JIMMA UNIVERSITY
INSTITUTE OF HEALTH SCIENCE, FACULTY OF PUBLIC HEALTH,
DEPARTMENT OF ENVIRONMENTAL HEALTH SCIENCES AND TECHNOLOGY

LAND-USE EFFECT ON THE DISTRIBUTION OF FRESHWATER SNAIL INTERMEDIATE HOSTS AND SCHISTOSOMIASIS INFECTION IN OMO-GIBE RIVER BASIN, SOUTHWEST ETHIOPIA

By: ETANA JALETA

A THESIS SUBMITTED TO INSTITUTE OF HEALTH SCIENCE, FACULTY OF PUBLIC HEALTHS, DEPARTMENT OF ENVIRONMENTAL SCIENCE AND TECHNOLOGY; IN PARTIAL FULFILLMENT OF THE REQUIRMENT FOR MASTERS DEGREE IN ENVIRONMENTAL SCIENCE AND TECHNOLOGY

LAND-USE EFFECT ON THE DISTRIBUTION OF FRESHWATER SNAIL INTERMEDIATE HOSTS AND SCHISTOSOMIASIS INFECTION IN OMO-GIBE RIVER BASIN, SOUTHWEST OF ETHIOPIA

BY**: ETANA JALETA**

ADVISORS:

1. SEID TIKU (PhD, Asso. Prof.)
2. DELENESAW YEHUWALAW (PhD, Prof.)
3. BELAYHUN MANDEFRO (MSc, PhD Candidate)
4. YIHUNE ABDIE (MSc, PhD Candidate)
5. ABEBE BEYENE (PhD, Asso. Prof.)

June, 2018
Jimma, Ethiopia

ASSURANCE OF PRINCIPAL INVESTIGATOR

I, the undersigned declare that this thesis is my original work, has not been presented for a degree in this or other universities and that all sources of materials used for this have been fully acknowledged.

Name of the student: Etana Jaleta Date____________________ Signature_____________________

Approval of the Advisors:

This thesis has been submitted for examination with my approval as University advisor.

Name	**Date**	**Signature**

1. SEID TIKU (PhD) _________________Signature_____________________________
2. DELENASAW YEHUWALAW (PhD) ____________Signature_________________
3. BELAYHUN MANDEFRO (MSc, PhD candidate.)________Signature__________
4. YIHUNE ABDIE (MSc, PhD Candidate)________Signature____________________
5. ABEBE BEYENE (PhD)__________________Signature _______________________

Approval of the Examiners:

1. **External Examiner:**

____________________Signature__________________________

2. **Internal Examiner:**

_____________________Signature__________________________

Department Head:

Embiale Mengistie (PhD.) ______________________________Signature_________________

Abstract

Introduction: *In Omo-Gibe river basin the extent of land-use is high due to anthropogenic activities this leads to the invasion of freshwater snail intermediate hosts distribution. Agricultural and human settlement areas increased the whole periods. Land-use change leads to the invasion of freshwater snail intermediate hosts which causes schistosomiasis. Most intermediate snail hosts of human Schistosome parasites belong to the two genera Biomphalaria and Bulinus. In Addition, Lymnea is another important host of Fasciola which cause Faciolasis in domestic animals and human. This study informs snail intermediate host distribution and infection prevalence.*

Objective: *to determine and map the effects of land use on the distribution of freshwater snail intermediate hosts, snail infection, and schistosomiasis infection prevalence in Omo-Gibe River basin, Southwest Ethiopia.*

Methods and Materials: *A cross-sectional study was conducted from March 22, 2016 to May 05, 2016. We surveyed 130 sampling stations from different sites which include rivers, lakes, dams, spring, wetlands and irrigation ditches of Omo-Gibe river basin. ArcGIS software of version 10.3.1 was used to map snail distribution. ANOVA is used to analyze the mean comparison and post Hock for mean separation using SPSS package of version-20 where chi-square and F-test are applied to evaluate significance. Prevalence of cercaria infection in snails and schistosoma infection rates in humans were determined by descriptive statistics.*

Results: *Over all 2559 snail intermediate host collected from 130 surveyed stations in Omo-Gibe river basin, which belonged to four genera and seven species. In addition one was in family level. Of these snail intermediate hosts, 1749 belonged to the genera of Bioamphalaria, Lymnea, Bulinus and Physa. Biomphalaria pfeifferi was the predominant accounted for 35.4% of the total snail collection and 39.2% were sampled significantly (p=0.000) from lakes, wetlands, rivers and irrigation ditches. The highest collection of Biomphalaria pfeifferi (89.2%) was from rivers. Majority of cercaria shading recorded on L. natalensis (10.1%) next to B. pfefferi (85.3%) insignificant association (P=0.297) to land-use types. The overall prevalence of S. mansoni was 9.2% and the highest S. mansoni prevalence (31.1%) was recorded in Seto-Yido schoolchildren which is insignificantly (P=0.300) associated to land-use.*

Conclusions and Recommendations: *In general the freshwater snail intermediate hosts: Biomphalaria, Bulinus and Lymnaea were collected from lakes, rivers, wetlands, irrigation ditches. Lymnea was predominant and infected snail next to B. pfefferi. For schistosoma study only S.*

mansoni prevalence was (9.2%) recorded. The study had shown negative for S. haematobium. From the finding, the study seams to show the foci of snail intermediate hosts distribution and snail infection; therefore, it helps stake-holders to develop monitoring and mass treatment measure at snail hot spot area and further studies will provide better insight for new infestation and indication of schistosomiasis prevalence in the same study area and other parts of Ethiopia.

Key Words: *Land-use, freshwater snails, Schistosomiasis, Biomphalaria, Bulinus, Lymnea, Omo-Gibe river basin, Ethiopia.*

Acknowledgement

I would like to express my deepest gratitude to my advisors Abebe Beyene (PhD), Seid Tiku (PhD), Yihune Abdie (Msc, PhD candidate), Belayhun Mandefro(Msc, PhD candidate), and Delenesaw Yehuwalaw (PhD) for their provision of constructive comments and guidance as well as their support and vital advices throughout the research period.

My thank also goes to Mr. Getachew Yigezu, Ato Zewudu Ephirem, Yifrashewa Mengesha, Mahmud Ahmednur, Zeleke Kebebew and Seiyum Derib for their cooperation during data collection in the field, experience share and laboratory work.

I would also extend my thanks to Jimma Teachers' College, department of Physics especially to Mr. Alemu Gurmesa and Dereje Kenea for their supports in sharing my pain and work load to achieving this goal.

Furthermore, Jimma University, College of Health Sciences, Department of Environmental Health Science and Technology also properly acknowledged for giving me this opportunity.

Contents

List of Tables

List of Figures

List of Plates

Acronyms:

BOD Biochemical oxygen demand

CCNP Chebera Churchura National Park

CI Confidence interval

COD Chemical oxygen demand

DEM Digital elevation model

DO Dissolved oxygen

EC Electric conductivity

GIS Geographical information system

GPS Global positioning system

IWMI International Water Management Institute

LU land -use

NTU Nephelometric turbidity unit

RS Remote sensing

TH Total hardness

UTM Universal transvers Mercator

WHO World Health Organization

WQ Water quality

CHAPTER ONE: INTRODUCTION

1.1. Background

Land-use includes grassland, forest, settlements/ urban features, farming, shrubs and riparian vegetation (Maldonado, 2010). The “land-use” concept has evolved during recent decades and it is now considered as the socioeconomic function of land. It is recognized that the terms of these land-use categories are a mixture of land cover (e.g., Forest land, Grassland, Wetlands) and land-use (e.g. Cropland, Settlements) classes (Penman et al., 2003). Land-use changes are complex and interrelated expansion of one land use type is at the expense of others (Gashaw et al., 2014). Study of (Abate & Lemenih, 2014) in Nada Asendabo watershed of Omo-Gibe concluded that land-use/ land-cover must be improved, towards the resources management and conserving of the existing vegetation and other natural resources. The study of (Patrick et al., 2000) concluded that the main direct drivers of tropical deforestation are agricultural expansion, high levels of wood extraction, and the extension of roads and other infrastructure into forested areas. Due to the increase of human population and changes in land use, the freshwater ecosystems are under constant pressure (Maldonado, 2010). The review of (Galbraith et al., 2005) on International Water Management Institute (IWMI) also reported irrigation or activities associated with agricultural irrigation can cause adverse impacts on wetland ecological resources ranging from localized and subtle, to long-distance and severe. Their report concluded that treating of each new project and scheme as a “natural experiment” where the ecological resources and effects are quantified from before the project is implemented. Until this is accomplished, the risk of repeating the same mistakes that made in the past was run.

LU change due to human settlement and his domestics can affect water quality as indicated by (Abebe, 2014). Report of (PAHO/WHO, 2007) showed large water bodies such as lakes, rivers, irrigated lands, and dams are also key for Schistosomiasis transmission and epidemiology, particularly in Africa. Schistosomiasis is a disease caused by infection with schistosome parasites (Ayanda, 2009). As (Gebresenbt, 2015) also indicated that forests and vegetation have been cleared in Omo-Gibe river basin, southwest Ethiopia through increased human activities and regional growth to urbanization. Study of (Abate, 2014) also comfirmed change in the extent of agricultural and built up has increased the whole periods in Nada, Omo-Gibe river basin. For example, the hydropower generation dam project of Gilgel-Gibe (I, II, III) and resettlement made in parallel to its usefulness at the area basically can alters the problem. Therefore, physico-chemical parameters of water bodies could influence the abundance and distribution of snail intermediate host (TONY, 2011). Different surveys and studies showed the change in invasion of freshwater snail intermediate hosts in Ethiopia. But some of fresh water snail species are medically important. They are intermediate hosts for a number of trematodes. The trematodes rely on specific species of snails to complete their life cycle; hence the ecology of the snail is a key element in transmission of the parasites, schistosomiasis (Pedersen et al., 2014). The epidemiology of schistosomiasis and its intermediate snail host in Ethiopia is well documented. However, new snail foci and infectious areas have been discovered in different parts of the country mainly due to land-use changes. In Ethiopia the prevalence of human schistosomiasis has been known to be endemic and causes substantial public health and socio-economic impact (Amsalu et al, 2015). The current uncontrolled agricultural and water resource development in Awash Valley is a witness for the cause of schistosomiasis prevalence (Laikemariam et al., 2005).

Different studies conducted in Ethiopia showed that Omo-Gibe river basin also changed due to human activities. This change may cause the freshwater snail intermediate hosts distribution in areas. Land-use maps were stitched together in Geographic Information System (GIS) to produce a seamless map along the lower Omo-Gibe flood plains by the analysis of (UNEP, 2012) that showed the area under cultivation or agriculture, including recession agriculture, was around 3, 738ha. Diseases and the agents causing them are spatially and temporally distributed and geodatabases integrating data from multiple sets of information are managed within the frame of GIS to identify the disease cluster and distribution (Fletcher, 2013). Thus, as (Simoonga et al., 2009) indicated, the use of remote sensing (RS) and GIS have been instrumental for identification and mapping of high-risk areas of Omo-Gibe river basin in order to prioritize national schistosomiasis control programs.

1.2. Statements of the problem

Globally, next to malaria, nearly 800 million people are currently exposed to schistosomiasis and more than 600 million live in Africa. More than 200 million people are infected with schistosomes of which 95% are live in sub-Saharan Africa and many more are living in areas where transmission is on-going (Jourdan, 2012). From (WHO, 1994) report schistosomiasis principally affects people who are unable to avoid contact with water, either because of their profession (agriculture, fishing) or because of a lack of a reliable source of safe water for drinking, washing and bathing. As a result of a low level of resistance and intensive water contact of children aged between 10 and 15 years are the most heavily infected group.

For vector-borne infections, the distribution and abundance of vector organisms and intermediate hosts are affected by various physical (temperature, precipitation, humidity, surface water and wind) and biotic factors (vegetation, host species, predators, competitors, parasites and human interventions) are the causes explained by (Woodward, 2003). The effect of schistosomiasis on human health is high especially in resource poor countries like Ethiopia. There are five main schistosome species may cause disease in humans: *S. haematobium*, *S. mansoni*, *S. japonicum, S. intercalatum* and *S. mekongi* (Jourdan, 2012). *S. haematobium* is causing urinary schistosomiasis whereas; *S. mansoni*, *S. japonicum, S. intercalatum* and *S. mekongi* are causing intestinal schistosomiasis. Intestinal schistosomiasis is the major causes of morbidity in most parts of Ethiopia. Most intermediate snail hosts of human Schistosoma parasites belong to two genera. These are Biomphalaria, a host for *S. mansoni* which causes intestinal schistosomiasis and Bulinus a host for *S. haematobium* which causes urinary schistosomiasis (Obikwelu, 2016). *Biomphalaria pfeifferi* is generally considered to be the most important *S. mansoni* transmission in Ethiopia, due to its widespread distribution (Alebie et al. 2014). People are in contact with infested fresh water during their normal daily activities of fishing, farming, swimming, washing, bathing, recreation, and irrigation (Jember, 2014). School age children are the vulnerable segments of the population (Mesfin, 2015). This was supported by most of the studies in Ethiopia like: an epidemiological study with the objective to assess the establishment of transmission of *S. mansoni* in Tikur Wuha area, southern Ethiopia (Mitiku et al; 2008), an infection prevalence of human intestinal schistosomiasis; *S. mansoni* in communities living near three rivers of Jimma town, Omo-Gibe river basin (Mengistu et al., 2011) respectively.

Numerous studies conducted in different localities of Ethiopia mainly deal with the prevalence of *S. mansoni* infection and its control only. Yet its endemicity has long been established and new foci have also been continuously reported (Amsalu et al., 2015). Still information on the environmental factors affecting the distribution of freshwater snail intermediate host and schistosomiasis infection prevalence is not widely reported.

Spatial risk mapping basically indicate the suitability of an area for the emergence or spreading of the intermediate freshwater snail hosts and the prevalence of schistosomiasis diseases. Therefore, this study is useful to: (1) determine the effects of land-use on the distribution of freshwater intermediate hosts in area of Omo-Gibe river basin where to organize containment measure in a cost-effective manner and map the distribution of freshwater snail intermediate hosts, cercariae shedding snail species, and schistosomiasis prevalence in Omo-Gibe river basin.

1.3. Significance of the Study

The information obtained from this study will:

- Inform snail intermediate hosts fauna, distribution and infection prevalence,
- Support measures to control freshwater snail species which are vectors of schistosomiasis,
- Allow integrated intervention among different stakeholders to monitor the distribution of potential medically important freshwater snail species and schistosomiasis infection prevalence.

Moreover, this study will provide important base line information for further comprehensive investigation in the Omo-Gibe river basin, South-west Ethiopia.

CHAPTER-TWO: LITERATURE REVIEW

2.1. Intermediate snail host Biology

Some freshwater snail species are possible medical or veterinary importance. Most intermediate hosts of human Schistosoma parasites belong to three genera, Biomphalaria, Bulinus and Oncomelania. The snails can be divided into two main groups: aquatic snails that live under water and cannot usually survive elsewhere (Biomphalaria, Bulinus), and amphibious snails adapted for living in and out of water (Oncomelania), (WHO, 1994).

2.2. Intermediate snail hosts Taxonomy

Some of the fresh water taxonomy includes kingdom animalia, phylum Mollusca (Snails, Slugs or gastropods, mussels, squids, and others). Mollusks are a group of soft-bodied animals that includes snails, scallops, clams, and sea slugs. Most mollusks have shells: univalves, like snails, have one shell; bivalves, like clams, have two. Some mollusks, such as the squid and octopus, have lost their shells during their evolution. The phylum Mollusca (including snails and slugs (Gastropoda), mussels and clams (Bivalvia), squids and octopuses (Cephalopoda), and a few other less well-known species distributed in five other classes) is the second most diverse taxonomic group of freshwater snail, (Christine, 2008). On the other hand, (BAKER, 2004) described, Mollusca can be grouped to Bivalves, Prosobranchia or gastropods, and Pulmunate or gastropods which includes different families such as Lymneaidae, Physidae, Planorbidea and Valvatidea,

2.3. Intermediate snail hosts Ecology

Freshwater Snail habitats include almost all types of freshwater bodies ranging from small temporary ponds and streams to large lakes and rivers, (WHO, 1994). Their ecological requirements are qualitatively similar but quantitatively different. The quantitative ecological differences between species can relate either to the optimum conditions or to the tolerable extremes presented by the various environmental factors or to both. A few species are ecologically specialized and are adapted to particular optimum conditions, (BENGT, 1947). The specimens of snail intermediate hosts identified as G. ticaga based on the following characters: elliptical shell aperture; projected rounded apex on the posterior right quadrant of the shell, flexed to the right, sometimes extended beyond the right margin; protoconch with an apical depression, with a short smooth and flat area followed by an area with irregular punctuations; teleoconch with concentric growth lines; radial lines absent or present; mantle with dark pigmentation, sparse, tending to concentrate in the left side; anterior right elliptical muscle scar, tear drop-shaped; anterior left muscle scar and posterior muscle scar rounded from (Luiz et al., 2011).

2.4. Intermediate snail hosts Morphology

Freshwater snails come in a variety of shapes and sizes. Some snails are almost completely round in shape, but most species are generally conical. Adults of some species are smaller than the head of a pin and others larger than a baseball, (Johnson et al., 2009). On the other hand study of (Joshua et al., 2015) indicated, there are three species of freshwater snails (*B.forskalli, B.globosus and L.natalensis*) were identified based on shell morphology and standard criteria.

2.5. Schistosomiasis prevalence and Epidemiology

Schistosomiasis is a water-borne parasitic disease endemic in tropical and subtropical areas. Its transmission depends upon the presence of snails, which serve as intermediate hosts for the parasite (Xu et al., 2004).

People become infected when they come into contact with water bodies harboring freshwater snails that have been infected during the urine and feces of infected people contaminate the water body in which they live (Stephanie et al., 2013). In addition, (Isabwe et al., 2012) reported that people are contaminated with schistosomes when they get in contact with fresh water containing potential intermediate host snails. This is mainly done when exposure to an activities like water collection and washing clothes, or swimming in water bodies such as lakes and ponds (Isabwe et al., 2012). As a result of a low level of resistance and intensive water contact when playing and swimming, children aged between 10 and 15 years are the most heavily infected. Increased population movements help to spread the disease,(WHO, 1994).The parasite leaves the snail and enters the skin of people when they are in the water for use. The eggs of these parasites cause massive damage to tissues and organs, resulting in illness and even death (Stephanie et al., 2013).

2.6. Schistosomiasis prevalence Global situation

Many species of the freshwater snail species belongs to the family planorbidea are intermediate hosts of the trematode larva of the genus *schistosoma* which causes schistosomiasis in Africa, Asia, and America. Globally, next to malaria, nearly 800 million people are currently exposed to schistosomiasis and more than 600 million live in Africa. More than 200 million people are infected with schistosomes of which 95% are live in sub-Saharan Africa and many more are living in areas where transmission is on-going (Jourdan, 2012). In addition, (Mohamed et al. , 2011) reported several environmental factors appear to affect the snail populations, in particular, the presence or absence of the aquatic weeds which may be cleaned to reduce the populations of snails those act as intermediate hosts for trematodes. The report of (WHO, 1994) indicated that schistosomiasis principally affects people who are unable to avoid contact with water, either because of their profession (agriculture, fishing) or because of a lack of a reliable source of safe water for drinking, washing and bathing.

2.7. Schistosomiasis prevalence Regional and National situation

The impact of animal activities did show significant effect on the *L. natalensis* in Lake Babati, Tanzania. This might be of highly importance because the prevalence of Fasciola infected livestock in the area where large populations of Lymnea spp. was found to be directly associated with human and domestic animals contact (Lydig, 2009). As (Kock et al., 2004) comfirmed, *B. pfeifferi*, intermediate host of *S. mansoni*, plays a major role in the transmission of intestinal schistosomiasis in the endemic areas of South Africa. The survey of (Mebrate et al., 2014) and the epidemiological study of (Alebie et al., 2014) also indicated as the prevalence of schistosome infection in *B. pfeifferi* was high so that *S. mansoni* is common in Ethiopia. *Schistosomiasis mansoni* infected young children, the collection of *Biomphalaria sudanica* infected with schistosome cercariae, and the establishment of infection in the laboratory all confirmed the transmission of *S. mansoni* in Tikur Wuha, Ethiopia by (Mitiku et al., 2008). The predictive risk map could serve as a practical guide for the effective implementation of interventions for health professionals in local schistosomiasis control stations (Qiu et al., 2014). A predictive map of environmental suitability of (Walz1 et al., 2015) for schistosomiasis transmission can support measures to gain and sustain control. Therefore, the risk map of land use effect on schistosomiasis prevalence in Omo-Gibe can provide the potency of snail intermediate host distribution that needs an attention to withstand control. There are different ways to control the prevalence of schistosomiasis: (a) improved detection and treatment of sick people (b) improvement of sanitary facilities for safe and acceptable disposal of human excreta (c) provision of safe drinking-water (d) reduction of contact with contaminated water and (e) snail control (WHO, 1994). To control schistosomiasis prevalence the control of snail intermediate hosts is the major component. Therefore, Environmental (Boelee & Madsen, 2006) and Biological (Moses et al., 1996) control of snails intermediate host offers good alternative approaches in reducing man-water contact as well.

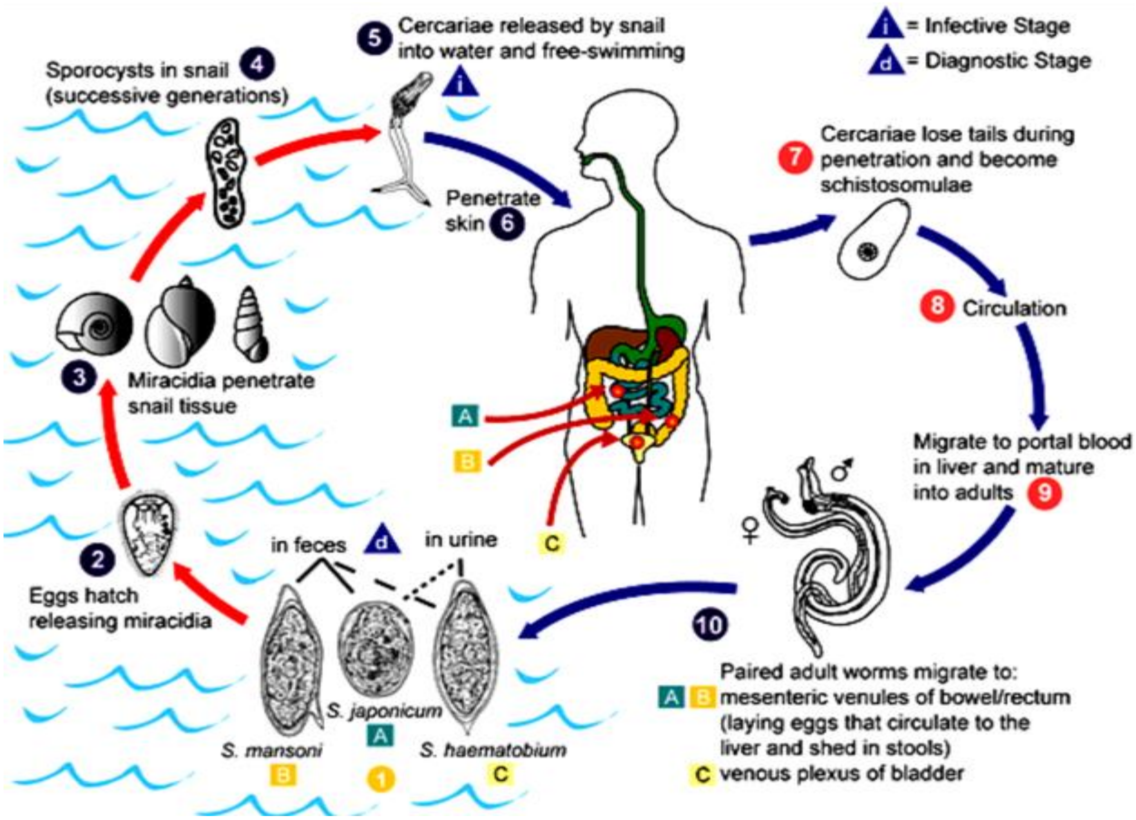

Figure1: Life cycle of schistosoma species, (Laikemariam et al., 2005)

2.8. Land-use Changes and anthropogenic activities

Land use change is one of the most commonly cited contributing factors to infectious disease emergence, yet the mechanisms responsible for such changes and the spatial scales at which they operate are rarely identified (Hartson et al., 2011). Land-use and anthropogenic activities can have an impact on freshwater snail species distribution and control (Qiu et al., 2014). Also, changes in the river quality influenced by land-use including intensive agriculture and settlements (Maldonado, 2010). It is recognized that the names of these land categories are a mixture of land cover (e.g., Forest land, Grassland, Wetlands) and land-use (e.g., Cropland, Settlements) classes. For convenience, they are here referred to as land- use categories (Penman et al., 2003).

The vegetation loss rate is higher than the nation's deforestation rate. This loss is compensated by the increase in the Built-up/Bare surface area mainly due to human activities (Antwiagyakwa, 2014).

Vegetation nearby a settlement is most likely to be over exploited, like most parts of Ethiopia people. Thus, settlement has been considered as one of the factors that influence vegetation vulnerability of the study area (Amdie, 2007).

The land-use change in Nadda, Asendabo area of Omo-Gibe may affect natural resources (Abate & Lemenih, 2014). Their study concluded that current trends in land use must be improved, towards the resources management and conserving of the existing vegetation and other natural resources.

2.9. Land-use effect on water quality and habitat conditions

Other land uses affect stream condition, including forestry, mining, and recreation. However, most landscape studies influence of land-use on streams have contrasted the varying extent of agricultural, settlement, and natural (usually forested) land (Allan et al., 2012). The physical and chemical parameters in- and near-stream variables, which can be categorised as anthropogenic activity, were identified as adequate predictors of macroinvertebrate community composition within the upper catchment of the River basin (Maldonado, 2010). The rapid population growth and increasing settlement on Oahu has resulted in substantial stream habitat alteration (Anne et al., 2001). Instream habitat characteristics at the settlement and mixed (settlement and agriculture) land- use sites were markedly different from those at the forested sites. Both physical characteristics and water quality parameters are pertinent to characterization of the stream habitat. The information required includes measurements of physical characterization and water quality made routinely to supplement biological surveys (Barbour, 1998). Water quality can be affected when watersheds are modified by alterations in vegetation, sediment transport, fertilizer use, industrialization, urbanization, or conversion of native forests and grasslands to agriculture (Agency, 2008). In addition, water physicochemical parameters (transparency, turbidity, dissolved oxygen, conductivity, hardness, nutrients and pH) were taken to establish their influence on the snail abundance and habitat preference (Gabriel et al., 2014). Conservation and recovery efforts for freshwater snails include artificial culture, water pollution control, and most importantly, habitat protection and restoration (Johnson & Aquarium, 2009).

Hence, as the study of (Abate & Lemenih, 2014) the level of agricultural and built up in Omo-Gibe has increased the whole periods that affects other land-use mainly grass land, forest land, riverine forest land and Shrubsland. This change in natural conservation may affect the water physical and chemical quality that can facilitate the occurrence of freshwater snails.

2.10. Land-use effect to Occurrence of Freshwater Snail species

Freshwater snail abundance for each 30 m resolution grid was then predicted by regressing field survey data with land-cover and land-use fractions. Mapping of freshwater snail intermediate hosts in the three geographical zones of Imo-State was determined by surveys of selected community water contact sites such as swamps, pond fast and slow flowing water bodies (NJOKU, 2011). Subsequently, a snail density map was generated using the territory of each of the over 200 residential groups as a mapping unit (Xu et al., 2004). On the other hand study of (Joshua et al., 2015) indicated, there are three species of freshwater snails (*B.forskalli, B.globosus and L.natalensis*) were identified based on shell morphology and standard criteria. Sometimes the number of freshwater snails observed in surveyed land-use can be decline. For instance, the freshwater snails in Toa Dum Forest, Saiyok National Park investigated by (Krailas, 1999), only one species of snail the family Pleuroceridae was found in the stream.

As (Sangwan et al.,2016) study indicated, within the semi-arid and irrigated districts of Rohtak and Jhajjar, India, freshwater snails are more likely to be present in areas growing rice. The central, eastern and north-north-eastern parts of the two districts of India farm land area were shown to have the highest risk of snail occurrence with the south-west and south-east having the lowest risk (Sangwan et al.,2016). The study of (Xu et al., 2004) suggested also, snails of the species Oncomelania hupensis live along the edges of irrigation ditches in crop fields. The distribution maps shows that many of the freshwater Mollusca were not found throughout (i.e., their distributions were non- random). As (Lydig, 2009) described this distribution and natural division of the genus Bulinus into two different subgenera: Physopsis and Bulinus spp. which also includes the old subgenus Pyrgophysa. Lymnea, family Lymnaeidae, is a fresh water snail with a thin dextral (right) opening shell and in Africa.

2.11. Land-use in relation to freshwater snail intermediate hosts distribution

Freshwater snail abundance for each 30 m resolution grid was then predicted by regressing field survey data with land-use fractions. Mapping of freshwater snail intermediate hosts in the three geographical zones of Imo-State was determined by surveys of selected community water contact sites such as swamps, pond fast and slow flowing water bodies (NJOKU, 2011). Subsequently, a snail density map was generated using the territory of each over 200 residential groups as a mapping unit (Xu et al., 2004). Sometimes the number of freshwater snails observed in surveyed land-use can be decline. For instance, the freshwater snails in Toa Dum Forest, Saiyok National Park investigated by (Krailas, 1999), only one species of snail the family Pleuroceridae was found in the stream.

As (Sangwan et al.,2016) study indicated, the central, eastern and north-north-eastern parts of the two districts of India farm land area were shown to have the highest risk of snail occurrence with the south-west and south-east having the lowest risk (Sangwan et al.,2016). The study of (Xu et al., 2004) suggested also, snails of the species *Oncomelania hupensis* live along the edges of irrigation ditches in crop fields. The distribution maps shows that many of the freshwater Mollusca were not found throughout (i.e., their distributions were non- random). As (Lydig, 2009) described this distribution and natural division of the genus Bulinus into two different subgenera: Physopsis and Bulinus spp. which also includes the old subgenus Pyrgophysa. Lymnea, family Lymnaeidae, is a fresh water snail with a thin dextral (right) opening shell and in Africa.

2.12. Association of land-use and cercaria shading snail distribution

The distributions of parasites with complex life cycles depend on interactions between multiple host species, suggesting the net effects of land-use on infection patterns may be difficult to predict the prior (Hartson et al, 2011). Trematodes require one definitive host and one or two intermediate hosts to complete their life cycle. In these hosts, the trematode passes through different development stages, including the adult, egg and various larval stages, such as the miracidium, cercaria and others. One of the hosts of these trematodes is almost always a snail that acts as an intermediate host, in which the cercaria stage is developed. Eggs are eliminated with feces or urine under optimal condition hatch in to miracidia which swim and penetrate specific snail intermediate hosts develop to cercaria (Laikemariam et al., 2005). The infective cercaria leaves the snail host to water and swims around till it finds the next host in its life cycle (Graham, 2003).

Major types of cercariae are: *Brivifurcate apharyngeate diastome cercariae* (BAD), *Amphistome cercariae*, *Brivifurcate apharyngeate monostome cercariae* (BAM), *Furcocercous cercariae*, *Echinostome cercariae* and *xiphidiocercariae*. The investigation of (Krist, 2014) also found four different trematode cercarial types such as *Echninostome cercariae*, *Furcocercous cercariae*, *monostome cercariae*, and *Xiphidiocercaria*.

Biological characteristics species of cercariae-producing snail are also insufficient for identification on the species level because the same snail species may be host for more Schistosoma species within the same geographical area (Frandsen et al., 2015).

The most common type of cercariae recovered from irrigation canals of two important agricultural schemes, at an area of about 8000 km^2 located in the north- eastern part of Khartoum, Sudan was xiphidiocercariae from *B. truncatus* snails infections, (Mohammed et al., 2016). In addition, freshwater snails sampled from swamp forests Chitwan district of central Nepal, the types of trematode cercariae like *Amphistome*, *Brivifurcate-apharyngeate* and *xiphidiocercaria* are reported by (Ramesh et al., 2011).

Conceptual Frame Work

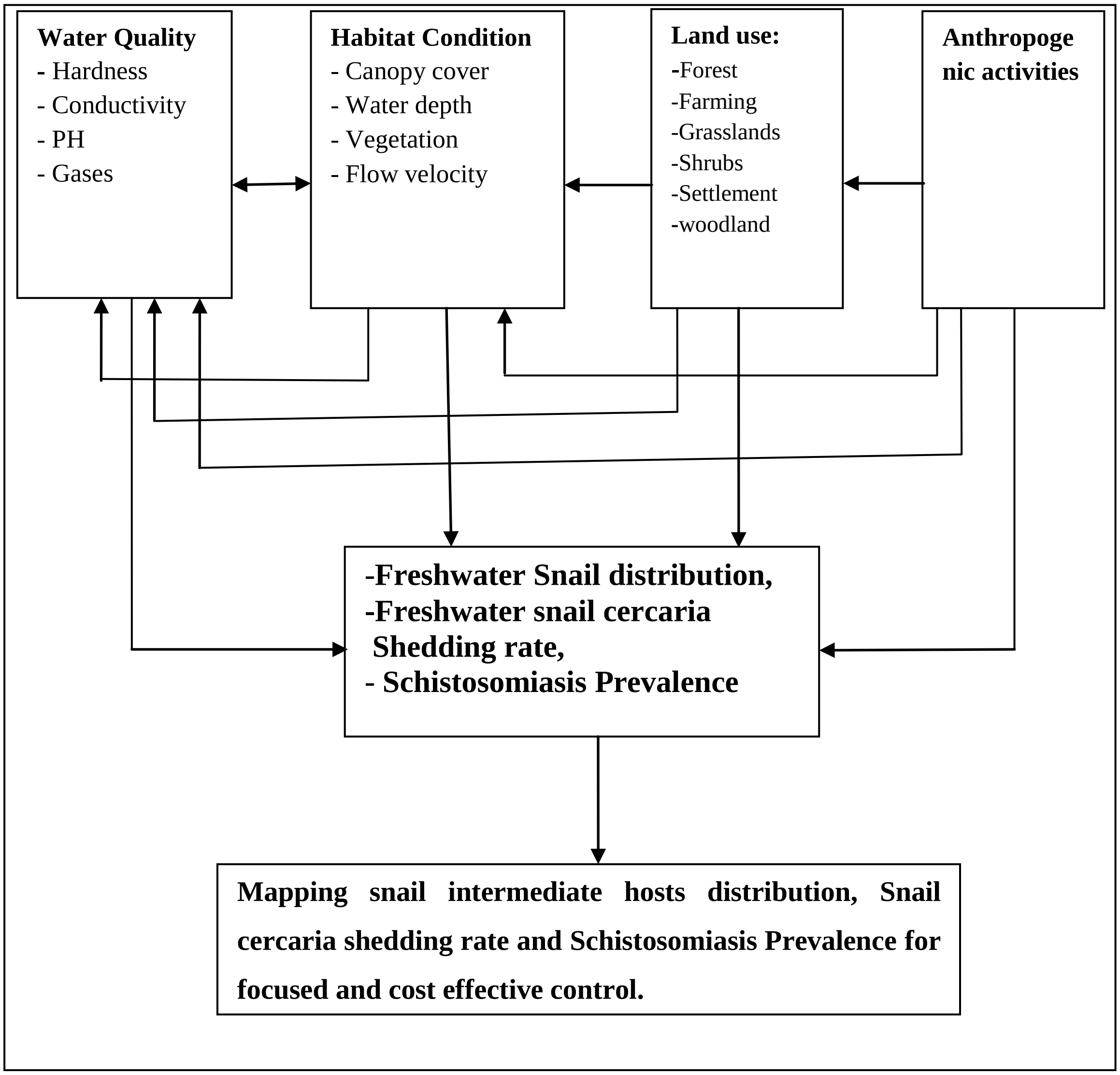

Figure 1: Conceptual frame work of the study.

CHAPTER THREE: OBJECTIVES

3.1. General objective

The general objective of the study is to determine and map the effects of land-use on the distribution of freshwater snail intermediate hosts, cercariae shedding snail species, and schistosomiasis prevalence in Omo-Gibe River basin, Southwest Ethiopia.

3.2. Specific Objectives

The specific objectives of this study are:

- To locate/map land-use on distribution of freshwater snail intermediate hosts in Omo-Gibe river basin.
- To indicate cercaria shedding rate distribution of freshwater snail intermediate hosts in Omo-Gibe river Basin.
- To indicate the prevalence of schistosomiasis in schoolchildren in Omo-Gibe river basin.

CHAPTER FOUR: METHODS AND MATERIALS

4.1. Study Area

The study was carried out in one of the nine river basins of Ethiopia, Omo-Gibe southwest Ethiopia, extending from 4°25'51.611" to 9°22'28.047"N latitude and from 34°57'7.941"E to 38°24'42.242"E longitude (Figure 2). Elevation data derived from digital elevation model (DEM) imagery shows that the area is located at an altitude range between 299 and 3851 m.a.s.l. (Hurni et al., 2015). Altitude classification from DEM also indicate that the watershed has four Agro-ecological zones which include Kolla (38%), Weyna Dega (37%), Bereha (19%), and Dega (6%). This river basin has a total length of 760km, and annual water volume of 17.96BMC. The areas under the basin of the study comprises Chebera Churchura National Park (CCNP) which is located within Dawro zone and in Konta special district, about 300 and 580 km southwest of Awassa and Addis Ababa, respectively. It lies between the coordinates 36°27′00″ - 36°57′14″ E longitude and 6°56′05″ - 7°08′02″ N latitude. It also lies at the center of Omo-Gibe River Basin (Datiko & Bekele, 2013) with two main crater lakes, Bulo (koka) and Keribela. Another areas of the sampling stations lies in Oromia Regional state, Jimma Zone, Gilge-gibe tributaries and Nile tributaries.

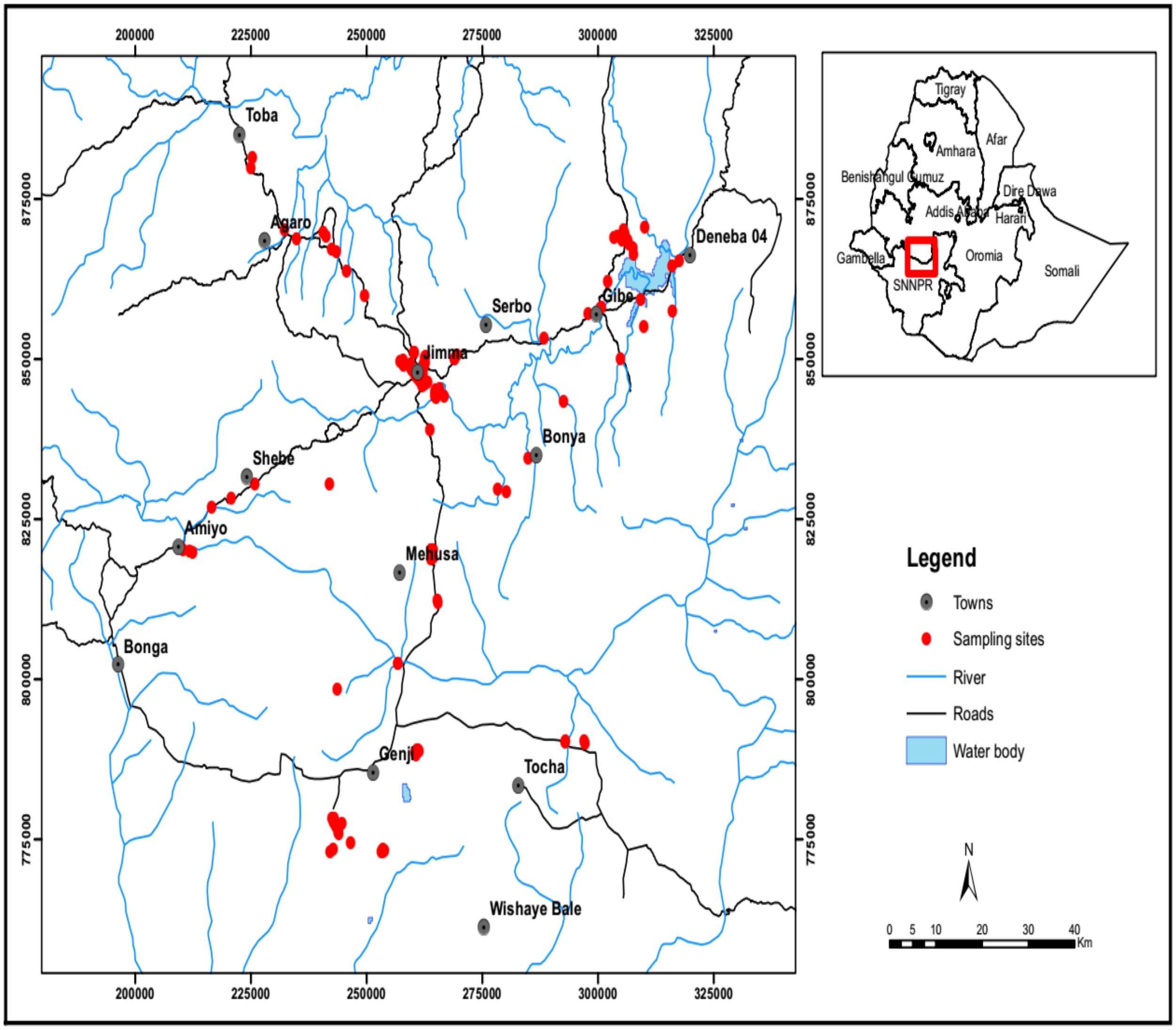

Figure 2: Map of the sampling stations in Omo-Gibe River basin, Ethiopia.

4.2. Study design and Period

A cross-sectional study was employed from February to May, 2016 in dry season to determine and map the effect of Land use on the distribution of freshwater snail intermediate hosts and prevalence of schistosomiasis infection in Omo-Gibe river basin, southwest of Ethiopia.

4.3. Study Variables

- Water quality related variables
  - pH
  - DO
  - BOD
  - TH
  - NO_3^-
- Land use related variables
  - Settlement areas,
  - Farmlands,
  - Grassland,
  - Open woodlands,
  - Forest,
  - Shrubslands/Bush.

Independent Variables

- Snails intermediate hosts related variables
  - Snail fauna abundance and distribution,
  - Snail shedding rate,
  - Schistosomiasis prevalence.

Dependent Variables

4.4. Study Site selection

Prior of the sampling, the sites were randomly selected based on preliminary survey to represent a gradient of human impact levels, from most-impaired to least-impaired by anthropogenic activity (such as irrigation canals, dams, mining, washing, grassing, farming…) according to pilot study by (Abraham, 2011) and personal observation during sampling on the surrounding area in addition using digital GPS material for gathering data of land-use which to be feed in GIS tools. The aim of the random site selection was for covering the catchments in order to determine the effect of land-use on freshwater snail distribution and schistosomiasis prevalence in the river basin. The sampling sites were includes habitats like: Lakes (Bulo/Koka Five sampling stations, Keribela five sampling stations), Rivers (Ninety-three sampling stations), spring water (One sampling station), Wetlands (Twenty-two sampling stations), Irrigation ditches (Two sampling stations) and Dams (Two sampling stations). Totally One-hundred and thirty (130) sampling stations were selected and surveyed.

Plate 1: Snails sampling stations selected from different habitats in Omo-Gibe river basin, Ethiopia.

4.5. Snail Collection

Snails were collected from 130 sampling stations between the periods of March 22, 2016 to May 05, 2016. At each station data related to land use with their relative coordinates by (Penman et al., 2003), anthropogenic activities by (Antwiagyakwa, 2014), freshwater snails by (DNRE, 1999), water samples by (APHA, 1999) and related articles were collected. During snail collection for personal protection materials (PPE) such as Gloves-shoulder length (3 pairs), Glove-wrist length (3pairs), Chest waders/ Hip boot (5 pairs), and Glove-short length (2 pairs) were used To consider the difference in ecological effects of the streams the sampling stations were carefully analyzed with in 300m to 500m radius (Boothroyd et al., 2001). On field the water samples were handled in cooler box with an ice. All the samples were transported to the laboratory of Department of Environmental Health Sciences of Jimma University.

4.6. Sample size and sampling Technique for Schistosoma

For *Schistosomiasis* infection study on filed examination was done by taking sample of stool from each selected school age children at six different elementary schools for Kato-Katz technique which adapted from laboratory procedure of (Nascimento et al., 2017). The materials used were: Light microscope, Mesh, plates, Spatula, Reagents, Weighing scale, Piece of paper, Marker, a pair of scissor/scalpel, and distilled water, (Nascimento et al., 2017).

The sample size was determined by single population proportion formula which the CI was 95% considered.

$$\boxed{n = \frac{(z_{\alpha/2})^2 \cdot pq}{d^2}}$$

, P (1-P) = p q, where (1-p) = q.

P = expected prevalence rate of (0.5)

Z = statistics for level of confidence

d= marginal error or measure the precision of the estimate

n= Minimum sample size

$Z\alpha/2$= the standard normal variable at 1-α% (1.96)

Therefore, [$n = (1.96)^2 * 0.5(1-0.5) / (0.05)^2 = 384 \approx 380$].

But four samples were rejected because of the stool was not suitable for the Kato-Katz technique since diarrheal stool. The schools were selected based on the proximity of the water body where the snail intermediate hosts for cercaria shedding were collected. Numbers of schoolchildren were selected based on the proportional allocation for schools and from each school students (schoolchildren) were selected by the simple random sampling technique using student's master sheet (Roster) as a sample frame.

Plate2: Snail collection from different habitats of Omo-Gibe river basin, Ethiopia.

4.7. Snail Identification

Snails were collected from each sampling sites using a scoop (20 x 30cm) with a mesh size of 300µm. Each collection entails a 10-minute kick sampling at a radius of 10 meters (DNRE, 1999). Time was allotted proportionally to cover different meso-habitats such as open water and emergent vegetation. The bottom sediment was disturbed by foot during sampling in order to collect the benthic macroinvertebrates (Gabriels et al., 2007). Snails were sorted on white Enamel pan using Forceps and stored in to vials containing (70% - 80% ethanol) and labeled for morphological identification (Barbour et al, 1998). Live snails were sorted carefully by hand covered with Glove and put in clean plastic buckets half filled with water from the same habitat and labeled on the field. Afterwards, snails were maintained and feed with fresh lettuce leaves and identified to species and family level using a stereomicroscope (10 x magnifications) according to the identification key method of (Javier, (2011), Barth, (1958) used in the laboratory of Department of Environmental Health Sciences of Jimma University.

Each snail was examined for cercaria shedding by placing in a petri dish containing 10 ml water in the sun for 2 hours and cercariae were identified using keys of (Cheng, (1986) and (Daily, *et. al.*, (1996). Freshwater snails and cercariae harvested from the study sites were morphologically identified under the microscope by the standard method of (Sharif et al., (2010), (Fatima et al., (2018). Finally both cercariae and snails were preserved in (70%-80%) ethanol, (Barbour et al, 1998). Also the macroinvertebrates data were collected using a (scooping net) from different habitats types (rifle, pool and open water emergent vegetation) based on the sample processing protocol (Boothroyd et al., 2001).

Plate3: Morphological identification of snails to species using Dissecting Microscope and water quality analysis.

4.8. Habitat Sampling

Sampling habitats for snails included similar areas within or adjacent to other habitat types, for example pockets of emergent, floating-leaved or submerged vegetation occurring within a shrubs around wetlands, lakes, irrigation ditches, dams, rivers and springs. The physical features measured including vegetation cover, canopy cover, water depth variables and adjacent land-use type with anthropogenic patterns (grazing, car washing, tree removal/plantation, clay mining, draining, waste dumping, land filling and water abstraction) were seen according to (Mereta et al., 2012).

The habitats sampling sites were included watersheds of Omo-Gibe River basin according to (Javier etal.,(2011),(Difranco,(2014).

Plate4: Snail, water and other macroinvertebrates sampling from different sites selected from Omo-Gibe river basin, Ethiopia.

4.9. Water Quality Parameter

To see variations in water quality parameter due to land-use change, a number of environmental parameters of the water were recorded during the study.

Chemical pollution was a factor in most streams so that the major chemical pollutants (i.e. the physico-chemical parameter) were recorded (States, 1998). Temperature (^{0}C), conductivity (µS.cm^{-1}), pH, dissolved oxygen saturation (DO %), dissolved oxygen concentration DO (mg/L), turbidity (NTU) using multi-meter probe (HQd4 single input Multi-parameter Digital Meter, Hatch), and transparency(cm) of wetlands and lakes were measured by a Secchi-disc (UNEP/WHO, 1996) onsite at each sampling location using hand electrodes material according to the standards (Barbour et al., 1998; Lamberti, 2007).

Water from each sampling stations was collected using a thoroughly rinsed one-liter volume materials (1000 mL sizes of PVC plastic bottles) and taken to laboratory of Department of Environmental Health Science of Jimma University, using cold box and water sample was kept deep freezer for further analysis of total Hardness (TH), biochemical oxygen demand (BOD_5), orthophosphate(PO_4^{2}), total suspended solids (TSS), Calcium & Magnesium (Ca^+, Mg^+), Electrical conductivity (EC) and nitrate (NO_3^-) concentration according to the standard methods as prescribed by (APHA, 1999). The habitat data: the water channel width, water depth, flow velocity, riparian vegetation, canopy cover, and water sinuosity were estimated following the method described by (Service, 2014 and Barbour et al., 1999).

4.10. Data Analysis

The snail species, land-use type data and site coordinates (Latitude, Longitude) were collected. The coordinates from each station collected using hand-held GARMIN GPS unit from the sampling sites and had been converted to UTM and entered to Microsoft Excel. Then the data that entered to Excel was verified and converted to shape file using ArcGIS software version 10.3.1 and utilized for mapping of freshwater snail species distribution, freshwater snail species density, Cercaria shedding snail species distribution and prevalence of schistosomiasis in schoolchildren.

In addition, data were entered into Microsoft Excel and exported to SPSS version 20.0 for statistical analysis. Thus, ANOVA is used to analyze associations between factors where chi- square and F-tests are applied to evaluate significances and the symmetric value of phi coefficient was used for strength association of variables. Prevalence of cercaria shedding rates in snails and schistosoma infection prevalence in humans were determined by descriptive statistics. The $p \leq 95\%$ (or $p \leq 0.05$) was considered significant during the analysis.

4.11. Operational definitions

Land use: is the effect of Agricultural land use types, i.e. forest cover, agriculture and mixed cover (forest plus agriculture) and Grazing in the long process.

- is the classification of land in to Agriculture, Grazing, Forest cover, Mixed of activities, etc. on land (Maldonado, 2010).

Intermediate host: the organism which harbors the larval stages of the parasite or an asexual cycle of development takes place.

Parasite: is a living organism, which takes its nourishment and other needs from a host.

Cercariae: the free-swimming larva of a trematode (usually possessing a tail) which escapes from molluscan host and constitutes the transfer stage to the next host.

Schistosomiasis Infection*:* any of various tropical and sub- tropical diseases caused by parasitic blood flukes of the genus schistosoma (Bilharzia).

Infection: Containing the property of producing infection; Invasion of a host (tissues or cells) resulting in injury and reaction to that injury, i.e. disease.

Forest: Mostly refers to canopy or crown cover, which is essentially the percentage of ground area shaded by the crowns of the trees when they are in full leaf.

4.12. Ethical considerations

Ethical clearance was obtained from ethical committee of Jimma University, College of Public Health and Medical Sciences. In line permission paper was obtained from different concerned authorities and offices. For study prevalence of *S. mansoni* ethical clearance also obtained from Jimma University College of public Health and medical science. Consent was obtained from guardians/parents for schoolchildren to participate in the study. Those who were positive to *S. mansoni* treated in according the national guideline treatment by experienced health officers and nurses.

4.13. Quality Control and Quality assurance

Samples were preserved and identified in the laboratory. The sampling mechanism was followed the procedure that it was started from downstream proceeded to upper stream. Kicking materials were clean enough in frequencies of kicking for sampling and for the better quality of sampling replicates of kicking from one composite site of aquatic species (Duncan, 2008).

4.14. Dissemination

The findings of this study will be disseminated to CBE bureau, to College of health science, to Department of Environmental Science and Technology, to other concerned bodies of health program managers where to deploy containment measures and target interventions in a spatially explicit and cost effective manner.

Finally, efforts will be made to publish the findings of this study at national and international journals.

CHAPTER FIVE: RESULTS

5.1. Occurrences and Abundances of Freshwater snail intermediate hosts

The overall 2559 freshwater snail samples collected in 130 surveyed stations of Omo-Gibe river basin, 1749 were belonging to medically important snail species which include: *Biomphalaria pfeifferi* and *Biomphalaria sudanica* (Intermediate host for intestinal schistosomiasis), *Bulinus globosus* (Intemediate host for urinary schistosomiasis), *Lymnea natalensis* and *Lymnea truncatula* (intemediate host of Fasciola that causes *Fascioliasis*). Other none intermediate species recorded during the survey were *Physa acuta* and *Physa spps. B. pfeifferi* was the predominant snail species accounting for 35.4% of the total collection and mainly encountered in (39.2%) of the surveyed stations. It was collected from lakes, wetlands, rivers and irrigation ditches. It was highly prevalent (89.2%) in rivers. However, it was not encountered in springs and dam reservoir shores. *Lymnea natalensis* was the second predominant snail species accounting (16.45%) of the snail population and encountered in (29.2%) of the surveyed stations. The prevalence of *L. natalensis* in wetlands, rivers and irrigation ditches was (69.6%), (24.7%) and (2.10%) respectively. *Bulinus globosus* accounted for only (2.07%) of the total snail population and (16.9%) of the surveyed sites; they were encountered with a frequency of (41.5%) in lakes, (41.5%) in wetlands and (17%) in rivers habitat types. The least common snail species were *L. truncatula,* and *B. sudanica* which were encountered less than 10% of the observation stations, Table (1and 6). The statistical analysis of (Pearson chi-square: x^2 =296.554, and $p<0.05$ or p =0.000) showed significant association to the categorical habitat types.

Table 1: Frequency and abundance of freshwater snail species recorded in different habitats in Omo-Gibe river basin, Ethiopia.

		Habitat Type						
		Lake	Wetland	River	Dam	Irrigation ditch	Spring	
Snail Species		n%	n%	n%	n%	n%	n%	Total
L. natalensis	Frequency	3.60%	69.60%	24.70%	0.00%	2.10%	0.00%	100.00%
	Abundance	15	293	104	0	9	0	421
L.truncatula	Frequency	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	100.00%
	Abundance	0	0	18	0	0	0	18
P. acuta	Frequency	0.00%	83.60%	16.40%	0.00%	0.00%	0.00%	100.00%
	Abundance	0	281	55	0	0	0	336
P. Spp.	Frequency	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100.00%
	Abundance	0	7	0	0	0	0	7
B. pfefferi	Frequency	2.90%	6.40%	89.20%	0.00%	1.50%	0.00%	100.00%
	Abundance	26	58	808	0	14	0	906
B. sudanica	Frequency	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
	Abundance	8	0	0	0	0	0	8
B. globosus	Frequency	41.50%	41.50%	17.00%	0.00%	0.00%	0.00%	100.00%
	Abundance	22	22	9	0	0	0	53
Sphaeriidae	Frequency	0.00%	77.80%	22.20%	0.00%	0.00%	0.00%	100.00%
	Abundance	0	630	180	0	0	0	810
Total	Frequency	2.80%	50.40%	45.90%	0.00%	0.90%	0.00%	100.00%
	Abundance	71	1291	1174	0	23	0	2559

5.2 Habitat conditions in relation to land-use types

Table 2 shows that the mean water flow velocity in different land-use patterns. It was highest at Woodland with (Mean=0.67) and the least was recorded at Grassland areas with (Mean=0.19). On the other hand the highest mean water depth was recorded from Settlement areas with (Mean=0.49). Canopy cover and vegetation cover were comparatively higher in Forest areas with (39.7% and 28.6%) respectively. There was significance difference among different land use patterns ($p < 0.05$). In relation to canopy cover, the percentage mean association was significant, Table 2.1, annex-1.

Table 2: The mean difference of flow velocity, water depth, canopy cover and vegetation cover between land-use types in Omo-Gibe river basin, Ethiopia.

Land-use Types	Flow Velocity (m/s) (M±SE)	Water depth (m) (M±SE)	Canopy cover (%) (M±SE)	vegetation cover (M±SE)
Forest	0.2±0.25	0.3±0.24	75.23±23.58	1.00±0
Shrubsland	0.29±0.36	0.38±0.23	14.21±16.01	0.53±0.513
Grassland	0.19±0.23	0.38±0.26	18.07±24.92	0.63±0.492
Farmland	0.32±0.3	0.31±0.25	28.13±24.72	0.28±0.457
Woodland	0.67±0.31	0.24±0.11	40.5±27.02	1±0
Settlement	0.26±0.27	0.49±0.4	22.5±19.75	0.45±0.51

Among the physical variables shown in Table3, flow velocity, canopy cover and vegetation cover were found to have significant association to land-use types. For the first two variables of analysis of variance was used to compare their average values. In contrasting to this chi-square was used to check the association for vegetation cover to land-use types since it was categorical variable.

The analysis of variance showed that the mean difference between land-use types were statistically significant association in terms of flow velocity and canopy cover at [One Way ANOVA: $F= 4.687$, $P=0.001$ and $F =21.007$, $p=.000$)] respectively, (Table 3).

The post hoc test using Tukey HSD for mean separation and the multiple comparisons in (Table 2 and annex-1), illustrated that there was significant association of mean value in habitat condition, flow velocity, between Woodland ($M=0.67$, $SD=0.31$) and the other land-use types ($p<0.05$). Except with Forest areas, the habitat conditions such as water depth and vegetation cover of the sampling sites have no significance in mean value between themselves, (Table 3 and Table 2.1, annex-1).

Table 3: Mean difference association of the habitat factors groups in relation to land-use type in Omo-Gibe river basin, Ethiopia.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Flow Velocity	Between Groups	1.908	5	.382	4.687	.001
	Within Groups	10.094	124	.081		
	Total	12.001	129			
Water depth	Between Groups	.638	5	.128	1.743	.130
	Within Groups	9.077	124	.073		
	Total	9.715	129			
Vegetation cover	Between Groups	5314833.803	5	1062966.761	2.200	.058
	Within Groups	59923775.774	124	483256.256		
	Total	65238609.577	129			
Canopy cover	Between Groups	55365.634	5	11073.127	21.007	.000
	Within Groups	65361.873	124	527.112		
	Total	120727.508	129			

Vegetation cover among 130 sampling stations observed to have existed in 75 sampling stations. This roughly accounts for about 59.2%; the majority of these located or situated in Forest (16.9%) and Grassland (13.1%) areas, Table 4, annex-1. Therefore, statistical analysis showed significant association between land-use type and vegetation cover, (chi-square: X^2= 37.024, & $p<0.05$ or p=.000), (Table 2.1, annex-1).

5.3 Water quality in relation to land-use types

The water chemical content was analyzed for all 130 sampling stations in relation to land-use types; Table 5 shows the result of water quality analysis.

Therefore, in terms of **pH** content the highest value (M=8.46) was recorded in Settlement area (range 5.3± 6.5 to 7.8 ± 6.5) (Table 5). However, least pH mean value (M=6.87) was recorded in Shrubsland (range 6.28±0.36 to 7.40±0.36). The dissolved oxygen saturation (**DO** %) highest in Forest areas with mean percentage (M=83%) which (range 39.20±67.04 to 376±67.0) whereas the least mean percentage DO (49.6%) was recorded from settlement area (range 2.49±15.60 to 67.50±15.60), Table 5. The water dissolved oxygen concentration (DO mg/L) highest in Settlement areas with mean value (M=21.2 mg/L) which (range 2.36±78.10 to 353.00±78.10) while the least mean value of DO (M=3.87 mg/L) recorded in Shrubsland areas (range 2.40±0.84 to 5.30±0.84). The nitrate concentration (**NO_3^-** mg/L) of the water highest mean value (M=6.04 mg/L) was recorded in Settlement area (range 2.36±78.10 to 353.00±78.10) while the least mean value (M=0.57 mg/L) was recorded in Forest area (2.66±1.06 to 5.74±1.06).

The highest mean value (M=59.55 mg/L) of total hardness (**TH** mg/L) was recorded in Forest area (range 6.00±32.08 to 112.00±32.08) while the least mean value (M=23.80 mg/L) was observed in Woodland area (range 8.00±22.95 to 86.00±22.95). The five days biochemical oxygen demand (**BOD_5** mg/L) highest mean value (M=14.11 mg/L) was recorded in Shrubsland (range 7.50±4.19 to 26.00±4.19) while the least mean value was recorded (M=11.59 mg/L) in Settlement area (range 0.35±6.34 to 28.00±6.34).

Further the analysis of variance was used for compering the water quality parameters mean difference between land-use types showed significant difference only for (**DO**%) [One way ANOVA: F= 3.158, p=0.01], (**TH** mg/L) [One way ANOVA: F = 3.014, p=0.013] and (**NO_3^-** mg/L) [One way ANOVA: F = 4.023, p=0.002], (Table 5.1, annex-1).

Table 4: Results analysis of major Water quality parameter analysis in different land-use types of Omo-Gibe river basin, Ethiopia.

W/Q variables	Land-use types	Mean±SE	SE	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Min	Max.
pH	Forest	7.64±0.19	0.19	7.26	8.03	5.59	9.26
	Shrubsland	6.87±0.08	0.08	6.69	7.04	6.28	7.40
	Grassland	7.04±0.14	0.14	6.76	7.33	5.97	9.10
	Farmland	7.35±0.08	0.08	7.19	7.51	6.31	8.40
	Woodland	7.18±0.16	0.16	6.83	7.53	6.15	8.13
	Settlement	8.46±1.17	1.47	5.39	11.53	5.26	7.81
DO%	Forest	83.21±14.29	14.29	53.49	112.94	39.20	376.00
	Shrubsland	55.20±2.65	2.65	49.63	60.77	35.50	70.40
	Grassland	58.58±3.24	3.24	51.91	65.26	33.20	89.50
	Farmland	62.39±2.27	2.27	57.77	67.02	5.30	86.00
	Woodland	68.04±1.40	1.40	64.87	71.21	63.20	76.20
	Settlement	49.57±3.49	3.49	42.27	56.88	2.49	67.50
DO(Mg/L)	Forest	4.68±0.23	0.23	4.21	5.16	2.66	5.74
	Shrubsland	3.87±0.19	0.19	3.46	4.27	2.40	5.30
	Grassland	3.92±0.21	0.21	3.50	4.35	1.72	5.53

	Farmland	6.50±2.16	2.16	2.10	10.90	2.90	75.50
	Woodland	4.94±0.09	0.09	4.74	5.13	4.60	5.40
	Settlement	21.20±17.46	17.46	-15.4	57.75	2.36	353.00
EC (µS/cm)	Forest	233.64±25.79	25.79	180.01	287.27	63.00	416.00
	Shrubsland	125.37±12.04	12.04	100.07	150.66	42.00	254.00
	Grassland	272.12±113.9	113.9	37.39	506.84	74.00	3107.00
	Farmland	182.21±13.89	13.89	153.91	210.51	82.00	352.00
	Woodland	126.20±19.0	19.00	83.22	169.18	71.00	287.00
	Settlement	231.47±31.52	31.52	165.49	297.45	18.40	549.00
PO_4^{3-}(mg/L)	Forest	0.20±0.05	0.05	0.11	0.30	0.01	0.77
	Shrubsland	0.20±0.05	0.05	0.09	0.32	0.01	0.60
	Grassland	0.16±0.06	0.06	0.03	0.28	0.00	1.29
	Farmland	0.24±0.04	0.04	0.16	0.33	0.00	0.69
	Woodland	0.23±0.08	0.08	0.04	0.42	0.02	0.77
	Settlement	3.26±2.88	2.88	-2.77	9.29	0.00	58.00
TH (mg/L)	Forest	59.55±6.84	6.84	45.32	73.77	6.00	112.00
	Shrubsland	29.79±4.12	4.12	21.13	38.45	10.00	72.00
	Grassland	40.62±7.39	7.39	25.39	55.84	2.00	180.00
	Farmland	43.58±5.19	5.19	33.00	54.15	4.00	108.00
	Woodland	23.80±7.26	7.26	7.38	40.22	8.00	86.00
	Settlement	43.22±5.25	5.25	32.22	54.22	4.00	78.00
NO_3^-(mg/L)	Forest	0.57±0.12	0.12	0.31	0.83	0.00	2.26
	Shrubsland	1.00±0.31	0.31	0.35	1.65	0.00	5.37
	Grassland	0.93±0.29	0.29	0.33	1.53	0.00	5.62
	Farmland	1.08±0.20	0.20	0.67	1.49	0.00	4.95
	Woodland	1.10±0.33	0.33	0.34	1.85	0.07	3.33
	Settlement	6.04±2.62	2.62	0.56	11.52	0.00	41.53
BOD_5(mg/L)	Forest	13.89±1.04	1.04	11.73	16.04	6.50	21.50
	Shrubsland	14.11±0.96	0.96	12.09	16.12	7.50	26.00
	Grassland	11.94±0.97	0.97	9.94	13.95	3.00	24.50
	Farmland	13.02±0.68	0.68	11.63	14.40	3.00	22.00
	Woodland	11.65±1.57	1.57	8.10	15.20	3.00	20.50
	Settlement	11.59±1.42	1.42	8.63	14.56	0.35	28.00
COD(mg/L)	Forest	20.83±1.55	1.55	17.60	24.06	9.75	32.25
	Shrubsland	21.16±1.44	1.44	18.13	24.19	11.25	39.00
	Grassland	17.91±1.46	1.46	14.91	20.92	4.50	36.75
	Farmland	19.52±1.02	1.02	17.44	21.60	4.50	33.00
	Woodland	17.48±2.35	2.35	12.16	22.79	4.50	30.75
	Settlement	17.39±2.13	2.13	12.94	21.84	0.53	42.00

5.4 Distribution of freshwater snails in relation to land-use types

As indicated in Table 7, totally about 2559 freshwater snails representing seven species under four genera and one family level were collected from 90(69.2%) stations of the total 130 sampling stations in Omo-Gibe river basin. The presence or absence of freshwater snails showed in (Table 6 and Table7); Lymnea species freshwater snails, the intermediate hosts of Fasciola, which can cause *Faciolasis*. For instance, *L. natalensis* was collected from the total thirty-eight sampling stations such as seven sampling stations in Forest, six sampling sites in Shrubsland, seven sampling stations in Grassland, six sampling stations in Farmland, one sampling sites in Woodland, and eleven sampling sites in Settlement land-use types respectively. This snail species was not observed in ninety-two sampling stations of all the land-use types. The distribution of *L. truncatula* was observed at seven sampling stations and this snail species was not found at 123 sampling stations of the land-use types except in Forest and Shrubsland of Omo-Gibe river basin.

B. pfefferi, the most known intermediate host of *S. mansoni*, was found frequently in 14 stations of Farmland followed by 12 stations of Settlement land-use types. This freshwater snail species was collected from fifty-one sampling stations of the total 130 sampling stations in all land-use types except at Woodland. From the total sampling stations *B. pfefferi* was not found at seventy-nine sampling stations in all land-use types of Omo-Gibe river basin.

B. globosus is the known intermediate hosts of *S. haematobium*. This freshwater snail species was collected in 8 stations of Forest followed by 5 stations in Settlement of the sampling stations. Generally, it's less distribution observed in all land-use types of the sampling stations except in Woodland. However, it was not found at 108 sampling stations of different land-use types. *B. sudanica* freshwater snail species is also the intermediate hosts of *S. mansoni*. This snail species was collected from 2 sampling stations at the Forest and not found at 128 sampling stations of all land-use types of Omo-Gibe river basin. As can be observed from chi-square, (Table 6.1, annex-1), the distribution of freshwater snail intermediate hosts was insignificant (Pearson chi-square: X^2= 12.985, p=0.024) to land-use types, since the chi-square value was lower than the cut off (21.7) value.

The summary in (Table 6) and (Table 7 annex-2), illustrated that number of sampling stations and the freshwater snails collected from the total sampling stations of Omo-Gibe river basin. For instance, in a Forest land-use type the samples were taken from 22 stations, from Shrubsland 19 sites, from Grassland 27 sites, from Farmland 32 sites, from Woodland 10 sites and from Settlement 20 sites. The predominant and the intermediate host of *S. mansoni* snail species, *B. pfefferi* was highly distributed at Farmland 407(44.9%) followed by Settlement 285(31.4%) and Grassland 114 (12.58%) land-use types respectively.

Table 5: Summary of freshwater snail species distribution recorded in the sampling stations of Omo-Gibe river basin, Ethiopia.

Land-use Types	No. of sites	Freshwater Snail Species							
		L.natalensis	*L.truncatula*	*P.acuta*	*P.spp*	*B.pfefferi*	*B.sudanica*	*B.globosus*	*Sphaeriidae*
Forest	22	31	0	0	0	28	8	22	27
Shrubsland	19	20	0	13	0	72	0	4	106
Grassland	27	26	1	63	1	114	0	10	26
Farmland	32	31	12	10	6	407	0	8	49
Woodland	10	1	2	0	0	0	0	0	77
settlement	20	312	3	250	0	285	0	9	525
Total	130	421	18	336	7	906	8	53	810

Among these freshwater snail species collected, the majority of snail species, more than half 54 % (1384) were collected from Settlement followed by 20.4 % (523) at Farmland land-use type. The least number of fresh water snail species about 3.1 % (80) were collected from Woodland, (Table 4 annex-2).

As showed in Figure 8, the distribution of freshwater snails were numerous at the cultivated or farmed land rainfed; cereal land cover system; that lightly stocked, near forest montane broadleaf; open (20-50% crown cover) and settlement areas followed by grassland moderately stocked and grassland unstocked (woody plant), shrubland; open (20-50% woody cover), but less distribution observed at woodyland; open (20-50% tree cover) types of land-use. On the contrary at the land-use types like forest; montane broadleaf; dense (50-80% crown cover), and moderatly stocked the distribution of freshwater snail species was not observed. The distribution of freshwater snails was observed at same land-use types, Figure 8.

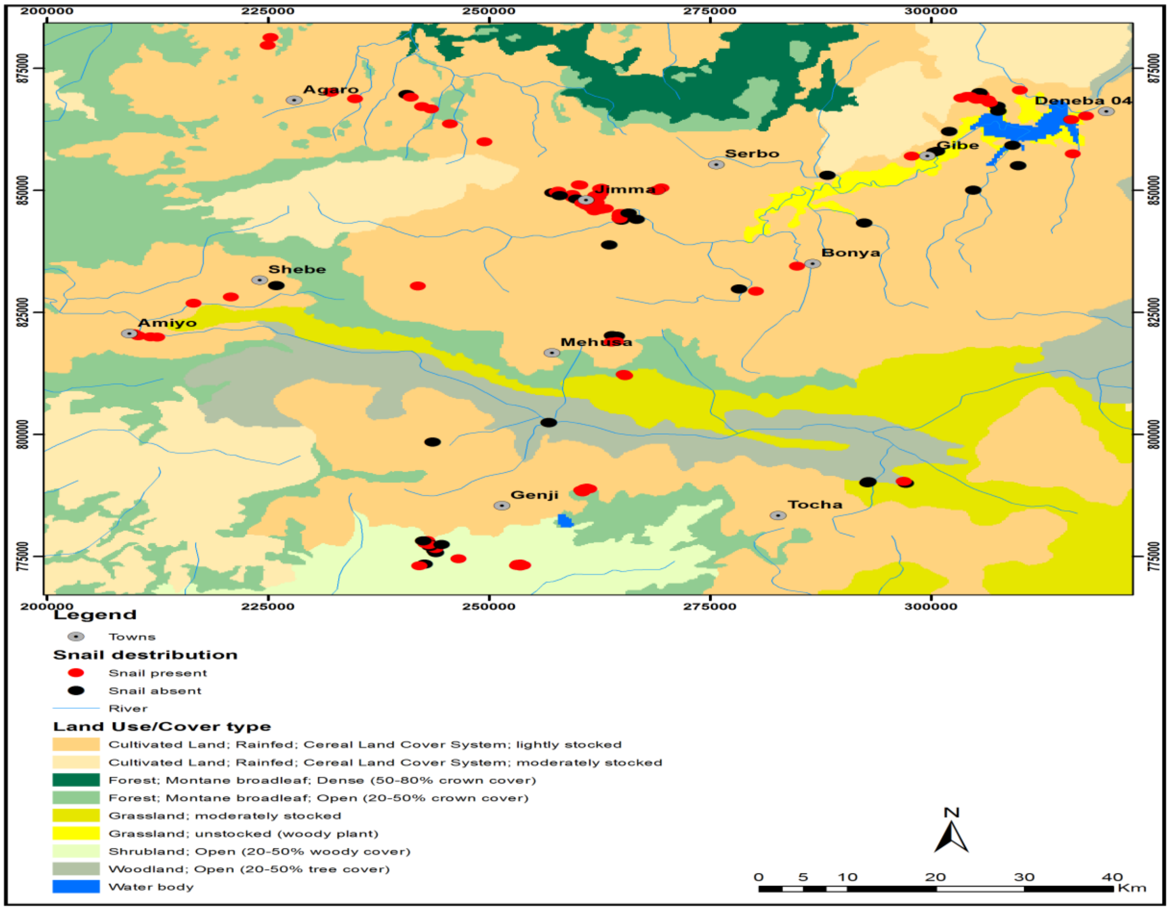

Figure 4: Map of freshwater snail species distribution in different land-use types in Omo-Gibe river basin, Ethiopia. (* red dots show stations where snail present and black dot showed sites snails not present).

The distribution of freshwater snail species in different land-use types of (n=130) sampling stations in Omo-Gibe river basin is shown in (Figure 5a). The highest presence of freshwater snail species (*L.natalensis*=312) at the Settlement land-use types followed by (*P. acuta*=250) were counted at similar land-use types. The presence of (*L. truncatula*=12) and (*P. spps*=6) at Farmland of similar land-use types were counted respectively. The distribution of (*B. pfefferi*=407) at Farmland types of land-use followed by (*B. globosus*=22) and (*B. sudanica*=8) were counted at similar type of Forest land-use respectively. Though medically not important, the highest distribution of Sphaeriidae (family) was counted at the settlement land-use type, (Figure 5b).

As can be observed from the statistical analysis, the distribution of freshwater snail species was insignificant across land-use types since (Pearson chi-square: x^2= 12.985) value is lower than the cut off value 21.7 and ($p<0.05$ or $p=0.024$) indicated under the, (Table 6.1, annex-1).

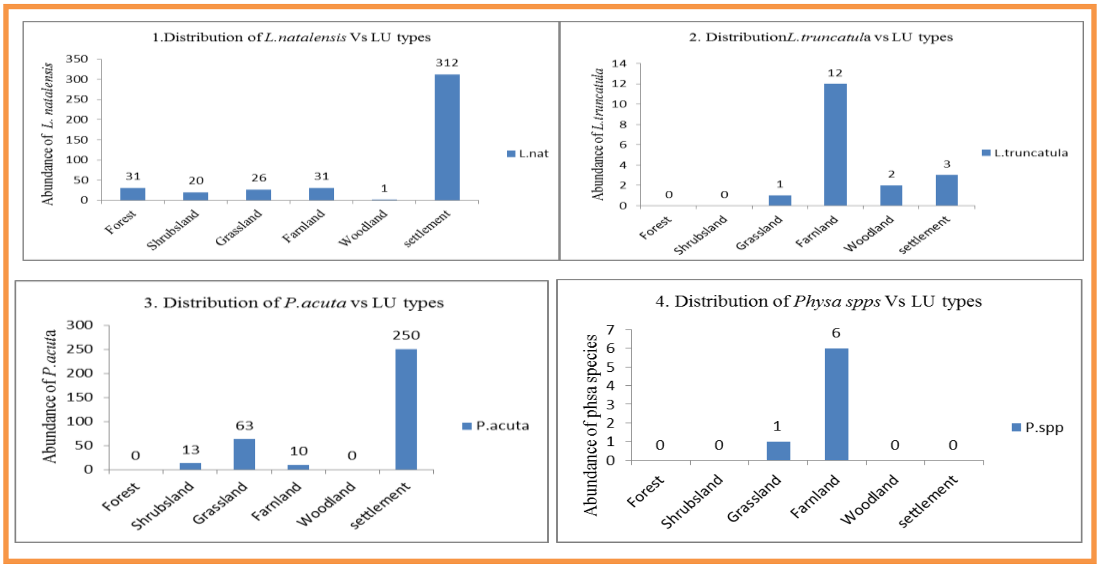

Figure 5.a: Distribution of each freshwater snail species (L. natalensis, L.truncatula, P.acuta and P. spps) by land-use types of Omo-Gibe river basin, Ethiopia.

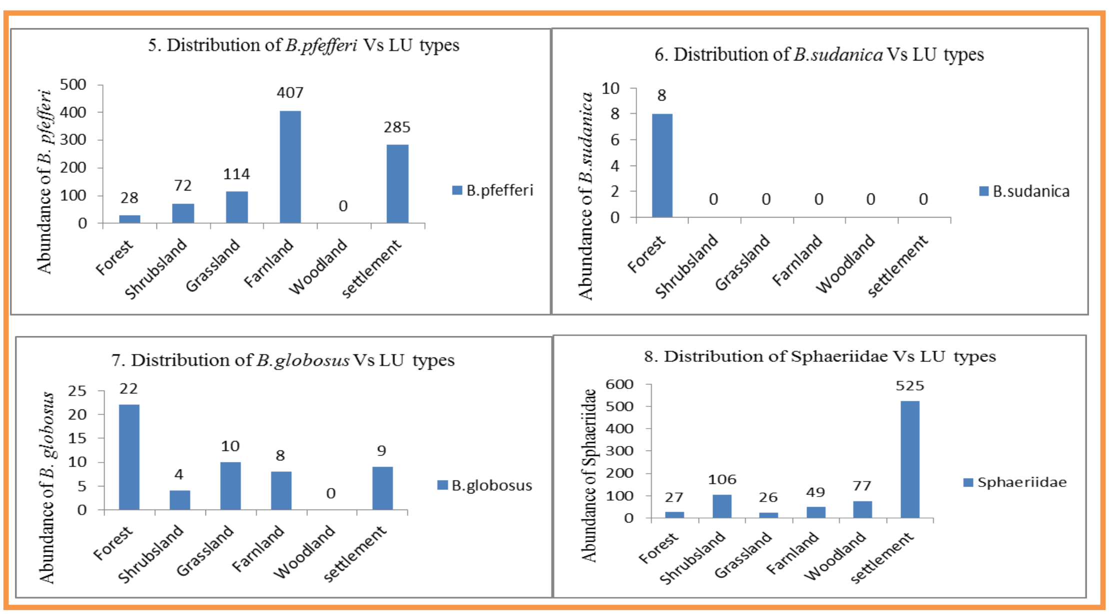

Figure 5.b: Distribution of each freshwater snail species (*B.pfefferi*, *B.sudanica*, *B.globosus*, and Sphaeriidae) by land-use types of Omo-Gibe river basin, Ethiopia.

As illustrated in Figure 6, the freshwater snail species density in the sampling stations at the land-use types like cultivated land lightly stocked and moderately stocked, shrubs lands, woodland open, grass land unstocked, grass land moderately stocked, forest montane broadleaf (open:20-50% crown) and Settlement areas were highly dispersed in less (i.e 0-10) population per station. On the other hand the density of freshwater snail species of (i.e 10-50) population per station provided at the land use types like cultivated lands lightly stocked, grass land moderately stocked, Shrubsland and Forest montane broadleaf (open: 20-50% crown) were moderately diffused. The freshwater snail species population for density (250-745) per station at the land-use types of Omo-Gibe river basin was not observed. The density of freshwater snail species of (50-100) population per station were dispersed at land-use types of cultivated land lightly stocked, and at forest montane broadleaf stations. Whereas, the freshwater snail species population (100-250) per site were observed at the land-use types like cultivated land lightly stocked of settlement.

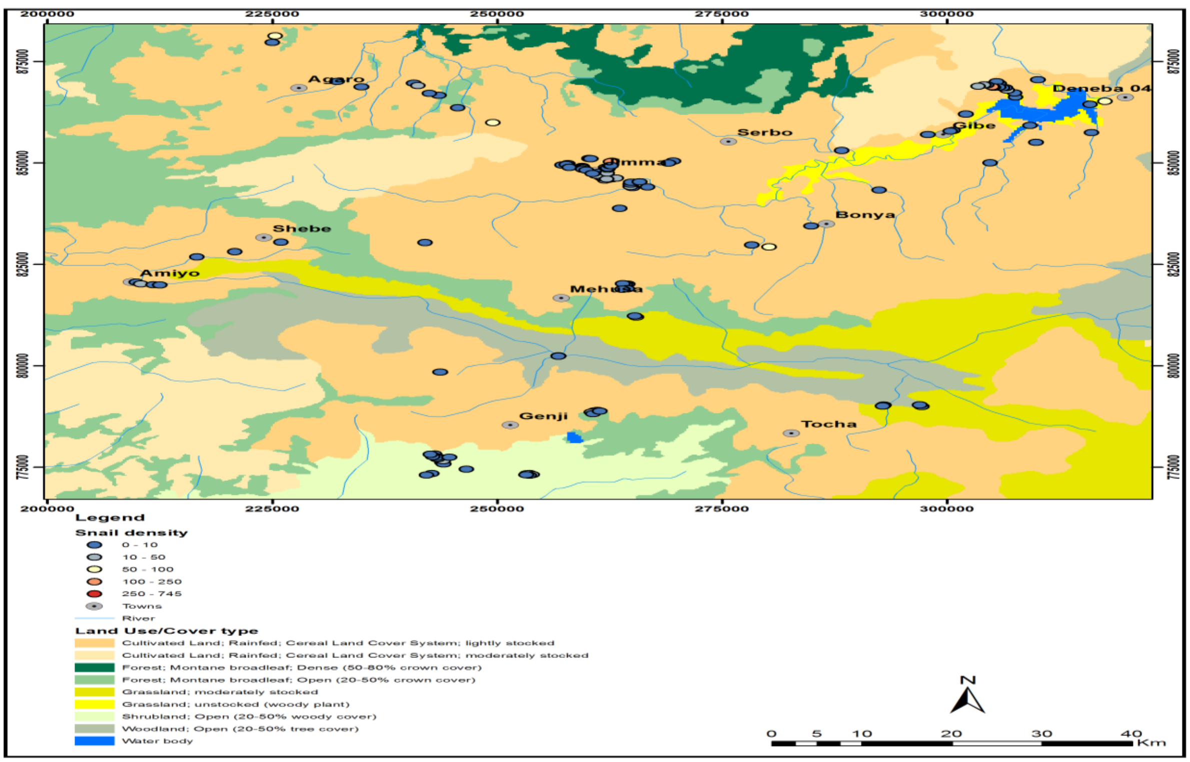

Figure 3: Map of snail distribution in different land-use types of Omo-Gibe River basin, Ethiopia.

5.5 Distribution of cercariae shedding snails in relation to land-use types

The cercariae positive freshwater snail intermediate hosts were recorded at eleven stations of the surveyed land-use types. Cercariae shedding freshwater snail intermediate hosts were recorded at the Settlement area, Grassland area, Farmland areas and Shrubsland areas were (14), (40), (49) and (6) respectively. The medically important snail species recorded include, *L. natalensis, B. pfefferi* and *B. globosus*. The majority of snail intermediate hosts cercaria shedding (82%) was observed in Farmlands and Grasslands area, (Table 9 annex-2). The association of the cercaria shedding to land-use types was insignificant (Pearson chi-square: X^2= 4.909, P> 0.05 or P=0.297), (Table 8.1, annex-1).

Further, *B. pfeifferi* was the most cercaria shedding (85.3%) snail species of different types of cercariae. But freshwater snail species such as *B.globosus* (4.6%) and *L.natalensis* (10.1%) were shed more than one and same type of cercariae. This shedding infection was determined from the analysis of cercaria shedding. However, none of the *B. sudanica* and *P. acuta* snail intermediate hosts was shed cercaria for trematode infection.

Table 6: Number of cercariae positive freshwater snail species recorded in Omo-Gibe river basin, Ethiopia.

Snail species	Total no. Snail inf.	No. of snail shedding cercariae							
		Echinostome	***(BAD)***	***(BAM)***	***Amphistome***	***Xiphidiocercariae***	***Metacercariae***	***Un-fur cer***	***Un- sing cer***
B.pfeifferi	93	28	39	1	19	0	5	2	1
B.sudanica	0	0	0	0	0	0	0	0	0
B.globosus	5	3	0	0	2	0	0	0	0
L.natalensis	11	7	0	0	0	3	0	1	0
Total	109	38	39	1	21	3	5	3	1

NB: (BAD) = *Brivifurcate apharyngeate diastome* cercariae, (BAM) = *Brivifurcate apharyngeate monostome* cercariae, (Un-fur cer) = *Un-identified furcocercous* cercariae, *(*Un-sing cer.) = *Un-identified single tail cercariae* types.

The *B. pfeifferi* and *B. globosus* were cercariae shedding freshwater snail species which found in cultivated land; rainfed, cereal land cover system; lightly stocked and moderately stocked land-use type. *Biomphalaria pfeifferi* was also found in Grasslands moderately stocked of land-use type with

L. truncatula. The cercaria shedding of *L. truncatula* was not observed. Whereas, *L. natalensis* cercariae shedding was observed in settlement and cultivated land; rainfed, cereal land-use types, (Figure 7).

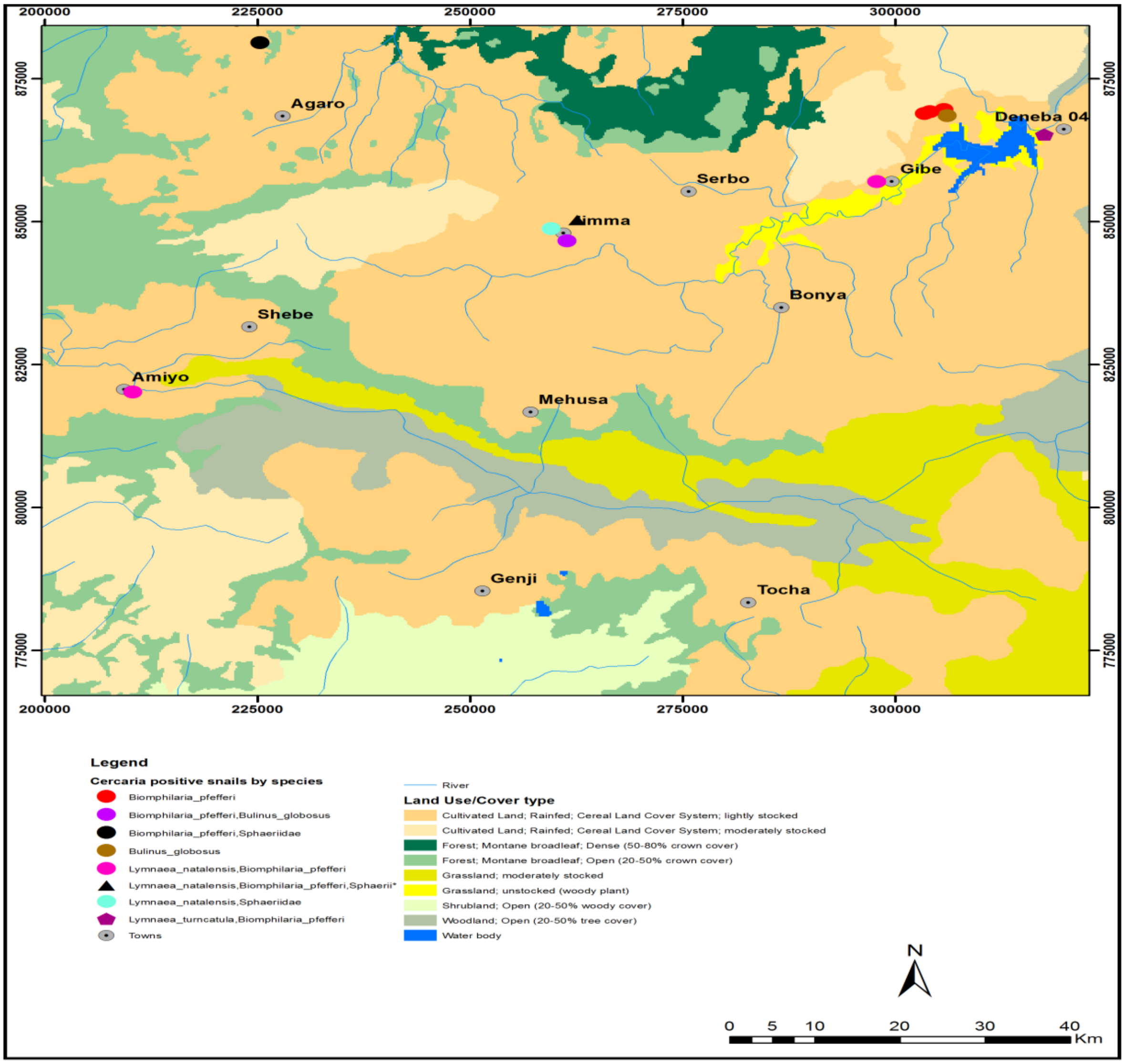

Figure 7: Map of the distribution of cercariae positive freshwater snail species in Omo-Gibe river basin, Ethiopia.

5.6 Prevalence of schistosomiasis infection in relation to land-use types

As shown in Figure (8a b, c), from six different elementary schools in Jimma zone, 380 schoolchildren were tested for *S. mansoni* and the prevalence was 35(9.2%) to positive schoolchildren and the study did not shown for *S. haematobium* in parallel. The prevalence of *S.*

mansoni in each school such as Iggo, Dimtu, Deneba, Seto Yiddo, Kito and Hamle-19 elementary school was (6.7%, 7.9%, 1.1%, 31.1%, 5.6%) and 13.7%), respectively.

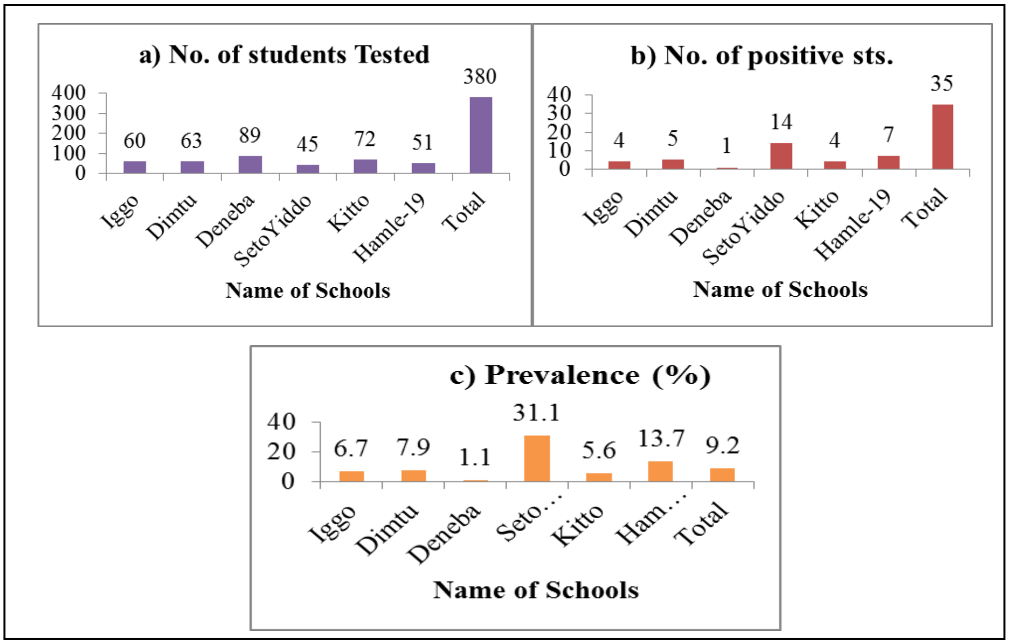

Figure 8: Prevalence of *S. mansoni* in schoolchildren, Jimma Zone, Ethiopia.

Furthermore, the result of Figure 9 revealed that the *S. mansoni* infection prevalence on the basis of cercariae positive freshwater snail species harbored from the proximity water bodies of the sampling sites in relation to the land-use types observed at cultivated land lightly stocked in Omo-Gibe river basin. However, statistical analysis revealed that prevalence of schistosomiasis infection in relation to land-use types association was insignificant (Pearson chi-square: X^2= 3.667, $p<0.05$ or $P=0.300$). This implied that the prevalence of schistosomiasis infections cannot be influenced by the land-use types in Omo-Gibe river basin, (Table 10.1, annaex-1).

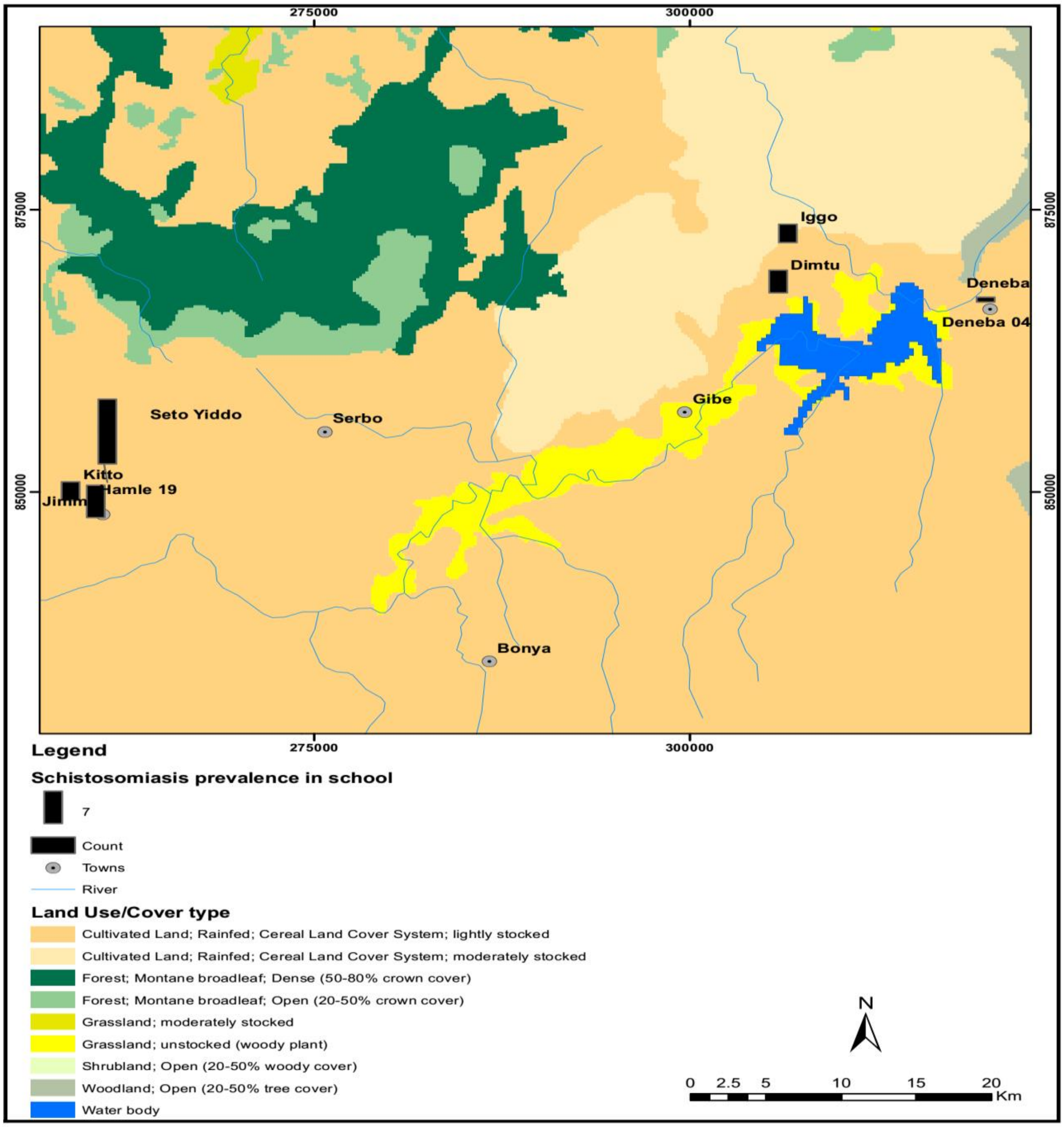

Figure 9: Map of schistosomiasis prevalence in schoolchildren, Jimma zone, Ethiopia.

Strength Association of the Statistical Significance test

The symmetric measures value of phi coefficient was 0.534 which indicated that the medium strength association of the analysis of variance for comparison, mean difference; chi-square for variable association, and standard deviation variation value obtained, (Table 11, annex-1).

CHAPTER SIX: DISCUSSION

This study investigated medically important freshwater snail intermediate hosts, distribution, occurrences and abundances in relation to land-use types. It encompassed seven freshwater snails at species level under four genera and one at family level in association to six land-use categories of Omo-Gibe river basin. These freshwater snail species were: *Biomphalaria pfeifferi* and *Biomphalaria sudanica* (intermediate hosts of intestinal schistosomiasis), *Bulinus globosus* (intemediate host for urinary schistosomiasis), *Lymnea natalensis* and *Lymnea truncatula* (intemediate host of *Fasciola gigantica* & *hepatica* that causes fascioliasis) while *Physa acuta* and *Physa spps (*Which are non-intermediate hosts) and Sphaeriidae (family) which are not medically important. The land-use types included: Forest, Shrubsland, Grasslands, Woodlands, Farmlands and Settlements. Even though, snail not found in dam and spring water, the habitat types during the survey comprised: Lakes, Rivers, Wetlands, Dams, Irrigation ditches and springs. This is because of the snails' habitat can include almost all types of freshwater bodies ranging from small temporary ponds and streams to large lakes and rivers, (WHO, 1994). *Biomphalaria pfeifferi* was the predominant freshwater snail species accounting for 35.4% of the total snail collected and encountered 39.2% from all habitats except spring and Dam. This may be due to the depth of Dam (Obikwelu, 2016), fish predators there and (Mccreesh et al., 2014) unconducive of spring temperature for snails. The highest prevalence of (89.2%) *B. pfeifferi* was recorded in river habitat of the surveyed sites. The greater occurrence of snails in river habitat may due to their run-off by flood, current water velocity of river that moving them from one site to another, common in water where plants are abundant and in water moderately polluted with organic matter, such as faeces and urine (WHO, 1994). From the study of (Kock, 2004) conducted in South Africa, explained that the distribution of *B. pfeifferi* from Kuruman River, South Africa was present in different habitats, but the highest percentages were collected from dams (27.5%) and (27.2%) which is lower collected in rivers. The reason may be *B. pfeifferi* is quiet water surface feeding snail and could be washed down to the dam easily. It finds a resting place when the speed of water current becomes greatly reduced whereas *B. globosus* can stick to or settle to the bottom of the water and later come out to the surface as (Ayanda, 2009) studied in Nigeria.

In addition, study of (Ayanda, 2009) conducted in Nigeria on the prevalence of freshwater snail vector, 69.58% found from stream were *B. globosus* and 30.42% *B. pfeifferi* respectively. Similarly, 49.49% *B. globosus* and 50.51% *B. pfeifferi* were collected from the dam. The freshwater snail abundance varied significantly from one site to the other was agreed by (NJOKU, 2011) in Imo state is one of the states of the federal republic of Nigeria. The reason accounted may be the seasonal variation, habitat preference and the natural behavioral mode of adaptation which is different for both species.

Moreover, (Gabriel et al., 2014) in Mara River in Kenya and Tanzania, explained that *L. natalensis* was the dominant species (59%) followed by *B. pfeifferi* (27%) in Mara river, Tanzania. From our study, the second predominant snail species was *L. natalensis* accounting for 16.45% of the snail population and encountered 29.2% of the surveyed sites with high prevalence of 69.6% in wetlands, 24.7% in rivers and 2.1% in irrigation ditches of habitat types. This may be due to irrigation canals and wetland structures can become snail-breeding stations as (Boelee & Madsen, 2006) explained in their study on irrigation and schistosomiasis in Africa. *Bulinus globosus* occurred in the same habitats except in irrigation ditches with *B. pfeifferi* which accounted for only 2.07% out of the snail population with prevalence of 41.5% in lakes, 41.5% in wetlands and 17% in rivers habitat types. The highest prevalence of these snail species were in river habitat. The study of (Salawu & Odaibo, 2012) in rural community of Nigeria also indicted from eight different freshwater snail species; *B. pfeifferi*, *B .globosus* and *L. natalensis* were prevalent in the river habitat. However, in this study, the simple and least common snail species such as *L. truncatula, B. sudanica and Physa spps* which encountered less than 10% of the surveyed stations in rivers, lakes and wetland habitats respectively. AS (Kock et al., 2003) also investigated in South Africa, that *L. truncatula* was mostly (42.0 %) recorded from swamps habitat. The occurrences of these freshwater snail intermediate hosts was significant association at ($p <0.05$) to the habitat types in Omo-Gibe river basin. Study of (Ofulla et al., 2013) in western Kenya, supported that significantly more Biomphalaria spp. than Bulinus spp. were recorded in different physical habitats such as dams, swamps, ponds and streams.

The current study also used a continues analysis of variance to compare mean value of some habitat variables (physical variables) like water velocity, canopy cover and water depth for the mean association between them in relation to land-use types. This may to shape the impact of land-use on habitat condition in regard of the occurrences and abundances of freshwater snail species. Study of (Lydig, 2009) in Babti district, Tanzania, agreed that because of the kinds of habitats also provides a relatively stable environment for the snails; the habitats which have natural vegetation are more inclined to supply areas with shelter, organic material for snails food. Further, in this study, descriptive statistics showed the flow velocity mean value was highest at Woodland areas (Mean=0.67) while the minimum mean value was recorded (Mean=0.19) in Grassland areas. On the other hand the highest mean value (Mean=0.49) for water depth recorded in Settlement areas whereas in this study canopy cover and vegetation cover were comparatively higher in Forest with (39.7%, 28.6%) of the total mean respectively. But the study of (Simeon et al., 2014) at Central Africa, Doula-Cameroon, canopy cover was not observed at the level of all the stations situated but meanwhile of Settlement areas. In regard to freshwater snail species, (HUBENDICK, 1956) study at State Museum of Natural History, Stockholm, Sweden confirmed depth of water has very little direct influence on the molluscan fauna. Study of (Lydig, 2009) supported that both *B. pfeifferi* and *L. natalensis* were significantly affected by vegetation in the surrounding and found in habitats with grass, shrubs and trees more favourable before farmland and forest areas. This study shown except for water-depth all the habitat factors were found to have significant association with the land-use types. Further, the analysis of variance in this study, (Table 3) shown the comparison of mean value between land-use types was significant association in terms of flow velocity and canopy cover at (p=.000). As (Simeon et al., 2014) in his study at Central Africa, Doula-Cameroon indicated, water current velocity varied significantly between different seasons at settlement station stream. The reason behind may be seasonal variation that can cause the instability of water depth and velocity. Moreover, in this study the statistical analysis between land-use types and vegetation cover showed significant at (p=.000). As study of (Abate & Lemenih, 2014) conducted at Nadda, South Western Ethiopia confirmed, the rapid increase in farmland and settlement areas are associated with decreasing trend in vegetation cover of certain area. This also agreed by (Anne et al., 2001) that rapid increasing built up in Oahu island, Hawaii has resulted in stream habitat alteration characteristics at settlement and farmland areas with markedly different from forest areas.

Moreover, in this study the water quality was analyzed based on the mean value between land-use types regarding if its situation for freshwater snail species distribution. Thus, the pH content highest mean value (M=8.46) was recorded in Settlement area (range 5.3± 6.5 to 7.8 ± 6.5), (Table 5). However, least pH mean value (M=6.87) was recorded in Shrubsland areas (range 6.28±0.36 to 7.40±0.36). This difference may be pH can fluctuate in the same habitat as agreed by (Lydig, 2009) at Tanzania. Even though, this study showed large value of standard error, study of (Ftsum et al., 2015) on four sites of Elala River using ANOVA showed significance association of pH vary from a minimum of 7.47 ± 0.03 and a maximum of 7.91 ± 0.19 which is in the permissible limit of WHO water for drinking and irrigation. As (Yirenya et al, (1981), Mccaffrey, (2012) comfirmed a mean pH 6.4 level is very conducive for snail vector development and also pH range of (6.5 – 8) is optimal for freshwater. Also the supportive study of (Salawu & Odaibo, 2012) indicated the pH mean value range 6.5 ± 0.72 is conducive in regard of snail intermediate hosts development and growth. The reason accounted for low pH (<6.0) value may be harmful to snail intermediate hosts of schistosomiasis in the coagulation of the mucus on exposed skin surfaces, (Yirenya et al., 1981).

From the current study, dissolved oxygen saturation (DO %) highest in Forest with mean percentage (M=83%) which (range 39.20±67.04 to 376±67.0) whereas the mean percentage DO (49.6%) was recorded from settlement area (range 2.49±15.60 to 67.50±15.60), Table 5. From (Qi Liu et al., 2015), the mean concentrations of (DO%) was close to the standard values, the exceeding rate was (20.48%–55.42%) , which indicated that the potential risk of nitrogen pollutions in the Dongjiang River basin of China. As study of (Patil et al., 2012) in India, dissolved oxygen refers to the volume of oxygen present in water and it is a basic indicator of ecosystem health. This may due to partly surface aeration for shallow water depth resulted from forests with less variety of living things, (CTI Engineering, 2009). The water dissolved oxygen concentration (DO mg/L) highest in Settlement areas with mean value (M=21.2 mg/L) which (range 2.36±78.10 to 353.00±78.10) while the least mean value of DO (M=3.87 mg/L) recorded in Shrubsland areas (range 2.40±0.84 to 5.30±0.84), Table 5. This may due to shallow water depth and overgrowth of aquatic vegetation that has role for photosynthesis process with great variety of living things, (CTI Engineering, 2009). This was supported by (Camara et al., 2011) at Banco National Park, Ivory Coast (West Africa) that lowest value (0.3 mg/L) of oxygen concentration may be due to sampled in dry period at high temperature. The prior study of (Ftsum et al., 2015) at Elala River, Mekelle, reported from the investigations of Physico-Chemical Parameters at Elala River, Mekelle, the concentration of (DO mg/L) values ranges from 5.03 to 5.81 mg/L, with an overall mean concentration of (5.90 mg/L), which is suitable for life of the aquatic ecosystem. According to this study report the maximum DO concentration measured in Settlement land-use may be due to human activities like swimming, washing, deforestation, and waste damping in and around the water body that rises water temperature, (CTI Engineering, 2009) in Vientiane City. In addition, Dissolved oxygen levels fluctuate throughout the day and night time flux by 10 mg/L, (Anderson, 2005) in Western Corn Belt Plains of the central U.S and low dissolved oxygen concentrations may be caused by density stratification of the water column and excess nutrient inputs, by (Denise et al., 1994) river near Solomon, Maryland, USA. The finding also indicated that at 95% confidence level, there was insignificant association of land-use types to other water quality variables.

The study shown biochemical oxygen demand (BOD) was highest mean value (M=14.11 mg/L) recorded in Shrubsland while the least mean value was recorded (M=11.59 mg/L) in Settlement area. But the free dissolved oxygen (DO) in water at the Shrubsland recorded was low. This may due to run off nitrogen and phosphorus from the water shade to water through shrubsland site increase BOD**,** the need for oxygen by all aerobic organisms, is one of the main processes that deplete DO in aquatic systems so that aerobic, heterotrophic organisms such as bacteria, fish and invertebrates consume oxygen and comprise a significant portion of BOD in an aquatic system, (Kamer, 2003). Reduced dissolved oxygen and increased biological oxygen demand in the water column may due to reduced photosynthetic activity as a result of mortality of algae from anthropogenic activities cause high demand of BOD, (Steve et al., 2014).

By this study, the highest mean value (M=59.55 mg/L) of total hardness (TH mg/L) was recorded in Forest area (range 6.00±32.08 to 112.00±32.08) while the least mean value (M=23.80 mg/L) was observed in Woodland area (range 8.00±22.95 to 86.00±22.95). This may be due to limestone and topography of land at the forest region. Regarding freshwater snails, in soft water (under 20 mg/L CaCO3) their survival and reproduction were poor. Therefore, snails, at maximum range of water hardness may be ability to tolerate the wide range of water hardness as the result of (Marie et al., 2015) reported in relation to freshwater snail species.

In addition, this study result revealed the nitrate concentration (NO_3^- mg/L) of the water highest mean value (M=6.04 mg/L) was recorded in Settlement area (range 2.36±78.10 to 353.00±78.10) while the least mean value (M=0.57 mg/L) was recorded in Forest area (2.66±1.06 to 5.74±1.06). As (Yirenya et al., 1981) reported, the nitrate concentration level of the Kpong head pond, below the Akosombo dam, Volta River Ghana was varied between 0.9mg/L and 1.4 mg/L. Also (Qi Liu et al., 2015) concluded that settlement land-use was strongly positive association with nitrate concentrations. The reason behind may be due to organic pollutants which is chemical drop let like fertilizers from storage during for use and a contamination of chemicals from the residence areas, waste damping and swimming open water.

Further one-way analysis of variance for the comparison of water quality mean value between land-use types to DO, TH and NO_3^- only shown significant association, ($p<0.05$). This may due to the change in land-use can affect to the level of DO in water, run-off nitrate in grass and lawn after fertilizer to water bodies. As agreed by (Qi Liu et al., 2015) at Dongjiang River Basin, Southeastern China, the proportion of forest land-use was positively associated with dissolved oxygen. However, the result of this study showed regarding the occurrences and distribution of freshwater snail species like *B. pfefferi*, *L. natalensis* and *B. globosus* were encountered in stream (river, wetland, lake) habitats of different water quality parameters in relation to all land-use types of Omo-Gibe river basin. The reason accounted by (Sharma et al., 2013) at river of Gho-Manhasan area may be many freshwater snail species are tolerant to most physico-chemical parameters and their occurrence is affected by the quality of bottom sediments, abundance of vegetation and suitable substrate.

The current study considered the distribution of medically important freshwater snail genera like Lymnaea spp. and Biomphalaria spp. The snail species such as *L. natalensis* were collected in 38 stations and absent in 92 stations of the total sampling stations in all land-use types while *L. truncatula* was collected from seven sampling sites and this snail species absent in 123 of the sampling stations of Omo-Gibe river basin in all land-use types except in Forest and Shrubsland. This was supported by the study of (Sangwan et al., 2016) in Rohtak and Jhajjar districts of Haryana, India that Forty-four of the 99 sampled were found with snails of 44% Indoplanorbis, Lymnaea or both species resulting in a prevalence at the same land-use, Settlement area. Moreover, by this study, *B. pfefferi* was found in frequent at 14 stations of Farmland followed by 12 stations in Settlement. This snail species was found in fifty-one sampling sites of all land-use types except at Woodland but not found at seventy-nine sampling stations of all the land-use types in Omo-Gibe river basin, Table 6 and Table 7. The other freshwater snail species, *B. globosus*, is the known intermediate hosts of *S. haematobium*, was found numerously at eight stations of Forest followed by five sites at the Settlement land-use type. Among these different snail species the majority, more than half 54 %(1384) were collected from Settlement followed by Farmland 20.4 %(523) land-use type. This was agreed by the study of (Qiu et al., 2014) that farmland structure is important in relation to snail distribution. In addition, *P. acuta*, *L. natalensis*, *B. pfeifferi*, and *B. globosus* snail species were collected at nine of the ten settlement areas by study of (Simeon et al., 2014) in Douala, Cameroon. However, the distribution of these snail intermediate hosts was insignificantly associated at (Pearson

Chi-square: X^2= 12.985, p=0.024) to land-use types in Omo-Gibe river basin. This may due to anthropogenic activities and organic pollutants that can cause the land-use change in facilitating substrate, suitable habitat condition fast current water that displaces the freshwater snail species (Luka et al., 2015) in Borno State, Nigeria.

Like wise, this study result, (Figure 8, 10) indicated distribution and density map of freshwater snails species were numerous at cultivated or farmed land rainfed; cereal land cover system; that lightly stocked, near forest montane broadleaf; open (20-50% crown cover) and settlement areas followed by grassland moderately stocked and grassland unstocked woody plant, shrubland; open (20-50% woody cover), while least number of snail collected at woodyland; open (20-50% tree cover) types of land-use. By this study, presence of *L.natalensis* (312) was highest at the Settlement followed by *P. acuta* (250) in the similar land-use types. But, the study of (Selpha et al., 2011) indicated, (425) *B. pfeifferi* whereas (227) *B. globosus* was identified in different habitats of Lake Victoria, at settlements. This may be because of the sites are along lakeshore and inland environmental condition and ecological variation (Luka et al., 2015). The presence of *L. truncatula* (12) and *Physa spps* (6) similarly at Farmland were observed respectively, Figure 9a. The distribution of *B. pfefferi* (407) at Farmland followed by *B. globosus* (22) and *B. sudanica* (8) were accounted at similar type of Forest land-use respectively, Figure 9b. As (Camara1 et al., 2011) agreed the appearance of freshwater snails in the Banco River basin reflected a eutrophic process due to anthropogenic activities. In addition, (Sime et al., 2014) explained, the distribution of freshwater snails in Douala river basin reflected the polluted status of its urban streams due to anthropogenic activities. But the statistical analysis obeyed the distribution of freshwater snail species was insignificant (P> 0.05) to the land-use types. This may be due to micro habitat suitability, fast water current to displace and anthropogenic activities related rather than land-use change that direct cause the snail distribution in Omo-Gibe river basin.

By the current study result, cercariae shedding freshwater snail intermediate hosts were insignificantly distributed at eleven sampled sites at land-use types such as Settlement, Grassland, Farmland and Shrubsland in Omo-Gibe river basin. These snail species included *L. natalensis, B. pfefferi* and *B. globosus* of the medically important. The majority of snails intermediate hosts shed cercaria were observed at Farmland and Grassland with the prevalence of (81.5%), which is sufficient to maintain in the level of schistosome transmission to human and animals, Table 8 and

Figure 11. This due to eggs of schistosoma which may the dispose during open defection at the occasional woody plants and animal fecal at farm areas and at grazing areas can be washed to close water. In addition, season of sampling may have contribution from (Luka et al., 2015) Borno State, Nigeria agreed. Further, by this study, the most abundant snail species of *B. pfeifferi* (85.3%) were registered shedding different types of cercariae. The study of (Mohammed et al., 2016) supported the most abundant snail species *B. pfeifferi* for cercaria shedding in lower percentage to our study, were registered in 37.4(14.7%) *xiphidiocercariae* from snails collected with respect to irrigation ditches of two important farmland areas, in Khartoum, Sudan. This is lower infection registered when compared to our study. On the other hand, study of (Luka et al., 2015) reported that three species (Bulinus forskalli, Bulinus globosus and Lymnae natalensis) of snails were identified based on shell morphology and standard criteria which was same identification registered in our study. During our study, snail species, *B.sudanica*, infection by trematode cercariae was not observed, (Table 9) which was supported by (Mohammed et al., 2016). The reason may due to the resistance of snails to trematode infections and the prevalence of larval trematode infections are dependent on snail numbers (Mohammed et al., 2016). Further, in this study, infection of *B.globosus* and *L.natalensis* by more than one and same type of cercariae was observed during cercaria shedding snails. This may due to run off eggs of trematodes lost by humans, birds, and animals found from pools adjacent to the river rather than the land-use effect. The reason accounted by (Devkota et al., 2008) also explained that degree of infection may vary in snails of the same species from one location to another, even though the areas might be apparently similar and geographically proximate to each other.

Similarly, the reason accounted by (Jayawardena et al., 2010) in Sri Lanka, indicated because of the trematode infected snails and variation in infection can easily arise as a consequence of the distribution of second intermediate and final hosts and/or habitat characteristics which affect the risk of infection.

Moreover, this study investigated the prevalence of schistosomiasis for evidence based on the proximity of the habitats where freshwater snail species sampled and tested for *S. mansoni* from schoolchildren enrolled in six elementary schools. Therefore, from the total 380 children tested for the case of *S. mansoni* infection at each school collectively encountered 35(9.2%) schoolchildren were positive which shown prevalence in the study area. The highest prevalence of infection observed in Seto Yiddo by 14(31.1%) which followed by Hamle-19 7(13.7%) from the schoolchildren. Further, the risk map for the location of the prevalence of *S. mansoni* obeyed on the basis of cercariae positive snail species collected from the proximity of the water bodies where the cercaria shed snail intermediate hosts collected in relation to the land-use types was at cultivated land lightly stocked, Figure 9. However, the prevalence of *S. mansoni* infection was insignificant (P=0.300) to land-use types in Omo-Gibe river basin. The reason accounted may be due to other anthropogenic activities like open defection, swimming, fishing, waste damping nearby water bodies and the suitable habitat condition can stimulate the parasite cycle. The supportive study of (Assefa et al., 2013) explained, in Mekelle city, Tigray, from the examination conducted on 457 schoolchildren, the overall prevalence of *S. mansoni* was (23.9 %) which is higher than the prevalence of our study. In addition, study conducted by (Mebrate et al., 2014) in Finchaa Sugar Estate, from most *S. mansoni* affected camp 7 shown (37.5%) prevalence also higher than ours. Moreover, evidence from (Mengistu et al., 2011) explained that among residents nearby three rivers of Jimma town, the prevalence of *S. mansoni* was (26.3 %) whereas (Alebie et al., 2014) reported at Sanja town, Amhara region, the prevalence of *S. mansoni* was (82.8%) which is extremely higher than the prevalence indicated in this study. The reason accounted for the variation in prevalence rate may be the proximity of the schools to the potentially infective water and situation of schoolchildren for the exposure by (Asmelash, 2010) in Tigray. However, the main reason in the project work of (Krauth, 2009) at Sichuan Province, China, identified the relationship between reduced vegetation cover and anthropogenic related land-use changes can potentially influence schistosomiasis disease transmission. Likewise, the prevalence of *S. mansoni* infection is associated with the distribution of the snail intermediate hosts observed at the continuing large-scale agricultural land-use contributes to the spread of schistosomiasis in Tigray, (Asmelash, 2010).

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

This study result revealed the seven species of freshwater snail intermediate hosts (such as *B. pfefferi*, *B. sudanica*, *B. globosus*, *L. natalensis*, *L. truncatula*, *Physa. spps*) occurrence and distribution in relation to habitat conditions and land-use types. In addition, the distribution of cercaria infected snail species and schistosomiasis infection prevalence in school children with supportive map. Therefore, the significance of *B. pfeifferi* occurrence was predominantly in all habitats except dam and spring with highest frequency in river. *B. globosus* snail observed at similar habitats except in irrigation ditches. The second significantly occurred snail species was *L. natalensis* in wetlands, rivers and irrigation ditches of habitat types. The significant of more *Biomphalaria spp*. than *Bulinus spp*. were observed in different physical habitats. Further, continues analysis of variance and descriptive statistics used to compare mean value of some habitat variables in association to land-use types. Significant canopy cover and vegetation cover averagely high at forest but low at settlement and farmland in adjacent with occurrence and abundance of freshwater snail species like *B. pfeifferi*, *L. natalensis* and *Bulinus spps* were observed. The water quality of Omo-Gibe river basin was analyzed for different chemical parameters. Further analysis of one-way ANOVA showed the mean comparison of water quality significant to land-use types only for (DO%, TH and NO_3^-). Thus from Table 5, the nitrate content of the water is high at Settlement and low at Forest land-use. The dissolved oxygen concentration mean value recorded high at Settlement and low mean value recorded at shrubsland. Likewise, the occurrence of freshwater snail intermediate hosts recorded at different water chemical quality of the 90 (69.2%) sites where snails collected.

The study concluded the distribution of Lymnaea spp. and Biomphalaria spp. in relation to land-use types insignificantly. These snail species mainly distributed at the Farmland and Settlement.

Finally, this study showed insignificant cercariae infected freshwater snail species such as *Lymnea spp.*, *B. pfefferi* and *B. globosus* distribution in relation to land-use types. The majority of infection observed at Farmland and Grassland with most abundant of *B. pfeifferi* and least number of *L. natalensis* by different type of cercariae. The Kato-Katz technique used for the examination of schistosoma on school age children of six different elementary schools shown the overall prevalence of 35 (9.2%) of only *S. mansoni* genera shedding recorded in the snail infection distribution stations. No *S. haematobium* observed in parallel in this study area.

From the study, the dominance of *L. natalensis* next to *B. pfefferi* snail intermediate hosts distribution, majority infection due to cercaria shedding of the *B. pfefferi* and lest number of *L. natalensis* snail intermediate hosts and the evident map of *S. mansoni* prevalence, we concluded that risk of transmission of schistosomiasis and the estimation of Faciolasis transmission due to the infection of *L. natalensis* distribution in the upper stream of Omo-Gibe river basin.

7.2. Recommendations

Based on the study findings the following points to be considered:

- This risk map has identified the foci of freshwater snail intermediate hosts; therefore, stakeholders (health sectors, community and government) providing the cost-effective monitoring measures at snail hot spot areas.
- The distribution of infected snail intermediate hosts and schistosomiasis prevalence were looks indicated in the study. Therefore, health sectors need to develop awareness of the communities and undergo mass treatment activities in the school children.
- The study appears to show that the distribution of cercaria positive Lymnea species which are important in Faciolasis transmission. Therefore, special attention should be given to the cattle grazing areas, to mitigate the transmission of Faciolasis from infected Lymnea habitats to cattle.
- The study seems to show that medically important snail species occurrence and abundance at anthropogenic activities (open defecation, swimming, fishing) affecting land-use areas. Therefore, the concerned bodies should run appropriate awareness to communities using intensive farming methods and controlling waste released from house hold to water bodies, which are identified snail habitats.
- Further studies should be conducted to provide better insight for new infestation snail intermediate hosts and the indication of schistosomiasis prevalence in relation to other environmental factors in other parts of Ethiopia.

REFERENCES

(WHO). (1994). Freshwater snails (pp. 337–356).

A. Isabwe, E. Ruberanziza, D. Mupfasoni, J. Ruxin, J. Clerinx, P. W. (2012). POTENTIAL FOR TRANSMISSION OF SCHISTOSOMIASIS IN KAYONZA DISTRICT, *69*(June), 14–19.

A.Lamberti, F. R. H. and G. (2007). *METHODS IN STREAM ECOLOGY*.

Abate, A., & Lemenih, M. (2014). Detecting and Quantifying Land Use / Land Cover Dynamics in Nadda Asendabo Watershed , South Western Ethiopia, *3*(1), 45–50.

Abebe, B. A. (2014). Modeling the Effect of Climate and Land Use Change on the Water Resources in Northern Ethiopia : the Case of Suluh River Basin Dissertation to obtain the doctoral degree.

Abraham, K. (2011). Oregon ' s Wetland Monitoring and Assessment Program : A Pilot Study (pp. 1–61).

Agency, U. S. E. P. (2008). Nutrient Criteria Technical Guidance Manual Wetlands.

Alebie, G., Erko, B., Aemero, M., & Petros, B. (2014). Epidemiological study on Schistosoma mansoni infection in Sanja area , Amhara region , Ethiopia. *Parasites & Vectors*, 1–10.

Allan, J. D., Arbor, A., & Allan, J. D. AND RIVERSCAPES : The Influence of Land Use on Stream Ecosystems (2012).

Amdie, Z. (2007). Land Use / Land Cover Dynamics and Vegetation Vulnerability Analysis : a Case Study of Arsi Negele Approved By Board of Examiners :, (July).

American Public Health Association, American Water Works Association, & Water Environment Federation. (1999). Standard Methods for the Examination of Water and Wastewater. In *Standard Methods* (p. 541).

Amsalu, G., Mekonnen, Z., & Erko, B. (2015). A new focus of schistosomiasis mansoni in Hayk town , northeastern Ethiopia, 1–6. http://doi.org/10.1186/s13104-014-0965-z

Anderson, D. G. H. J. (2005). Dissolved Oxygen Fluctuation Regimes in Streams of the Western Corn Belt Plains Ecoregion, (130).

Anne M.D. Brasher, Reuben H. Wolff, and C. D. L. (2001). Associations Among Land Use , Habitat Characteristics , and Invertebrate Community Structure in Nine Streams on the Island of Oahu , Hawaii , 1999 – 2001, 1999–2001.

Antwi-agyakwa, K. T. (2014). Assessing the Effect of Land Use Land Cover Change on Weija Catchment By Assessing the Effect of Land Use Land Cover on Weija Dam. *Geomatic Engineering, UMaT).*

Asmelash, T. D. and T. (2010). Schistosomiasis Mansoni among School Children of Different Water Source Users in Tigray, Northern Ethiopia, *2*.

Assefa, A., Dejenie, T., & Tomass, Z. (2013). Infection prevalence of Schistosoma mansoni and associated risk factors among schoolchildren in suburbs of Mekelle city , Tigray , Northern Ethiopia, *5*(1), 174–188.

Ayanda, O. I. (2009). Prevalence of snail vectors of schistosomiasis and their infection rates in two localities within Ahmadu Bello University (A . B . U .) Campus , Zaria , Kaduna State , Nigeria, *3*(4), 58–61.

BAKER, Z. S. A. & M. A., & Abstract: (2004). Freshwater snails of Jordan, *2*, 221–227.

Barbour, M. T. (1998). *Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers :*.

Barbour, M. T., Gerritsen, J., Snyder, B. D., & Stribling, J. B. (1999). Habitat assessment and physicochemical parameters. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish,* 1–35.

BENGT HUBENDICK. (1947). Factors conditioning the Habitat of Freshwater Snails, 1072–1080.

Boelee, E., & Madsen, H. (2006). Irrigation and Schistosomiasis in Africa: Ecological Aspects.

Boothroyd, D., Harding, G., Maxted, S., & Scarsbrook, R. (2001). Protocols for sampling macroinvertebrates in wadeable streams, (1).

Christine E. Parent. (2008). ActionBioscience - promoting bioscience literacy.

CTI Engineering International Co., L. (2009). *Methodology of Water Quality Monitoring Periodical Monitoring ,Report* (Vol. 9).

D. R. Yirenya-Tawiah, A. Abdul Rashid, G Futagbi, I. A. and M. D. (1981). Prevalence of Snail Vectors of Schistosomiasis in the Kpong Head Pond , Ghana, (1954).

Datiko, D., & Bekele, A. (2013). Species composition and abundance of small mammals, *5*(June), 95–102. http://doi.org/10.5897/JENE12.045

Denise L. Breitburgl, Nancy steinberg', Sarah : Cynthia cooksey, E. D. (1994). Effects of low dissolved oxygen on predation on estuarine fish larvae : u, *104*, 235–246.

Difranco, J. L. (2014). Protocols for Sampling Aquatic Macroinvertebrates in Freshwater Wetlands, (April).

Duncan, N. (2008). Survey Protocol for Aquatic Mollusk Species: Preliminary Inventory & Presence/Absence Sampling, Version 3.1, (July), 52.

Fatima Muhammad Abdulkadir, D. B. Maikaje, Y. A. U. (2018). Cercarial Diversity in Freshwater Snails from Selected Freshwater Bodies and Its Implication for Veterinary and Public Health in Kaduna State , Nigeria, *12*(2), 47–53.

FLETCHER, G. C. and S. (2013). A brief review of spatial analysis concepts and tools used for mapping , containment and risk modelling of infectious diseases and other illnesses, (141), 581–601. http://doi.org/10.1017/S0031182013001972

Frandsen, F. / Christensen, N. . (2015). An introductory guide to the identification of cercariae from African freshwater snails with special reference to cercariae of trematode species of medical and veterinary importance.

Ftsum Gebreyohannes1, Abraha Gebrekidan2*, A. H. and S. E. (2015). Investigations of Physico-Chemical Parameters and its Pollution Implications of, *7*(2), 240–257.

Gabriel O. DidaAnyona, D. N., Matano, A., Abuom, P. O., Adoka, S. O., Ouma, C., Kanangire, C. K., … Ofulla, A. V. O. (2014). Distribution and abundance of schistosomiasis and fascioliasis host snails along the Mara River in Kenya and Tanzania, *1*, 1–7.

Gashaw, T., Bantider, A., & Mahari, A. (2014). Full Length Research Paper Evaluations of Land Use / Land Cover Changes and Land Degradation in Dera District , Ethiopia : GIS and Remote Sensing Based Analysis, *2*(6), 199–208.

Gebresenb, T. S. (2015). Modeling of Cascade Dams and Reservoirs Operation for Optimal Water Use: Application to Omo Gibe River Basin, Ethiopia.

Hartson, R. B., Orlofske, S. A., Melin, V. E., Jr, R. T. D., & Johnson, P. T. J. (2011). Land Use and Wetland Spatial Position Jointly Determine Amphibian Parasite Communities. *EcoHealth 8*, 485–500. http://doi.org/10.1007/s10393-011-0715-9

Hector Galbraith, A., & Huber-Lee, A. (2005). *The Effects of Agricultural Irrigation on Wetland Ecosystems in Developing Countries : A Literature Review A Literature Review*.

HUBENDICK, B. (1956). Factors conditioning the Habitat of Freshwater Snails, 1072–1080.

HurniChristina Seeberg, Richard Thomas, Nicola Favretto, N. S. (UNU-I. (2015). *THE E CONOMICS OF L AND D EGRADATION ELD Initiative : User Guide*.

I.A. Camara, Y.K. Bony, D. Diomandé, O.E. Edia, F.K. Konan, C.N. Kouassi, G. G. & J. P. P. (2011). Freshwater Snail Distribution Related to Environmental Factors in Banco National Park, An Urban Reserve in the Ivory Coast (West Africa).

Javier Oscoz · David Galicia Rafael Miranda. (2011). *Identification Guide of freshwater Macroinvertebrates of Spain*.

Jayawardena, U. A., Rajakaruna, R. S., & Amerasinghe, P. H. (2010). CERCARIAE OF TREMATODES IN FRESHWATER SNAILS IN THREE CLIMATIC ZONES IN SRI LANKA. *Cey. J. Sci. (Bio. Sci.)*, *39*(2), 95–108.

Jember, T. H. (2014). Challenges of schistosomiasis prevention and control in Ethiopia : Literature review and current status, *6*(6), 80–86. http://doi.org/10.5897/JPVB2014.0155

Jiao Ding , Yuan Jiang , Lan Fu , Qi Liu, Q. P. and M. K. (2015). Impacts of Land Use on Surface Water Quality in a Subtropical River Basin: A Case Study of the Dongjiang River Basin, Southeastern China, 4427–4445. http://doi.org/10.3390/w7084427

Johnson, P. D., & Aquarium, T. (2009). Freshwater Snail Biodiversity and Conservation.

Jourdan, P. M. (2012). *Schistosoma haematobium infection in the female genital mucosa Immunohistochemical and clinicopathological analyses with respect to*.

KN de Kock, C. W. and M. B. (2004). Distribution and habitats of Biomphalaria pfeifferi , snail intermediate host of Schistosoma mansoni , in South Africa, *30*(1), 29–36.

Kock, K. N. De, Wolmarans, C. T., & Bornman, M. (2003). Distribution and habitats of the snail Lymnaea truncatula , intermediate host of the liver fluke Fasciola hepatica , in South Africa, *2*(Table 2), 117–122.

Krailas, D. (1999). *Preliminary Report on Freshwater Snails in Toa Dum Forest , Saiyok District , Kanchanaburi Province* (pp. 194–205).

Krauth, D. Evaluation of Land Use Changes on Schistosomiasis Disease Prevalence in Sichuan Province, China (2009).

Krist, M. L. and A. (2014). Trematode prevalence and richness in Teton county, Wyoming, (SCI-0039).

Krista Kamer, E. S. (2003). Concentration as a Potential Indicator of Water Quality in Newport Bay : A Review of Historical Data , and.

Laikemariam Kassa, Anteneh Omer, Wutet Tafesse, T., & Taye, Fekadu Kebebew, A. B. (2005). Schistosomiasis Diploma Program For the Ethiopian Health Center Team (pp. 1–81).

Luiz Eduardo M. Lacerda1 ; Igor C. Miyahira1 & Sonia B. Santos1, 2 1. (2011). Shell morphology of the freshwater snail Gundlachia ticaga (Gastropoda : Ancylidae) from four sites in Ilha Grande , southeastern Brazil Shell morphology of the freshwater snail Gundlachia ticaga (Gastropoda : Ancylidae) from four sites in Ilha Grande, (July). http://doi.org/10.1590/S1984-46702011000300007

Luka, J., & Albert Wulari Mbaya. (2015). Cercarial shedding of trematodes and their associated snail intermediate hosts in Borno State , Nigeria. *Asian Pacific Journal of Tropical Disease*, *5*(4), 293–298. http://doi.org/10.1016/S2222-1808(14)60786-6

Lydig, A. (2009). Factors conditioning the distribution of fresh water pulmonates , Biomphalaria spp ., Bulinus spp ., and Lymnea spp ., in Babati.

Maldonado, V. G. M. (2010). Land use influence on the benthic macroinvertebrate communities of streams in Nyangores and Amala tributaries of Mara River , Kenya ., (April).

Mandahl-Barth, G. (1958). Itermediate Hosts of Schistosoma.

Mccreesh, N., Arinaitwe, M., Arineitwe, W., Tukahebwa, E. M., & Booth, M. (2014). Effect of water temperature and population density on the population dynamics of Schistosoma mansoni intermediate host snails, 1–9. http://doi.org/10.1186/s13071-014-0503-9

Mebrate Dufera, Beyene Petros, Berhanu Erko, Nega Berhe, S. G. G. (2014). Schistosoma mansoni Infection in Finchaa Sugar Estate :, *7522*(June), 155–161.

Mengistu, M., Shimelis, T., Torben, W., Terefe, A., Kassa, T., & Hailu, A. (2011). Human intestinal schistosomiasis in communities living near three rivers of jimma town, South Western ethiopia. *Ethiopian Journal of Health Sciences*, *21*(4), 111–8. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3275858&tool=pmcentrez&rendertype=abstract

Michael T. Barbour, Jeroen Gerritsen, Blaine D. Snyder, J. B. S. (1998). *Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers :* (pp. 17–339).

Mitiku, H., Legesse, M., Teklemariam, Z., & Erko, B. (2008). Transmission of Schistosoma mansoni in Tikur Wuha area ,.

Mohamed A. Hussein1, Ahmad H. Obuid-Allah1, A. A. M. and H. M. F. (2011). Population dynamics of freshwater snails (Mollusca: Gastropoda) at Qena Governorate, Upper Egypt, *3*(1), 11–22.

Mohamed- Assem S. Marie, Fatma Afifi Aly El-Dee, Wafaa S. Hasheesh, Rehab Atef Mohamed, S. S. M. S. (2015). Impact of Seasonal Water Quality and Trophic Levels on the Distribution of Various Freshwater Snails Borno State, Nigeri, *3*(4), 117–126. http://doi.org/10.12691/aees-3-4-4

Moses J. Chimbari a,,, Jerikias Ndamba b, H. M. c. (1996). Food selection behaviour of potential biological agents to control intermediate host snails of schistosomiasis : Sargochromis codringtoni and Tilapia rendalli, *61*, 191–199.

Nascimento, C. S. B. ; E. C. S. G. ; J. M. R. M. ; K. R. L. J. C. ; W. R. C. (2017). Quality control of the slides by Kato-Katz method for the parasitological diagnosis of schistosomiasis infection by Schistosoma mansoni, (April), 110–114.

Nidal A. I. Mohammed, H. M. and A. A. A. R. M. A. (2016). Types of trematodes infecting freshwater snails found in irrigation canals in the East Nile locality , Khartoum , Sudan. *Infectious Diseases of Poverty*, *5*(16), 1–10. http://doi.org/10.1186/s40249-016-0108-y

NJOKU- TONY, R. F. (2011). EFFECT OF SOME PHYSICO-CHEMICAL PARAMETERS ON ABUNDANCE OF INTERMEDIATE SNAILS OF ANIMAL TREMATODES IN IMO STATE, NIGERIA, *3*(4).

Obikwelu, O. O. I. and M. E. (2016). Factors affecting seasonal abundance of gastropods of public health importance found at Agulu Lake shorelines in Nigeria, (April). http://doi.org/10.18782/2320-7051.2264

Ofulla, A. V, Adoka, S. O., Anyona, D. N., Abuom, P. O., Karanja, D., Vulule, J. M., … Gichuki, J. (2013). Spatial distribution and habitat characterization of schistosomiasis host snails in lake and land habitats of western Kenya, (Brown 1994), 197–215. http://doi.org/10.1111/lre.12032

PAHO/WHO. (2007). *Epidemiological Data Needed to Plan Elimination of Schistosomiasis in the Caribbean (Grenada,.*

Patil. P.N, Sawant. D.V, D. R. . (2012). WATER QUALITY CONTROL PART II .

Patrick Gonzalez, Rashid Hassan, Petro Lakyda, Ian McCallum, Sten Nilsson, J. P. (2000). Forest and Woodland Systems (pp. 587–621).

Paul D. Johnson, Research scientist, Tennessee Aquarium Research Institute, Cohutta, G. S. (2009). Freshwater Snail Biodiversity and Conservation.

Pedersen, U. B., Stendel, M., Midzi, N., Mduluza, T., Soko, W., Stensgaard, A., … Kristensen, T. K. (2014). Modelling climate change impact on the spatial distribution of fresh water snails hosting trematodes in Zimbabwe, 1–12. http://doi.org/10.1186/s13071-014-0536-0

Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., … Ngara, T. (2003). *Intergovernmental Panel on Climate Change Good Practice Guidance for Land Use , Land-Use Change and Forestry Edited by* (pp. 4–559).

Qiu, J., Li, R., Xu, X., Yu, C., Xia, X., & Hong, X. (2014). Identifying Determinants of Oncomelania hupensis Habitats and Assessing the Effects of Environmental Control Strategies in the Plain Regions with the Waterway Network of China at the Microscale, 6571–6585. http://doi.org/10.3390/ijerph110606571

Ramesh Devkota, P. B. B. and R. G. (2011). Trematode cercariae infections in freshwater snails of Chitwan district , central Nepal, *7*(9), 9–14.

Rupiah Mesfin, B. J. A. and D. U. T. (2015). An evaluation of the effect of schistosomiasis on human Health. *African Journal of Parasitology Research*, *2*(5), 98–103.

Salawu, O. T., & Odaibo, A. B. (2012). Preliminary study on ecology of Bulinus jousseaumei in Schistosoma haematobium endemic rural community of Nigeria, 441–446.

Sangwan, A. K., Jackson, B., Glanville, W. De, Pfeiffer, D. U., & Stevens, K. B. (2016). Spatial analysis and identi fication of environmental risk factors affecting the distribution of Indoplanorbis and Lymnaea species in semi-arid and irrigated areas of Haryana , India. *PAREPI*. http://doi.org/10.1016/j.parepi.2016.05.005

Selpha Opisa1, 2, Maurice R Odiere1*, Walter GZO Jura2, D. M. K. and P. N. M. (2011). Malacological survey and geographical distribution of vector snails for schistosomiasis within informal settlements of Kisumu City , western Kenya, 1–9.

Service, U. S. D. a F., & S, C. P. C. U. (2014). National Riparian Vegetation Monitoring Prepared by.

Sharif M, Daryani A, Karimi SA. A faunistic Survey of cercariae isolated from lymnaeid snails in central areas of Mazandaran, Iran. Pak J Biol Sci 2010; 13: 158-163

Sharma, K. K., Bangotra, K., & Saini, M. (2013). Diversity and distribution of Mollusca in relation to the physico-chemical profile of Gho-Manhasan stream , Jammu (J & K), *5*(April), 240–249. http://doi.org/10.5897/IJBC12.127

Simeon Tchakonte, Gideon A. Ajeagah, Dramane Diomande, Adama Idrissa Camara, N. P. (2014). Diversity , dynamic and ecology of freshwater snails related to environmental factors in urban and suburban streams in Douala – Cameroon (Central Africa), *2*, 379–395. http://doi.org/10.1007/s10452-014-9491-2

Simoonga, C., Utzinger, J., Brooker, S., Vounatsou, P., Appleton, C. C., Stensgaard, A. S., … Kristensen, T. K. (2009). Remote sensing , geographical information system and spatial analysis for schistosomiasis epidemiology and ecology in Africa, 1683–1693. http://doi.org/10.1017/S0031182009006222

States, U. D. of A. (1998). Stream Visual Assessment Protocol.

Stephanie Ogden, Kerry Gallo, Susan Davis, Courtney McGuire, Erika Meyer, D. A. (2013). *WASH and the Neglected Tropical Diseases A GLOBAL MANUAL* (pp. 23–25).

Steve Omari Ngodhe, P. O. R. and A. A., & University. (2014). The impact of water quality on species diversity and richness of macroinvertebrates in small water bodies in, *6*(January), 32–41. http://doi.org/10.5897/JENE2013.0403

Tiku, S., Boets, P., Ambelu, A., Malu, A., Ephrem, Z., Sisay, A., … Goethals, P. L. M. (2012). Ecological Informatics Analysis of environmental factors determining the abundance and diversity of macroinvertebrate taxa in natural wetlands of Southwest Ethiopia. *Ecological Informatics*, *7*(1), 52–61. http://doi.org/10.1016/j.ecoinf.2011.11.005

UNEP. (2012). *E thiopia ' s G ibE iii D am*.

UNEP/WHO. (1996). Chapter 6 - FIELD TESTING METHODS.

WHO. (1994). Freshwater snails (pp. 337–356).

Woodward, A. (2003). Climate change and human health Editors.

Www.waterwatch.nsw.gov.au. (n.d.). WATER QUALITY PARAMETERS & INDICATORS (pp. 0–3).

Xu, B., Gong, P., Biging, G., Liang, S., Seto, E., & Spear, R. (2004). Snail Density Prediction for Schistosomiasis Control Using Ikonos and ASTER Images, *70*(11), 1285–1294.

Yvonne Walz, Martin Wegmann1, Stefan Dech, Penelope Vounatsou, Jean- Noël Poda, Eliézer K. N'Goran, Jürg Utzinger, G. R. (2015). Modeling and Validation of Environmental Suitability for Schistosomiasis Transmission Using Remote Sensing, 1–22. http://doi.org/10.1371/journal.pntd.0004217

ANNEXES

1. **Analysis of land use effect in relation to habitat condition, water quality, occurrence and abundance of freshwater snails, Distribution of cercarial infection and schistosomiasis prevalence.**

Table1.1: The significance level on occurrence and abundance of freshwater snails.

	habitat type	abundance of freshwater snails
Chi-Square	296.554[a]	562.754[b]
df	5	36
Asymp. Sig.	.000	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 21.7.

b. 37 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 3.5.

Table 2.1: Tukey HSD multiple comparisons test for mean difference significance among groups of habitat variable of the sampling stations.

Multiple Comparisons

Tukey HSD

Variables			Mean Difference (I-J)	Std. Error	Sig.	95% CI Lower Bound	95% CI Upper Bound
Flow Velocity (m/s)	Woodland	Forest	4.691E-001*	1.088E-01	.000	1.54E-01	7.84E-01
		Shrubsland	3.776E-001*	1.115E-01	.012	5.49E-02	7.00E-01
		Grassland	4.749E-001*	1.056E-01	.000	1.69E-01	7.81E-01
		Farmland	3.501E-001*	1.034E-01	.012	5.09E-02	6.49E-01
		Settlement	4.096E-001*	1.105E-01	.004	8.98E-02	7.30E-01
Canopy cover (%)	Forest	Shrubsland	61.017*	7.190	.000	40.20	81.83
		Grassland	57.153*	6.594	.000	38.06	76.24
		Farmland	47.102*	6.359	.000	28.70	65.51
		Woodland	34.727*	8.756	.002	9.38	60.07
		Settlement	52.727*	7.093	.000	32.19	73.26

*. The mean difference is significant at the 0.05 level.

Table 7: Vegetation cover recorded in 130 sampling stations of Omo-Gibe river basin, Ethiopia.

vegetation cover in relation to land-use types; Cross tabulation									
			Land-use Types						Total
			Forest	Shrubsland	Grassland	Farmland	Woodland	Settlement	
vegetation cover	No	Count	0	9	10	23	0	11	53
		% of Total	0.0%	6.9%	7.7%	17.7%	0.0%	8.5%	40.8%
	Yes	Count	22	10	17	9	10	9	77
		% of Total	16.9%	7.7%	13.1%	6.9%	7.7%	6.9%	59.2%
Total		Count	22	19	27	32	10	20	130
		% of Total	16.9%	14.6%	20.8%	24.6%	7.7%	15.4%	100.0%

NB: **Yes**- indicted there was a protection for width riparian vegetation; **No**- indicated there was no protection of width riparian vegetation at the sampling sites.

Table4.1: The significant association using Chi-square for vegetation cover in relation to land-use types.

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	37.024[a]	5	.000
Likelihood Ratio	48.331	5	.000
Linear-by-Linear Association	8.812	1	.003
N of Valid Cases	130		
a. 1cells (8.3%) have expected count less than 5. The minimum expected count is 4.08.			

Table5.1: One-way analysis of variance (ANOVA) for detail water quality group factor significant.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
PH	Between Groups	32.952	5	6.59	0.956	0.448
	Within Groups	855.171	124	6.897		
	Total	888.123	129			
DO%	Between Groups	14499.19	5	2899.837	3.158	0.01
	Within Groups	113847.7	124	918.127		
	Total	128346.9	129			

DO(Mg/l)	Between Groups	4607.095	5	921.419	0.945	0.454
	Within Groups	120886.5	124	974.891		
	Total	125493.6	129			
EC (µS/cm)	Between Groups	348714.1	5	69742.82	0.919	0.471
	Within Groups	9413852	124	75918.16		
	Total	9762566	129			
PO43-(mg/L)	Between Groups	157.887	5	31.577	1.237	0.296
	Within Groups	3165.8	124	25.531		
	Total	3323.687	129			
Total Hardness	Between Groups	13078.16	5	2615.632	3.041	0.013
	Within Groups	106648.8	124	860.071		
	Total	119727	129			
NO3-(mg/L)	Between Groups	445.969	5	89.194	4.023	0.002
	Within Groups	2749.209	124	22.171		
	Total	3195.178	129			
BOD5(mg/L)	Between Groups	121.339	5	24.268	1.038	0.399
	Within Groups	2900.338	124	23.39		
	Total	3021.677	129			
COD(mg/L)	Between Groups	273.013	5	54.603	1.038	0.399
	Within Groups	6525.76	124	52.627		
	Total	6798.773	129			

Table 5.2: The Post Hock tests multiple comparison of water quality factor with land-use types.

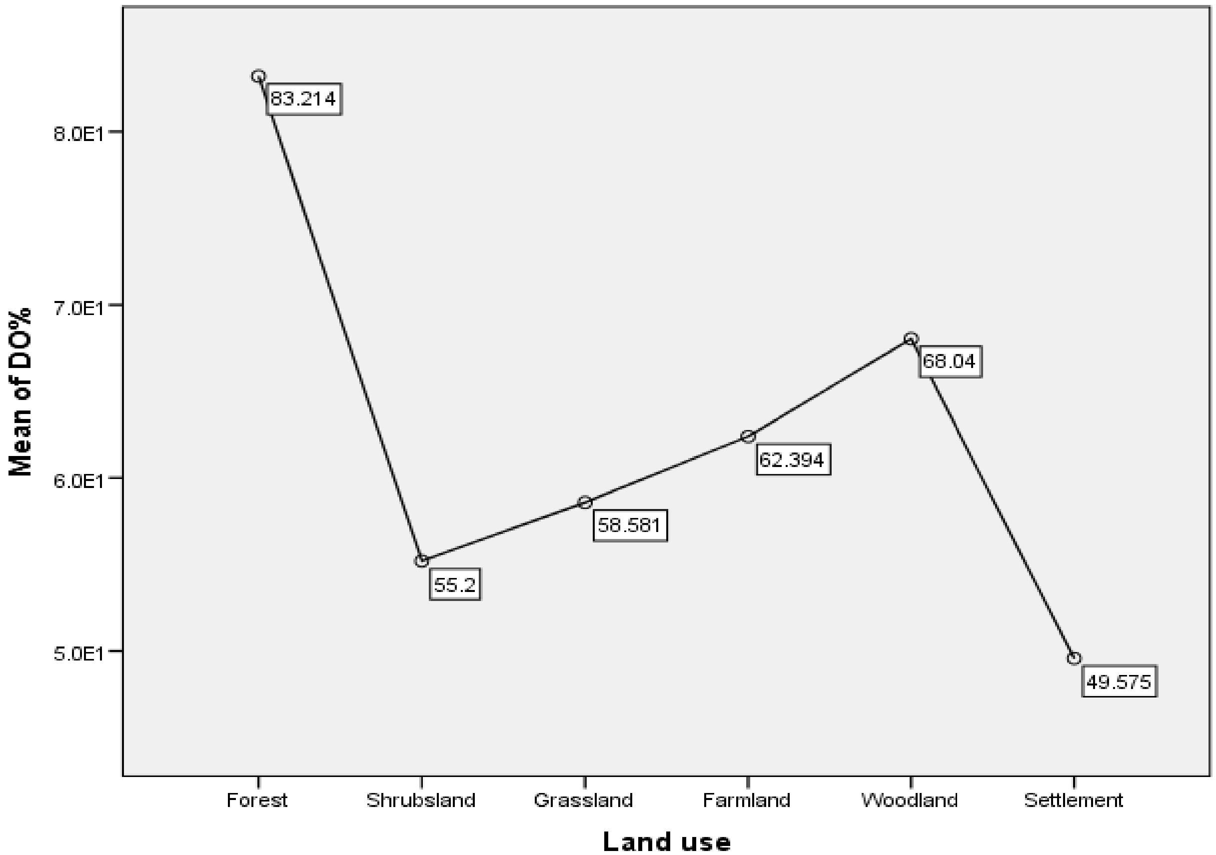

Table6.1: Chi-square test for insignificance of freshwater snail species distribution in relation to land-use types.

Freshwater snail species distribution		
	land use type	Total distribution
Chi-Square	12.985[a]	551.369[b]
Df	5	36
Asymp. Sig.	.024	.000
Exact Sig.	.024	.000
Point Probability	.001	.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 21.7.

b. 37 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 3.5.

Table8.1: The chi-square test statistics of cercarial prevalence to land-use types.

Test Statistics			
	land use	snail infected	number of infected snails
Chi-Square	1.000[a]	4.909[b]	.818[c]
df	3	4	9
Asymp. Sig.	.801	.297	1.000

a. 4 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 2.8.

b. 5 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 2.2.

c. 10 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 1.1.

Table10.1: The insignificance level of schistosomiasis prevalence to land-use types.

	land use	freshwater snail species per site	*B. globosus*	*B. pfefferi*	*L. turncatula*	*L. natalensis*	P. acuta
Chi-Square	3.667[a]	7.630[b]	16.333[c]	4.481[c]	19.593[c]	4.481[c]	19.593[c]
df	3	4	1	1	1	1	1
Asymp. Sig.	.300	.106	.000	.034	.000	.034	.000
Exact Sig.	.325	.115	.000	.052	.000	.052	.000
Point Probability	.043	.022	.000	.033	.000	.033	.000

Table11: The symmetric measure value of Phi coefficient which show strength association.

Symmetric Measures			
		Value	Approx. Sig.
Nominal by Nominal	Phi	.534	.000
	Cramer's V	.534	.000
N of Valid Cases		130	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

2. Some of the Results Table and Figures:

Table 8: Association of freshwater snail species and land-use types of the sampling stations in Omo-Gibe river basin, Ethiopia.

		Land-Use types						
		Forest	Shrubsland	Grassland	Farmland	Woodland	Settlement	
Snail Spp.	A/P Site	(n=22)	(n=19)	(n=27)	(n=32)	(n=10)	(n=20)	Total
	P	7	6	7	6	1	11	38
L. natalensis	A	15	13	20	26	9	9	92
	P	0	0	1	3	1	2	7
L.truncatula	A	22	19	26	29	9	18	123
	P	0	1	2	1	0	4	8
P. acuta	A	22	18	25	31	10	16	122

	P	0	0	1	1	0	0	2
P.Spp.	A	22	19	26	31	10	20	128
	P	7	10	8	14	0	12	51
B. pfefferi	A	15	9	19	18	10	8	79
	P	2	0	0	0	0	0	2
B. sudanica	A	20	19	27	32	10	20	128
	P	8	2	4	3	0	5	22
B. globosus	A	14	17	23	29	10	15	108
	P	2	7	4	5	7	6	31
Sphaeriidae	A	20	12	23	27	3	14	99

NB: (p) for presence, (A) for absence and (n) shows the number of stations samples were taken.

Table 9: Freshwater snail species collected from 130 sampling stations in relation to land-use types of Omo-Gibe river basin.

Total distribution				
Land use type	**n**	**Sum total Snails**	**% of Total snail Sum**	**% of Total (n)**
Forest	22	116	4.5%	16.9%
Shrubsland	19	215	8.4%	14.6%
Grassland	27	241	9.4%	20.8%
Farmland	32	523	20.4%	24.6%
Woodland	10	80	3.1%	7.7%
Settlement	20	1384	54.1%	15.4%
Total	130	2559	100.0%	100.0%

Table 10: The number of freshwater snail species tested for cercarial positive at eleven stations of the study area**.**

Land-use type	Total N/sum	number of infected snails
settlement	N	2
	Sum	14
grassland	N	2
	Sum	40
farmland	N	4
	Sum	49
Shrubland	N	3
	Sum	6
Total	N	11
	Sum	109

NB: **N-** represented the number of land-use types and **sum-** represented the total number of freshwater snail species infected.

3. **Freshwater Snails and other Macroinvertebrates Sampling Protocol (2016)**

General information:

1. DD/MM/YY…………………………………………… Time (………..am,…………pm)
2. Site Name………………………………Sampling station…………………………………
3. Location:

a) Latitude……^{o}……'…..''N to……^{o}……'……''N Longitude……^{o}……'……''E to ……^{o}……'………''E

b) Altitude: …………………………. (m.a.s.l)

4. Name of Freshwater……………………………………. Sampling station………………….
5. Weather condition………………………………………………………………………

a. Storm (heavy rain)……………….. b. Rain (steady rain)…………………………………..

b. Showers (intermittent)…………….d. Cloud cover………………………….................%

c. Clear or sunny……………………f. Others……………………………………………….

6. Previous day rain history………………………………………………………………..
7. Photo number……………………………………………………………………………
8. Size of site under assessment (ha)………………………………………………………
9. Size of total freshwater complex………………………………………………………..

Note and/or sketch of the site:

Physico-chemical parameters (Field)

10. Ambient Temperature (^{0}C) ………………………pH…………………………………………
11. Water temperature (^{0}C)……………………DO (mg/L)…………%........EC (µs/cm)………...
12. Turbidity (NTU)………………Transparency (cm)……………………………………………
13. Chlorophyll a (ABS)………………… (0.1309*ABS+11.274) ………………………..(µg/L)
14. Color…………………………………..Odor ……………………………………………….
15. Water velocity (m/s)……………………………………………………………………….

Physico-chemical parameters (laboratory)

16. COD ………………………………… NO_2^-……………………………………………
17. Chloride……………………………NH_4……………………………………………
18. TSS…………………………….. TN…………………………………………..
19. BOD_5 ………………………………TP……………………………………………
20. NO_3^- ……………………………….PO_4^{3-} …………………………………………

Hydrogeomorphological assessment

21. Wetland geomorphic setting
a. Riverine…………………………………………………………………………
b. Depressional…………………………………………………………………….
c. Meandering flood plain…………………………………………………………
d. Other……………………………………………………………………………
22. River/stream geomorphic setting
a. Reach length……………………………………………………………………..
b. Stream width……………………………………………………………………..
c. Reach area…………………………………………………………………………
d. Stream depth………………………………………………………………………
e. Stream velocity…………………………………………………………………….
f. Canopy cover………………………………………………………………………
g. Stream proportion…………………………………………………………………..
h. Channelized (straightening of stream, bridge abutment, road crossing, diversions, others specify)………………………………………………………………………………..
i. Dam present/absent…………………………………………………………………
23. Pond geomorphic setting
a. Natural: Permanent……………………….. Intermittent……………………………………..
b. Artificial: permanent……………………….. Intermittent………………………………….
24. Dam geomorphic setting
a. Embankment dams (built of earth or rock)…………………………………………
b. Concrete gravity dams (built of masonry blocks & concert or roller-compacted concrete…………………………………………………………………………..
c. Arc dams (concrete dams that carve up-stream toward the flow of water)……………
d. Buttress dams (depend for support on a series of vertical support)…………………...
25. Irrigation ditches
a. Surface……………………………………………………………………..
b. Localized……………………………………………………………………..
c. Drip……………………………………………………………………………..
d. Sprinkler……………………………………………………………………..
e. Sub irrigation/seepage……………………………………………………………..
26. Site Setting/degree of isolation from other wetlands
a. The site is connected upstream and downstream with other wetlands

b. The site is only connected upstream with other wetlands
c. The site is only connected downstream with other wetlands
d. Other wetlands are nearby (within 0.25mile) but not connected
e. The wetland site is isolated

27. Free water depth (cm)
a. Minimum…………..b. Maximum………………. C. average………………………………

28. Sludge depth (cm)
a. Minimum………….. b. Maximum…………………. c. Average………………………….

29. Apparent hydroperiod
a. Permanently flooded
b. Seasonally flooded
c. Saturated (surface water seldom present)
d. Artificially flooded
e. Artificially drained

30. Hydrogeological modification
a. Ditch inlet and outlet……………. … d. Culverts………………………………………
b. Drainage……………………………. e. Filling or bulldozing…………………………
c. Storm water input…………………… F. Other (specify)……………………………….

Land Use

31. Adjacent land use pattern
a. Agriculture tilled…………………… e. Road ……………………………………………
b. Pasture ……………………………..f. Commercial ………………………………………
c. Native vegetation………………….. g. Industrial …………………………………………
d. Residential area………………….. h. Recreational……………………………………….
i. Forest………………………………j. Field or pasture……………………………………..

Habitat Assessment

32. Hydrophytic vegetation coverage (%)
a. Woody plants ……………………………e. floating macrophytes…………………………
b. Water grasses ……………………………f. periphyton……………………………………..
c. Emerged macrophytes……………………g. Filamentous algae…………………………….
d. Submerged macrophytes……………………………………………………………………..

33. Substrate
a. Cobble (hard substrate)……………………………………………………………………..%
b. Snags…………………………………………………………………………………………..%
c. Vegetated bank ……………………………………..%
d. Submerged macrophyte ………………………………………………………………………%
e. Sand and other fine sediments………………………………………………………………%
f. Others………………………………………… ……………………………………………%

34. Factors conditioning freshwater snails
    a. Size, volume & depth………………………………………………………………………

b. Shore profile (erosive activities of water movement)…………………………………
c. Water movement (wave action and current; eg. Floods or turbulence)………………
d. Change in water level (shallow, Deep)……………………………………………….
e. Insolation (intensity of light)……………………………………………………….
f. Substratum and vegetation of the water body……………………………………..
g. Dissolved minerals (Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-})…………………………………………
h. Dissolved gases (Oxygen, Carbon dioxide, Nitrogen, Ammonia, Hydrogen sulfide, Hydrocarbons)……………………………………………………………………….
i. Other organisms:
-Algae………………………………………………………………………………
-predators…………………………………………………………………………..
-Macroinvertebrates………………………………………………………………..
-others………………………………………………………………………………

35. Name of dominant macrophytes
a. ………………………………………………………………………………………
b. ………………………………………………………………………………………
c. ………………………………………………………………………………………
d. ………………………………………………………………………………………

36. Freshwater Fauna
a. Birds (ducks)……………………………………d. Anurans…………………………………
b. Fish……………………………………………e. Hippopotami……………………………
c. Snails and other invertebrates……………………f. others specify…………………………..

37. Anthropogenic activities	Freshwater	Uplands
a. Cultivation	…………………….	…………………………
b. Tree removal	……………………..	………………………….
c. Shrub removal	……………………..	…………………………..
d. Tree plantation	……………………..	…..………………………
e. Grazing	……………………….	………………………….
f. Grass cutting	………………………	…………………………..
g. Brick making	…………………………	………………………….
h. Car washing	…………………………	……………………………
i. Clay mining	………………………….	…………………………..
j. Waste damping	…………………………	…………………………..
k. Fishing	………………………….	…………………………
l. Swimming	……………………………..	…………………………
m. Cloth washing	………………………………..	…………………………
n. Riparian substrate disturbance	…………………	…………………………
o. Alteration of large woody debris	…………….	…………………………

38. Any additional coments……………………...
…………………………………………………………………………………………………

4. **Laboratory Equipment Specifications used for sample collection of Habitat Suitability modeling and mapping of Freshwater snails distributions in Omo-Gibe River Basin, Southwest Ethiopia.**

S/N	Name of Laboratory Equipment		Amount needed	Purpose	Remark
1.	Sampling Equipment	D-Frame Net 250-500µm	2		
2.		Sieve Bucket	3		
3.		Scoop Net	1		
4.		1 L Sample Bottles (at least 64)	64		
5.		Fyke Net	10		
6.		Fish Jar for voucher	2		
7.		Gloves - shoulder length	3 pairs		
8.		Gloves - wrist length	3 pairs		
9.		Chest waders/Hip boot	5 pairs		
10.		Bucket(Plastic)	3		
11.		Permanent marking pen	5		
12.		Meter stick	1		
13.		70% ethanol for storage of specimens	2L		
14.		Specimen vials with caps or stoppers	80		
15.		White plastic or enamel pan (15cm x 23cm) for sorting	3		
16.		Global Positioning System (GPS) Unit	1		
17.		Flow or velocity meter	1		
18.		Pencils or waterproof pens	5		
19.		Forceps	10		
20.		Cooler with ice	5		
21.		Dropper	3		
22.		Binocular	1		
23.		Spatula	3		
24.		Knife	1		
25.	Meters/ Measuring	pH meter	1		
26.		D.O. Meter	1		
27.		Cond. Meter	1		
28.		Tape Measure	1		
29.		Camera	1		
30.		Thermometer	1		
31.		Transparency measure/Secchi depth	1		

32.		Sludge depth meter	1		
33.		Fish Measuring board	1		
34.		Spectrophotometer/fluorometer for chlorophyll a	1		
35.		Waterproof Plaster	1		
36.		Altimeter	1		
37.		Glass slide	120		
38.		Filter membrane	2		
39.		Lugol (Iodine solution)	2L		
40.		Snail identification key	Bouchard 1999/2004		
41.		Aquarium	1		
42.		Sand	1.5kg		
43.		Lettuce leave	1kg		
44.		Petri dish	64		
45.		Dissecting Microscope	1		
46.					