive and nearly inactive at temperature as low as 2°C – 4°C. Laboratory experiment conducted by Seto show that snails can survive temperature between 14°C-42°C. In dry cold environment at -3°C, snail were found to survive for 31 days. If the environment becomes too hot and cold too dry, the snails will protect themselves into their shells. At high temperature of 29°C to 30°C and 38°C to 42°C, even with access to water snails will die with in 48 and 12 hours respectively. (Seto *et al*, 2002)

When stranded on dry land by a falling water level the snails make little or no attempt to escape back to the water, thus being exposed to the risk of death by desiccation or predation. This causes a large proportion, although not all, of the snails to die. Snails can survive dry spells longer if temperature is low. Hence, dry spells in summertime temperatures are most detrimental to snails.

2.7.1.2 Rainfall

Rainfall is one of the most determining factors for the habitat stability or habitat permanence defines the pattern of schistosomiasis. On his thesis for the requirement of masters of Science degree, study conducted at hayek towan, Amsalu state that, the seasonal changes in rainfall and/ or water level cause marked fluctuations in snail population densities and transmission rates in most areas.

Further he stated that, rainfall could enhance transmission of schistosomiasis by increasing the amount of surface water which can be suitable environment for breeding of snail intermediate host, or rainfall may denote the cessation of active transmission either in dry season when no or little rainfall or when there is too much raining that can wash the infected snails away from the transmission sites. Hence, foci are common where the transmission is negatively inhibited as a result excessive rain or prolonged dry season. Most aquatic snail species die when stranded on dry land in the dry season. (Amsalu, 2010)

2.7.1.3 Soil moisture

The composition of the soil is also an important factor for snails. Snails prefer soils rich in phosphorus, calcium, nitrogen, and organic matter. The presence of organ matter is particularly important for snail nutrition. (Seto *et al*, 2002). In Sich wan ~province, several geographic land covers are suitable for snail habitat: however. Snails are most abundant in sediment vegetated and unaffected by flooding (Seto et al, 2002). This land has the highest levels of nitrogen, phosphorus, and organic matter, Areas at the margin of flooding, with lower levels of soil nutrients, were found to be less suitable for snails.

2.7.1.4. Altitude

Altitude is also an important consideration in schistosomiasis transmission. In Ethiopia, altitude between 1,200 to 2,000 meters is optimal for *Schistosomiasis mansoni* transmission and the majority of endemic areas are located in this altitudinal range, (Terefe *et al* ,2011). Varies studies suggested that, the odds of *Schistosomiasis mansoni* infection decreases with increasing altitude, (Worner *et al*, 2007).

2.7.2. Socio- Economic factor

2.7.2.1 Water development

Water resources development is vital for addressing the growing demand of energy and food of today's world. This development can result in hydrologic and land use changes. Surface irrigation for agriculture and hydroelectric is the most widely used technique in many part of the world, for these purpose huge dams and reservoirs are constructed. A typical dam, for example, can be modified in a way appropriate for the creation of habitat ideally suited to the breeding of snails that serve as an intermediate hosts for the parasite.

Irrigation canals often become places where major water contact occurs. Increased habitat for snails, coupled with lack of adequate sanitary facilities offer great opportunity for the spread of schistosomiasis. Most irrigation systems in Africa create specific conditions that may favor establishment of intermediate hosts and the subsequent transmission of schistosomiasis, especially where drainage is not always adequate.

In Morocco, the transmission of urinary schistosomiasis increased with the development of modern open canal irrigation systems. This extensive irrigation scheme, which was established in the late 1930s, is one of the most conducive areas for the transmission of schistosomiasis in Mali (Boelee, 2006). After The Gezira irrigation scheme in Sudan, which was started in 1924, the prevalence of intestinal schistosomiasis is high in the Gezira Agricultural Scheme, while that of urinary schistosomiasis is variable but generally low (Boelee, 2006). However, urinary schistosomiasis, which affected less than one percent of the population before World War II, increased in the 1950s to affect almost a quarter of the adult population and half the population of children. The number of people affected by intestinal schistosomiasis increased even more, especially among children. (Boelee, 2006.) The Nile dams in Sudan contributed effectively to the existing transmission of schistosomiasis related to the dams of Upper Egypt and to its impact throughout the country. (Boelee, 2006.)

2.7.2.2 Land use land cover

Most snails prefer heavily vegetated soils. Snails often cling to the base of grasses, which provide a perfect environmental buffer, protecting them from direct sunlight, rain, and extreme fluctuations in temperature and moisture. Their preference for vegetated soil was

confirmed by a field study that found a positive correlation between grass density and snail density, with high grass areas having 65 percent snail density, medium grass areas having 38 percent snail density, and low grass areas having 0 percent snail density (Seto *et al*, 2002).

Water plants form a desirable but not an essential feature of the habitat of the snails. Plants apparently favorable to the aquatic snails include, among many others, *Nymphaeaceae*, *Potamogeton*, *Pistia* and *Myriophyllum*. Some species of plants have been shown to be antagonistic to the snails, including *Saponaria*, *Balanites*, *Eucalyptus*, *Tephrosia* and *Schwartzia*. Broad-leafed plants provide suitable surfaces for the deposition of eggs and for the growth of unicellular green algae which form a favorite food of the snails. The microflora and fauna on the leaves of these plants are more important to the snails as a food source than the plants themselves. (Larsson, 1994)

2.7.2.3 Migration

Population movements which may occur for various reasons have led to an important increase in the spread of schistosomiasis. Infected individuals carry parasites with them when they travel. Transmission of schistosomiasis may become more intense in manmade water bodies than natural water bodies due to population movement and the resulting higher human population density. Migration does not only intensify infection in endemic areas but also introduce new infection to previously non endemic areas given the presence of susceptible intermediate snail hosts (Steinmann *et al*, 2006).

2.8 Analytic Hierarchy Process

The analytic hierarchy process (AHP) is a comprehensive, logical and structural framework, which allows improving the understanding of complex decisions by decomposing the problem in a hierarchical structure. The incorporation of all relevant decision criteria, and their pair wise comparison allows the decision maker to determine the trade-offs among objectives. The AHP allows decision-makers to model a complex problem in a hierarchical structure showing the relationship of the goal, objectives (criteria), sub-objectives, and alternatives. In the procedure for Multi-Criteria Evaluation using a weighted linear combination outlined above, it is necessary that the weights sum to one. In Saaty's technique, weights of this nature can be derived by taking the principal eigenvector

of a square reciprocal matrix of pair wise comparisons between the criteria (www.wikipedia.com).

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

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

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

2.9 Experiences of Using RS and GIS in Public Health

Geographic Information System (GIS) have opened new horizons to the researchers and the public people with having features including the ability to obtain and exchange data from Various sources, organize, receive and display information timely, various data analysis and the possibility of providing multipurpose services. From several years ago until now, this technology has been working in wide fields including environment, management and decision support systems, medical and disaster management and its importance is growing day to day.

2.10 The Application of RS and GIS in Schistosomiasis Study

The scientific study of the spatial epidemiology of schistosomiasis and other helminthes has been greatly enhanced by the use of geographical information systems (GIS) and remote sensing (RS) over the past 20 years. The former has enabled data to be geo-referenced, stored, extracted, integrated in new ways and displayed by the user, whilst the latter has provided high-resolution data on climate and land cover features (Brooker ,2006).LandsatTM satellite data to predict the occurrence of schistosomiasis was first used in the Philippines and the Caribbean (Cross *et al.*, 1984), an increasing number of studies have employed GIS/RS to predict the distribution of schistosomiasis on the basis of associations between infection and large-scale environmental variables (Brooker ,2006).

The use of GIS and remote sensing for the study of Schistosomiasis was also done in several other countries: GIS and the environmental risk of schistosomiasis in Bahia, Risk Mapping of Schistosomiasis in Minas Gerais, Brazil, Using MODIS and Socioeconomic Spatial Data in Brazil (Bavia *et al*, 1999). Bayesian spatial risk prediction and remote sensing were used to predict schistosomiasis mansoni infection in west Cote d’Ivoire. (Worner *et al*, 2007). GIS based predictive risk maps of urinary schistosomiasis were also done in Ogun State, in Nigeria. Comprehensive mapping of urinary schistosomiasis using GIS in kano state, in Nigeria (Ekpo et al ,2008, Abduallahi *et al*, 2009).).Epidemiology of schistosomiasis is done using GIS and Remote sensing in poyang lake, Jiangxi province and The Use of Remote Sensing for Predictive Modeling of Schistosomiasis, in China, (Davis *et al* ,2002, Seto *et al*, 2002). Remote sensing, geographical information system and spatial analysis for schistosomiasis epidemiology and ecology in Africa.(Simoonga *et al* ,2009).The above list are some of the research that applied GIS and Remote sensing to study the transmission , distribution and risk of schistosomiasis in varies regions of the world.

3.1 Location

The study site is located on the southern part of Blue Nile (*abay*) river basin 357 km from Addis Ababa on the East welega zone of oromia regional state in Finchaa sugar estate valley Kebele with latitude $9^{\circ}30' - 9^{\circ}60'$, N and longitude $37^{\circ}30' - 37^{\circ}10'$ E covering a total area of 8,500 hectares. (Figure 3.1) The elevation of the estate farm is 1550 m above msl. Finchaa valley is found in Abey chomen Woreda ,Horo Gudroo welega zone, ,finchaa valley Kebele .The Finchaa Sugar Factory covered the entire Kebele with seven major villages, alphabetical named village A,B,C,D,E , the main town (Agemsa ,kuyisa) and korkie. The area can be reached through the main highway from Addis Ababa to Gedo (192 km) west of Addis Ababa then take all weathered gravel road root from Gedo to Finchaa town , the 54 km from Finchaa town to finchaa sugar estate valley. (Figure 3.1)

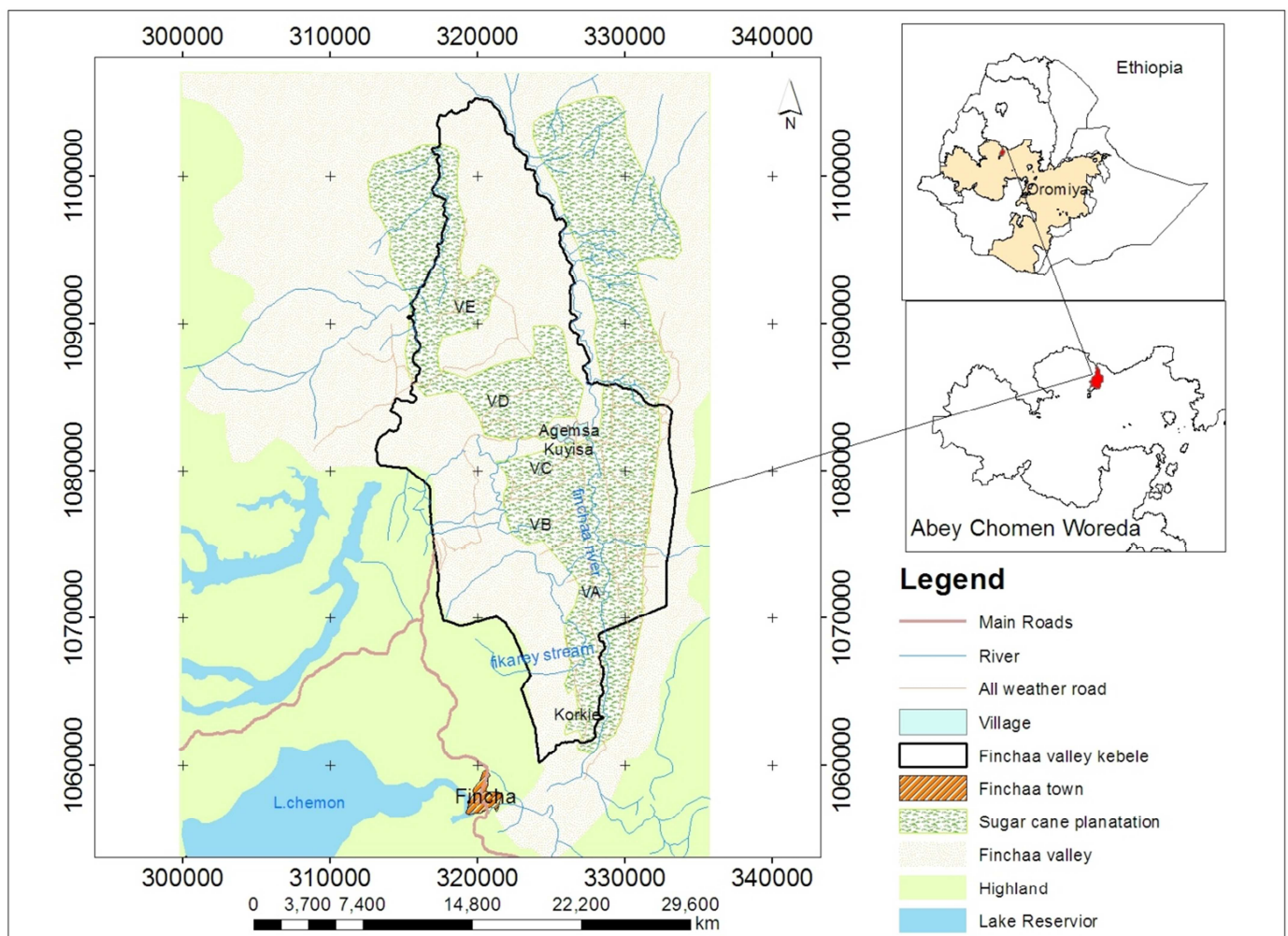


Figure 3.1: Location map of the study area

3.2 Topography

The Finchaa valley is surrounded by steep escarpment along its southern, eastern and western sides which rise approximately 700-850 m above the valley floor.

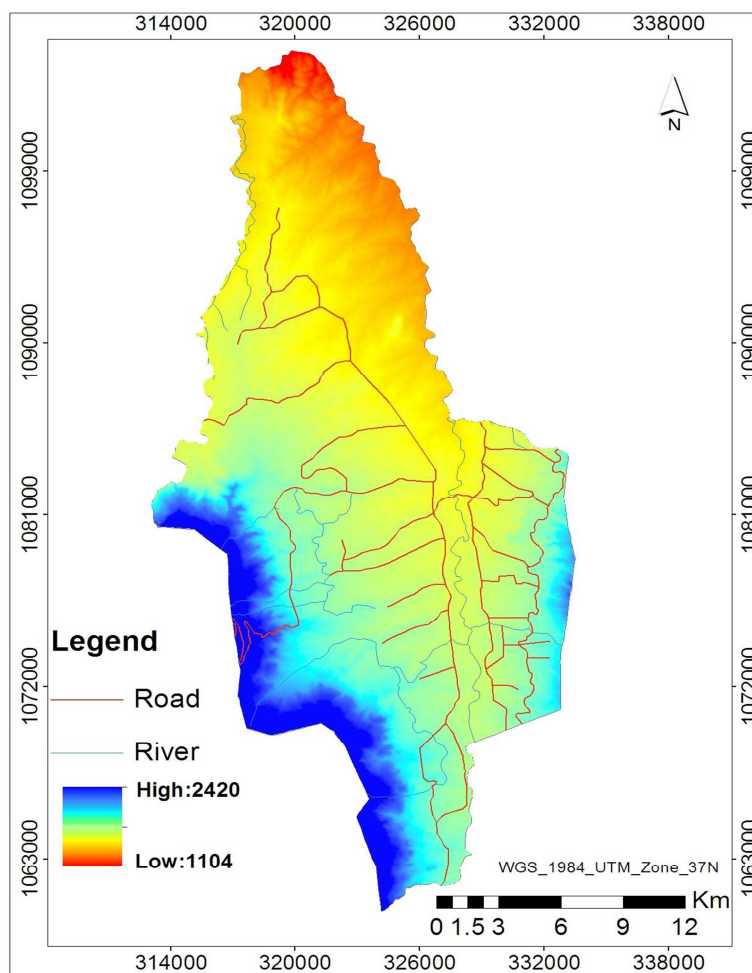


Figure 3.2: Topography map

Surrounding the factory, especially along the south, west and southeast perimeter, there are some streams and canal outlets of water including Finchaa River. (Figure 3.2) There is a dam a head of Finchaa valley for the purpose of storing irrigation water and generating hydroelectric power. 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, Hagemesa, Gogoldas, Badessa and Badessa Kala all flow toward Agul river crossing villages “A”, “B” and the main town (Agamsa and Kuyisa).

Finchaa River divides the valley into west and east banks. The width of the valley, generally increase from south to north with an average size of 25-30km. (Figure 3.1)

Many streams joins Finchaa River, The main tributaries are Hagemesa, Korke, Fakare, and Boye from the western side and Sargo-Gobana, Aware, Sombo and Andode from eastern side.

The two major soil types are Red to Reddish brown friable Luvisols and black heavy clay Vertisols. More than 75 % of the soil of irrigated land is Luvisols and the rest is Vertisols. Most of the Luvisols are situated in the middle of the interfluves and have slopes of 2-5 %.19% of the Luvisols are moderately deep. Vertisols is found mostly in the lower areas near the Finchaa River and at the upper ends of the interfluves. This soil is deeper than the Luvisols, going as deep as 120 centimeters.

3.3 Populations

The 2007 Population and Housing Census of Ethiopia, put the population of finchaa sugar estate valley kebele to be more than 18,623,out of the total population of the kebele 10,040 are male and 8,583 are female. The total number of household is 5,058 and the total numbers of housing units are 4,716. But the record of finchaa valley kebele shows that, the total population for 2012 is estimated to be 22,599 as shown on the figure 3.3 below.

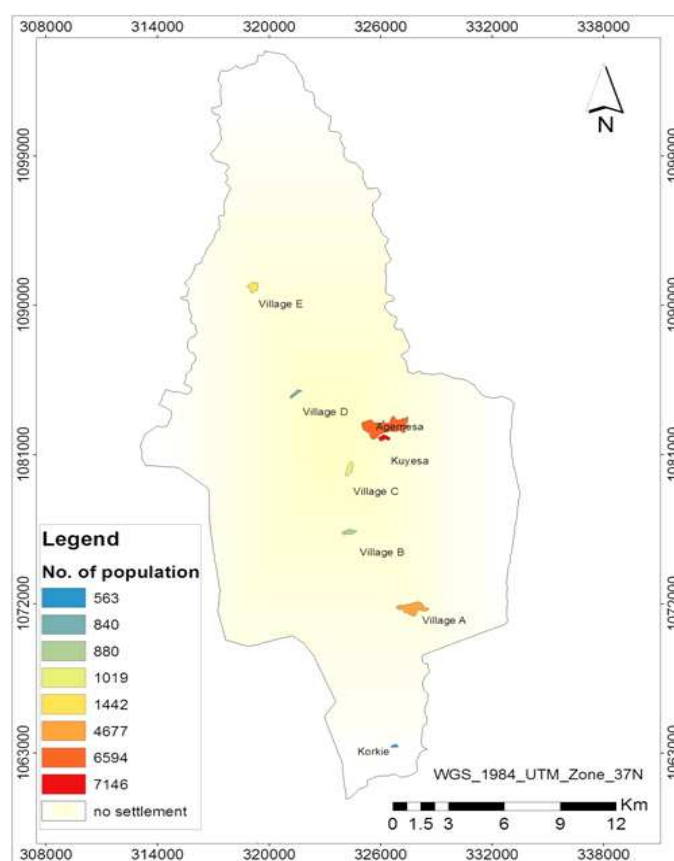


Figure 3.3 Population map

3.4 Population density

The estimated population density of the finchaa sugar estate valley Kebele ranges from 7108 person/ km² at village D to 2772 person /km² at kuyisa see figure 3.4. The inhabitation of the main town are worker of the sugar factory and varies settlers from different regions who came looking for work and inhabitants of villages scattered within the kebele , whom are daily labor that work at the sugar cane field and their village are established as a camp.

The boundary of the village is not exactly delineated so in order to calculate population density, the average of estimated area of the village from the Finchaa Sugar Factory Kebele and digitizing the area of the village from Google earth taken as the area for calculating the population density. The map below shows the estimated population density of the Finchaa Sugar Factory villages.

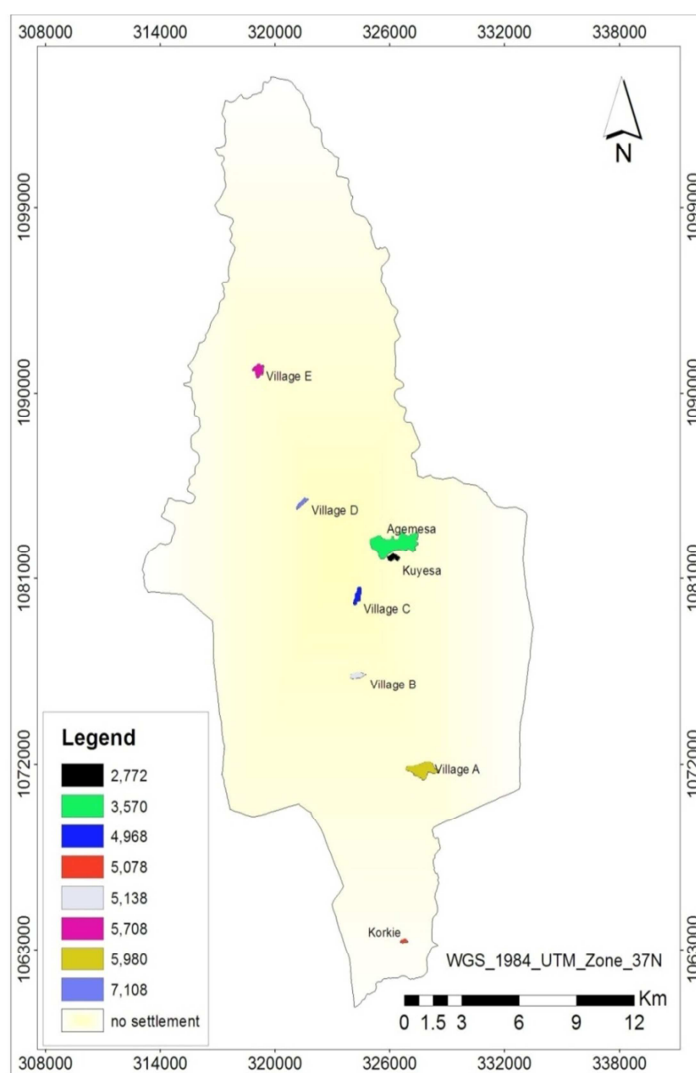


Figure 3.4: Population density/ km²

Table 3.1 Finchaa Village population

Village Name	Female	Male	Total population
Korkie	260	303	563
Village A	2262	2415	4677
Village B	429	451	880
Village C	554	465	1019
Village D	395	445	840
Village E	764	678	1442
Agemsa	2673	3921	6594
Kuyisa	3706	3440	7146
Total	11043	12118	23161

Source: Finchaa valley kebele, 2012

3.5 Health Facility

In finchaa sugar estate valley kebele 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 (figure 3.5). The clinics provide basic health services entirely based on clinical symptoms within the respective villages. However, laboratory based medical treatment including schistosomiasis is provided only at the finchaa sugar estate valley health center located in the main town Agemsa. There was no hospital in the area; Ambo, Nekemte and Addis Ababa hospitals were commonly used for referral health service.

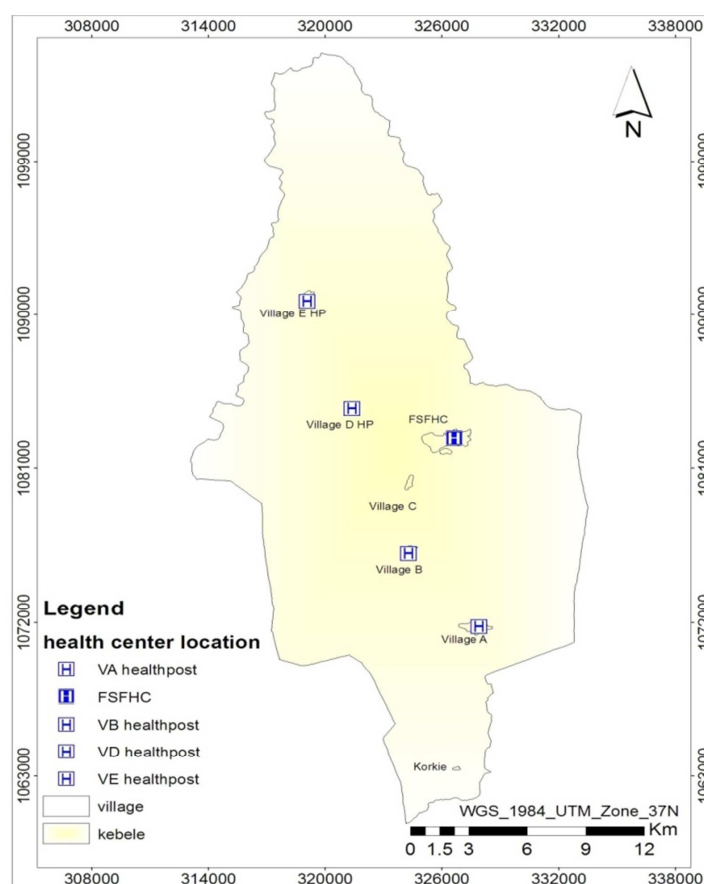


Figure 3:5 Distribution of health center

3.6 Temperature and Rainfall

The valley is typically characterized by semi-arid climate with mean relative humidity of 61%. The mean annual precipitation received is 1302 mm .while the mean temperatures are 26.1°C and 20.9°C respectively refer to table 3.2 and figure 3.6 for visual understanding.

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.

Table 3.2: Monthly Mean Temperature, Average rainfall and mean humidity of 2000-2012

Month	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Mean temp	22.95	24.6	25.7	26.1	25.7	23.7	21.9	20.9	22.4	22.55	22.45	22.35
Average rainfall/mm/	2.7	6.3	32.1	40.3	90.0	220.2	337.1	284.1	208.6	60.9	14.5	5.2
Mean relative humidity/%/	51.9	44.7	47.7	51.5	57.3	71.2	79.7	80.6	77.5	68.1	43	57.8

The area receive minimum amount to rainfall from January- May, the amount of rainfall reach it maximum from June to September. Mean monthly Temperature of the area show that, the minimum temperature is experienced in August whereas the maximum temperature is in April. Figure 3.6 better illustrate the mean annual temperature and rainfall from the year 2000-2012.

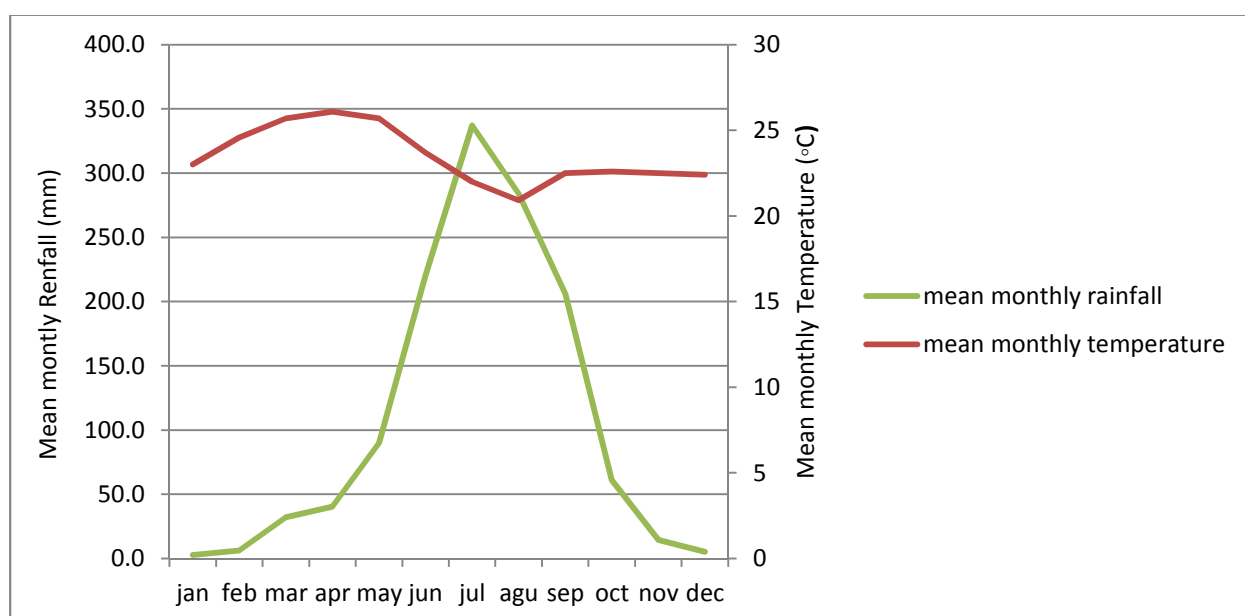


Figure 3.6 Monthly mean temperature and rainfall of 2000-2012

4.1_Data Sources and Software used

Data were collected and analyzed in order to meet the objectives of the study. To conduct this research the input data was taken from various offices and sources where relevant information was available. Accordingly, the list of data gathered and software used is shown in Table 4.1 and Table 4.2.

Table 4.1: List of data type and data source

S.No	Data type	Source
1	Meteorological data	Finchaa Research Meteorological Station
2	Literature	Internet and different books
3	Altitude	1:50000 topographic map(EMA)
4	Epidemiological Data	Fincha sugar factory ploy clinic
5	Population Data	CSA, Finchaa valley Kebele
6	Health facility Location	Collected by GPS
7	Study Area Administrative boundary	EMA
8	Land Surface Temperature	Landsat ETM(p169r053)
9	Topo sheet(1:50000)	EMA(0739C3&A4)

Table 4.2. List of Hardware and Software used

Type	Name	Utility
Software	ERDAS Imagine 9.2	Image processing and data analysis
	ArcGIS 9.3	Data base creation, land use/cover, contour, overlay analysis, map preparation
	MS Word 2007	File conversion
	IDRISI 15.0	Documentation, statistical analysis and presentation
		Multi Criteria Evaluation (MCE)
Hardware	Laptop computer	For storage, software and internet support

4.2. Research Methodology

The aims of this research is the assessment of *schistosomiasis mansoni* risk areas in relation with environmental factors and tries to analyze *Schistosomiasis mansoni* incidence with some of the natural and socio-economic factors using RS and GIS techniques. Therefore, in the following sections, the application of the techniques and the analysis is discussed in detail.

4.2.1. Assessment of Topographic and Climatic Factors Schistosomiasis Manson Hazard Areas Identification

The datasets required for the assessment of *schistosomiasis mansoni* Hazard areas were derived using the available different RS and GIS techniques. Rainfall data gathered from Finchaa Research Meteorological Station and Temperature data is derived from Landsat ETM 2010.

Water bodies are a convenient habitat for intermediate host fresh water snails, therefore close proximity to perennial lotic and lentic environments were calculated to identify which parts of the villages are more vulnerable and at risk of *schistosomiasis mansoni* transmission.

Altitude of the study area were considered as another factor for promoting *schistosomiasis mansoni* transmission and the altitude factor was derived from the contour map and also the slope was derived from the altitude Layer using ArcGIS spatial Analysis tool.

All the derived datasets were reclassified accordingly. The reclassification was done into different classes using the spatial analysis tool giving the value 5 for more suitable attributes and the rest accordingly depending on their suitability.

After all the rainfall, temperature, altitude, slope ,land use land cover , distance from river ,population density, and distance from health center were reclassified; weight is given to each dataset depending on their intensity of importance using IDRISI software. This helps to avoid biased and subjective judgment towards giving the weight to each dataset. Then using the GIS analysis - weighted overlay tool the weight was given to each factor using pair wise comparison (Table 4.3) .While giving the weight for each dataset, the software provides a value ranging from 1–9 indicating their intensity of importance. The weight was given until it reaches the acceptable consistency ratio which is less than 0.10.

Table 4:3 weight for Pair-wise comparison of factor maps for schistosomiasis mansoni hazard

S.No	Level of importance	Weight
1	Temperature	45.84 %
2	Rainfall	21.89 %
3	Altitude	14.16 %
4	Distance from river	8%
5	Slope	7.76 %
6	Distance from health center	2.35 %

The outcome of the weight produced 0.04 Eigen Vector value

4.2.2. Assessment of Socio-economic Factors schistosomiasis Manson Risk Area

The second step in *schistosomiasis mansoni* risk mapping is assessment of the risk Areas by ranking and weighting the risk element such as land use land cover, population density and the *schistosomiasis mansoni* hazard map itself to assess the extent of *schistosomiasis mansoni* risk over the area. To produce *schistosomiasis mansoni* risk map, the risk computation model which is developed by (Shook, 1999) were used. Shook's risk computation model is the multiplication of "Hazard (H)" which is the probability of occurrence of a potential damaging natural phenomenon within a specified period of time and within a given area , "Element at risk (E)" which includes the population, buildings, and civil engineering works, economic activities, public services, utilities and infrastructures, etc., at risk in a given area and "Vulnerability (V)" which is the exposure of a given element or set of elements at risk resulting from the occurrence of a damaging phenomenon of a given magnitude.

As result, "Risk (R)" which is the expected degree of loss due to a particular natural phenomenon, can be expressed as the product of hazard (H), vulnerability (V), and element at risk (E).

$$\text{RISK} = (\text{Hazard}) * (\text{Element at Risk}) * (\text{Vulnerability})$$

$$R = H * E * V$$

The *schistosomiasis mansoni* risk map was produced from *schistosomiasis mansoni* hazard layer, computing and reclassifying the population density map which is the element at risk

layer and vulnerability map that is produced by reclassifying land use/land cover layer. The layers were given weight in IDRISI software, then using the GIS analysis – weighted overlay tool the weight was given to each factor using pair wise comparison.

The tables 4.4 show weighs give for pair –wise compassion for spatial analysis in order to produce risk map of the study area .

Table 4.4 weighted Pair-wise comparison of factor maps for schistosomiasis mansoni risk

S.No	Level of importance	Weight
1	Hazard Map	75 %
2	LULC Map	8%
3	Population Density	17%

The outcome of the weight produced 0.06 eigen vector value

Finally, the risk map of the study area was produced .the overall work flow or methodology applied in this research was presented on the following page of figure 4.1.

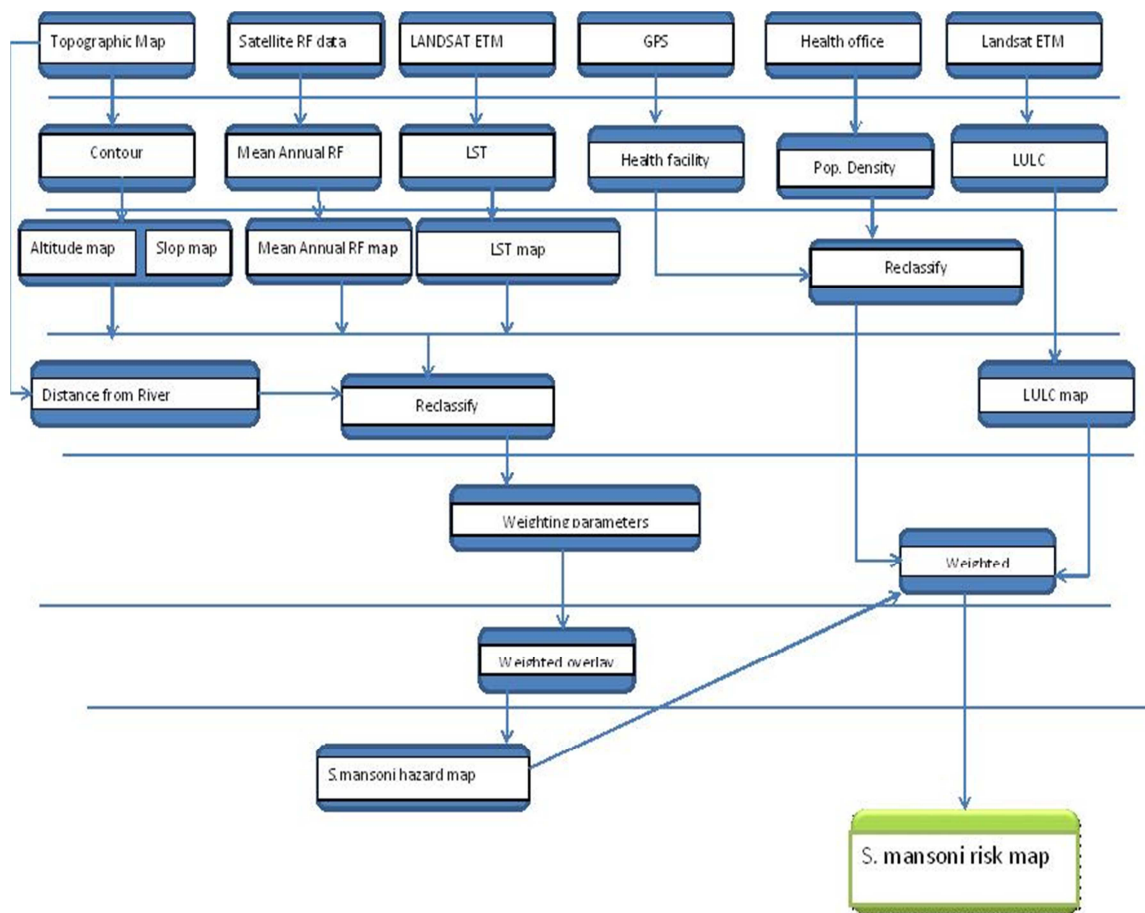


Figure 4:1 Schematics of methodology

4.3 Data Analysis

4.3.1 Temperature

Temperature is important both for the survival of the parasite and the intermediate host fresh water snail. The optimum temperature that is tolerated by Snail transmitting schistosomiasis is between 22°C and 26°C, but they can withstand extreme temperatures for a considerable period of time. (Seto *et al*, 2002). The thermal death point temperature of 29°C to 30°C and 38°C to 42°C, even with access to water, snails will die with in 48 and 12 hours respectively. (Seto *et al*, 2002).

The Land surface temperature of the study area was estimated from Landsat ETM image of year 2010 thermal band. Two approaches have been developed to recover LST from Landsat imagery thermal band. The first approach utilizes a radiative transfer equation to correct the at-sensor radiance to surface radiance, followed by an emissivity model to separate the surface radiance into temperature and emissivity. The following equation is used to convert sensor radiance to surface radiance.

Conversion of DN Values to Radiance

$$L_{\lambda} = \frac{L_{max} - L_{min}}{Q_{calmax} - Q_{calmin}} * (Q_{cal} - Q_{calmin}) + L_{min} \dots\dots\dots eq1$$

Where:

L_{λ} = Radiance at wavelength λ

L_{max} = Maximum detected spectral radiance for the scene

L_{min} = Minimum detected spectral radiance for the scene

Q_{CALMAX} = Maximum Quantized and calibrated data digital number = 255

Q_{CALMIN} = Minimum quantized and Calibrated data digital Number = 1 for

LPGS (Level 1G product Generation System)

Q_{CAL} = Digital Number

The second approach applies the split-window technique for sea surfaces to land surfaces, assuming that the emissivity in the channels used for the split window is similar. This model separates the surface radiance into temperature and emissivity. But the emissivity of

a surface is controlled by such factors as water content, chemical composition, structure and roughness. Equation used to convert surface radiance to surface temperature is read as follows.

Conversion Radiance to Temperature

$$T = \frac{k_2}{\ln\left(\frac{k_1}{L\lambda} + 1\right)} \dots\dots\dots \text{eq2}$$

Where T = Effective at-satellite temperature in Kelvin

K1 = 666.09

K2 = 1282.71

$L\lambda$ = Spectral Radiance

There are different techniques use to estimate emissivity for ground object such as the NDVI method. To implement this NDVI model was used. Then another model was used to calculate surface kinetic temperature. Lastly conversion model was used to convert degree Kelvin to degree Celsius. The surface temperature layer used in this study was the output of the last model. The equation for emissivity presented below.

Emissivity formula

$$\varepsilon () o x y = 1.009 - 0.047 \ln NDVI x y , , \dots\dots\dots \text{eq3}$$

Where: $\varepsilon () o x, y$ = emissivity of each pixel values

$NDVI = (Band4 - Band3) / (Band4 + Band3)$

Based on equation 1, 2, 3, an output layer of land surface temperature of the study area was produced. Based on these the maximum land surface temperature is 26°C while the minimum land surface temperature is 13°C. the output layer was further classified into five classes based on optimum temperature. The classes were given very low, low, Moderate, High and very high classes (Figure 4.2).

The classes labeled as very low referred as area where the temperature was create list favorable condition for transmission of *schistosomiasis mansoni* and survival of the

intermediate host fresh water snail, while class labeled as very High create most favorable condition for both transmission of the disease and intermediate host fresh water snail.

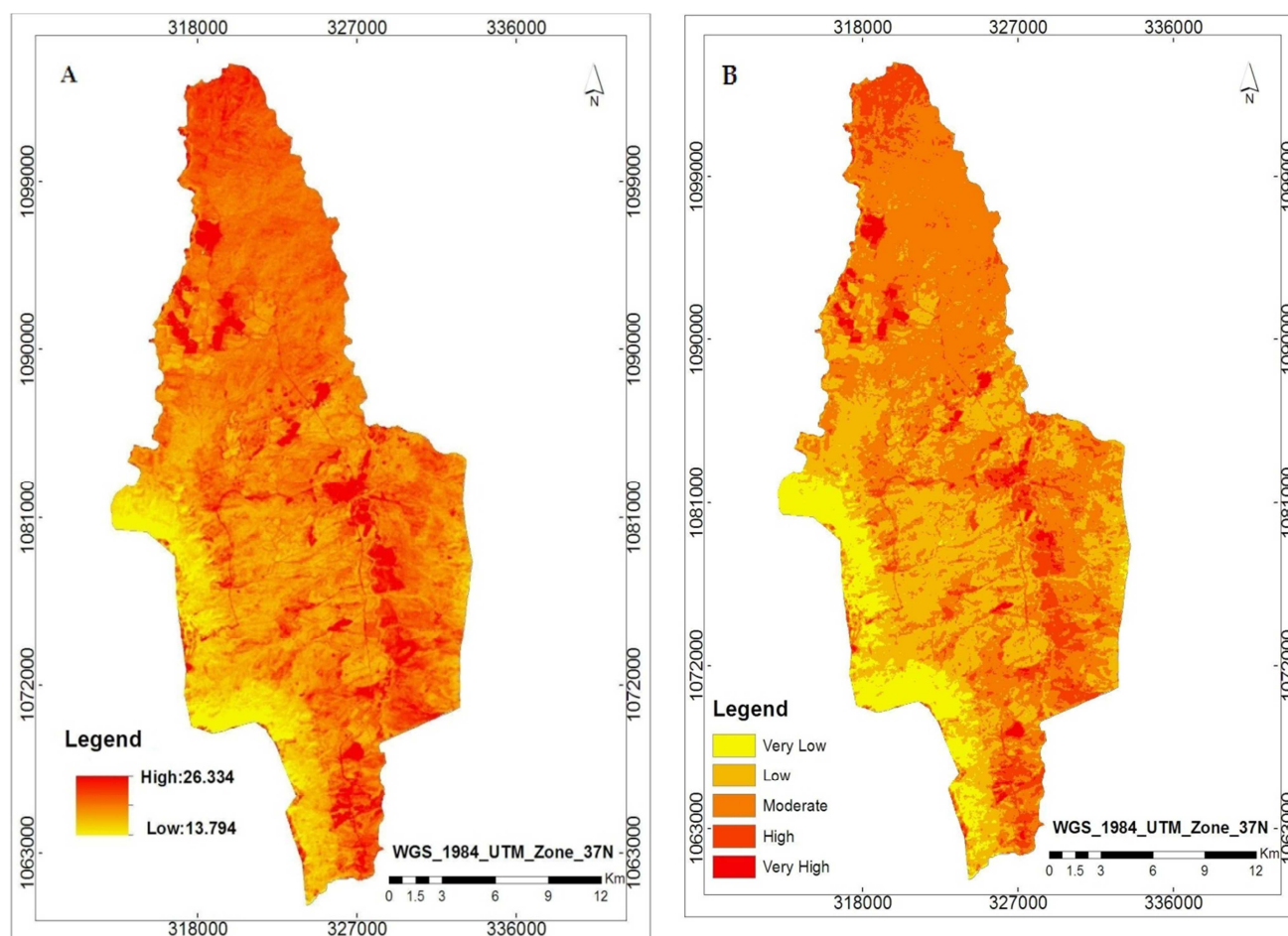


Figure 4.2 (A) Land surface temperature map and (B) Reclassified land surface Temperature map

From land surface temperature map, the western escarpment of the kebele is characterized with temperature ranging from 13°C-16°C.while the eastern part with temperature range from 16°C-18°C. The northern lowland area have temperature 18°C-26°C,(figure 4.2)

4.3.2 Rainfall

Rainfall could enhance transmission of schistosomiasis by increasing the amount of surface water which can be suitable environment for breeding of snail intermediate host, or rainfall may denote the cessation of active transmission either in dry season when no or little rainfall or when there is too much raining that can wash the infected snails away from the transmission sites.

For example ,Initial geographical analysis made in Uganda showed that the geographical distribution of *Schistosomiasis mansoni* is restricted to in areas where total annual rainfall

above 900 mm at an altitude <1400 m above sea level (Kabatereine *et al*, 2004). In Ethiopia, during the big rainy season of June to September and the small rainy season of March to April which increase the amount of surface water in Lakes, rivers ,streams and pond , these condition increase the number of fresh water snail population in the coming months after the rainy season in over.

Rainfall layer of the study area was created using data from finchaa research metrological station and by applying Inverse Distance Weight (IDW) in ArcGIS environment.

The output rainfall map was reclassified in to five class based on the optimum amount of rainfall for the distribution of *schistosomiasis mansoni*. Hence, the classes were labeled in Figure 4.3 and as very high, high, moderate, very low, low based on the level of vulnerability of those areas to *schistosomiasis mansoni* incidence.

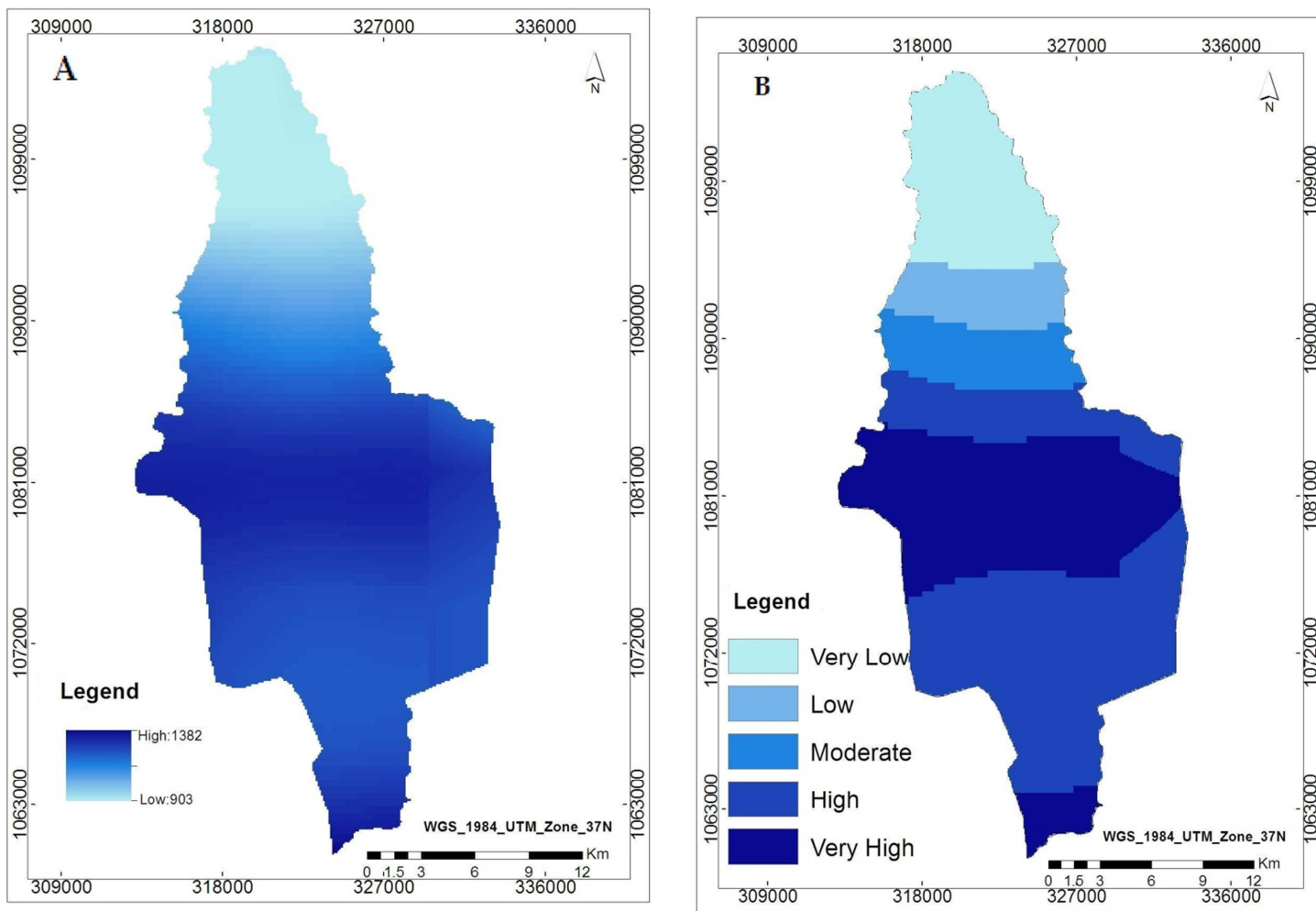


Figure 4.3 (A) Rainfall Map and (B) Reclassified Rainfall Map

From figure 4.3, the highest amount of rainfall was received in most of the kebele with intensity of 1382 mm annually with the exception of the northern lowland area which receive 903 mm rainfall annually.

4.3.3 Altitude

Altitude is very importance environmental factory for temperature and rainfall. Variation in altitude affects the amount of temperature and rainfall, which directly influence distribution of intermediate fresh water snail and transmission of the disease. *Schistosomiasis mansoni* is widely distributed in Ethiopia within the altitude limit of 800m-2200m above.(Kloss *et al*, 1988).

The elevation layer of the study area was derived by digitizing contour from top sheet map of the study area which was prepared by Ethiopian Mapping Agency. From the digitized couture, digital elevation model (DEM) was derived. The digital elevation model layer were reclassified in five class based on the extent of schistosomiasis prevalence at different altitudes given (Kloss *et al*, 1988). Elevation layer class are labeled from most favorable altitude for survival and development of intermediate fresh water snail and also for the transmission of the daises ,as very high ,high, moderate, low and very low . The highest altitude runs along the western part to southern part, while low altitude was in northern part of the kebele. (Figure 4.4)

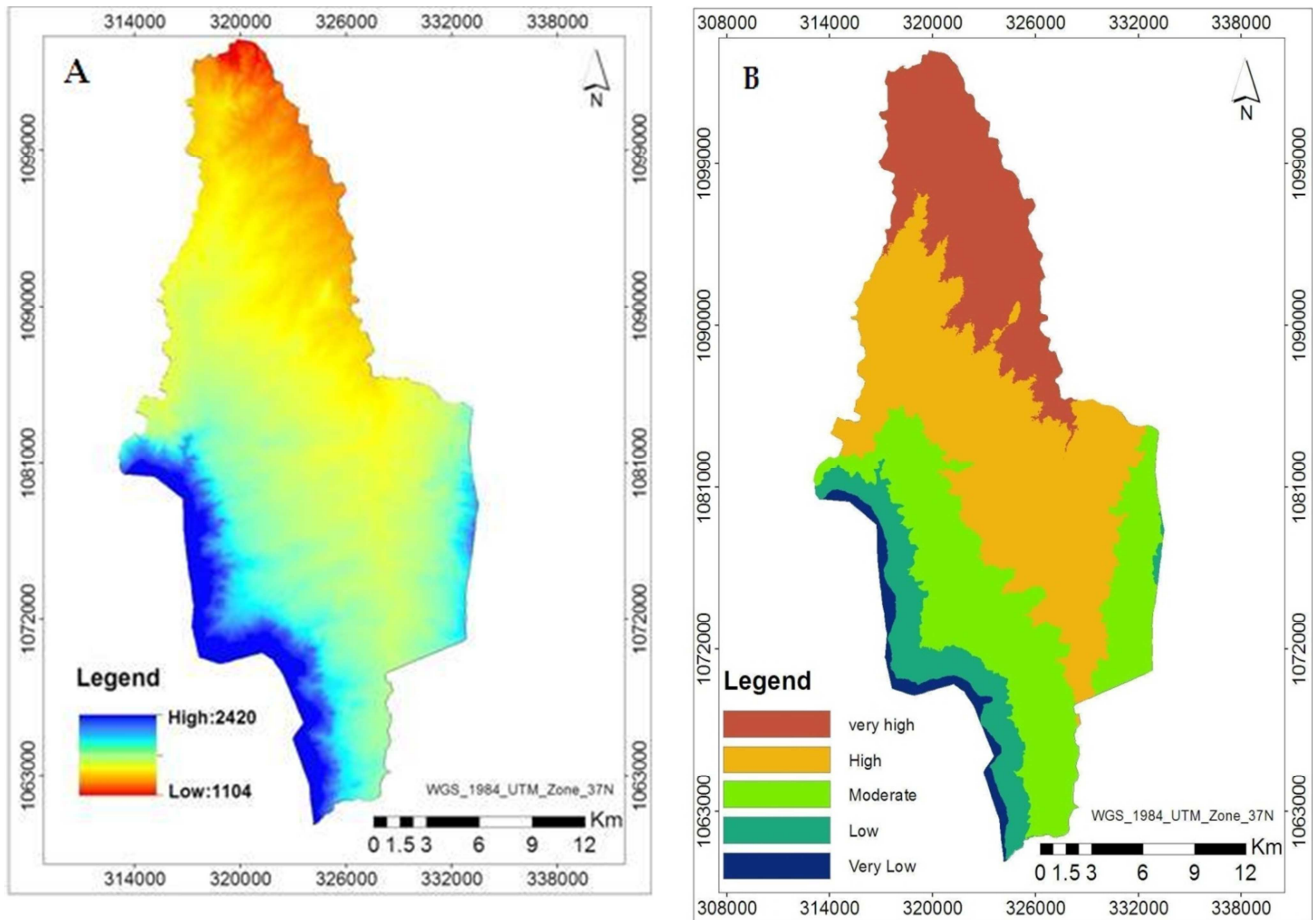


Figure 4.4 (A) Altitude Map and (B) Reclassified Altitude Map

4.3.4 Slope

The slope was used as a crucial factor of water stagnates. This is because in areas with low slopes, water tends to be dammed, this condition aggravated by the physical soil properties which are lodged or impermeable. Lodged water creates favorable habitat for fresh water snail. In area with slope of 20 m/km were water tend to move slowly or logged, this area came to be favorite spot for snail (Boelee *et al*, 2006.) The slope layer of the study area was derived from digitized contour. The slope map was reclassified five class based on the optimum slope that create water to collect in one place or tend to move slowly. The low level of slop was observed in the middle part of the kebele creating flat surface. The western part of the kebele were considered as high slop area with a few area on the eastern and northern part.(figure 4.5)

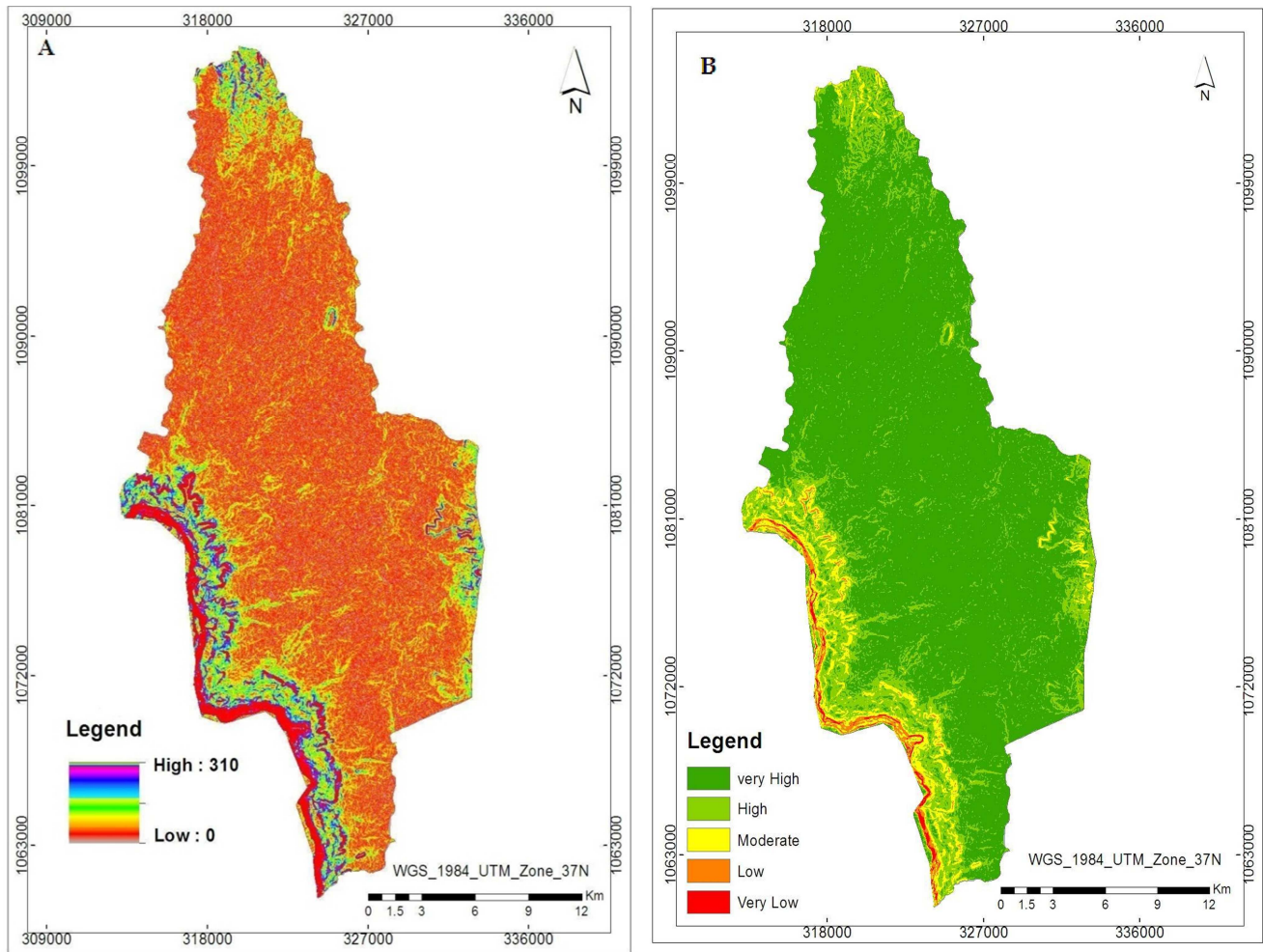


Figure 4.5(A) Slope map and (B) Reclassified slope map

4.3.5 Land Use Land Cover

Land use land covers especially type of vegetation create favorable habitat for the Intermediate host snails. They are often associated with aquatic plants, especially the submerged species, as these provide ideal surfaces for snails to graze and to deposit their egg masses. At the same time, the aquatic vegetation provides protection for these species against high water flow velocities and against predators such as fish. Thus, removal of aquatic plants would affect snails directly and, under certain circumstances, expose them to predators.

The land use and land cover layer was produced from Landsat ETM+ image of 2010, the layer were classified into six classes, as built-up area, water body, sugar cane plantation tree

canopy and bare soil. Built-up class represent urban infrastructure like road, housing unit's e.tc. , Water body represent starting from small stream to rivers, pond and aquatic vegetation, plantation represent, area cultivated by Finchaa sugar factory for sugar cane production. Tree canopy represented scattered trees and bushes; finally the last class is bare soil. Based on suitability for transmission of schistosomiasis, cercaria penetration and snail population, the land use land cover classes were reclassified as Very high, high, moderate, low and very low .(figure 4.6)

The middle and eastern part of the kebele was covered by sugar cane plantation accounting 44 % of the entire area. Finchaa River. Through the middle part, finchaa river runs toward the northern direction dividing the sugar cane plantation in to western an eastern bank, fikary stream which attributer to Finchaa River runs along village A and korkie . Theses Rivers and some other small water bodies account 6% of the entire area. Number of denies and scattered tree canopy were found on the northern and north eastern part of the kebele covering 2 % of the area. The villages are distributed in the middle part of the kebele with addition to other administrative building roads and irrigation canals, the built up area account for 9 % of the entire kebele. The rest 39 % of the kebele is covered with bare soil. (Figure 4.6)

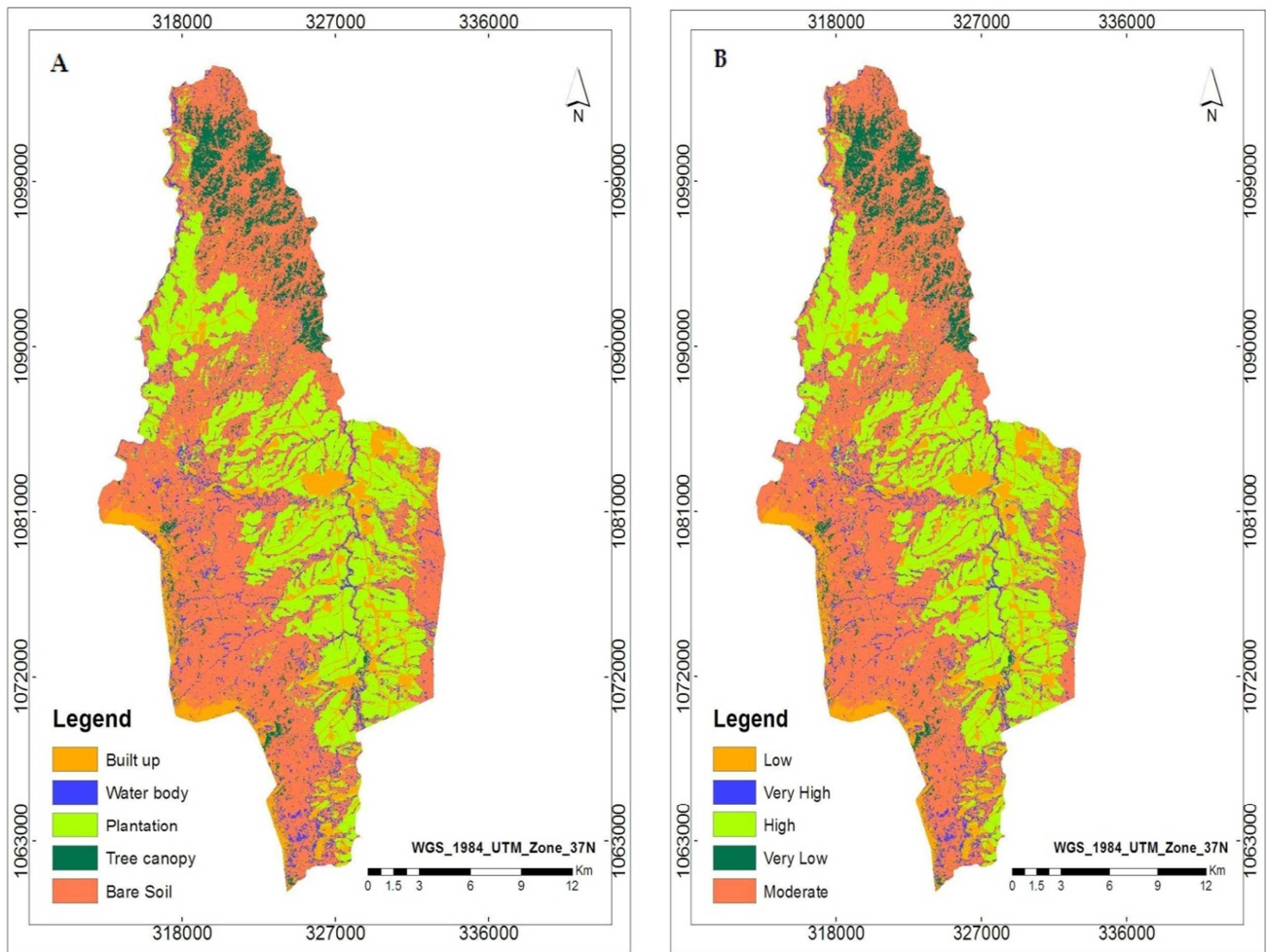


Figure 4.6. (A) Land use Land cover Map and (B) Reclassified land use land cover map

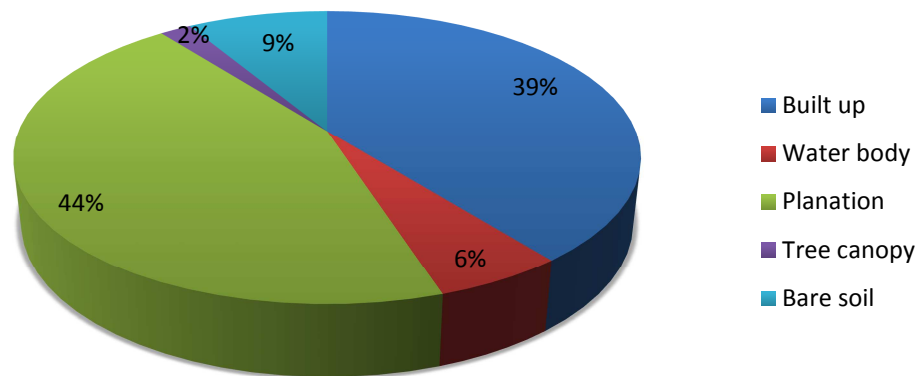


Figure 4.7 Total land use and land cover area

4.3.6 Distance from water body

The nature and extent of an individual's water contact activities have a direct effect on his or her risk for schistosomiasis infection. These demonstrate that duration of water contact, exposure and the proportion of the body immersed that are primarily related to the incidence of infection.

In many areas water use is influenced by local cultural factors, which determines who performs the various work activities involving water and when (e.g. fishing, farming, washing, bathing etc.).

In areas where water is present almost continuously, such habitats easily become the more popular sites for human water contact and, thus, schistosomiasis transmission is established.

The mean annual rainfall of Finchaa sugar estate is averagely 1302 mm, with two main rivers (Finchaa, Fikary river), several reservoirs, earth dams, temporary pools that are scattered all over the estate. Overhead sprinkler feed the sugar cane plantation increasing humidity and soil moisture. Fikary river is infested with *Bulinus* snail, that transmit *schistosomiasis mansoni*, proximity to these river and stream starting from it increase the vulnerability to *schistosomiasis mansoni* infections.

Distance from river layer was produced by digitizing river layer from topographic sheet map.

The layer then, converted to raster dataset using ArcGIS spatial analysis. Distance to the closest source which is water body was calculated using Euclidean distance. Output layer indicate that area within 694m distance of water body were considered as very high, 1574

m and 2561 m ,3629m , 6777m were considered as high moderate ,low and very low respectively.

The output layer were further reclassified in to five class based on proximity to river or water bodies. The classes are labeled as very high, high, moderate, low and very low.

(Figure 4.8)

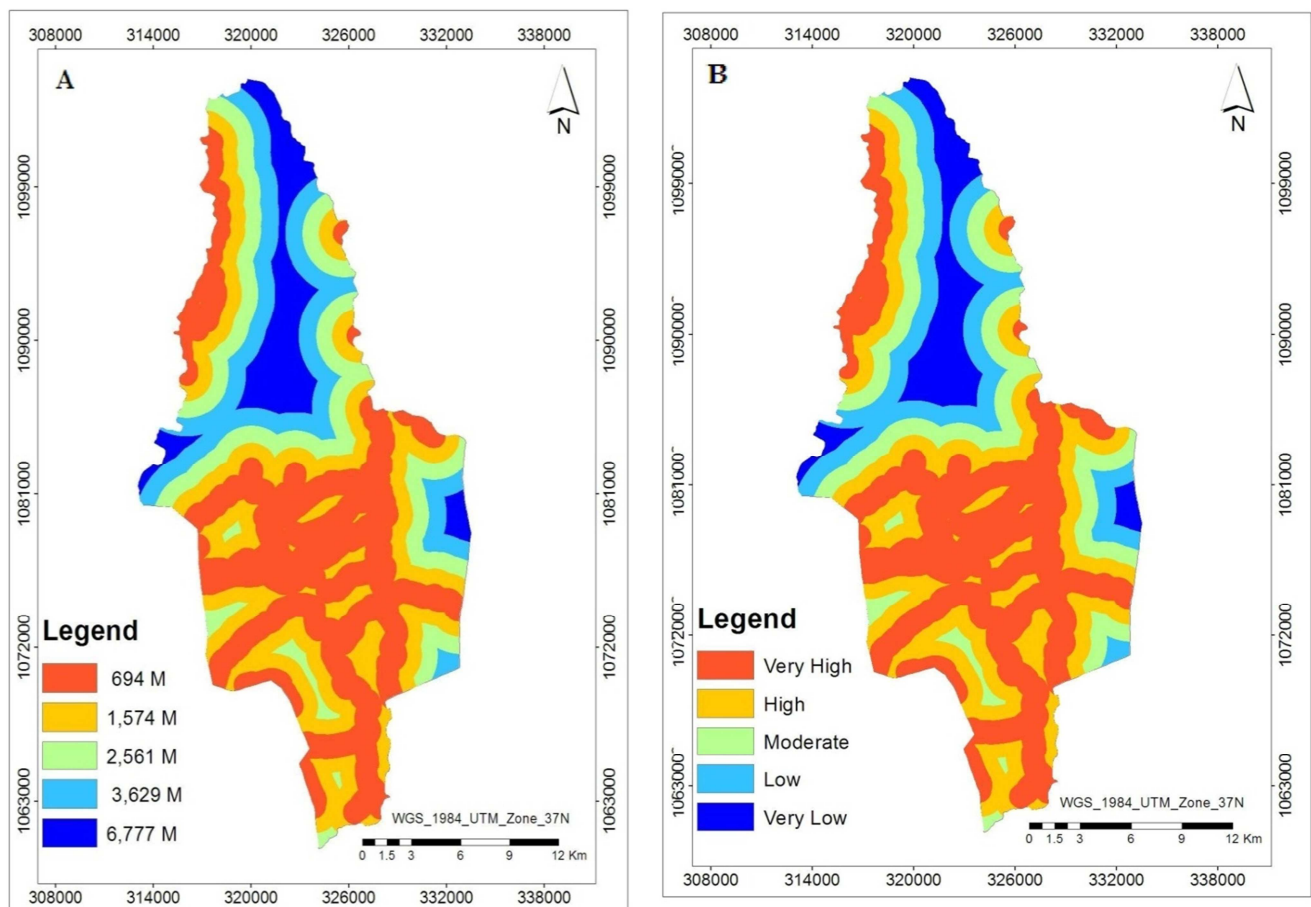


Figure 4.8. (A)Distance from river and (B) Reclassified distance from river

4.3.7. Distance from health center

To identify health institutions accessibility and for their effectiveness for those inaccessible areas, spatial location of health institutions within the study area were collected with GPS on field survey for accessible areas.

Five health institutions were recorded and located using GPS in the study area. Distance from each health institutions were calculated using Euclidean distance and reclassified using coordinate collected from field. The classes were labeled according to distance from health center 0-694 m, 694m-1574m, 1574m-2561m, 2661m-3629m, 3629m-6777m and used to see their relationships with *schistosomiasis mansoni* prevalence. Based on risk to *schistosomiasis mansoni* classes were assigned as Very low, Low, Moderate, high and Very High respectively. (Figure 3.9)

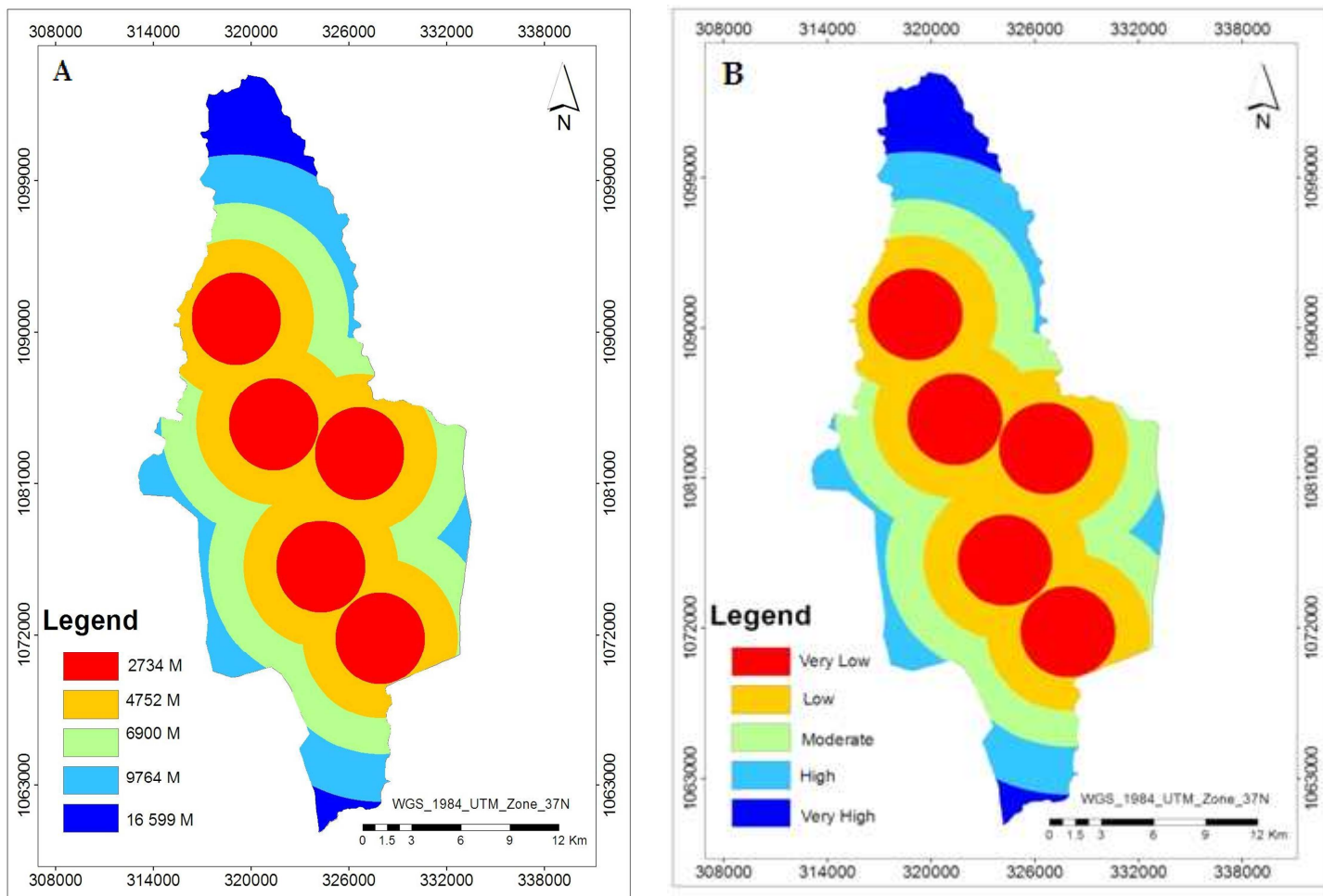


Figure 4.9. (A)Distance from health center and (B) Reclassified distance from health

4.3.8 Population density

The population of the study area comprises of workers of the estate farm, their families and new arrivals in search of job opportunities each year. Currently, data from finchaa sugar factory kebele put the number of population around 23,161 in the valley.

The population density of the study area was calculated by dividing the total population by total area of each village and classified in to five classes from the lowest density, which has very low risk (2772 Person/km²) to the highest density, which has very high schistosomiasis risk (7108 Person/km²) .(figure 4.10)

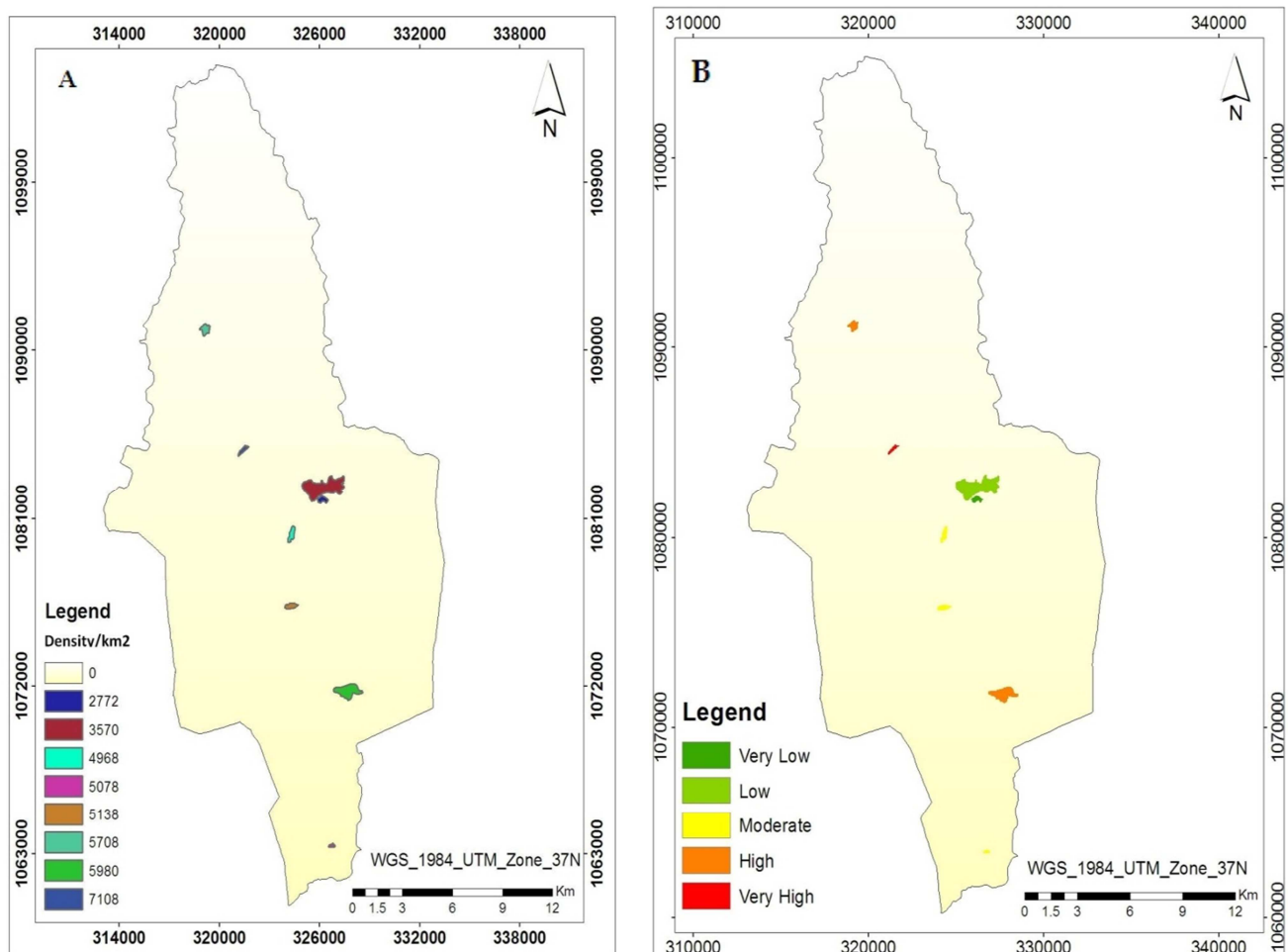


Figure 4.10. (A)Population density and (B) Reclassified population density

5.1 Results

5.1.1. Schistosomiasis mansoni prevalence versus Temperature

Temperature is most important determinants of the population dynamics of intermediate host fresh water snails that transmit schistosomiasis. Fresh water snail can be found in dry cold temperature with very low survival rate. The optimal temperature for the development and survival is around 22-25°C. Above 30°C snail mortality increases, and thermal death occurs at 40 °C. (Seto *et al*, 2002). The figure 5.1 show mean annual temperature of the study area from Finchaa research meteorological station and laboratory confirmed case of reported schistosomiasis mansoni from the villages within the factory. Temperature and prevalence have indirect relationship .From January-April both temperature and prevalence continue smoothly, after April temperature a start declining little while prevalence increase little bit too. After the end of rainy season temperature remain within 20°C-25°C, but prevalence start to grow. These due to abidance of water every were it provide shelter, place to lay eggs and source of food. If snails are infected with *miracidium* they produce thousands of cercaria, every one of which is capable of infecting man. Human activity of summing, bathing and other water related activities increase because water is very were in ponds, seasonal rivers, stream and swamps, these condition will lead to high degree risk of infection.

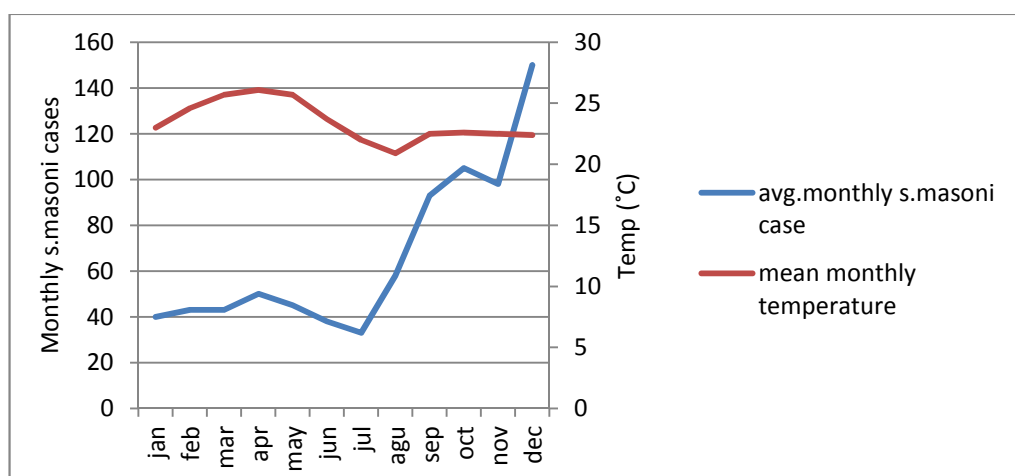


Figure. 5.1 Mean monthly temperature of 2000-2012 vs Schistosomiasis mansoni prevalence of 2002-2011

5.1.2. Schistosomiasis mansoni prevalence versus Rainfall

Rainfall is very critical both for transmission and survival of fresh water snail, In sub-tropical regions, where high rainfall intensity season snail were washed off from their existing habitat of ponds, lakes, river while, where low intensity rainfall, some natural habitats dry out for a substantial part of the year, due to this environmental conditions snail population dramatically decrease. It is difficult to quantify precisely the spatial relationships between rainfall and snail population dynamics and schistosoma transmission since the effect of rainfall varies according to snail species and geographical location. The figure 5.2 shows the relationship between rainfall and schistosomiasis mansoni cases. During rainy season from May to September the rate of schistosomiasis case is low but after the rainy season was over it increases. These show as that, rainfall and schistosomiasis prevalence in these cases shows indirect relationship.

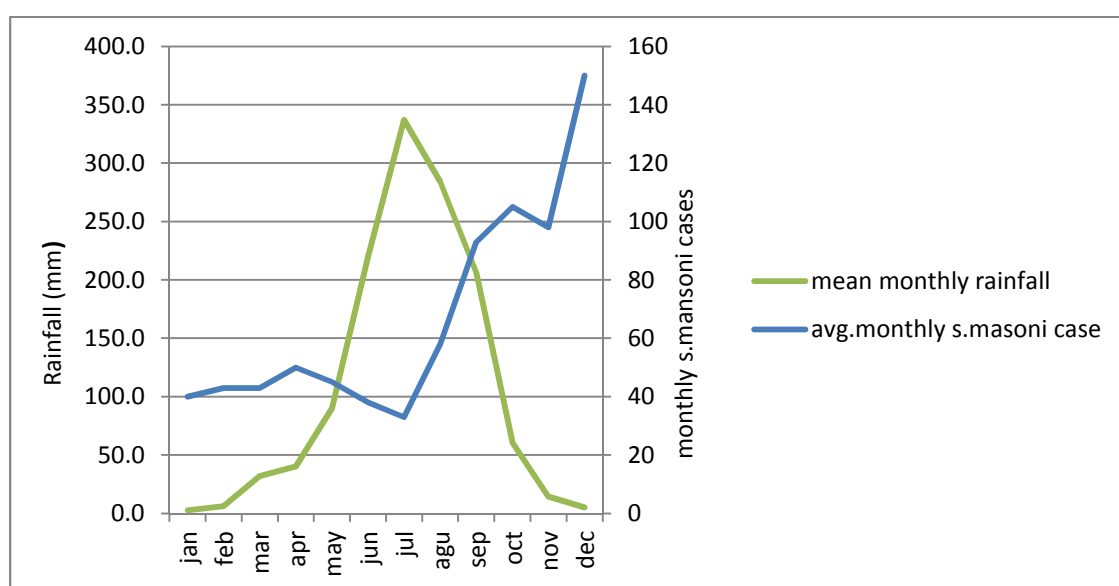


Figure. 5.2 Average monthly rainfall of 2000-2012 vs Schistosomiasis mansoni prevalence of 2002-2011

5.1.3. Identifying Areas of Schistosomiasis mansoni Hazard

In order to produce Schistosomiasis mansoni hazard map, temperature, rainfall, altitude, slope, and distance from river data were aggregated in to ArcGIS environment using spatial analyst module after each factor was given the appropriate weight in using IDRISI software. (Table 4:3) The schistosomiasis mansoni hazard map, in Figure 5.4 and the graph

in Figure 5.5 illustrates that, 3799.5 ha of the area were considered as high level of schistosomiasis mansoni vulnerability, 4046 ha of the area were considered moderate level of vulnerability and 654.5 Ha of the total area of the study area considered lower level of vulnerability .(figure 5:3)

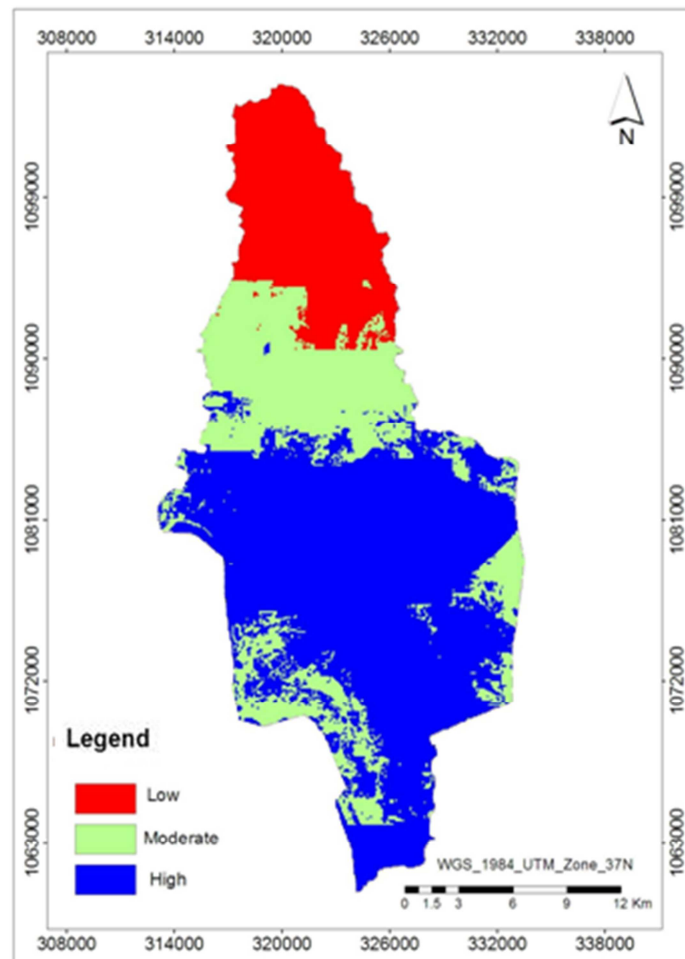


Figure 5:3 Schistosomiasis mansoni hazard map

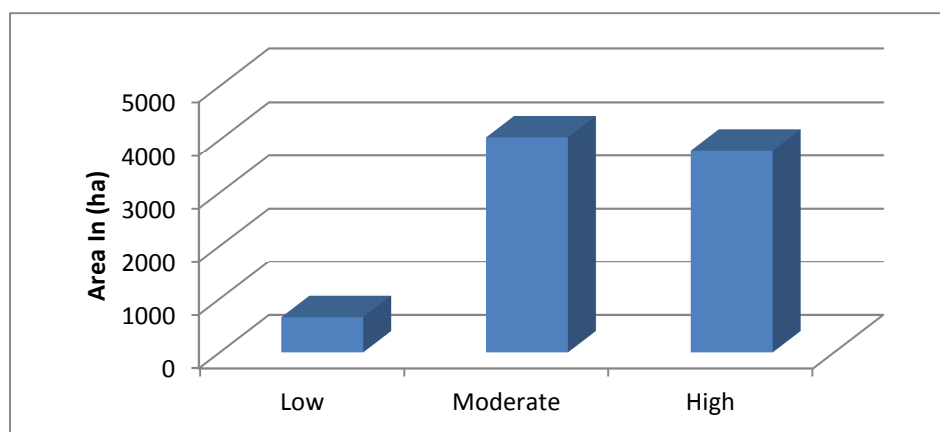


Figure 5.4 Area coverage of schistosomiasis mansoni hazard areas

Hence, from these figures it is possible to conclude that over 44.7 percent of the total area is in high and 47.6 percent of the total area is moderate Schistosomiasis mansoni hazard and the remaining 7.7 percent area was considered lower level of hazard.

5.1.4. Identifying Areas of Schistosomiasis mansoni Risk Area

Schistosomiasis mansoni risk map, in Figure 5.6 and the graph in Figure 5.7 illustrates that 4020.5ha high, 4462.5 ha moderate and 17 ha Low level of schistosomiasis mansoni vulnerability, that are representing from the total area 47.3 percent, 52.5 percent and 2 percent of the study area respectively are subject to high moderate and low level of schistosomiasis mansoni susceptibility.

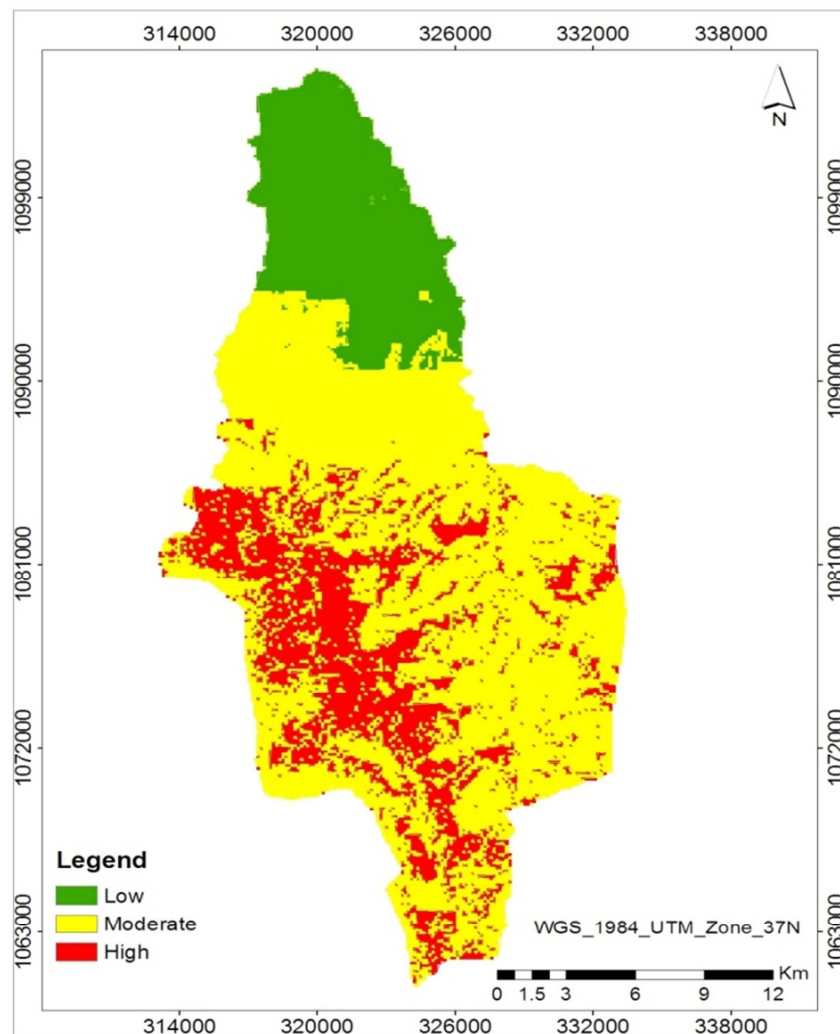


Figure 5.5 Schistosomiasis mansoni risk map of the study area

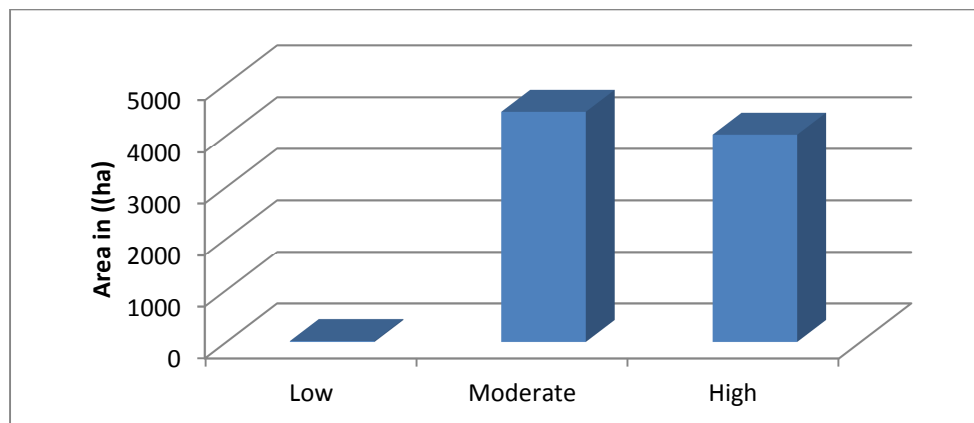


Figure 5.6 Area coverage of schistosomiasis mansoni risk area

5.1.5. Comparing schistosomiasis mansoni risk with villages

Out of the village within the finchaa sugar factory kebele, village A, village C, the main town Agemsa and korkie are fall within high vulnerability to schistosomiasis mansoni. Village B, village D, village E, and Kuyera fall within moderate vulnerability to schistosomiasis mansoni.

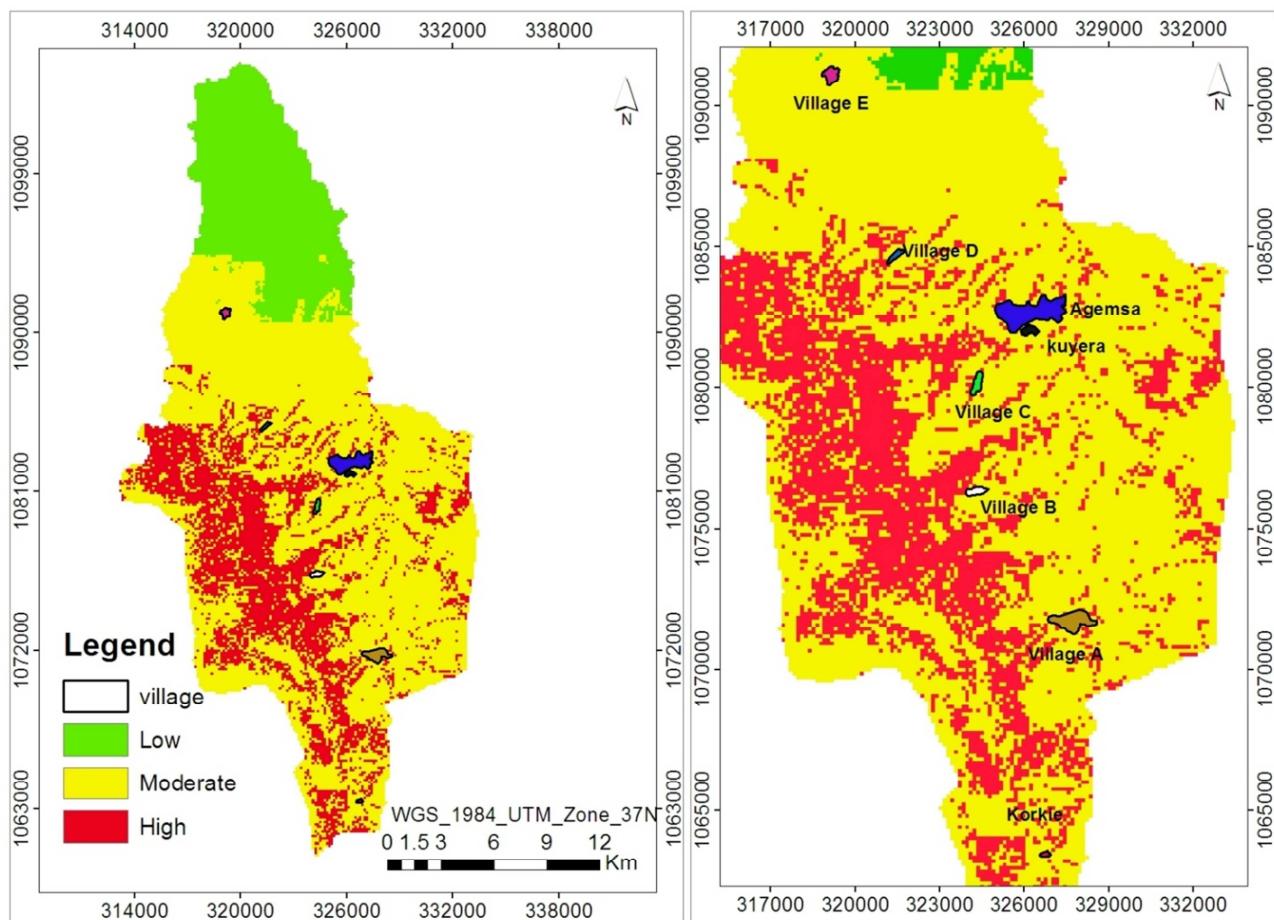


Figure 5.7 Risk vs. Village map

5.1.6 Validation of the Result

From table 5.1, we can observe schistosomiasis mansoni case for the year 2010/11 for each village except kuyera in the study area. The data shows that, village A, village C, Agemsa and kuyera has high number of laboratory confirmed case of schistosomiasis mansoni, while village B, village D, village E show moderately a number of individual with confirmed case of the disease.

From figure 5.8 this villages, A, C, Agemsa and korki are within area delineated as high schistosomiasis mansoni risk . Village B, D, E are within area delineated as moderate level of schistosomiasis mansoni case

Kuyera is an illegal residential village built without the consent of the sugar estate administrative body and most of individual living there are daily labors and those who's looking for work in the sugar estate factory. Due to this factory data for it was difficult to get recorded data for this village, if there is it was integrated with data from neighboring Agemsa.

Table 5.1 Risk versus villages

S.No	Village	Easting	Northing	S.mansoni case	Risk model
1	Village A	37327904	1071772	75	High
2	Village B	37324288	1076042	27	Moderate
3	Village C	37324311	1080160	46	High
4	Village D	37321385	1084506	23	Moderate
5	Village E	37319076	1090802	19	Moderate
6	Agemsa	37326198	1082412	56	High
7	Kuyera	37326162	1082039	-	Moderate
8	Korkie	37326726	1063443	61	High

5.2. Discussion

5.2.1 Schistosomiasis mansoni versus climatic factors

The climatic and topographic set up of the finchaa sugar factory kebele favor biomphalaria preffier species of fresh water snail's growth and development which favors schistosomiasis mansoni prevalence. It also correlates similarly with the facts stated in different researches. The area possesses mean annual temperature of 26.1°C and 20.9 °c and altitude of 800m-2200m m.a.s.l. But areas within temperature of 22°C to 26°C and below 2000 m.a.s.l. are potential schistosomiasis mansoni areas. (kloss et al,1988)

Snail transmitting schistosomiasis favor temperature about $25 \pm 2^\circ\text{C}$. growth and reproduction drop steady with decline temperature and eventually cease, but mortality is low and population remain stable above lethal temperature of 30°C snail growth accelerates above optimum temperature ,but so too does snail mortality as the thermal death point (35°C - 40°C). (Mohamud, 2001).

5.2.2. Schistosomiasis mansoni topographic factors

Research work by Terefe *et al* (2011) in Ethiopia shows that there is an inverse relationship among schistosomiasis incidence. altitude between 1,200 to 2,000 meters is optimal for *Schistosomiasis mansoni* transmission and the majority of endemic areas are located in this altitudinal range, Various studies suggested that, the odds of *Schistosomiasis mansoni* infection decreases with increasing altitude, (Worner *et al* ,2007). This is because as altitude increases there is a decrease in temperature and increase in rainfall and this produce unfavorable condition for the parasites even if there are intermediate host fresh water snails. Slope has a direct relationship with schistosomiasis incidence because the decrease in inclination of slope creates stagnant water, which is habitat for snails. Water contact habits in area prone to schistosomiasis have higher risk of infection. (Seto *et al*, 2002)

5.2.3 Schistosomiasis mansoni case in finchaa sugar estate farm

Schistosomiasis mansoni has been known to be endemic in Finchaa sugar estates (Kloos *et al*, 1988). In Finchaa sugar estate, the disease has increased as result of population migration associated with irrigation development (Erko *et al*, 1997a). An attempted was made, but failed to date the earliest reported case of schistosomiasis mansoni in finchaa sugar estate factory. But it's believed to exist long before but aggravated after the establishment of the factory. In 1990 schistosomiasis control program was initiated by institution of pathobiology until. The objective of the program was to undertake prior work of schistosomiasis endemic by applying endod. Different application method of endod, as spray, drip feeding and saponification were implemented and also tested for maximum lethal effect on snails, of which planting endod along riverine and irrigation canals was found to be the most effective method of reducing the transmission and distribution by of the disease. Finally, in 1998, compilation of the pilot control activities were handed over to the medical service department.

Most of the schistosomiasis cases in finchaa sugar factory polyclinic found on the main town Agemsa are reported from residents of village A and korkie village. The villages are the most affected by intestinal schistosomiasis. The polyclinic annual report indicated that the number of schistosomiasis cases has decreased. There were 103 cases of Schistosomiasis mansoni in the year 2003/04 which is 0.29% of all patients in the polyclinic. In the year 2007/08 cases of schistosomiasis were only 22 (0.05% of all cases). In 2009/10 cases of schistosomiasis were increased to be 307(0.76%). The polyclinic annual report of schistosomiasis in Finchaa Sugar Estate for the past 8 years is shown in the figure 5.9. In addition, monthly reported cases of Schistosomiasis mansoni from the Finchaa polyclinic reports are given in Appendix 1and 2.

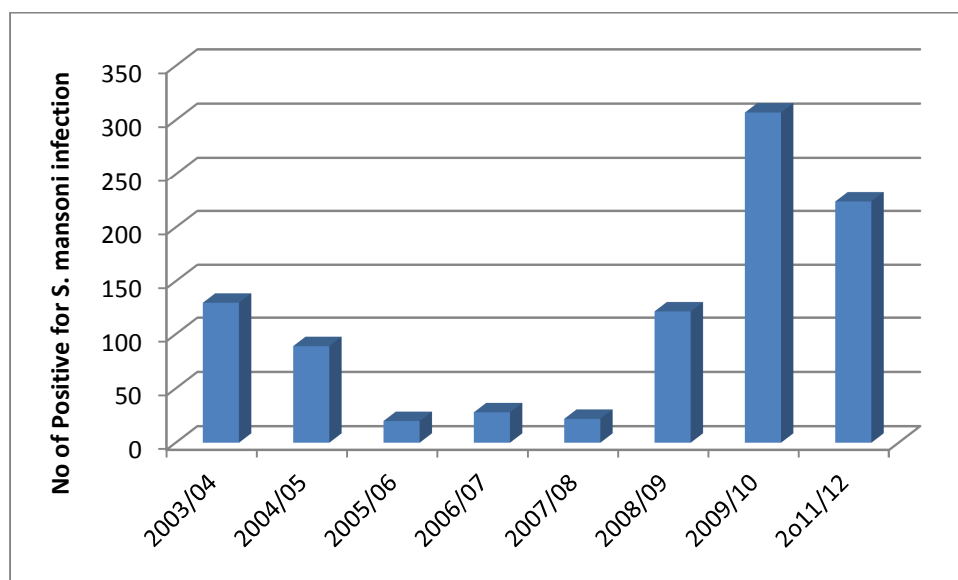


Figure 5.8: The polyclinic annual report of schistosomiasis in Finchaa Sugar Estate for the past 8 years

6.1. Conclusion

Schistosomiasis remains one of the most infectious vector born parasitic disease in the world, and one of the most significant cases of chronic morbidity. While the ecology of transmission has been well studied, and the contributing causes of human infection have been defined eradication of schistosomiasis has been achieved in only a few endemic area.

Effective implementations of schistosomiasis control schemes requires detailed understanding of the critical points of schistosomiasis transmission ,along with post intervention epidemiological monitoring to ensure utility of the outcome.

This study aims at producing maps of schistosomiasis mansoni prone and risk areas, by analyzing environmental and socio-economic factors in finchaa sugar estate factory Horo Guduru wollega zone of oromia regional state.

In this work, it was indicated that all villages in the study area kebele were considered risk to schistosomiasis mansoni. Village A, village C, the main town Agemsa and korkie are among area within high vulnerability to schistosomiasis mansoni. Village B, village D, village E, and Kuyera fall within moderate vulnerability to schistosomiasis mansoni.

In general, out of the total area of 8500 ha, 4020.5 ha or 40205 km² high, 4462.5 ha or 44625 km² moderate and 17 ha or 170 km² Low level of schistosomiasis mansoni vulnerability.

As result, from the total area 47.3 percent, 50.5 percent and 2 percent of the study area respectively are subject to high, moderate and low level of schistosomiasis mansoni susceptibility. It is possible to conclude that over 99.8 percent of the total areas are in high and moderate schistosomiasis mansoni hazard and the remaining area was low risk to schistosomiasis mansoni.

6.2. Recommendations

As the kebele is mainly classified as High schistosomiasis mansoni risk, it is necessary to draft strategy and program that considers the difference in risk. The strategy to be crafted to address the disease must be changed to plan of action for prompt prevention and control of schistosomiasis. Since maps are considered as one of the very vital input it is therefore, critical to use them in every aspect of planning, implementation, monitoring and evaluation of any development processes as well as schistosomiasis eradication and prevention program in the kebele.

Therefore the following are recommended:-

- ✓ Planners and decision makers should specifically apply the findings of this study to prioritize risk areas and make sure adequate resources are allocated to the high and very high schistosomiasis mansoni risk areas of the kebele.
- ✓ Schistosomiasis survey in the community (among villagers) should also be done more often accompanied with targeted chemotherapy for positive individuals.
- ✓ Public health education is also necessary on the transmission of schistosomiasis in communities as well as in schools.
- ✓ Community participation is necessary for a sustainable control of schistosomiasis. Therefore, control programs should be designed in such a way that can participate the communities living in the sugar estates.
- ✓ Socioeconomic developments of the labors in the sugar estates and their families are also necessary for reducing the risk of schistosomiasis infection.
- ✓ Besides PZQ intervention, molluscicidal application in irrigation and riverine ecosystem need to be intensified to control schistosomiasis.
- ✓ Proper data bases about detail patient data, the seasonal incidence of epidemics and about other related aspects of the schistosomiasis for each village should be made using appropriate technology especially GIS.

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Appendix 1: Intestinal schistosomiasis cases reported in Finchaa Sugar Estate Polyclinic

Monthly reported cases of intestinal schistosomiasis in Finchaa Sugar Estate Polyclinic from
2004/05 to 2007/08

Month	REPORT YEAR			
	2004/05	2005/06	2006/07	2007/08
July	6	0	0	0
August	11	1	1	0
September	9	2	9	4
October	2	0	3	0
November	0	0	0	12
December	0	3	4	2
January	1	1	1	1
February	2	2	1	0
March	2	0	3	1
April	1	1	5	0
May	0	10	1	0
June	13	0	0	2
Total	47	20	28	22

Appendix 2: Annual report of intestinal schistosomiasis cases in Finchaa Sugar Estate Polyclinic, 2002/03-2011/2012

	Total Patients	No of Positive for <i>S. mansoni</i> infection (%)
2002/03	43,445	78(0.18%)
2003/04	46697	130 (0.29%)
2004/05	42497	89 (0.11%)
2005/06	43673	20 (0.05%)
2006/07	44946	28 (0.06%)
2007/08	47674	22 (0.05%)
2008/09	48301	122(0.25%)
2009/10	40039	307(0.76%)
2011/12	50069	224(0.45%)