JIMMA UNIVERSITY

COLLEGE OF SOCIAL SCIENCES AND HUMANITIES

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

MSc. Thesis

Environmental Impact Assessment of Modjo River Pollution Using Geospatial Technologies: The Case of Modjo Watershed, East Shewa Zone, Oromiya National Regional State, Central Ethiopia

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October, 2019

Jimma, Ethiopia

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A Thesis Submitted to School of Graduate Studies of Jimma University in partial fulfillment of the requirements for the Degree of Master of Science (MSc) in Geographic Information System and Remote Sensing

October, 2019

Jimma, Ethiopia

Declaration

I, Workinesh Tesfaye Reta, here declare that the thesis entitled“Environmental Impact Assessment of Modjo River Pollution By Using Geospatial Technologies: The Case of Modjo Watershed, East Shewa Zone Oromiya National Regional State, Central Ethiopia” is my original work and it has not been submitted by anyone else to any other University or institution for the award of any degree or diploma and that all sources of material used for the thesis have been dully acknowledged.

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We, the undersigned, members of the board of the examiners of the final open defense by Workinesh Tesfaye have read, evaluated and received she's research work entitled "Environmental Impact Assessment of Modjo River Pollution using Geospatial Technologies: A Case of Modjo Watershed,East Shewa Zone,Oromiya National Regional State Central Ethiopia." This is, therefore, to certify that the thesis has been accepted.

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ACKNOWLEDGEMENTS

Special thanks to the Almighty God for his guidance and grace that allowed me to stay until this time and my work come to be successful. To the highest God be glory great things he has done for me and his shepherd is protected me from everything.

I would like to express my deepest gratitude and sincere thanks to my Advisors Dr.KenateWorku (Main Advisor) and Mr.DemisieTsega (Co-Advisor) for their supports,constructive comments,devoting precious time in guiding as well as correcting of this research.

I would like to thank my staff members and all my classmates for their moral support,discussions and helping me during the work. I would like to say thanks also Modjo town Environental protection department officers support by providing available information for the successful accomplishment of this study.

Finally, I would like to extend my heartfelt thanks to all my familiesspecially my brother Shibiru Argu enabling me to reach this stage of education and assisting me both in ideas and in material to accomplish this paper and I would like to say thanks my little sister Burtukan,Mr. Yewalashet Gorfu and Mignot Tamirat for encouraging me, great strength, support and love in the time of need.

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LIST OFABBREVIATIONS AND ACRONYMS

AAEPA: Addis Ababa Environmental Protection Authority

AHP: Analytical Hierarchy Process

BOD: Bio chemical oxygen demand

COD: Chemical oxygen demand

DO: Dissolved Oxygen

EC: Electrical conductivity

EEPA: Ethiopia environmental protection authority

EIA: Environmental impact assessment

EPAE: Environmental performance assessment engine

EPHA: Ethiopian Public Health Association

FEPA: Federal environmental protection agency

GIS: Geo information system

MCDM: Multi criteria decision making

NDVI: Normalized difference vegetation index
OECD: Organization for economic cooperation and development

OEPO: Oromiya environmental protection office

pH: Potential of Hydrogen

RS: Remote sensing

UNDP: United nation developmental programme

UNESCO: United Nations Educational scientific and cultural organization

WHO: World health organization

WLC: Weight liner combination

ABSTRACT

Rivers have been highly interlinked with economic growth and human welfare in the history of humankind civilization. In Ethiopia, most of industries were established nearer to surface water such as river and lakes. Likewise, Modjo River hosts various manufacturing industries that were established within its catchment area and now Modjo River is becoming dead water. The objectives of the study were to assess the Environmental impact of Modjo River pollution using geospatial technologies. Data for this study were collected from both biophysical and environmental data sources. Thus data generated from water sample, satellite image, GPS point, questionnaire, and interview. Quantitative socio economic data as part of household survey and interview with elders, experts, local administrator and focal persons were analyzed as well as qualitatively water sample data collected from sampled point, satellite image, GPS point were analyzed. The result of the study show that the extent of parameters such as BOD, COD, DO, Ph, EC, Pb Cr, Cd, turbidity were found in all observed point beyond the permissible limit set by EEPA and WHO further more BOD,COD,EC, turbidity were found in large concentration and DO found in zero. In spite of this the study shows that the environment, people and their livestock are susceptible to health implication and exposed to high socio economic and environmental crisis. Finally recommend that authorities have to be ensuring that all industries adopt efficient technology for waste water treatment and treat effectively Modjo River water by deposit lubricants at both site and using other methods to avoid contaminants from water in order to minimize the effect of Modjo river pollution into water resource, communities' livelihood and Environments.

Key words: River pollution, pollution assessment, environmental impact, Geospatial technology

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Water is the most vital element among the natural resources, and is critical for the survival of all living organisms, food production and economic development. In spite of its contribution for global food production through irrigation, which accounts 40% food supply, and reliance of wide varieties of industrial processes on water, worldwide many people are facing acute shortage of water (Halder et al., 2015). To this effect, water related problems such as shortage and pollution were and are continued to be challenge for both developing and developed nations.

The environment, economic growth, and developments are all highly influenced by water regional and seasonal variability and quality. On the other hand, the quality of water is affected by human activities such as urbanization, population growth, industrial production, climate change and other factors (Sarkar et al., 2016). The resulting water pollution is a serious threat to the well-being of both the Earth and its population. Because of the rapid increase in demand for water, and increase in occurrences of pollution of numerous water sources, environmental risks to humans and other life beings are enhanced. Due to changes in the quantity and quality of water, some environmental disasters are causing stress and hardships in a river basin in around the world (Bhuiyan et al., 2013).

The issue of surface and groundwater pollution has not been considered as a major problem in Ethiopia until recent times. The environmental quality of freshwater ecosystem has deteriorated by pollutants. Pollution of water bodies may take place due to the discharge of domestic and industrial wastewater, toxic chemicals used for agriculture and other purposes, solid waste due to garbage, and cleaning of vehicles, drainage from forms and land surface, dust fall, wastes due to recreational use and much more such activities.

Pollution caused by a plethora of human activities primarily affects physicochemical characteristics of water leading to the destruction of community disrupting delicate food webs and deteriorating aquatic environment (Ademe et al., 2014).Environmental pollution derived from domestic and industrial activities is the main threat the surface water qualities in Ethiopia.

According to Yohannes et al., (2017).Most of industries in the country discharges their wastewaters into nearby water bodies and open land without any form of treatment.

Tamiru et al. (2004) explains that like other developing countries whose sources of pollutions are from domestic, agricultural and industrial activities; Ethiopia is also facing the same. Apparently, in Ethiopia where there is no as such environmental protection practice, there are a number of pollutant sources that continuously deteriorate the quality of surface and groundwater. Accordingly, the adverse impact of human population on surface and groundwater was increasing.

Modjo River is one of the surface water resources that are passing through the Modjo watershed. A preliminary site visit in this study has shown that it is surrounded by settlements, industries and farm lands. During the site visit it has been observed that a number of pollutant sources adversely affect the quality of Modjo river water. The river is influenced due to rapid industrial growth around the bank and discharging of their waste water that contains organic and inorganic materials. This discharged waste water causes several environmental and socio-economic damage in the area through affecting ecological integrity, bio-waste, animal welfare, and production and productivity of agriculture.

Gebre et al., (2016) have assessed the pollution of Modjo River in their study. However, their study was focused on determining the pollution profile and identification of pollution loads from industrial waste and dispersed from upstream to downstream areas in Modjo River rather than on its environmental and social impact. Hence, the focus of this study was to analyze impact ofModjo river pollution on the surrounding environment and communities.

1.2. Statement of the Problem

Worldwide urban centers are characterized as a center for industries. Many urban centers have no treatment facilities that are antiquated or poorly maintained large percentage of waste products. Discharged directly into water sources without treatment especially in developing countries where sewage treatment is currently low (Ademe et al., 2014).Only a few countries have primary treatment facilities to remove about 40-50% of the organic load and very few use any secondary treatment process to remove more than 80% of the contamination.

Ethiopia is among countries that are characterized by rapid urbanization. These urban centers are also center of politics, economy and social activities. As a result, most of industries in the country are established near towns and cities. The overall goal of industrial policy is to improve and enhance the health and quality of life of all Ethiopians and to promote sustainable social and economic development through the sound management and use of natural, human-made and cultural resources and the environment as a whole so as to meet sustainability in environmental resource (EPAE, 1997).

Despite this fact, the Ethiopian Environmental protection Authority report indicates that the serious deficiencies in sanitation services and the inadequacy of sewerage infrastructure and random defecation in urban areas have created dangerous health and environmental problems (EPAE, 2005). Apparently, Modjo town is serving as center for different textile and tannery industries that uses the adjacent river as an outlet for its waste discharge.

The river has been serving as the main source of water for home consumption as well as for any other activities though they are serving as dumping areas of industrial waste. These waste discharges in addition to affecting water quality it affected peoples and animals health up to death such as skin rashes, both on animal and human being, stomach sickness and affecting by different water born disease and also Ecosystems are destroyed by the rising temperature in the water, aquatic animals caught and killed from suffocation by polluting river water.

Accordingly, Gebre et al., (2016) in their study identified that there are introduction of pollution loads from industrial waste and dispersed from upstream to downstream areas in Modjo River. Due to their toxicity, bioaccumulation, high tendency of persistence, biomagnifications through food chain, heavy metals expose itself a potential threat to ecosystem on human and animal health the accumulation of waste and soil erosion in streams and rivers sometimes causes flooding and drew the attention of environmentalist. Since a very large number of people have no other source of water for domestic use, agricultural irrigations and livestock watering, it is not surprising to come across acute and chronic health effects in evidence as a result.

Being polluted, Modjo River is causing different social and economic problems to the livelihood of the downstream residents. (OEPO, 2004) reported that due to the absence of alternative source of water in the areas, more than 63,000 people in the catchment areas of the rivers uses it for different purposes. Moreover, it causes changes in income, health condition, agricultural production and socio-cultural values adversely. This brought immense challenge to communities living nearby and adjacent to rivers in the watershed regions.

Above all, Modjo River is becoming dead water with growing impacts on the communities' livelihood. The waste discharges brought health problems such as water washed (e.g. skin rashes) and water borne (e.g. diarrhea, typhoid and livestock rapid weight loss up to death). The ecosystem is destroyed by the rising load of pollutants in the water, aquatic animals caught and killed from suffocation by polluting river water.

Since, there is no study which was conducted on Environmental impact of Modjo river pollution; this study will add some asset to explore the extent of impact in the study area and by identifying high risk areas due to contamination of Modjo River. Therefore, this study was intended to analyze the extent of Modjo River pollution hazard and the impacts on the surrounding environment using geospatial technologies.

1.3. Objectives of the Study

1.3.1. General objective

The general objective of this study was to assess the environmental impact of Modjo river pollution using geospatial technologies.

1.3.2. Specific objectives

Specifically, this study was intended:

- To assess the extent of pollution of Modjo river both by organic and inorganic nutrients.
- To analyze the impact of Modjo river pollution on the environmental and socio-economic activities.
- To identify risk area of Modjo river contamination effect in the catchment area.

1.4. Research Questions

1. What does the extent of Modjo river pollution on the surrounding environment looks like?
2. What are the impacts of Modjo river pollution on the environment and socio-economic activity?
3. How can the degree of the risk be known and mapped?

1.5. Significance of the study

The study finding may contribute knowledge on the levels and extent of industrial pollutant and their effect on water resource, communities' livelihood, health and environmental and as future reference to studies in the water sector. Further the study findings could be significant to experts and decision makers. Because, proper mapping of risk areas and identified it enables to minimize risk on life of communities and environment. The finding would also be shared with the ministry of industry and trade to help improve industrial policy implementation on water management and adding knowledge in the thematic area to scientific communities and decision makers to come up knowledge-based actions and strategies.

1.6. Scope of the study

Conceptually, this study dealt with assessing the environmental impact of Modjo River pollution. Geographically, this study emphasis only on Modjo watershed, East Shewa zone Oromiya Region. The impact was assessed in terms of communities'livelihood, health,living organism and vegetation cover based on socio-economic, satellite image and field data. As the core concern of this study is to assess the impact of water pollution various bio-physical and environmental data was investigated systematically and carefully.

1.7. Limitation of the study

River pollution environmental impact assessment requires high erudition in terms of to identify environmental, social and economic impacts of a river because it needs to consider the fundamental components of EIA such as screening, scoping, assessment and evaluation of impacts. Hence, there were challenges that were, to some extent, needed to be considered by other researchers when moving to field to do research on this area. Accordingly there is lack of transport access during data collection because of the target study area remote from the town, absence of adequate data and time series information on the subject area have been the main bottlenecks that this study has been obliged to face. Similarly the absence of laboratory for water sample analysis is another problem facing during this study but by communication peoples which work on this area and by incorporate with them solve it.

1.8. Organization of the Thesis

This thesis is divided into five chapters the First chapter provides the introduction to the study including background of the study, statement of the problem, objective of the study, question, scope, significant, and limitation of the study. The Second chapter presents review of related literatures, mainly including Conceptualization, Theoretical and Empirical related literature. The Third chapter deals with the description of the study area as well as the materials and methods employed in the study. The Fourth chapter presents the result and discussion and finally risky area identify and map in the study area. Chapter Five presents conclusion and recommendations.

CHAPTER TWO

2. REVIEW OF RELATED LITERATURE

2.1. Concepts and definitions

2.1.1. River and River Pollution

There is no universally agreed definition of river. Rivers and streams drain water that falls in upland areas. Moving water dilutes and decomposes pollutants more rapidly than standing water, but many rivers and streams are significantly polluted all around the world. A primary reason for this is that all three major sources of pollution (industry, agriculture and domestic)are concentrated along the rivers. Pollution defined as introduction of contaminants into the natural environment that cause adverse change or pollution is the introduction of harmful substances or products into the environment (John N., 2009)

River pollution occurs when unwanted materials enter into water, changes the quality of water and harmful to environment and human health. It is reported that 75 to 80% water pollution is caused by the domestic sewage. Waste from industries like, sugar, textile, electroplating, pesticides, pulp and paper are polluting the water. Polluted river have intolerable smell and contains less flora and fauna large amount of domestic sewage is drained into river and most of the sewage is untreated. Different industrial effluent that is drained into river without treatment is the major cause of water pollution. Hazardous material discharged from the industries is responsible for surface water and ground water contamination. Contaminant depends upon the nature of industries, 25% pollution is caused by the industries and is more harmful (ILO 2011).

Every industry may have a specific impact on water. Some of the impacts are direct due to the usage and management of water. Some are indirect because the projects are built on particular sites. That arouses more attention on environmental impact assessment(Galiani et al., 2005).

2.1.2. Environmental Impact Assessment

Environmental Impact Assessment is a procedure used to examine the environmental consequences or impacts. The purpose of EIA is to generate particular information on possible impacts that a proposal may have on environment in advance of decision making (Glasson et al., 2012;Riffat and Khan, 2006).The EIA will comprise of three components; Environmental baseline study; environmental assessment; and environmental impact statement. The environmental impact assessment may be submitted as the three components highlighted above or could be submitted as one document depending on the size and nature of the proposed project. The environmental baseline study will record the present quality of the environment within the area of influence before project implementation(Glasson et al., 2012).

This data will then be analyzed in the environmental assessment and will be used to predict and quantify impacts. The environmental assessment is basically the identification and assessment of impacts of the proposed project and of its alternatives. The EA will also consider mitigation measures to offset negative impacts and will assess the impact of implementing these measures on the environment. The environmental impact statement is a summary of the findings of the environmental baseline study and the environmental assessment and includes an environmental management plan(Riffat and Khan, 2006).

2.3.Global experience of Environmental Impact Assesment ofpolluted rivers

Excessive human pressures on the earth are causing a range of global environmental changes which impact on the safe and secured water for the lives in the world. Due to changes in the quantity and quality of water, some environmental disasters are causing stresses and hardships in a river basin in around the world (Bhuiyan et al., 2013).In such issues; water pollution is an important and essential issue in the world which requires ongoing evaluation and revision. In addition to the acute problems of water pollution in developing countries, developed countries continue to struggle with pollution problems as well.

In the most recent national report on water quality in the United States, 45 percent of assessed stream miles, 47 percent of assessed lake acres, and 32 percent of assessed bays and estuarine square miles were classified as polluted. Generally, water pollution is covered in water bodies of toxic chemicals and biological agents which exceed what is naturally found in water and may pose a threat to human health and the environment. The polluted water caused serious problems for human health as well as hampered ecological and environmental agents (Zaidi, 1994; Zhang et al., 2010).

Moreover, the range of health risks from climate change include direct, indirect (mediated), and diffuse and delayed effects. The posed by climate change are now beginning to challenge the skills, creativity, and policy engagement of researchers, policy analysts, and stakeholders (Tong et al., 2011). On the same way, studies identified that the huge number of chemicals released into the river which caused for environmental risk around the river basin area. (Beskow et al., 2009). Polluted water consists of Industrial discharged effluents, sewage water, and rain water pollution (Ashraf et al., 2010) and polluted by agriculture or households cause damage to human health or the environment (EPHA, 2009).

This water pollution affects the health and quality of soils and Vegetation Carter, 1985. Some water pollution effects are recognized immediately, whereas others don't show up for months or years (Ashraf et al., 2010). Estimation indicates that more than fifty countries of the world with an area of twenty million hectares area are treated with Polluted or partially treated polluted water (Hussain et al., 2001) and this poor quality water causes health hazard and death of human being, aquatic life and also disturbs the production of different crops in fact, the effects of water pollution are said to be the leading cause of death for humans across the globe.

Moreover, water pollution affects our oceans, lakes, rivers, and drinking water, making it widespread and global concern polluted water is complex water resource with both advantageous and also disadvantageous. (Ashraf et al., 2010; Scipeeps, 2009).Generally, the use of polluted water for irrigation has an advantage of crop production so benefits to farmers and the whole community but also harmful for the people and whole ecosystem of the concerned area. The main reason for the use of this polluted water is the non-availability of enough funding to treat polluted water before using for irrigation purposes.

As a result it degrades the environment as well as a cause of water borne diseases in the said area. All polluted Water contains plant nutrients and also organic matter other than high concentration of soluble Salts and heavy metals. Farmers use polluted water to save their expenses. Harmful effects can last for several years due to extensive irrigation of polluted water so it can not only leach down the soil but also has a negative effect on ground water quality (Scipeeps, 2009).

2.4. Environmental Impact Assessment of Polluted River in Africa

There are many water quality problems in both developing and developed countries. Allof the environmental concerns that developing countryface; the lack of adequate water of good quality is probably the most serious. The water quality situation in developing countries is highly variable reflecting social, economic and physical factors as well as state of development. And while not all countries are facing a crisis of water shortage, all have to a greater or lesser extent serious problems associated with degraded water quality.

In some countries these are mainly associated with rivers, in others it is groundwater, and in yet others it is large lakes; in many countries it is all three (Ebisemiju, 1993). Because the range of polluting activities is highly variable from one country to another, and the nature of environmental and socio-economic impacts is equally variable, there is no "one-size-fits-all" solution. bemoaned the lack of developing country EIA systems but about two-thirds of the approximately 110 developing countries had enacted some form of EIA legislation by the mid-1990s.

Just as there are huge differences in EIA systems in the developed world, so there are between EIA systems in developing countries. In Africa some have no EIA system (Kakonge, 1999). Within Africa, for example, while the South African EIA system has many of the attributes of a sophisticated developed country EIA system (Wood, 2002) and EIA is becoming important in Ghana (Appiah-Opoku, 2001) as yet EIA is unimportant in Somalia. Variation in the extent, regulatory form and practical application of EIA in developingcountries isdifferent.

It appears generally to be accepted that social as well as environmental impacts should be included in developing country EIAs and that positive as well as negative impacts should be emphasized (World Bank, 1991; Biswas, 1992; OECD, 1992). Each developing country EIA system should be designed to cover all the types of actions which have the potential to cause environmental damage in the local circumstances: there is no universally applicable model. (Lohani et al., 1997)

2.6. Extent of water pollution in Ethiopia

According to UNESCO national water development report for Ethiopia (2004), about 90 percent of industries which are found in country have simply discharged their sewage into nearby water bodies, streams, and open land without any form of treatment. As cited by (UNSECO,2004) in 1996 report ministry of health on the study of liquid waste management, out of 118 industrial establishments assessed in the city of Addis Ababa, 40 has solid waste discharges, 61 generates air pollutant discharges, while 62 generates liquid waste that was to be discharged to the surrounding environment.

Only six out of the investigated factories are found to have some form of wastewater treatment plants while the rest discharge their wastes without any form of treatment. According to the report of (AAWSA, 2000) most governmental hospitals in Addis Ababa are located far from existing sewerage lines. In addition to this other institution such as government offices schools and academic institutions, a large number of hotels, bars restaurants, garages, and fuel stations, industries in Addis Ababa and locate on other part of the country pollute both ground and surface water qualities (Maschal etal., 2018).

2.7. Effects of River Water Pollution

Water pollution occurs when the use by one segment of society interferes with the health and well-being of other members. Due to the pollution problem of the rivers, negative impact on the social, economic and environmental conditions have been observed. Strong toxic wastes effluents could kill all plants and animals in the stream in to which they are discharged. Less toxic pollution may also engender quite complex hazards whose ill effects are due to nutrients and suspended matter (Fufa, 2015).

2.7.1. Social Problems

Usually, the social problems of river water pollution are manifested in the form of human and animal health problems and its subsequent influences are on educational time and financial loss. Problems Associated with Human Health: Most polluted water contain substances such as nutrient elements, heavy metals and other toxic compound which can affect human health when present in excessive amounts, are regarded as potential contaminants. These contaminants may endanger the health of both human and aquatic organisms. The major potential negative impact of polluted water is an increase in the incidence of water-related diseases and infections.

Human infectious diseases are among the most serious effects of water pollution, especially in developing countries, ware sanitation may be inadequate or non-existent. Waterborne diseases occur when parasites or other disease causing microorganisms are transmitted via contaminated water, particularly water contaminated by pathogens originating from excreta. The infections related to water supply and sanitation are numerous and the relationships are sometimes complex.

Water-related diseases may be divided into those, which are caused by some chemical substances in water and water-related infections which are described because their transmission depends upon water. Human consumption in downstream of the polluted area of the river create health problem on children of school age due to river water is more pronounced problem that may have negative impact on their school attendance and educational performance (EPAE and AAEPA, 2006).

Problems Associated with animal health: these toxic substances can be health hazards to livestock when ingested with water. It is learned that animals become affected after consuming the water. Most of the time, sick animals, which were using polluted river water, show the symptoms like gastrointestinal disorders, bloat body diarrhea, nerves signs like tremors and paralysis, edematous swelling, dermatitis and loss of hair (FEPA 2005). The problem is further worsened by the fact that the river water has bad odors and unpleasant taste so that animals do not drink it on regular basis until they get very thirsty.

Thirsty animals consume high volume of water together with substantial amount of pollutants that could result in health problem. Pollutants may have their main effect on aquatic organisms by reducing the dissolved oxygen (DO) content of water. The amount of oxygen that is dissolved in water varies greatly, and the impact of pollutants on this DO can be measured either in terms of biological oxygen demand or in terms of chemical oxygen demand (Hanley, et al., 2001).Economic problems Apart from causing serious health problems to the dwellers living along the polluted river course, there is also a continuous economic loss, due to problems related to water pollution. The economic losses are divided in to direct and indirect losses.

i. **Direct economic losses**: Whenever, the water quality is affected due to pollution the usefulness of the water for irrigation is impaired. The uses of highly polluted irrigational river water utilizes for horticulture production purposes has chronic health implications. Because of its contamination and bad odor, the desire to use the polluted river decreases. This in turn affects the production and productivity of the farmers, creating a direct economic loss on their income (FEPA, 2005).

Another direct economic loss can be attributed to death of animals due to toxic or pollutant effect or loss of body condition, production such as milk and drought power of affected animals. The other direct economic loss caused due to the water pollution problems is financial loss often incurred for covering health expenses by each family. Human health problem adversely affects the labor, the working interest and initiations; lack of working interest in turn directly affects income.

ii. **Indirect economic losses**: Animals that use these rivers for drinking have poor health condition. Because of that, their body weight and physical appearance decrease resulting in decrease in price. Not only that, the other most indirect impact is the decrease in animal's reproduction performance. Such diminishing trend in size of animal population entails loss of economic benefit that the peasant could harness from the sale of animal products such as milk, butter, etc. Finally, regarding the pollution of surface water, the National Water Development Report for Ethiopia (December, 2004) has the following conclusion. The pollution that has been caused by the industrial wastewater discharge has reached to level of being a major concern. Almost all of the industries upon which a sample analysis has been done are discharging, effluents that contain pollutants well beyond the permissible and internationally accepted standards. The studies conducted on the streams that are flowing through Addis Ababa have shown that most of these streams are currently dead due to the pollution problem.

2.7.2. Ecological problems:

Solid and liquid wastes can be generated from industries, commercial areas, hospitals, construction and households. These wastes are differing in their types and amount. Some of the institutions like hospitals, leather factory and industries generate hazardous wastes and heavy metals. When these wastes are disposed improperly to open areas and natural resources like rivers, these will bring nuisance, health effect, social impact, and water and soil pollution which are going to be resulted to ecological problem (EPAE, 2006). Pollutants that contain phosphate and nitrate discharged from industrial, agricultural and municipal wastes can cause excessive algae growth that can kill fish and other aquatic biota in such stagnant water of the dam. Serious cases of fish mortality can occur following the leaching of poisonous biocides from agricultural fields to rivers or streams after rainfall. These can be resulted in biotic and aquatic changes to the environment and can cause ecological disruption.

2.5. Environmental Impact Assessment of polluted rivers in Ethiopia

Today river pollution problems are heard all over the world because of the ever-increasing population, industrialization, urbanization and other human activities. Though, Ethiopia is facing the problem that emanates from water quality deterioration in general (Awulachew et al., 2007). The extent and severity of the problem is glaringly manifested in major cities of the country. To overcome the problems of river water pollution governing the sources in wise ways is necessary. The pollution of water is attributed to many sources and types of pollutants. When pollutants are discharged in to a river, a succession of changes in water quality takes place, in the downstream side from a point of pollution. The study conducted by the Federal Environmental Protection Authority in 2006 identified the following major pollutants.

I. **Industrial sources**: In our country, industrial pollutions are observed around urban areas because urban areas have better infrastructure and they are suitable for the establishment of industries. In Ethiopia, most of the industries are found in metropolitan City of Addis Ababa and the surrounding areas. The major pollutant industries, which are found in this area, are food and beverage, leather factories, textile, tanneries, rubber and plastic, metallic and non-metallic mineral products and wood industries. Most of the industries that are found discharge their wastewater and liquid effluents into open ditches (municipal drainage), which finally ends up in the river.

Among these industries located in Addis Ababa about 90% of them discharge their wastes without any treatment in to the nearby water bodies and open spaces (National Water Development Report for Ethiopia, 2004). Industrial waste water has a wide range of pollutant concentrations; mainly: oil and grease, Total Suspended Solids (TSS), pH, and Biochemical

Oxygen Demand (BOD) and the priority pollutant heavy metals (Environmental Protection Branch of Canada, 1996). Electrical Conductivity (EC) is a measure of the capability of a substance to conduct an electric current.

It is an indirect measurement of the content of ions in the water. It relies upon the presence of ions, from their common concentration and the water temperature. High values of EC indicate the source of pollution in a particular water source (Durmishi et al., 2008). Conductivity is measured in terms of conductivity per unit length, and meters typically use the unit micro Siemens/cm (µS/cm). Potentiality of Hydrogen (pH) refers to the measure of acidity or alkalinity. Pure water has a pH of 7, acidic solutions have lower pH values and alkaline solutions have higher values. The pH of a material ranges on a scale from 1-14, where pH 1-6 is acidic, pH 7 is neutral, and pH 8-14 is basic.

Turbidity is an expression of the optical property that causes light to be scattered or absorbed rather than transmitted in straight lines through a water sample (Smith et al., 2001). Turbidity in water is resulted by the presence of suspended matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Biochemical Oxygen Demand (BOD) is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period (Walakira, 2011).

Chemical oxygen demand (COD) is the amount of oxygen required to completely oxidize the organic matter in waste water by use of a strong oxidant and to convert it to carbon dioxide and water (Walakira, 2011). COD measurements are commonly made on samples of waste waters or of natural waters contaminated by domestic or industrial wastes. It allows for assessment of the pollution load of wastewater, including pollution by undesirable organic compounds. COD is one of the most important measures for effluent discharge standards.

Dissolved Oxygen (DO) is an important pollution assessment parameter of the receiving water bodies (Vinod et al., 2012). It's an important ecological parameter because the level of DO allows breathing of living organisms in water. It is a requirement for almost all forms of life. Aquatic animals, plants and most bacteria require it for respiration (getting energy from food), as well as for some chemical reactions.

Ii. Municipal sources: Cities in developing countries are experiencing unprecedented population growth, because they are expected to provide better economic and social opportunities than do rural areas. Because of this, rural to urban migration is very high. Ethiopia is one of those developing countries, where by urban population growth rate is higher. When population increases, the municipal solid and liquid waste generation also increases accordingly. Miss-proportionality of the population growth and urban facilities can result to urban pollution.

Hence, it is apparent that one of the sources of river water pollution is the municipal waste of urban areas. The hazards resulting in from municipal and domestic pollution of the Akaki River and-in particular-its tributaries in the upper reaches were identified by studies conducted in the past (National Water Development Report for Ethiopia, 2004).

III. Municipal solid waste: "municipal solid waste" includes street sweeping waste, commercial, industrial and other institutions' solid wastes. When there is no adequate municipal solid waste management facility, the domestic solid waste is not collected properly. Often it is piled on available open grounds, stream banks, and bridge areas and is transported by storm and run off into the rivers. Municipal solid waste management problem is considered to be among the most serious environmental challenges that the world is currently encountering.

IV. Municipal liquids wastes: Domestic liquid waste from overflowing and seeping pit latrines, septic tanks. This municipal liquid waste is mainly caused by liquid waste from toilets, liquid waste from kitchens and bathrooms, open urination and defecation places. Public and communal toilets, open ground excreta defecation, flow to the rivers through drainage lines are the source of municipal liquid wastes.

V. Other Chemicals: Deferent types of used chemicals and stored obsolete chemicals are also observed in different organizations. Much of these chemicals can easily be washed away to the rivers, and chemicals used for different purposes in industries discharged to the river after finishing their process. Fuel stations, laundries and oils from garages are discharged their waste products to open space storage, drainages and rivers which can contaminate river and ground water. Generally, chemical pollution is one of the sources of rivers water pollution.

Prior to becoming a legal requirement in 2002, the application of EIA in Ethiopia was introduced by a few sectors. The practice of contemplating environmental and health impacts was introduced as early as 1980 into water resources development projects assisted by UNDP/WHO, though the main focus was limited to water-related and water-based health problems (Solomon, 2006). This practice then evolved into a formal requirement in international donor assisted and financed projects in various sectors.

The former Ethiopian Valleys Development Authority was the first national institution to incorporate EIA into its activities. The authority developed its own specific guideline for the application of EIA in pre-feasibility and feasibility studies of potential medium-scale irrigation projects (Solomon, 2006). Even though these efforts were limited to the irrigation sector and narrow in scope, and despite that they were donor-driven, they have nonetheless contributed to the emergence of the system of EIA that exists in the country at present.

2.8. Emperical Evidences on Environmental Impact Assessment of River Pollution

In previous studies most of them are not used the integration of GIS, RS and AHP for EIA of river pollution. Such as (Dirriba, 2014; Zhang, 2018; Mwenda, 2010)

Dirriba (2014) was carried out his work on the Environmental and health impacts of effluents from textile industries in Ethiopia: the case of Gelan and Dukem, Oromiya regional state. The study focuses only on four textile industries established in the peri_urban areas of Dukem and Gelan. The objectives of the study were to generate baseline information regarding the concentration levels of selected pollutants and to analyze their effects on biophysical environments. The findings of this study are based on data empirically collected from two sources: laboratory analysis of sampled effluents and socio-economic data to analyze the effects of effluents on biophysical environments. His main limitation was only on Dukem and Gelan town.

Zhang, (2018) has conducted, study on the watershed scale environmental risk assessment of Accidental water pollution: the case of Laoguan river china. To identify risk area he employed WAPRA approach which was proposed for accidental water pollution risk assessment at watershed-scale. The approach involves the integration of "source-habitat-impact" using a ranking system based on specific rules for watershed-scale risk assessment. A set of common criteria was constructed to rank the hazards from different sources and the vulnerability of receptors.

Mwenda, (2010) were conducted research on levels of industrial pollutant and their effects on water resources and livelihoods along Msimbazi sub catchment dares salaam, Tanzania. To undertake their studies the information is acquired from laboratory analysis of water sample data and socio-economic data. Based on this data the results show that the types and abundance of pollutants discharged by industries along the sub catchment were higher and to some points exceeding the WHO standard and affecting the water resources in terms of quality. Generally, most of the researches conducted on EIA related issue are lack of GIS and RS related analysis

2.2. Strategies to Mitigate Environmental Impact of River Pollution

Mitigation is the stage of the EIA process when measures are identified to avoid minimize or remedy impacts. These measures are implemented as part of the process of impact management, together with any necessary adjustment to respond to unforeseen impacts.

In order to reduce the negative impact of river pollution on environment at different level needed the following ways (Freni et al., 2010).

- ❖ The development of the landscape and planting of trees and vegetative cover should be carried out after construction work. To avoid the contaminant into water bodies, a system for the proper collection and disposal of lubricants at both site and maintenance depot should be maintained.
- ❖ Wastewater generated from foundation construction and related activities should be collected and discharged into storm drains after removal of silt and sand in a sedimentation facility.
- ❖ The quality of the discharged effluent in terms of suspended solids, pH, COD and other contaminated as specified in the discharge license should be monitored to check for compliance with the license's requirements.
- ❖ Suitable pH adjustment facilities would be required to lower than pH value of wastewater to an acceptable range.
- ❖ Building construction involves a large variety of construction activities. Wastewater would be generated from concreting, plastering, cleaning and polishing, internal decoration and similar activities. Direct discharge of wastewater into storm drains would pollute the water quality of the receiving water body. A suitably designed wastewater collection system should be provided on site to divert all the wastewater to the sedimentation facility. If necessary, pH adjustment should be undertaken to neutralize the wastewater.

2.9.GIS and Remote Sensing based EIA

The field of GIS and Remote Sensing has been referred to as the technology of today. (Jones, 1997) has observed that the largest primary source of digital data for use in GIS is undoubtedly that created by Remote sensing technology on board of satellites and other aircrafts. The discipline of Remote Sensing is therefore an important relative of GIS and from some point of view regarded as a sub discipline of GIS (Jones, 1997). The two are thus highly amenable to the study and conduct of environmental impact assessment. Geographical Information System (GIS) is a computer-based system which can be used to store, integrate, analyze, and display spatial and non-spatial data for undertaking an EIA study.

The key advantage of GIS for EIA is its ability to perform spatial analysis and modeling (Joao et al.,1996).For future urban growth projections in world developing and upcoming urban townships Environmental Impact Assessment can be defined as the systematic identification and evaluation of the potential impacts (effects) of proposed projects plans, programmes or legislative actions relative to the physical, chemical, biological, cultural and socioeconomic components of the total environment(Canter, 1996). GIS also have the capability for site impact prediction (SIP), wider area prediction (WAP), cumulative effect analysis (CEA), and environmental audits and for generating trend analysis within an environment.

Jones (1997) observed that GIS is highly indispensable because of its ability to conduct spatial analysis on input data. (Bachiller et al., 1995) commenting on its application in ETA studies submits that it is a veritable tool for generating terrain maps for slope and drainage analysis, land resources information system for land management, soil information system, geo scientific modeling of geological formations, disaster planning related to geographically localized catastrophe monitoring development, contamination and pollution monitoring, flood studies, linking of environmental database and constructing global database for environmental modeling. Erickson (1994) suggested 4 four ways of using GIS for EIA. These are:

- Overlay method: This involves overlaying of different layers of interest of the study area to achieve the needed result.
- Checklist method: This is the listing of environmental components, attributes and processes categorized under different groups.

- Matrix method: This is the relating of specific project activities to specific types of impacts.
- Network method: This defines a network of possible impacts that may be triggered by project activities. It involves project actions, direct and indirect impacts.

EIA identifies to minimize the adverse impacts to improve the project viability. GIS is an ideal tool for environmental monitoring. GIS is used to a much smaller degree as an active component of environmental monitoring systems. Environmental monitoring and GIS are more closely related. All in all, GIS will be a component of every environmental monitoring system within the next few years. GIS provides a valuable tool for information analysis, automated mapping and data integration. The GIS tools are easy access to large volumes of data. Remote sensing is the technique of deriving information about objects on the surface of the earth without physically coming into contact with them.

The use of GIS in EIA process is common for scoping in terms of time and money relative to the time and budgets allocated for EIA preparation and especially for scoping studies. Most of the environmental issues can be handled properly with the use of GIS techniques. The applications of remote sensing and GIS in Environmental Impact Assessments are numerous including environmental impact and compliance studies, site investigations and characterizations, natural resource inventory and management assessments, emergency planning, monitoring, transportation, telecommunication site, route and corridor selection and water and power plant site selection (Schaller, 1990).

2.9.1. Multi-Criteria Decision Making as tools for EIA

GIS-based multi-criteria decision analysis involves the utilization of geographical data, the decision maker's preferences and the combination of the data and preferences according to specified decision rules Multi-criteria approaches have the potential to reduce the costs and time involved in assessing the environmental impact based on predefined criteria and weights. Weighted Linear Combination (WLC) and Analytic Hierarchy Processes (AHP) are the two most known Multi-Criteria Analysis methods that were used for decision maker.(Malczewski, 2006).

WLC is a type of multi-criteria evaluation method in GIS environment used to evaluate the impact of the area. The WLC procedure is characterized by full tradeoff among all factors, average risk and offers much flexibility than the Boolean approaches in the decision-making process. The approach allows the decision maker to assign weights according to the relative impact of each risk map and combines the reclassified maps to obtain an overall risk score (Malczewski,2004). Because the technique can effectively be used for impact analysis in GIS environment via criteria establishment, standardization of factors, establishment of factor (Carver, 1991)

The first step employs GIS to Screening screen out, scoping, impact analysis, mitigation high risk and low risk areas based on standards and criteria set by national and international environmental acts and rules for environmental impact assessment areas. In the second step MCDM, is used for ranking the identified sites and rank the more risk area based on the weights assigned to each criterion. AHP is a powerful MCDM tool to assign weights and rank the after external weight was assigned to each layer, WLC techniques were apply to combine all the factors and prepare high risk area map. After creating a final risk map using GIS, the AHP process was applied again for comparing alternative high-risk area to each other against other criteria (size, distance from the center of the city and from nearby settlements) in order to choose the very risk area among existing risk(Saaty, 2008).

The Analytic Hierarchy Process (AHP) is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pair wise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker’s evaluations, thus reducing the bias in the decision-making process. The Analytic Hierarchy Process is a decision-making method for prioritizing alternatives when multiple criteria must be considered. (Nydicket al., 1992).

CHAPTER THREE

3. DESCRIPTION OF THE STUDY AREA AND METHODOLOGY

3.1. Description of the Study Area

3.1.1. Location, Topography and Climate

Modjo watershed is found in the Ethiopian Rift valley where Modjo town and other five small towns included namely Chefe-donsa, Robgebeya, Godino, Koka and Ejere. With area extent 129,874.91ha.It is part of the upper Awash River basin and covers partially Lumie, Ada'aa and Gimbichu Districts in Eastern Showa zone of Oromiya National Regional State. However, the vast majority of the study area is found in Lomie and Ada'aa Districts. Astronomically the study area lies between 38^0 54' 22" to 39^0 17' 18" E and 08^0 24' 15" to 09^0 07' 49"N.The surrounding area is accessible by all weather road and seasonal gravel roads (figure 1).

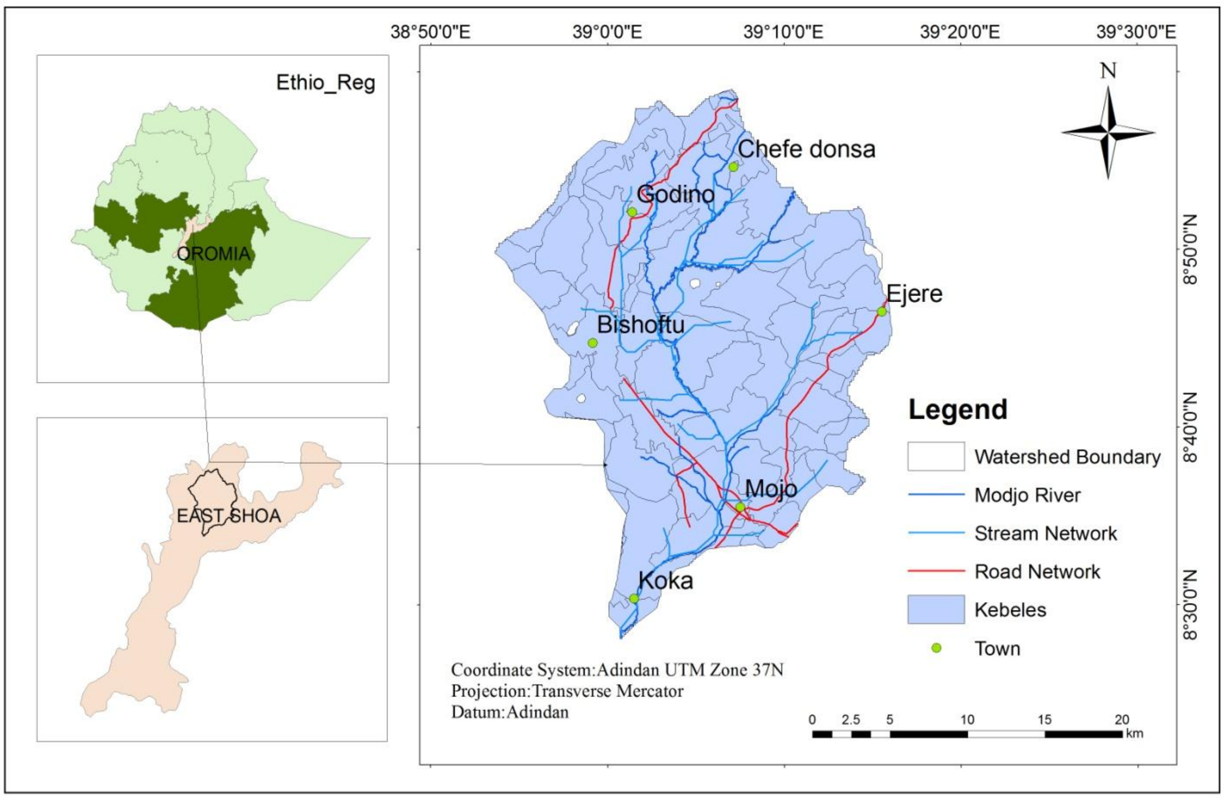

Figure 1: Location Map of Modjo Watershed

Source: (Extracted from Ethio_GIS and DEM of the study area)

3.1.2. Climate

The Modjo watershed falls under the Weyna-Dega (Tropical) (1740m to 2300 m) and Dega (Temperate) (2300m to 3060m) agro ecological zone. On the basis of climate data from three weather stations, Chefe-donsa (upstream part), Bishoftu (relatively midstream part) and Modjo(downstream part), the annual total precipitation is 700mm, 900mm and 1000mm, respectively (see figure2 and Table 2). Similarly, the mean annual temperature ranges from 16.6°C (upstream part) to 19.4°C (relatively midstream part) and 22.3^{0}C (downstream part) (see Table2).

Table 1: Average monthly rainfall in (mm) of study area

Station	Ja n	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chefedonsa	9.3	36.3	53.2	62.9	40.8	99.7	19.6	24.9	114	15.5	2.7	5.3
Bishoftu	10.4	14.7	56.7	53	37.3	99.3	192	195	90.8	23.4	4.2	4.4
Modjo	11.4	23.6	58.7	54.2	53	10.4	255	216	105	29.4	7.2	2.2
Koka dam	12.3	28.6	58.7	74.7	43.5	80.9	21.5	26.3	83.1	30.6	3.6	5

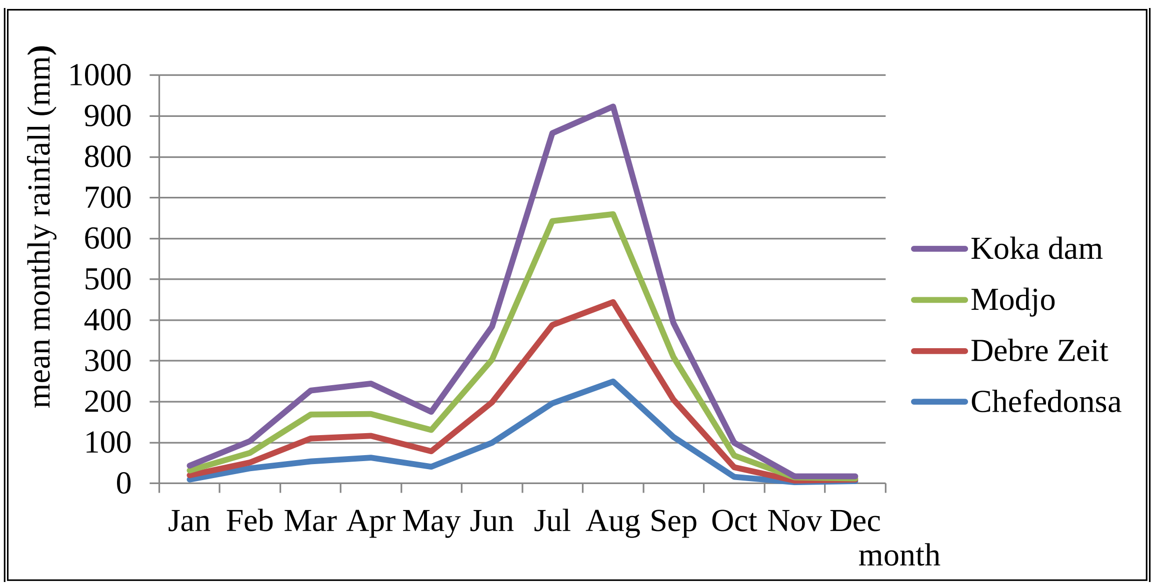

Figure 2: Average monthly rainfall of study area

Source :(Ethiopia Meteorological Agency, 2019).

Table 2: Average monthly Temperature (^oC) value of study area

station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Koka Dam	max	30.2	31.7	32.5	30.9	33.1	31.3	30.3	31.1	31.9	29	29.2	29.6
	min	12.9	14.5	15	14.3	15.1	14.1	14	14.2	14.2	11.6	12.3	12.3
	mean	**21.6**	**23.1**	**23.7**	**22.6**	**24.1**	**22.7**	**22.1**	**22.6**	**23.1**	**20.3**	**20.8**	**20.9**
Modjo	max	28.9	29.8	29.8	30.8	31.5	29.9	26.9	27.5	28.9	29.6	29.3	28.1
	min	8.88	9.78	11.2	12.3	12.7	9.74	10	10.2	10.1	9.0	8.58	6.68
	mean	**18.9**	**19.8**	**20.5**	**21.6**	**22.1**	**19.8**	**18.5**	**18.9**	**19.5**	**19.3**	**19.0**	**17.4**
Bishoftu	max	26.7	29.2	28.3	28.5	29.3	27.5	24.6	24.4	25.9	26.9	25.9	25.9
	min	10.5	11.4	12.9	13.5	13	13.1	13.7	13.9	12.8	10.4	9.34	8.98
	mean	**18.6**	**20.3**	**20.6**	**21**	**21.2**	**20.3**	**19.1**	**19.2**	**19.3**	**18.6**	**17.6**	**17.4**
Chefedonsa	max	21.7	23.7	23.4	23.7	25	23.4	21.1	21.1	21.7	22.2	21.7	21.2
	min	9.26	10.1	11.7	12.3	12.1	11.3	11	11.4	11.5	10.2	8.4	8.5
	mean	**15.5**	**16.9**	**17.6**	**18**	**18.6**	**17.3**	**16.1**	**16.3**	**16.6**	**16.2**	**15.0**	**14.8**

Source: (Ethiopia Meteorological Agency, 2019).

3.1.3. Topography

Modjo watershed is characterized by undulating topography with hills, mountains, plateaus, plains and river valley. The physiography of the watershed reveals a distinct variation with altitude that ranges from 1606masl (south of Modjo town) to 3026 masl (at Yerer volcanic ridges)with a mean value of 2142m respectively. The Elevation of the watershed varies from 1606m to 3026m above mean sea level (Figure3).

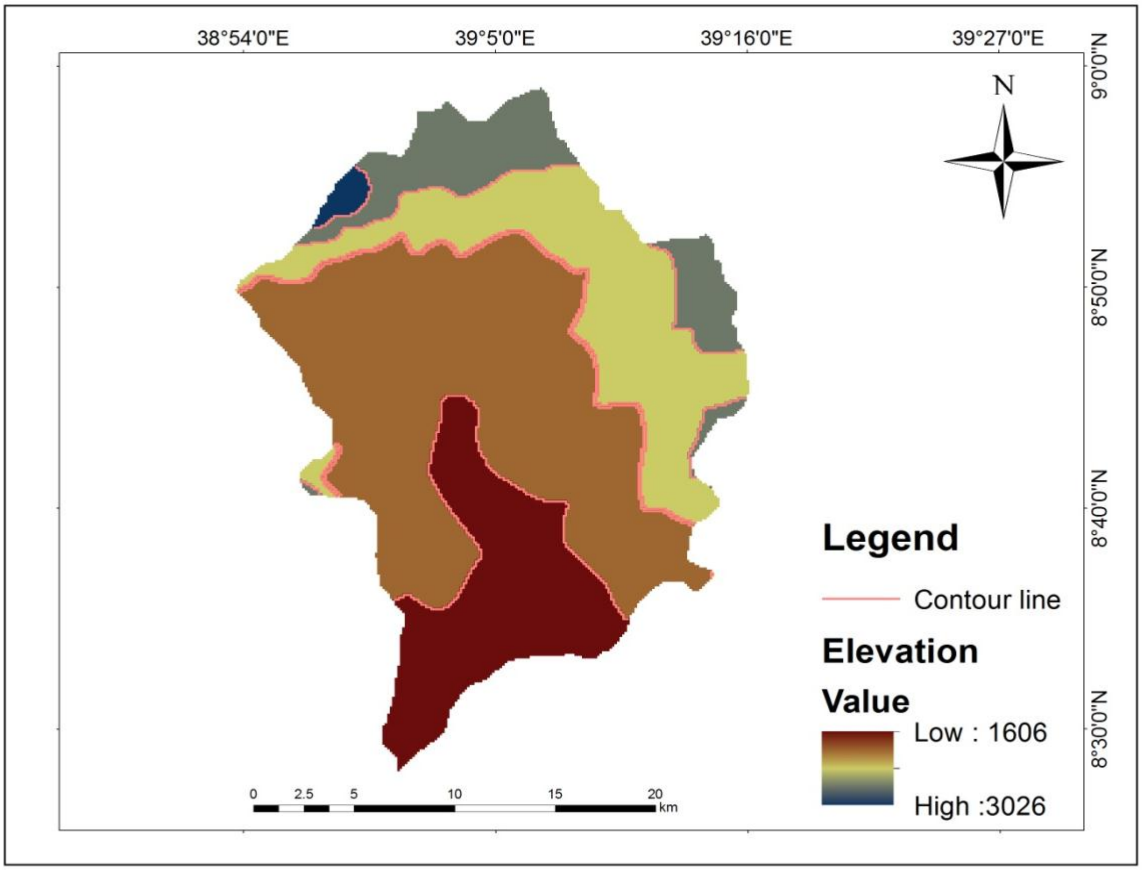

Figure 3: Topography map of the Study Area

Source :(Extracted from SRTM DEM (30*30), 2019)

3.1.4. Demographic and Socio-economic characteristic

3.1.4.1. Population

According to the (CSA, 2017) population and housing Census, the population of three Districts covering the study area was 434,126.most of the population (66.6%) are in the rural area and the remaining (33.4%) are in the urban areas (Table4) densely populated area are observed particularly in and around Modjo, Robgebeya, chefedonsa, Ejere and koka are some of the towns and villages found in the study area. Settlement has shared considerable size of land in urban areas whereas settlement patterns of the rural areas are in a very scattered way.

Table 3: Population of study area

		Urban			Rural			Urban +Rural		
No	District	male	female	Total	Male	female	Total	Male	Female	Total
1.	Lome	18937	19805	38742	40899	36860	77759	59836	56669	116505
2.	Gimbichu	3021	3306	6327	41771	38140	79911	44792	41446	86238
3.	Ada'aa	47938	52176	100114	68381	62892	131273	116319	115068	231387
	Total	69896	75287	145183	151051	137892	288943	220947	213183	434,126

Source:(CSA,2017)

3.1.4.2. Socio Economic Characteristics

Mixed agriculture system is the main economic activities in the watershed area. Economically, most of the residents in this area are engaged in agricultural, activities and as employees of industries. Trade and handcrafting are also economic sources for some residents. The area is accessible withdifferent infrastructures like road,water and electricity supply, Education,bank, health and telephone service. Transportation service in the area is highly accessible for neighboring towns. The major highway networks connect the town with Addis Ababa city,Adama town and Shashemene town.Socio-economic and industrial activities are growing in significant manner. In the area more than 24 industries exist such as textile industries, Tannery,flower industries, and so on. The growing of urban and industrial developments are all potential sources of surface and ground water pollution in the Modjo watershed (District Agriculture and Rural Development Office).

3.2. Methodology of the Study

3.2.1. Design of the Study

Method of research for this study was mixed research design. This design enables by integrating both qualitative and quantitative data provides better understanding of research problem than either of each alone. In order to address the stated objectives both qualitative and quantitative types were used. Qualitative method applied to describe the extent of Modjo river pollution and environmental impact. Quantitatively, different descriptive statistics were utilized for socio-economic impact analysis.

3.2.2. Data Types and Sources

For this study, both Biophysical and Environmental data sources were used. Thus, data were generated from Modjo River water, local people and elders, local administrators, environmental protection and health experts. Field observation, satellite imageries and GPS data

3.2.3. Method of Data collection

3.2.3.1. Biophysical data

The Biophysical data sources for this study were key informant interview, questionnaires (house hold survey), Population and Road Network data.

3.2.3.1.1. KeyInformant Interview

Key informant interview was used to obtain data from kebele administrators, environmental protection and health experts,local elders on existing condition of Modjo river pollution impacts looks like and what works done as a solution.

3.2.3.1.2. Questionnaires

Questionnaire was used to obtain socio-economic data from local residents. Close ended and open ended questions was primarily prepared in English language and translated into Afaan Oromo. Finally, it was re-translated to English language and then been analyzed.

3.2.3.2. Environmental data

Water sample data, field observation, and number of ground control point measured by GPS (Global position system) from field, satellite image and various factor maps that help in the analysis of the risk area that include: land use land cover type of the study area, topography of the study area, slope, geology, soil maps, and streams network factors were obtained from different sources. Moreover, documents journals, articles, books and reports were reviewed.

3.2.3.2.1. Water sample data

Water sample data was obtained from polluted Modjo River using sampling bottle for laboratory analysis. Four samples were taken at point before wastes inter to the river, where wastes entering the river, mixing point and at the center of the river. Based on pick hours (9:00Am, 11:00Am and 3:00Pm).

3.2.3.2.2. Field observation

Ground truth data on the field were collected by direct observation using GPS and Camera were used to take necessary data in the observed area.

3.2.3.2.3. Temporal Data of Satellite Image

In order to assess LULC change Land sat imagery of 2003 and 2019 cloud free image for Modjo watershed, path170 and row54 were acquired from website. These data's were used to produce the LULC maps of the study area and identify which LULC are susceptible to Modjo river pollution. The images were downloaded from the United States geological survey (USGS) earth explorer website and spatially referenced in the universal transverse Mercator(UTM) projection with datum world geodetic system (WGS) 1984 UTM Zone 37N.The images were extracted to tiff formats for processing.

3.3. Materials and Software

In this study different materials and software packages were utilized. The first one was instruments used to test water quality assessment parameters. These were portale multimeter, atomic absorption spectrometer and BOD bottle. Secondly, ArcGIS 10.5 was used for buffer analysis, reclassification and weight overlay. Thirdly, Erdas Imagine 2015 was used for image classification and change detection and NDVI. While IDRISI used for pair wise comparison matrix. In addition, Statistical Packages for Social Sciences (SPSS) version 20 was utilized to analyze socio-economic data. Lastly, GPS Garmin 64 and cameras were used to take field data.

3.2.4. Sampling Procedures and Methods

3.2.4.1. Setting of sampling station for water samples

In order to set sample station to take water samples issues like water course, waste discharge points of industries and pick hours were properly considered. Based on the topographic configuration that affects flow of river, water courses of Modjo watershed were primarily categorized into three courses, i. e., and upstream, middle stream and downstream were identified. Following each streams waste discharge points of industries were pinpointed. Accordingly, eleven waste discharge points were identified in the three courses of Modjo River. Behind each waste discharge point there are seven factories identified in the study site. These are Jorjishuu textile factory at upper stream (four waste discharge points); Ji Xin Zang Textile factory, Friendship Textile factory, Horaa Gojjee factory, Houdachen Textile factory and East Africa textile factory at middle stream (six discharge points); and Kolbaa Tannery factory (Gojjee) at downstream (one discharge point). Then, samples were taken at pick hours, i. e., 9 PM, 11 PM and 3 AM.

3.2.4.2. Sample Obtaining Procedures

After setting the location, four samples were taken. The first sample (Sample point A) was taken from an area where waste discharge was not reaching. So that, it was taken from upstream where no waste discharge affects the water quality and used to compare the water quality change due to entrance of waste from different sources. The remaining three samples were taken from the three river courses at intersection points of river and waste discharge. Hence, at upstream four intersection points samples were obtained and mixed together to one sample (Sample point B) for test. Similarly, at middle stream six intersection points samples were acquired and mixed to one sample (Sample point C) for analysis. In the same way, sample (Sample point D) was taken from one intersection point where waste discharge and river were come together at downstream.

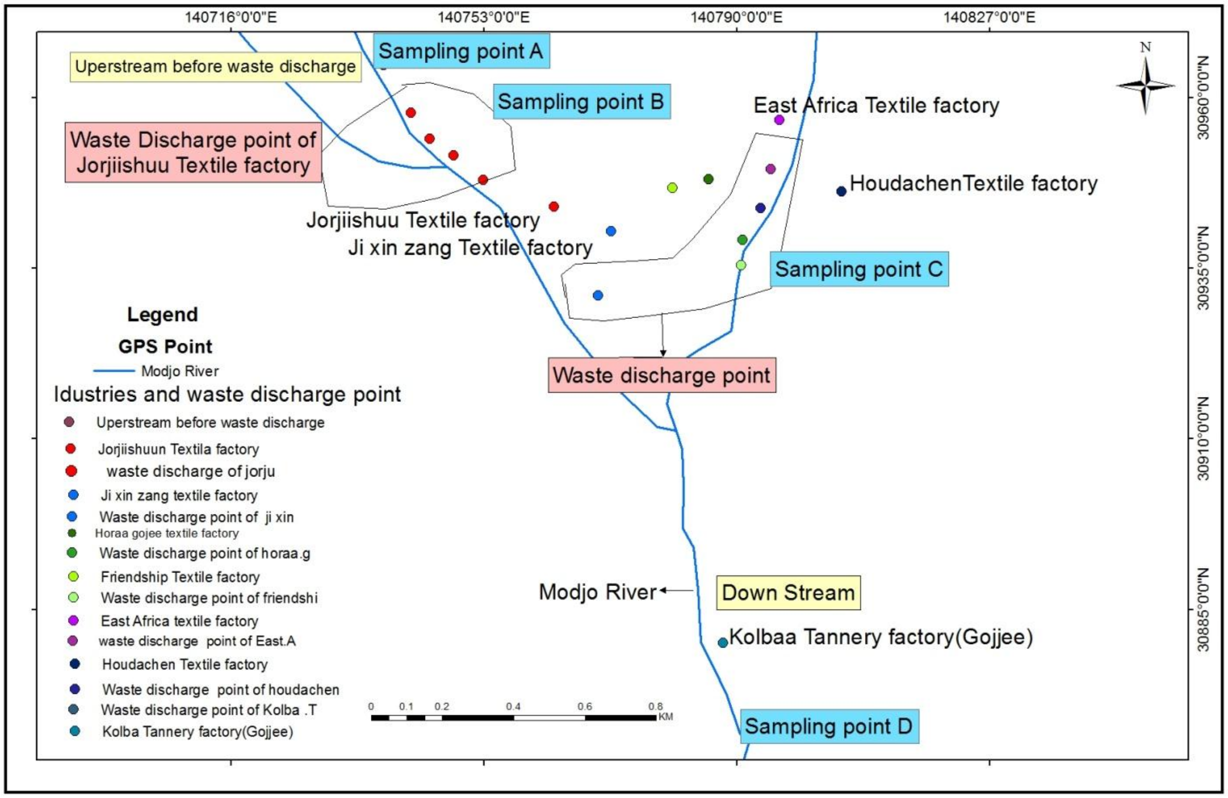

Figure 4: Location map of industrial waste discharge site and main sampling station

Source: Field survey (2019).

3.2.4.3. Household Sampling

3.2.4.3.1. Sampling Techniques

Five kebeles (out of sixty kebeles) in the watershed were purposively selected due to proximity and severity of the pollution at the three water courses. Thus, Momo shoki and Muda Senkele from upstream; Tafi Abo from middle stream; and Gongo and Goditi Goro rural *kebeles* from downstream were selected. Finally, sample respondents were selected using simple random sampling technique (lottery method).

3.2.4.3.2. Sample Size Determination

Using sample size determination formula, 173 household heads were selected from the total 2992 household heads in the selected five *kebeles*. Accordingly, sample size was determined based on equation adopted from Dirribsa and Tassew, 2015 as follow.

$$n = \frac{z^2 p.q.N}{e^2.(N-1) + z^2.p.q}$$

Where n= required sample size=173, N=Population=2992, Z= Confidence interval at 95% which is 1.96, e=5%, P= 0.5, q= 0.5, Z=95% confidence interval under normal curve 1.95. The samples of respondent are taken from each kebeles based on the formula given above). e= acceptable error term (0.05), P and q are estimates of the proportion of population to be sampled and N=total population.

Using the above formula, the sample size was calculated as follows:

Sample size $n = \frac{1.96^2.0.5.0.5.2992}{0.05^2.(2992-1)+1.96^2.0.5.0.5}$

$n = \frac{1466.08}{8.4379}$=173

The formula gives for this study sample size of 173households' heads.

The detail about the sample respondents from each kebeles which is computed using the above formula summarized and presented in Table 5 below.

Table 4: Sample size Determination

	Lists of kebele	Households	Sampled respondents(Household Heads)
1.	Tafi Abo	1000	58
2.	Gongo	680	39
3.	Momoo shokii	500	29
4.	MudaSenkele	450	26
5.	GoditiGoro	362	21
	Total	**2992**	**173**

3.2.5. Data Processing and Analysis Method

3.2.5.1. Data Processing

3.2.5.1.1. Water quality parameter processing

Except BOD and COD, all water quality parameters were directly tested and results were generated. BOD was analyzed through 5 days incubation at 20⁰C and measuring of initial and final dissolved oxygen by using Dilution water. The reagents used for this dilution water are:

Phosphate buffer, ($MgCl_2$) magnesium chloride, ($CaCl_2$) Calcium Chloride and ($FeCl_3$.6H2O) Ferric Chloride.COD was measured calculating from BOD values.

3.2.5.1.2. Image processing

Satellite image processing was carried out using ERDAS imagine 2015 software to correct for any distortion due to the characteristics of the imaging system, imaging condition and projection.

3.2.5.1.3. Socio-economic data processing

Data coding, editing and entering were done for those data obtained through questionnaire. Hence, all socio economic data were processed by using SPSS Software version 20.

3.2.6. Methods of Data Analysis

3.2.6.1. Laboratory Analysis

Water samples obtained from Modjo River were analyzed for parameters such as electrical conductivity (EC), water temperature (T), turbidity; dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and potentiality of hydrogen (pH) .inorganic components or heavy metals were also analyzed included lead (Pb), chromium (Cr), cadmium (Cd).Except BOD and COD, all water quality parameters were directly tested and results were generated. BOD was analyzed through 5 days incubation at 20^{o}C and measuring of initial and final dissolved oxygen by using Dilution water. The reagents used for this dilution water are: Phosphate buffer, magnesium chloride ($MgCl_2$), Calcium Chloride ($CaCl_2$) and FerricChloride ($FeCl_3$.6H2O).COD was measured calculating from BOD values.

3.2.6.2. Geostatistical Analysis

In order to analyze the concentration of water quality parameter of Modjo river Geostatistical spatial interpolation method was used. According to (Zhang W, 2015) results of different Geostatistical methods of spatial interpolation, the most efficient and prominent method for observed data was inverse distance weight (IDW) interpolation. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Thus IDW assumes that each measured point has a local influence that diminishes with distance.

3.2.6.3. Image classification

In the analysis of land use land cover for change detection and identify risk, the current study has employed supervised image classification techniques. A supervised image classification with the maximum likelihood statistical approach is selected because it is the most sophisticated and achieves good separation of classes. During the preliminary field visit the various land cover classes was taken by systematic sampling using GPS devise. These samples were used to representative signatures for the various land cover types identified.

3.2.6.4. Land use/land cover change detection and analysis

In change detection analysis, remotely sensed data is useful to detect the land use land cover changes of the study area. In this case, for assessing the impact of Modjo River pollution on land use/land cover within eight year interval two different (2003-2019) year satellite image acquired after the image classification step performed evaluated with" from-to" change information for all land use/land cover classes**.**

3.2.6.5. Accuracy Assessment of LULC

Land use land cover maps generated from remote sensing image contain some sort of errors. In order to use such maps for change detection and risk identification it is vital to quantity errors in term of classification accuracy. For this purpose 160 ground control points were selected from each land class of the study area. The commonly used assessment accuracy of classified image is the preparation of confusion matrixes. Congalton,(1991) defined confusion matrix as a square array of numbers structured in rows and columns which express the number of section units assigned to a particular class relative to the actual class as indicated by reference data. These produce overall classification accuracy, the percentage and the kappa coefficient.

3.2.7. Criteria for river pollution risk area identification

Selecting best criteria to identify river pollution risk area is important to minimize the negative impact of river pollution on the environment. Selecting factor for analysis is not an easy task rather it is tedious and need much concentration because it considered both environmental, physical and socio economic factors. In order to meet the goal of this study different literature were reviewed by the researcher and then best factors were selected as criteria. These selected criteria were also approved by the interviewed experts. Therefore, the following parameters such as Topography, Slope, Soil, LULC, Stream Network, Road Network, Population Density and Geology are selected to achieve the objective of the present study.

3.2.8. Proximity analysis

Proximity analysis is one of the data analysis systems in GIS environment. It can be done through buffering i.e. identifying area of interest around parameter for risk area of river pollution. Multiple ring buffers are common spatial analysis process performed on GIS that answers which area is nearest to a region of interest in the current study a distance of factors like road network, stream network and population density is determined by multiple ring buffers from polluted Modjo River. The buffering distance is done based on standards mentioned above for each factor. The buffered maps of each factor were converted to raster for reclassification purpose.

3.2.9. Reclassification of Criteria

To generate risk area of water pollution impact, eight factors were identified and evaluated. These are topography, slope, and proximity to stream network, proximity to road network, land use / land cover, soil type, population density, and geology. All these factors were rasterized, reclassified and evaluated to understand the level of risk. Finally, MCE using Arcgis10.5 and IDRISI software were applied to develop risk map.

3.2.10. Weight Overlay Analysis

Weighted overlay is a technique for applying a common measurement scale of values to different inputs to create an integrated analysis. The weight is given through empirical methods and subjective judgments by the decision maker. For this study, using weighted overlay analysis of each input layer of factors such as Topography,Slope,Soil,LULC,Stream Network,Road Network,Population Density and Geology. In this process,weight was assigned to different thematic layers based on their significance in identifying the risky area.

3.2.11. Multi-Criteria Evaluation by WLC

3.2.11.1. AHP (Analytical Hierarchy Process)

Analytical hierarchy process (AHP) was used as a decision rules to analyze the data for risk area identification using GIS. AHP consist of the construction of pair wise comparison matrices and the extraction of weights by means of the principal right eigenvector. Pair wise comparison matrix is created by setting out one row and one column for each factor in the problem. Therefore, the AHP divides the decision problems based on the factors into understandable parts; each of these parts is analyzed separately and integrated in a logical manner as suggested by Theo (2010). In AHP the 9 point scale which is ranging from 1(indifference or equal important)to 9(extreme preference or absolute importance)(Saaty, 2008) used in the decision making process for identifying risk area in the watershed. By considering above Saaty, argument in mind, all parameters were converted into raster.

Then all raster data were changed into similar resolution of 30*30 by using the resample extension tool in ArcGIS environment. All raster data were also reclassified according to their risk class for further risk area identification analysis. After reclassification process weights were assigned to each factor based on Saaty, 2008 comparison matrix because each parameter has different degree of influence for highly risk area of Modjo river pollution. The task of assigning weights is performed outside GIS on IDRSI decision wizard software. Finally, based on their assigned weight all factor maps were computed in the ArcGIS environment to generate the final risk area map.

3.2.12. Socio-economic Data Analysis

In order to identify the influence of water pollution on the surrounding community livelihood the level of susceptibility was analyzed using chi-square test. Hence, number of victims (human and livestock) to water borne/water washed problems was taken as dependent variable. Whereas household head’s distance from river, education level, sex and age were considered as independent variables.

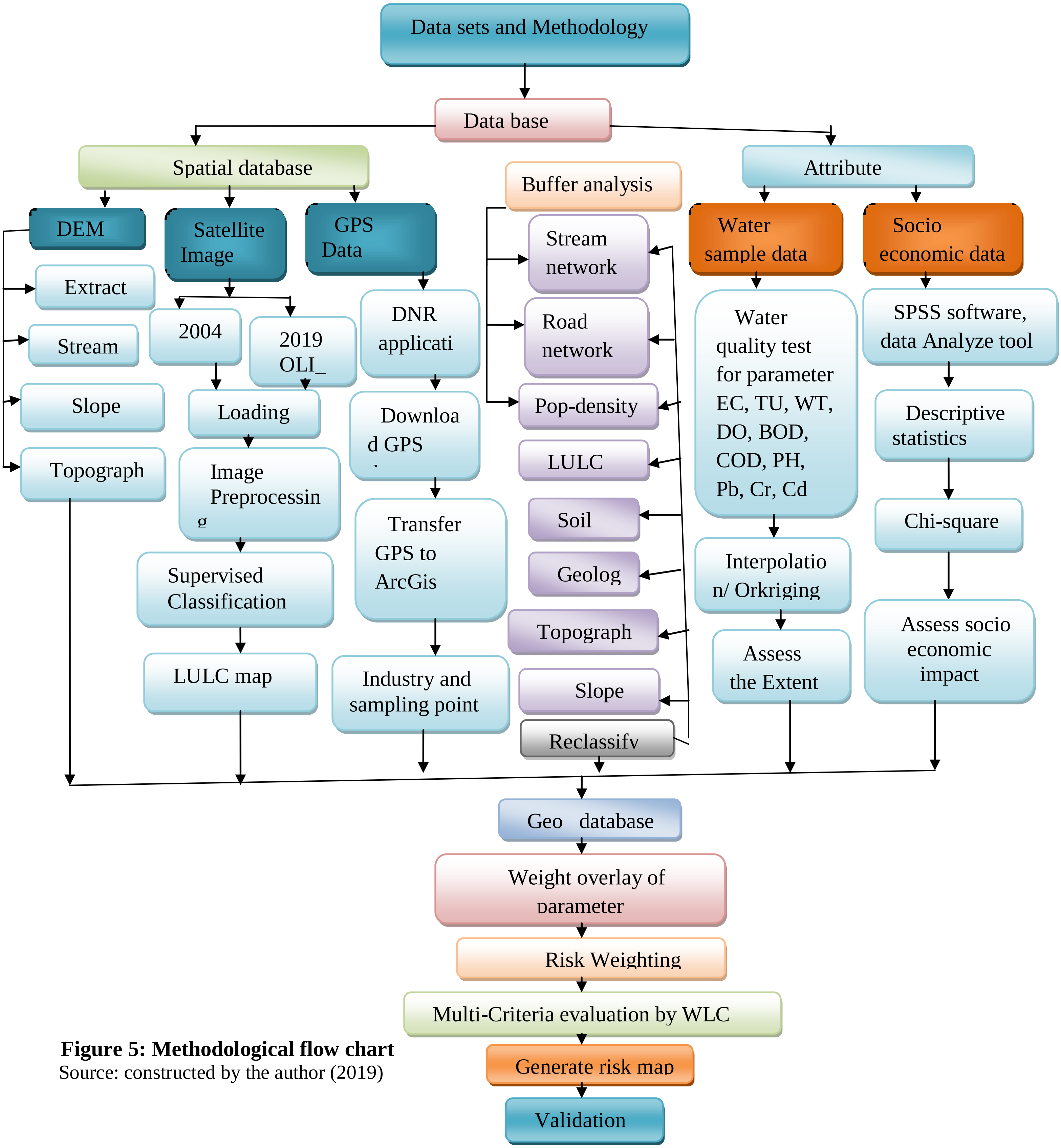

Figure 5: Methodological flow chart

Source: constructed by the author (2019)

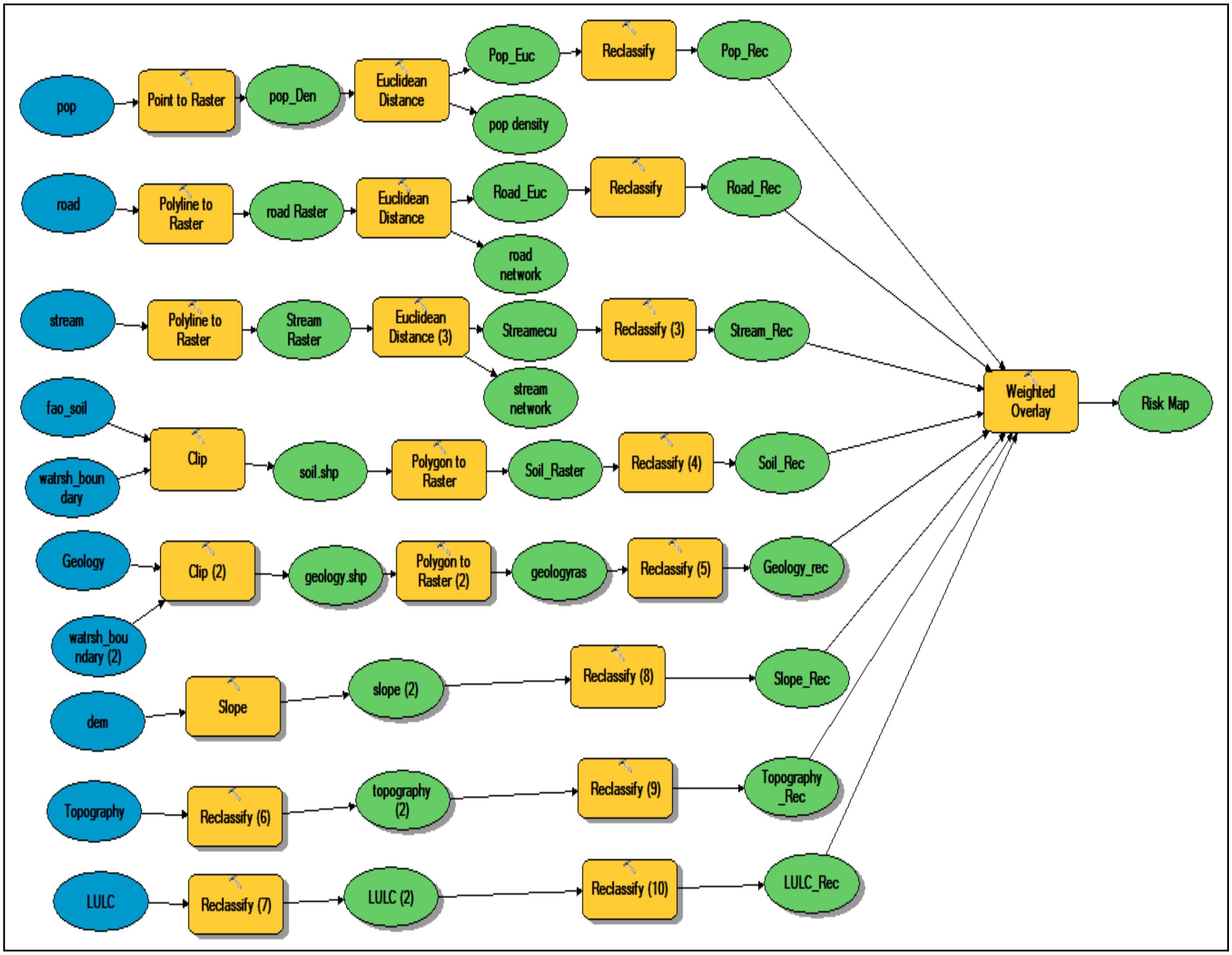

Figure 6: Model builder dialog box for Modjo river pollution risk area map

Figure 13 above shows the overall weighted overlay process starting from extraction of necessary factor map up to final result showing the areas which was susceptible for risk. Primarily five shape files are extracted from various data sources and converted in to raster format. Secondly road network, stream network and population density were buffered depend on its proximity to polluted river and all datasets were reclassified. Finally, all datasets considered for weighted overlay analysis purpose based on their influence for impact of the study area.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. RESULT

4.1.1.Extent of Modjo River pollution in the Watershed

Laboratory tests have been done based on the recommended (WHO, 2011) standard limits for each parameters of potable water for assessing the extent of Modjo river pollution as shown on Table13.Accordingly, physical parameters that includes Water temperature, Electrical conductivity and Turbidity were measured on site, as well as chemical parameters such as (PH) Potentiality of hydrogen, Dissolved Oxygen (DO),Biochemical Oxygen demand(BOD),Chemical Oxygen demand (COD) and inorganic component or heavy metals such as, Chromium(Cr), Lead (Pb),Cadmium (Cd) were measured in the laboratory.

Table 5: Physico-Chemical Parameters of Modjo river water

Parameters	Unit	WHO,2011	EEPA,2003	Sample.ID				Health problem
		Standards		A	B	C	D	
pH		6-8		7.5	7.13	7.19	7.63	
EC	µS/cm	3		683	2353	6400	7024	
DO	Mg/l	8-10	-	7.39	0.97	2.34	0.18	
BOD	Mg/l	10	50	2.57	755	432	700	
COD	Mg/l	60	150	35.07	943.75	540	875	
Turbidity	Mg/l	5		18	71.6	33.2	107	
Water Temp	^{o}C	23.6	40	28.33	24.0	23.8	23.9	
Lead	Mg/l	0.01			0.013617	0.036311	0.054466	Nervous &immune system &kidney damage embryo/fetotoxic
Chromium	Mg/l	0.05	1		0.04	0.2	0.12	Lung and skin damage, cancer
Cadmium	Mg/l	0.003			0.000179	0.003584	0.001792	Gastrointestinal, kidney and lung damage

Source: (Samples collected by the author and tested at JU and HU labs)

4.1.1.1. Physical Parameters and Results

4.1.1.1.1. Electrical Conductivity

EC measurement of the concentration of mineral constituents present in water. In water body higher electrical conductivity means higher pollution load of water.

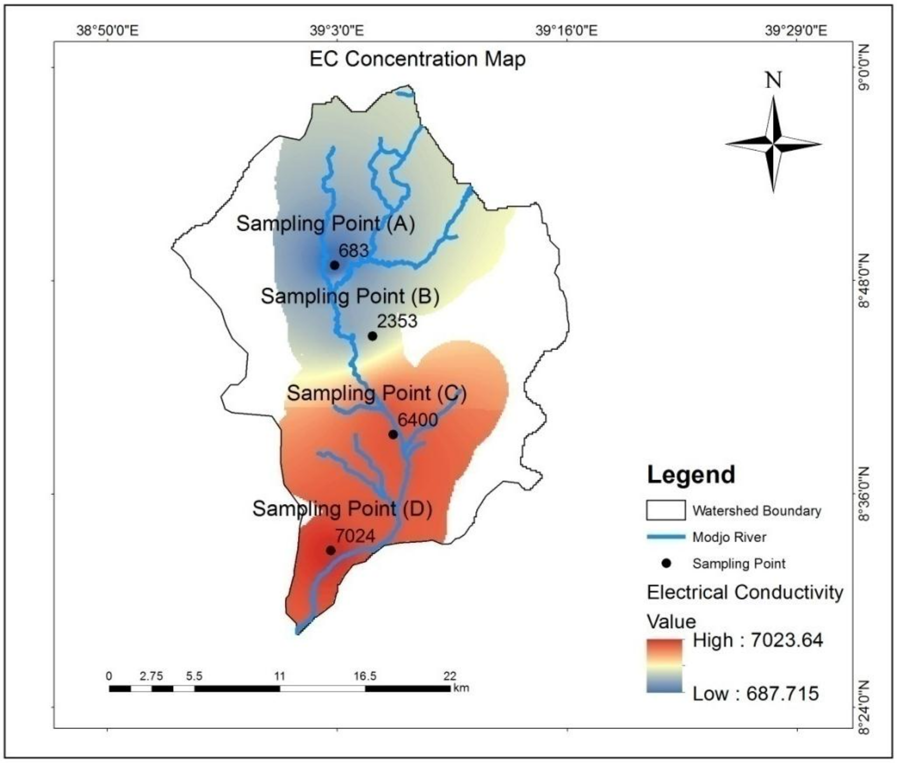

Figure 7: Electrical conductivity concentration of Modjo River

Source: Field survey (2019)

Figure 14 above shows that EC along Modjo River ranges from 683µS/cm to7024µS/cm. The lowest value of EC (683µS/cm) was measured at upstream while the highest (7024µS/cm)was measured at downstream. The mean value of EC (4115µS/cm) in the study areawas by far above the permissible limits of WHO, 2011 standards, i.e., 3µS/cm.The tremendous increment of EC as moved from upstream to downstream bring challenges to plants at large. In this regard, Sanches et al., 2003 indicated as higher EC cause the less water availability to plants.

4.1.1.1.2.Water Temperature

Water temperature is an important physical parameter for aquatic ecosystems. In the study area temperature was analyzed along Modjo River and the findings are presented in Table14 below.

Table 6: Water Temperature

Sampling Location	Water Temperature °C
Upstream (sampling site A)	23.8°C
Sampling site B	24.0°C
Sampling site C	23.9°C
Sampling site D	26.33°C

Source: Field survey (2019)

As indicated on table 14, water temperature increases toward downstream. An increase in water temperature influences biological activity and growth increasing the photosynthetic rate of aquatic plants and algae, which can lead to increased plant growth and algal blooms and harm the local ecosystems.

4.1.1.1.3. Turbidity

Turbidity is a measure of clarity of water. Based on laboratory analysis, the turbidity of the water in the study area was presented in figure15.

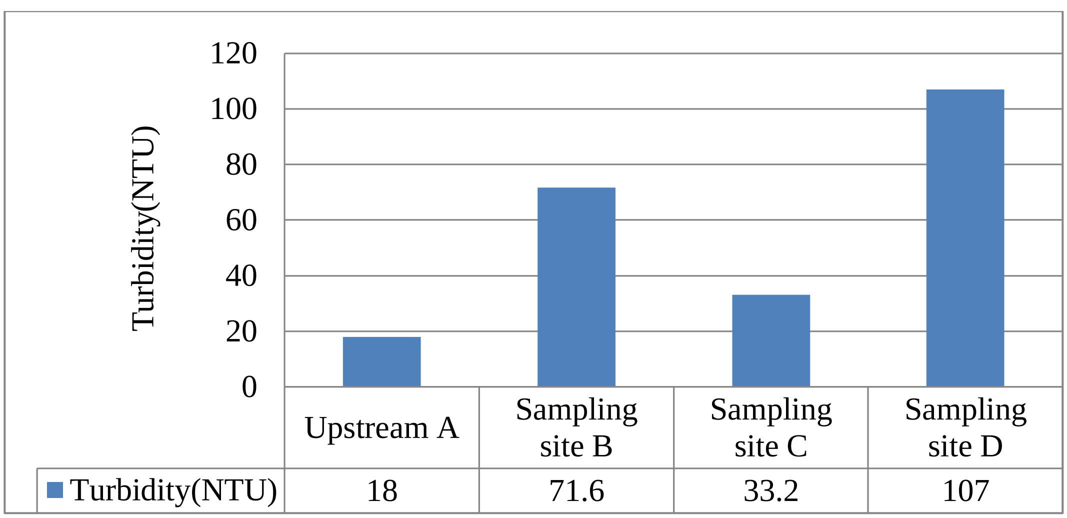

Figure 8: Turbidity level of Modjo river water
Source: Field survey (2019)

Figure 15 above shows that turbidity of Modjo River increased from upstream to downstream from 18mg/l at sample point A to 107mg/l at sample point D. The turbidity level upstream from industries sampling site A and sampling site C were within standards while the turbidity levels at sampling site B (71.6mg/L) and Sampling site D (107mg/L) exceeded the (WHO, 2011) acceptable levels whereas (WHO recommend 5mg/L).Moderately low levels of turbidity indicate a healthy well-functioning ecosystem, with moderate amount of microscopic plants and animals present to fuel the food chain. In other way, higher turbidity levels are often associated with higher level of viruses, parasites and some bacteria because they can sometimes attach themselves to the dirt in the water (WHO, 2011). Likewise, results from household survey confirmed as there were high vulnerability to water borne disease such as diarrheal, cholera, typhoid in the areas of high turbid water than low turbidity.

4.1.1.2. Chemical Parameters and the results

4.1.1.2.1. Potentiality of Hydrogen (pH)

pH indicates alkalinity or acidity level in the water. pH ranges on scale from 1-14, where pH ranges from 1-6 is acidic, pH 7 is neutral, and pH ranges from 8-14 is Alkalinity.

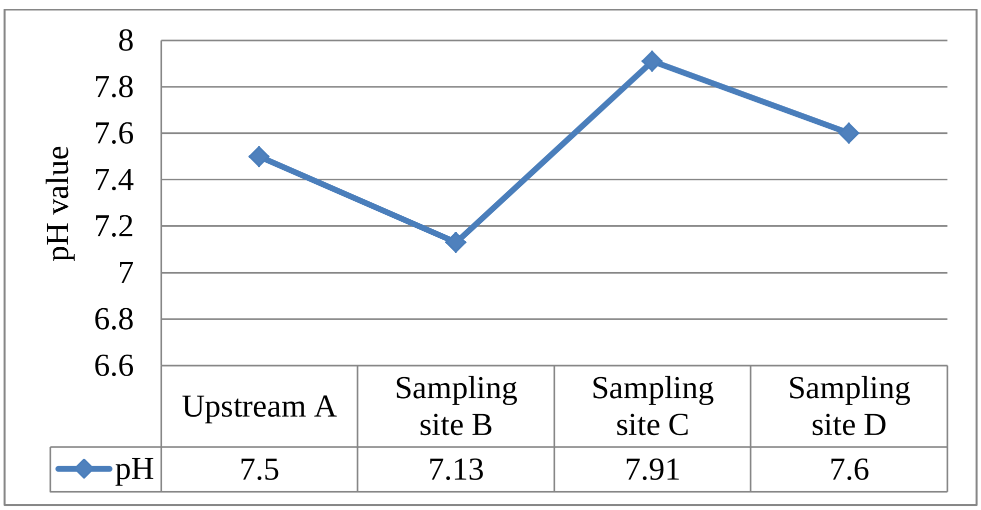

Figure 9: pH value of sample water taken from Modjo River

Source: Field survey (2019)

Figure 16 showed different values of pH that ranges from 7.13 to 7.91.Low pH value was measured at sampling site B and the highest value was measured at Sampling site C.The highest pH of the effluent indicates the basic nature of the effluents. The pH of the study area varies from one point to another due to industrial activities discharge wastes into the River. The normal range of pH for fisheries, agriculture and recreational activity is 7. But, the average pH in Modjo River is 7.13 to 7.91mg/L.It shows the poor condition of the water (DOE, 2013). This means the water of Modjo River is not suitable for fisheries,agriculture and recreational activities.

4.1.1.2.2. Dissolved Oxygen (DO)

Dissolved Oxygen (DO) is an important pollution assessment parameter of the receiving water bodies (Vinod and Chopra, 2012).It's an important ecological parameter because its level allows breathing of living organisms in water. It is a requirement for almost all forms of life. Aquatic animals, plants and most bacteria require it for respiration (getting energy from food), as well as for some chemical reactions. In the study area DO was measured and the finding are as presented in figure 17below.

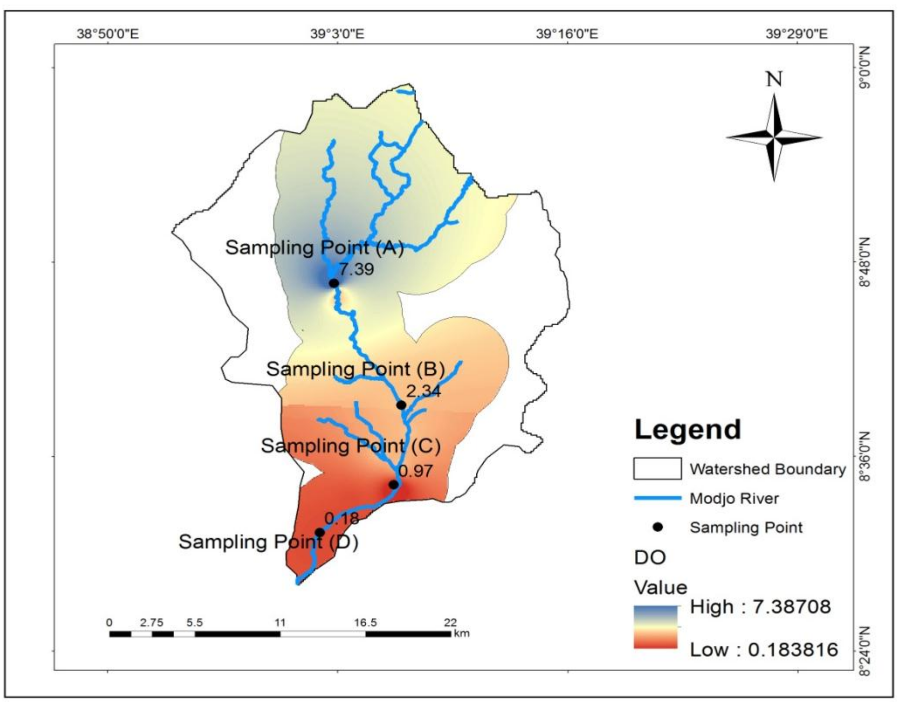

Figure 10: Dissolved Oxygen (DO) concentration of Modjo River water

Source: Field survey(2019)

Figure 17 above showed DO results for various sampling point along Modjo River. DO value for study area ranges from 0.18mg/L to 7.39mg/L.the highest value of DO (7.39mg/L)was measured at upstream from the industries while the lowest (0.18mg/L) was measured at downstream. The mean value of DO (2.72mg/L) in the study area was by far lower the permissible limits of WHO, 2011standards, i.e., 8-10mg/L. The great decrement of DO value as moved from upstream to downstream bring challenges to living organisms because the concentration of DO is an important indicator of health aquatic ecosystem. Persistently low dissolved oxygen harms most aquatic life because insufficient DO for organisms to use.

4.1.1.2.3. Biochemical Oxygen Demand (BOD)

The study analyzed Biochemical Oxygen Demand (BOD) from the water samples taken along Modjo River and the results are presented in figure 18below.

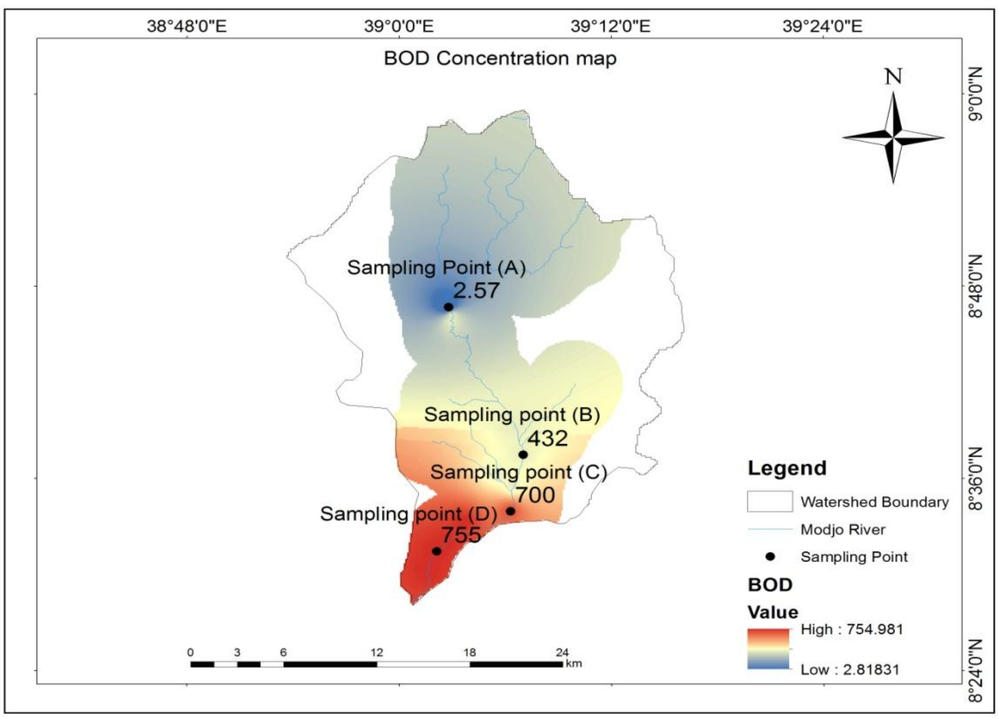

Figure 11: Biochemical Oxygen Demand (BOD) concentration of Modjo River

Source: Field survey (2019)

Figure 18 above showed BOD values of the study area ranges from 9.00mg/L to 755mg/L.The lowest value of BOD (9.00mg/L) was recorded at upstream from the industries, while the highest (755mg/L) was measured at downstream. The mean value of BOD(474mg/L) in the study area was by far greater the permissible limits of WHO,(2011) standards ,i.e., 10mg/L. BOD is a measure of the quantity of oxygen consumed by microorganisms during the decomposition of organic matter (DOE, 2013-14). So high value of BOD means high pollution loads of Modjo River this shows how Modjo River is not suitable for living organisms.

4.1.1.2.4. Chemical Oxygen Demand (COD)

The study analyzed COD of water sampled along Modjo River and the results are presented in figure 19 below.

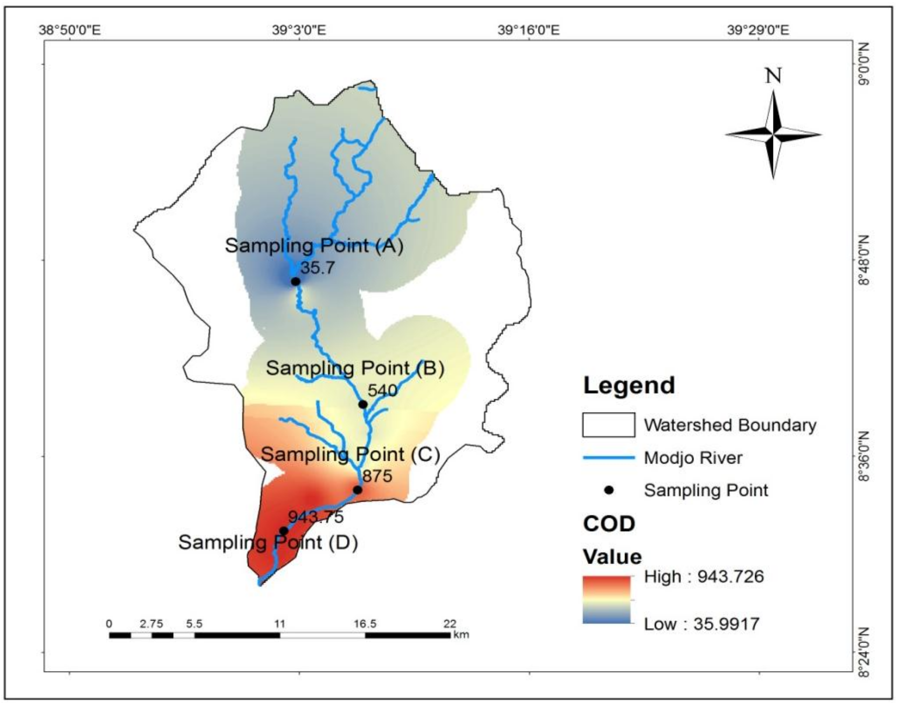

Figure 12: Chemical Oxygen Demand concentration of Modjo River
Source: Field survey(2019)

Figure 19 above presents COD from the various sampling points in comparison to the samples upstream from industries. The COD values ranges from 35.07mg/l to 943.75mg/l. The lowest (35.07mg/l) COD was recorded upstream from the industries while the highest value of COD (943.75mg/l) can be recorded at sampling site B. The mean value of COD 598.45mg/L in the study area was by far greater the permissible limits of WHO, (2011) standards, i.e.,60mg/l.The great increase of COD value as moved from upstream to downstream bring challenges to living organisms because COD measures the oxygen required for the oxidation of mainly organic matter by a strong chemical oxidant (Chapman, 1992).So high COD value showspoor condition of the water or pollution load of the water so the water is not suitable for living organisms and other living things.

4.1.1.2.5. Heavy Metals

The study analyzed heavy metal concentration as part of pollutants being discharged by industries along Modjo River.The heavy metals,such as Lead (Pb), Cadmium (Cd) andchromium (Cr) were selected due to their long term health effects on human and other living organisms. The concentration of metallic effluents that were analyzed is showed in Table 15 below.

Table 7: Heavy Metal concentration along Modjo River

Sampling location	Pb (mg/l	Cd (mg/l)	Cr (mg/l)
Sampling site B	0.013617	0.000179	0.04
Sampling site C	0.036311	0.003584	0.2
Sampling site D	0.054466	0.001792	0.12

Source :(HU Chemistry` Laboratory test, 2019)

4.1.1.2.6. Lead (Pb)

Figure20 below showed that lead value range from 0.013617mg/L to 0.054466mg/L.

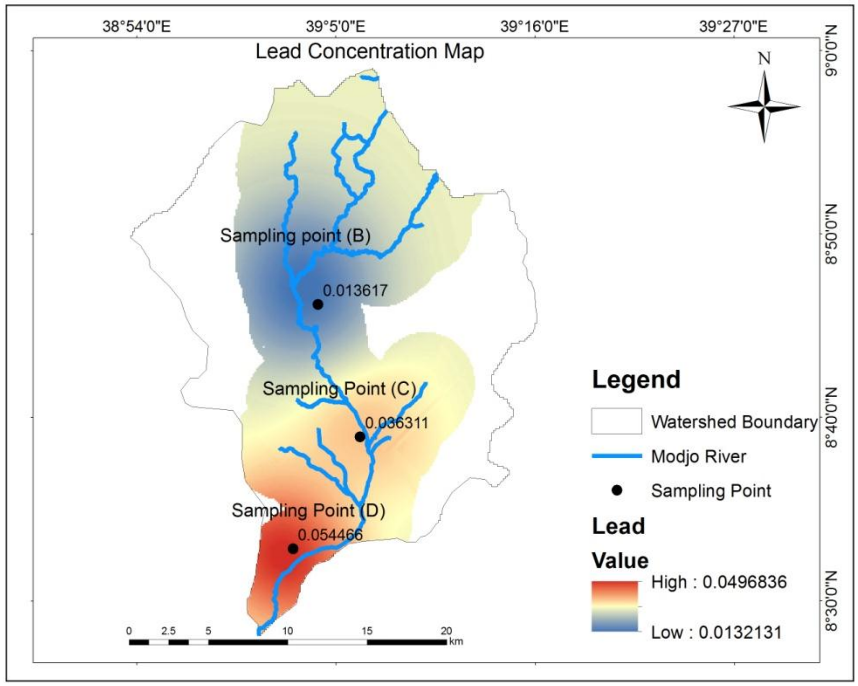

Figure 13: Lead Concentration of Modjo River water

Source: Field survey(2019)

Figure 20 above showed that lead ranged from minimum of 0.013617mg/l to maximum 0.054466mg/l value. The lowest value of lead (0.013617mg/l) was measured at upstream while the highest (0.054466mg/l) was measured at downstream. The value of lead was by far above the permissible limits of WHO, (2011) standards, i.e., 0.01mg/l.the increment of lead concentration as moved from upstream to downstream bring challenges to health problems both on human beings and on animals. In addition to this, the problem is acute in terms of affecting the ecological balance by death of living organism and destruction of vegetation.

4.1.1.2.7. Cadmium (Cd)

Figure21below showed that the findings of cadmium from different sampling points along Modjo River. The concentration of cadmium (Cd) ranged from minimum of 0.000179mg/l to maximum 0.003584mg/l in the sampling points**.** Except sampling point (C) the other two sampling points have cadmium value below WHO, 2011 allowable standards which are 0.003mg/l.

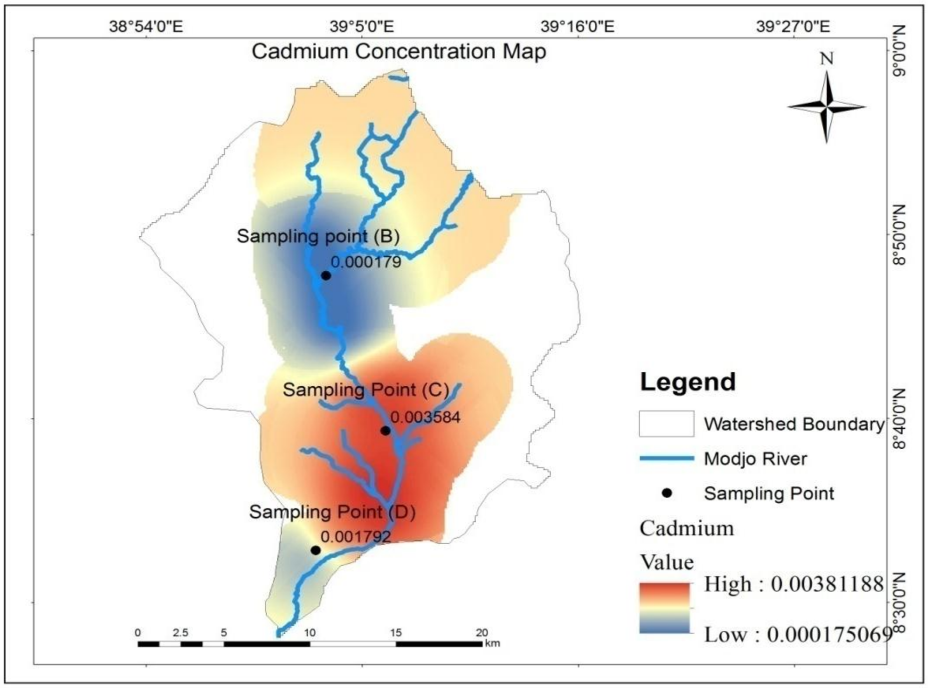

Figure 14: Cadmium concentration of Modjo river water

Source: Field survey (2019)

4.1.1.2.8. Chromium (Cr)

Figure 22below showed that chromium (Cr) value ranging between0.04mg/l minimum and 0.2mg/l maximum. The highest concentration of chromium (0.2mg/l) was measured at downstream while the lowest (0.04mg/l) was measured at upstream. Chromium value in the study area was above permissible limits of WHO, 2011 standards i.e., 0.05mg/l. The increment of chromium as moved from upstream to downstream bring challenges on the health of human being and animals.

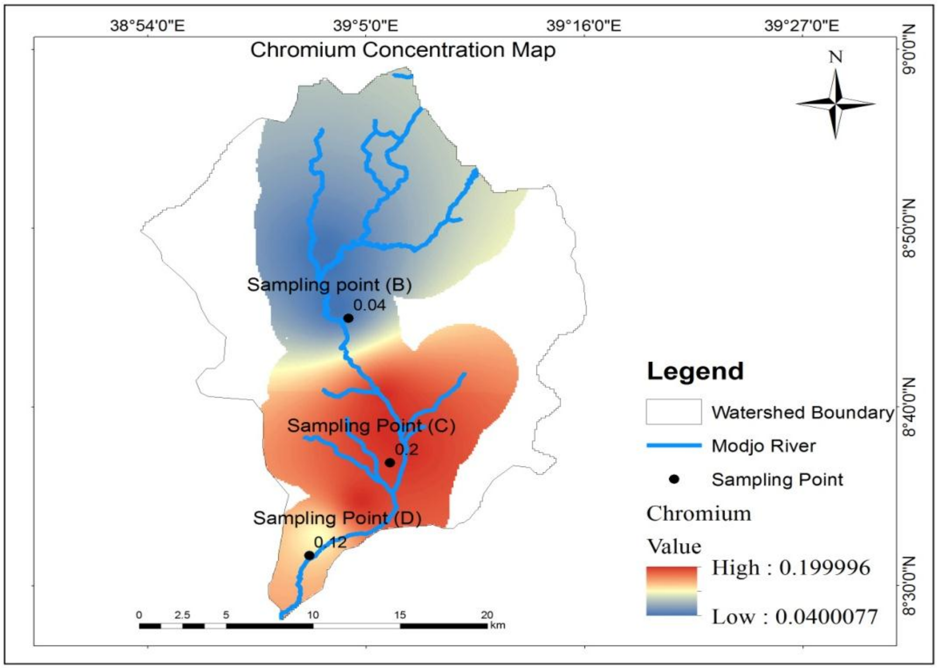

Figure 15: Chromium concentration of Modjo River water
Source: Field survey (2019)

4.1.2.Analysis of Socio-economic data and Results

Modjo river pollution has negative impacts in terms of socio-economic and environmental aspect of the watershed. To assess the socio economic impact of Modjo river pollution in addition to physico-chemical parameters the socio economic data (questioner) was analyzed and all demographic variables of the respondents are showed onTable16 below.

Table 8: Background of respondents

No	Description		Number	%
1	Sex	Male	146	88
		Female	27	12
2	Age	20-40	49	26.6
		40-60	116	67
		Above 60 years	8	6.4
3	Education status	Illiterates	80	46.2
		Read and write	49	28.3
		Primary	29	16.8
		Secondary	15	8.7
4	Work type	Farmer	138	79.8
		Employee	35	20.2

5	Distance to the River	5-30 minit	132	76.3
		30-50 minit	30	17.3
		Above 50 minit	11	6.4

Source: Field survey (2019)

Male respondents are about 88% while the female respondents are 12% almost all or about 79.8% of the respondents are farmer. The remaining 20.2% also employed on the industries. All of them are dwelling in the catchment area 76.3% of the respondent are living within 5-30minit 17.3% are living with a distance of 30-50minit and the remaining 6.4% of the respondents are living on the distance above 50 minits from Modjo river. Most of the questioners are living in the rural area performing agricultural activity. They are academically below grade eight from the total 46% of the respondents are illiterate while 28.3% only able to read and write 16.8% are primarily and the remaining 8.7% are secondary education status.

4.1.2.1. Causes for the pollution of Modjo River

Table 17 below showed that the probable causes for pollution of Modjo River are industrial waste discharge about 92% of the respondents describe and the remaining 8% are municipal wastes, Domestic wastes and other related wastes.

Table 9: Major causes of water pollution in the river

Source of pollutant	**frequency**	**percent**
Industrial waste Discharge	100	57.8
Domestic Wastes	40	23.1
Municipal Wastes	30	17.1
Industrial and municipal	2	1.2
other	1	6
Total	**173**	**100**

Source: Field survey (2019)

Physico-chemical parameter analysis result of Modjo river water showed that most of the parameters value are above permissible limits of WHO,(2011) standards at points industries are located in addition to this the results obtained from questioner showed that 57.8% of respondents describe industrial waste discharge bring changes into water quality of Modjo river; whereas 17.1% of respondent identified municipal waste;23.1% of respondent indicate domestic wastes;

1.2% both industrial and municipal 6% of respondents describe other source of pollutants. Therefore industrial waste discharges are contributing highly towards change the water quality of Modjo River.

4.1.2.2. Effect of industrial pollutants

Laboratory analysis result for physico- chemical parameters of Modjo river above showed that industrial pollutants have effect on water quality of Modjo River this supported by questioners which is collected from respondents. Figure16 below showed that 98.8% of the respondents says industrial waste discharge have effect on the quality of Modjo River water while 1.2% of the respondents identified industrial pollutants have no effect on water quality of Modjo river figure23 below.

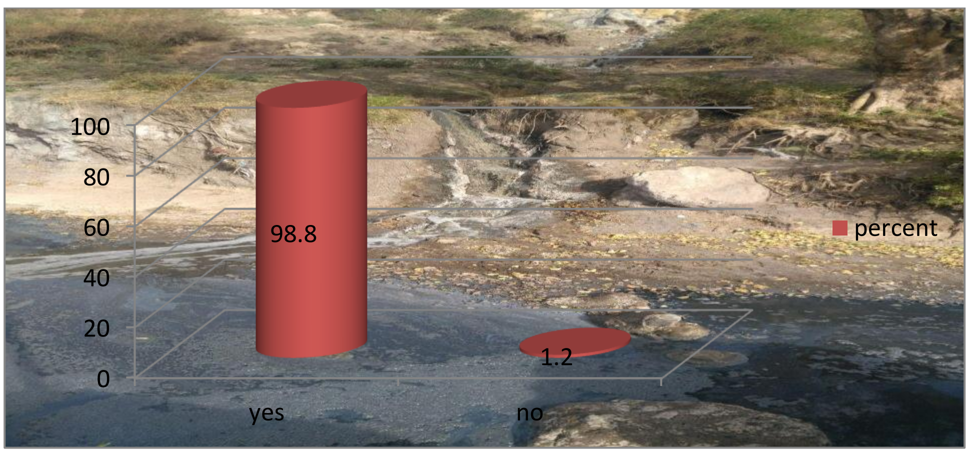

Figure 16: Percentage on effect of industrial pollutant

Source: Field survey (2019)

Further on the effect of industrial pollutant on water quality of Modjo river respondents reported and supported by laboratory analysis are shown on figure 24 below.

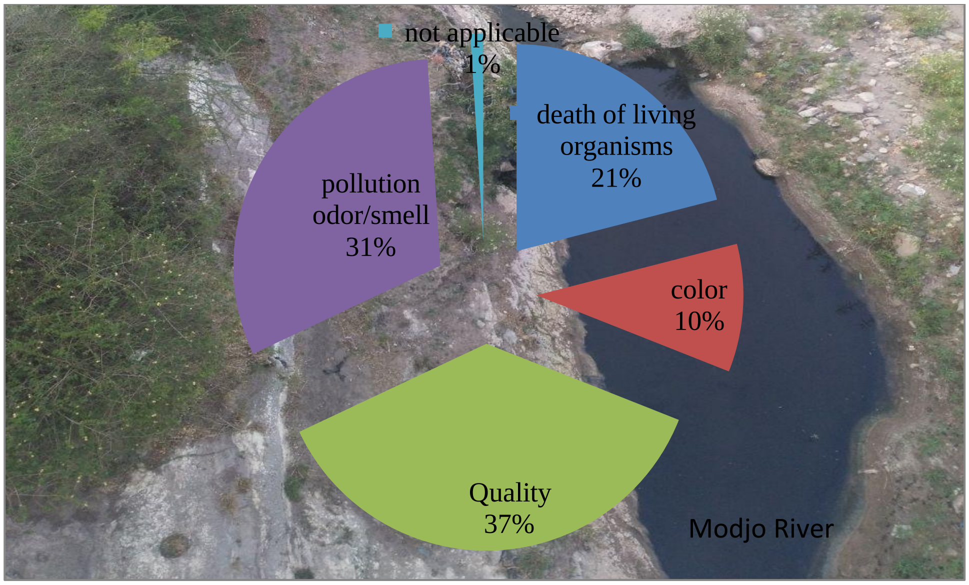

Figure 17: Effects of industrial pollutants on water resource

Source: Field survey (2019)

Figure 24 above showed that 37% of the respondents reported industrial pollutants changed the quality of Modjo River while 31% of the respondents reported industrial pollutants affected the odor/smell of the river: 21% of respondents reported that pollution of the river caused death of living organisms such as fish.10% of respondent reported color change to be the effects of industrial pollutants and on the other hand 1% of the respondent reported industrial pollutants have not any effect on water resources.

This all effects of industrial pollutants which are reported by respondents are supported by laboratory analysis. The gradual increasing Turbidity of Modjo River and decreasing in Dissolved Oxygen (DO), increasing Biochemical Oxygen Demand (BOD), Chemical oxygen demand (COD), Electrical conductivity (EC) and the value of other tested parameters are due to industrial pollutants showed changes on water quality of Modjo River, death of living organisms, and color change of Modjo river.

4.1.2.3. Socio economic Impact of Modjo River Pollution

The water quality of Modjo River shows pattern of behavior linked to industrial waste discharge, on the other hand anthropogenic sources with the intensity of human pressure domestic source and municipal wastes are identified as additional cause for the decline of Modjo

River water quality. Most of the measured parameters showed a similar declining quality trend from up to downstream of the river. This causes serious socio economic impacts on the communities of the study area. Polluted water bears two kinds of economic costs firstly, pollution reduce the total amount of adequate water available for household consumption or agricultural and industrial usage. Thus, there are economic costs of water held back from supply. Secondly there are costs related to the use of polluted water for consumption and production. The costs of using contaminated water for production refer to the decrease in both quality and quantity of products and health.

4.1.2.4. Effect of water pollution on community livelihood

The pollution of Modjo River brings loss of livelihood on the communities of the study area. Before examining what was the effect of Modjo River pollution on the communities' livelihood of the study area. Information obtained from respondents through questioner asking the question does Modjo river pollution affect your livelihood and livelihood activities. The result showed in figure 25below.

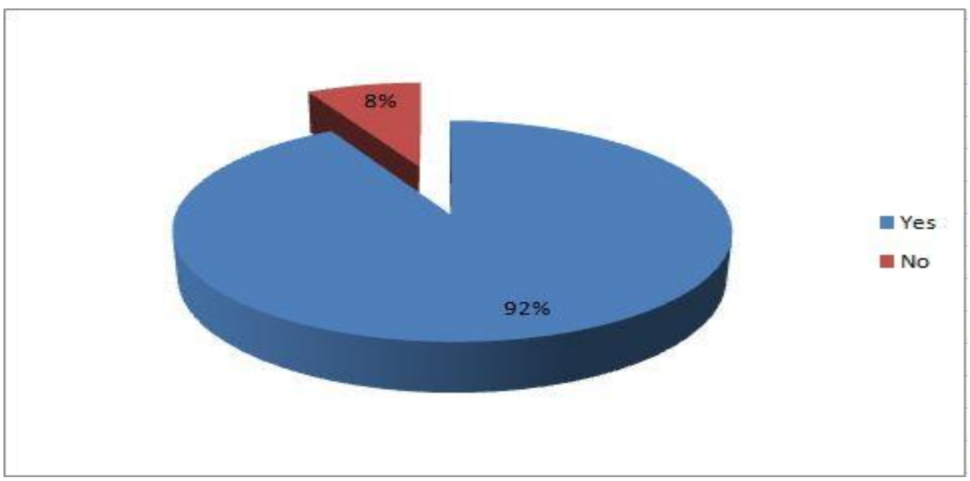

Figure 18: Effect of Modjo river pollution on livelihoods

Source: Field survey(2019)

Figure25above showed that92% of the respondents reported that Modjo River pollution to be affecting livelihood and 8% did not report any effect of water pollution on their livelihoods. Further the research went on examining what was the effect of Modjo River pollution on the communities' livelihood of the study area in detail shown below:

4.1.2.5. Effect of Modjo River Pollution on Livestock health

Livestock is a major source of income for many household in the study area. As Laboratory analysis result showed that there is existence of heavy metals and at some sampling point the concentration are above permissible limits of EEPA and WHO, 2011standards the existence of this toxic substances can be hazardous to livestock when they consume it. According to the data obtained from respondent in the study area respondents have faced cattle death, rapid weight loss of cattle and cattle skin diseases in the last eight years due to pollution of Modjo River. This is due to most of the livestock in the study area use Rivers and streams for their consumption.

Table 10: Main source of water for livestock drinking

Sampling kebele	River/stream		Pond water		Tap water		Total	
	f	%	f	%	f	%	f	%
Tafi Abo	57	66.2	1	5.6	0	0.0	58	33.5
Gongo	16	50.0	15	83.3	8	23.5	39	22.5
Momoshoki	15	83.3	8	23.5	6	18.8	29	16.7
Muda Senkele	15	83.3	3	4.8	8	23.5	26	15.0
Goditi Goro	20	58.8	1	5.6	0	0.0	21	12.3
Total							**173**	**100**

Table18 above showed that the principal source of water for livestock drinking are river and streams in Tafi Abo (66.2%), Gongo (50.0%),Momoshoki (83.3%), Muda Senkele (83.3%), GoditiGoro (58.8)use river for livestock drinking conversely households in Gongo (83.3%) use pond water to water their livestock. when compare to other source of water river/Streams are the main source of water for livestock drinking in the study area. In order to assess the impact of Modjo River pollution on livestock health and number of livestock affected by different health problem which is obtained from surveyed households is showed in Table19 below.

Table 11: Modjo river pollution and its impact on animal health

Did you encounter any of your livestock got sick due to drinking water from Modjo River?					Problem the livestock faced due to Modjo River pollution	**Frequency**	**Percent**
Sampling Kebeles	**yes**		**No**		Type of Problem		
	frequency	**%**	**frequency**	**%**			
Tafi Abo	32	24.4	25	59.5	Skin Disease	80	19.9

Gongo	38	29.0	2	4.7	Weight loss	90	22.4
Momoshoki	20	15.2	9	21.4	Loss of milk production	91	22.6
Muda Senkele	20	15.2	6	14.4	Animal death	130	32.7
Goditi Goro	21	16.0	-		Other related	10	2.4
Total	**131**	**100**	**42**	**100**		**401**	**100**

Source :Field survey (2019)

Table 19 above showed that about 80(19.9%) of livestock affected by skin disease, 90(22.4%) faced for rapid weight loss, while 91(22.6%) faced for loss of milk production, 130(32.7%) of livestock are dead and 10(2.4%) affected by other water related problems. The effect is varying from place to place. In order to assess the health condition of livestock and location in which locations the livestock are more vulnerable to health problem a chi-square test was conducted and the results show that there is association between distance from the river and number of livestock affected (χ^2, 40) =186.345, P=.000) Table20.

Table 12: Chi-Square Test of health condition of livestock and distance from the river

Statistic	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	186.345	40	.000
Likelihood Ratio	202.806	40	.000
N of Valid Cases	173		

The chi square test above showed that livestock close distance to river and live in the downstream part of the watershed is more affected than those in the upstream part and far away from polluted Modjo River. This is also supported by laboratory analysis result in this result most of the tested parameters concentration reach above permissible limits at the downstream part including the value of heavy metals. This show the presence of high organic load amounts to the presence of microorganisms (bacteria) that survive by decomposing organic loads. Therefore, the use of water infected with pathogens which is high risk for livestock health. Furthermore, in an expert interview a veterinarian expressed his view on the link between livestock sicknesses and Modjo river pollution.

"Generally, microorganisms, pathogens are known by causing human or livestock health problem and that some of the wastes discharge from industries contain high amounts of organic loads. To the presence of microorganisms that survive by decomposing organic loads. Therefore, the use of water for consumption infected with pathogens means high risks of contracting disease by the livestock. Based on this fact most of the livestock that were brought to the veterinary clinics for treatment were diagnosed for bacterial infections. Based on our data more cases were related with waterborne disease". (Expert interview conducted, 2019).

The role of livestock on the livelihoods of households in the study area is immense. Therefore, their long lasting sickness or even death can easily disrupt the economic situation of a household.

4.1.2.6. Impact of water pollution on Human Health

The harmful industrial waste discharges when mixed with rivers and streams endanger public health through different uses. The Modjo River pollution is paying a negative health effect on the residents of Modjo Watershed. Especially those living very close to the river and downstream along the discharge channels are more vulnerable than those who live far away from polluted river.

Table 21: Source of water for domestic uses

Source of water	Drinking		Cooking		Cleaning	
	f	%	f	%	f	%
River	29	27.6	35	33.3	41	39.04
Pond water	12	31.5	12	31.5	14	36.8
Tap water	17	56.6	9	30.0	4	13.3

Source: Field survey (2019)

The responses of respondent are shown in Table 21 above. They indicate that 27.6 % of the respondent use river water for drinking, 33.3% for cooking, and 39.4% for cleaning while31.5% use pond water for Drinking, 31.5% use for Cooking, 36.8% use for cleaning and 56.6% use tap water for Drinking, 30.0% use for Cooking and 13.3% use for Cleaning. As the above table21 Indicate that most of the peoples use river waters for different domestic purpose so the link between health problem and access of water relatively high. Effects on the health are manifested in the incidence of water related diseases such as cholera, skin infection, eye infection disease and Typhoid. Table22below shows the disease pattern of the area.

Table 14: Types and frequencyof infections encountered

Type of infection	Frequency of occurrence within a year	frequency	Percent
Water borne disease e.g. diarrhea, Typhoid	4 times	133	63.6
Water-washed e.g. skin and eye disease	3times	93	33.5
Other water related (if any)	2 times	40	2.9
Total		**266**	**100**

Source: Field survey (2019)

Most of the people (63.6%) in the study are affected by water borne disease, while (33.5%) are affected by water washed disease such as skin infection and eye disease and (2.9%) of people are affected by other water related disease such as respiratory disease like asthma.Regarding the frequency of occurrence, water- washed skin diseases (rashes on skin) are less severe than Water borne disease it occurs at least three times within year on about 93(33.5%)of family members. Accordingly, within a year 133(63.6%) of the household faced water- borne diseases at least four times and 40(2.9 %) are other water related disease at least two times in a year. Generally, almost half of the residences from surveyed household suffered by health problems that emanated from Modjo river pollution. In order to see the linkage between health problem and sex structure or which Gender is more vulnerable to this water related health problem Ch square test is conducted and the result showed below.

Table 15: Chi square test of health problem and sex structure

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	72.294	10	.000

The Chi-square test result showed that there was statistically significantly association between sex structure of the respondents and health problem (χ^2, 10) =72.294, P=.000 Table23. As the result showed that male are more vulnerable than female for Modjo river pollution health problems.

In the same fashion in order to identify which age groups are more vulnerable to health problem caused by polluted Modjo River the four age categories considered in this study and chi square test was conducted and the result is shown below.

Table 16: Chi square test of Age group and health problem

Chi-Square Tests

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	85.82	12	.000

Source: computed by the author (2019)

The Chi-square test result showed that there was a link between age group and health problem (χ^2, 12) =85.82, P=.000 Table24. As the result showed that the age group from 11-20 is more vulnerable to Modjo River pollution health problems. Because peoples within age group from 11-20 as the study area is rural use river for different purpose such as washing, showering, swimming and drinking. This problem does have an impact on the life span, labor productivity of the people and financial loss due to incur additional medical costs that adversely affect the livelihood of the people in the study area.

4.1.2.7. Economic Costs of human and Livestock Treatments

4.1.2.7.1. Cost of medical treatment for a family member

Modjo River is polluted and has hazardous health implication on residents of the study area. This exposed additional medical costs for health treatment. This section shows the estimated costs that a household might pay for a medical treatment that is needed due to exposure to polluted Modjo River at a kebeles health post. The mean costs for a treatment for sick individuals were more or less similar based on the interviews made with extension worker and drug dealers. The lowest costs arise when sick individuals purchase ‘’paracetamol’’ (also called pain-killer) in order to get relieve his/her pain or from an itching skin due to a skin allergy in extreme cases, however a patient may pay minimum costs up to 297Birr for first aid. These adversely affect residents' socio economic activity.

4.1.2.7.2. Economic Costs of livestock Treatment

In this regard, an attempt was made to collect information on the economic costs of livestock treatment in a veterinary health post. There is a variation in livestock treatment costs between 43 and 48birr the slight variation in the treatment costs was mainly attributed to the level of sickness and the type of veterinary health posts visited. On the other hand, the loss of livestock due to the exposure to polluted Modjo river water is a serious economic loss for the concerned households.

4.1.2. Analysis of Environmental data and Results

4.1.2.1. Death of living Organism due to Modjo River pollution

Figure24 showed that 21% of the respondents reported death of living organisms like fish invertebrates as one of the effect of industrial pollutants discharge to the river. According to the respondents, previously the River was used for fishing activities which are no longer done due to the water pollution. Based on the research findings, the respondents reported industries to be the cause of these changes along the Modjo River. This is supported by laboratory analyzed data whereby in some sampling stations the value of BOD are above the recommended value 9Mg/l. BOD is the amount of dissolved oxygen needed or demanded by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period.

Microorganisms living in oxygenated waters use dissolved oxygen DO to ox datively degrade the organic compounds releasing energy which is used for growth and reproduction. The total amount of BOD is more significance to food webs than to water quality. in the study area the measured BOD value are varies from 432mg/l to 755mg/l which means that the amount of BOD in the water are very low or the water are in poor condition and having high pollution load due to this the living organisms are not degrade the organic compounds releasing energy which is used for growth and reproduction as a result of this it become dead. Adequately Dissolved Oxygen is necessary for good water quality oxygen is necessary element to all forms of life.

The depletion of DO affects living organisms. Frequent death of living organisms such as fishes in waste water in fact do not come from toxicity of matters, but from deficit of consumed oxygen from biological decomposition of pollutants. When dissolved oxygen level in water drop below 5mg/l aquatic life is put under stress oxygen levels that remain below1-2mg/l for a few hours can result in large fish kills not only fish also invertebrates such as crabs, clams, zooplankton and other living organisms. So in the study area due to industrial waste discharge the value of DO in water are 2.34mg/l,0.97mg/l and 0.18mg/l from this value of DO in the study area it considers as a main cause for frequent death of living organisms.

On the other hand the turbidity of water also important for living organism. Turbidity affect organisms as eventually settle into the spaces between the gravel and rocks on the bed of water body and decrease the amount and type of habitant available for creatures that live in those crevices and sometimes those particles can clog fish gills, inducing disease, slower growth and, in extreme cases, death. Low levels of turbidity indicate a healthy well functioning ecosystem with moderate amount of microscopic plants and animals present to fuel the food chain but in the study area the measured turbidity varies from 33.2 to 107 mg/l which shows high level water turbidity.

Moreover everything relies on everything else the death of living organisms due to Modjo River pollution are its own impact on the environment. In an ecosystem each organism has its role and purpose disturbing the balance of an ecosystem can be disastrous for all the living things relying on it .when the ecosystem are disturbing many impact are faced the environment the same as true in our study area due to this ecosystem destroyed the area are faced for different problem like flooding, soil erosion, land degradation and rising temperature.

4.1.3. Analysis of Land use/Land cover data and Results

According to Elders and Environmental protection officer of the study area the expansion of industries into the watershed have significantly contributed to the pollution of the River. The area was predominantly covered with indigenous trees and other common bush and shrubs. During this time the river bank was used as a home servant for wild animals. but know there is no any wild animals this is as a result of decreasing amount of vegetable cover around Modjo river bank due to chemical content of the river the vegetables around river bank comes to dry, destroyed and know sparsely distributed. This is supported by evident from the satellite image of 2003 and 2019 below showed.

4.1.3.1. Land use land covers results

Land use land cover is a way of observing earth's surface and helps to answer what is on the land (land cover)and what is it for (land use)? (Ellis, 2007). Land use land cover change is a reflection of the impact of biotic and a biotic driver on the prevalent land use land cover of the region (Roy, 2010).According to Ellis (2007), biodiversity is reduced dramatically by land use land cover. Thus, the following section presents the LULC transformation in the study area.

4.1.3.2. Land use/ land cover categories

In order to map land use land cover of the study area, land sat images of 2003 and 2019 were used. Based on observed features four categories were utilized to estimate land use land cover of an area. Thus, it was classified into forest, farmland, settlement and bare land

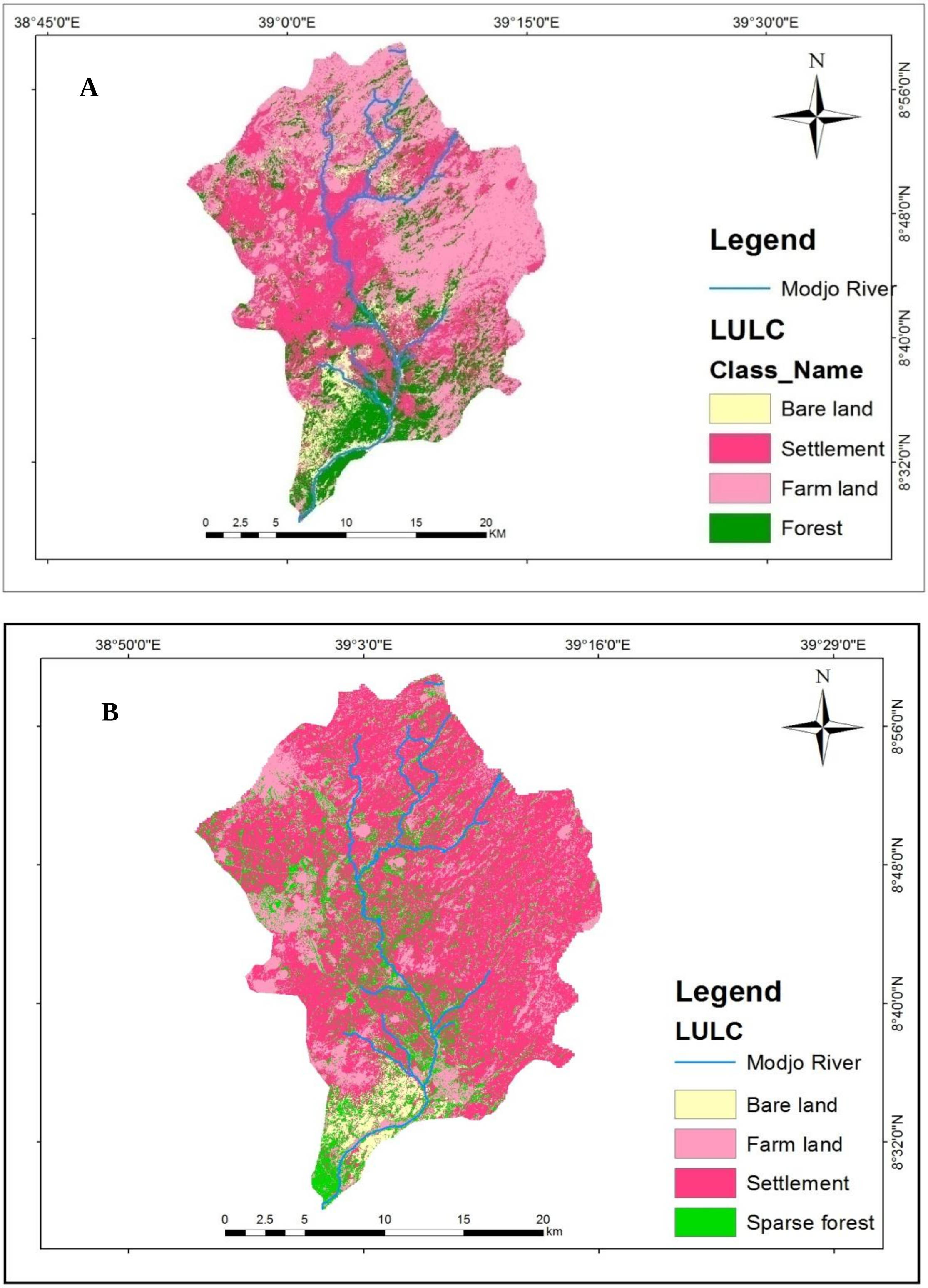

Figure 19: Land use land cover Map of Modjo Watershed (A) 2003 (B) 2019

Source: computed by the author (2019)

According to Table25 below, in 2003 farmland was covering larger parts of the study area 43.9% and followed by settlement 34.3%, the remaining parts were covered by forest 16.1% and bare land 5.7%. Currently in 2019, the proportion of classes in the study area showed that farm land sharply reduced to 20.7%, whereas settlement increased to 54.7%, forest 15.2% and bare land 9.4%.

Table 17: Land use land covers area in hectare and percentage

	2003		2019	
Land use land cover	**Area(ha)**	**%**	**Area(ha)**	**%**
Farm land	56987.44	43.9	26903.43	20.7
Settlement	44652.94	34.3	71115.61	54.7
Forest	20937.84	16.1	19777.4	15.2
Bare land	7296.44	5.7	12078.25	9.4
Total	**129874.69**	**100**	**129874.69**	**100**

Source: computed by the author (2019)

4.1.3.3. Trends of land use /land cover change from 2003 to 2019

The land use land cover was extremely changing in the two observation years (2003 and 2019). As a result, some of the classes exhibited an increase and others diminished. As specified in figure 26 farm land and forest cover have declined from 2003 to 2019,Settlement and bare land showed increment from 2003 to 2019.Hence, forest cover areas have declined particularly at the bank of the River over the last eight years Figure27.

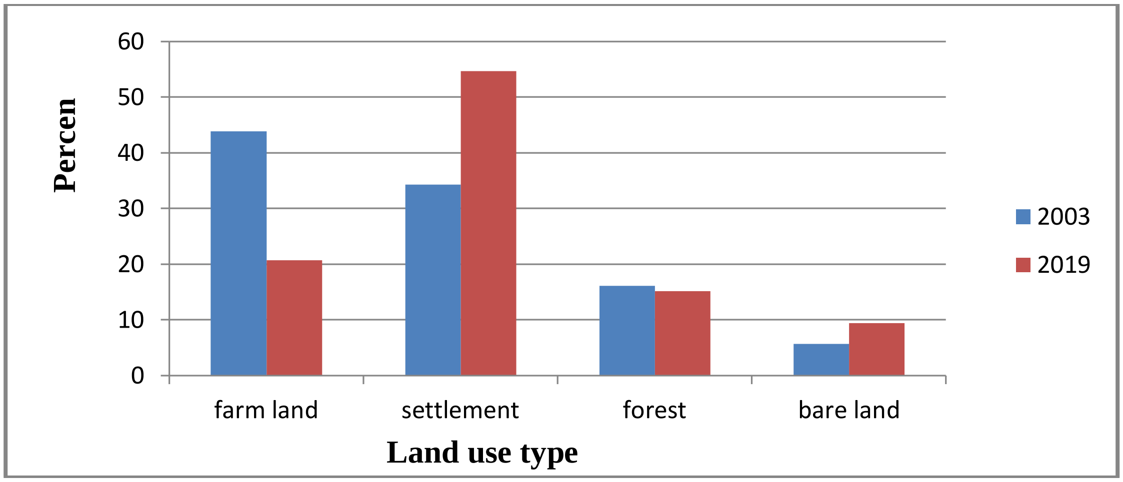

Figure 20: Land use land cover trend from 2003 to 2019
Source: computed by the author (2019)

4.1.3.4. Change Detection in the study area

Normalized difference vegetation index (NDVI) is very useful in vegetation studies. According to Holme et al., (1987) healthy vegetation absorbs most visible light and reflects large portion of the near infrared light. Contrary to this, if vegetation is un healthy and sparse the reflection of visible light will be more, while near infrared light reflection will be lesser, bare land on the other hand, reflects both red and infrared.

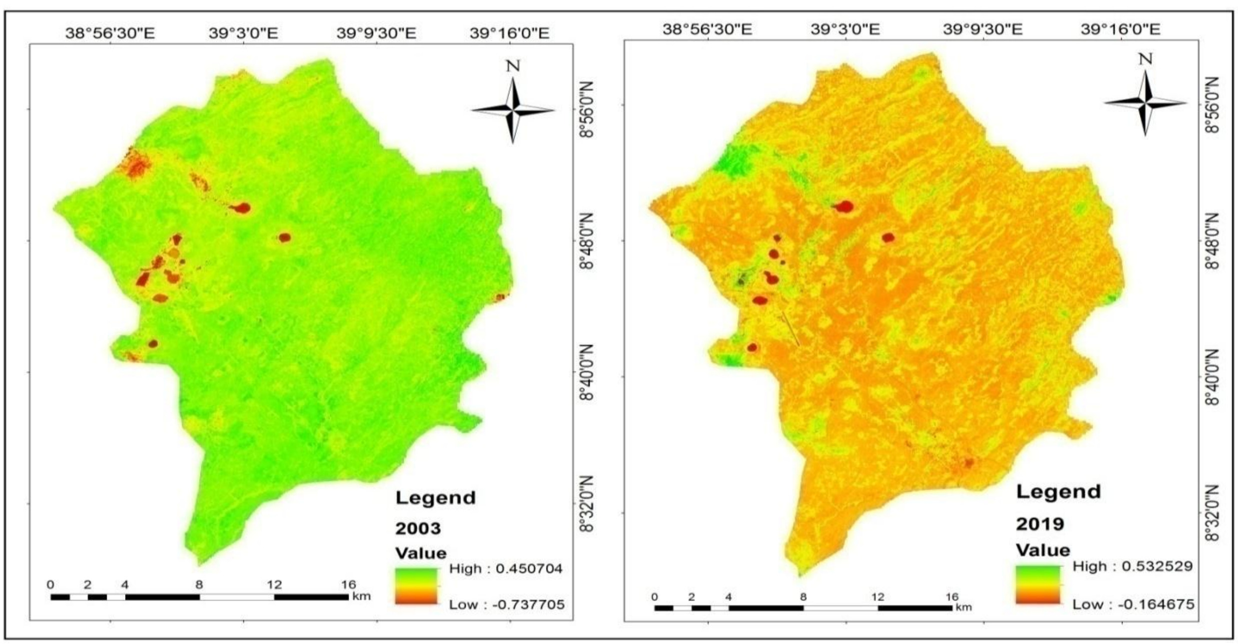

Figure 21: NDVI values of 2003 and 2019
Source: computed by the author (2019)

Analysis of the 2003 image shows that the minimum value was 0.74 and maximum value was0.45with mean value of 0.09 and standard deviation of 0.06.Moreover, in 2019 minimum, maximum mean and standard deviation of NDVI value of the study area were 0.16, 0.53, 0.13, and 0.05respectively. Standard deviation of 2003 and 2019 were 0.06 and 0.05 that manifested decreasing trend. Hence, the standard deviation result clearly showed that there was decline in vegetation cover. This is due to the concentration of Modjo River during plants prepare their food through photosynthesis process water and minerals in the soil are observed by the roots of the plants and transported to the leaves.

In the same way plants around river bank are observed by their roots this contaminated water which has heavy metals and other chemical contents. Moreover, due to the contamination of the river its physico-chemical parameter tests, such as BOD, DO and COD which is very important for breathing and living of animals and plants have revealed below and above the permissible limits. This bring the plants for drying, leave their natural content, destroyed and decreasing in amounts of vegetation cover of the study area. This vegetation cover change has negative response for environment such as land degradation, soil erosion, and climate change and so on. These are some of the problems which the environment is facing due to Modjo River contamination.

4.1.3.5. Accuracy Assessment

In order to check accuracy of classification commission and omissions were identified and producer and user accuracy were checked furthermore, to assess accuracy of overall classification in each year, overall accuracy and kappa coefficient of agreement was computed.

Table 18: Accuracy Assessment

Class name	Percentage of							
	Producer accuracy		User accuracy		commission		Omission	
	2003	2019	2003	2019	2003	2019	2003	2019
Settlement	100	98.3	76.6	97.7	0	9.26	1.67	1.01
Farm land	99.1	97.6	94.1	100	5.88	0	2.44	0
Forest	86.3	100	98.4	100	1.58	0	2.	6.67
Bare land	100	100	100	97.7	0	2.27	0	14

Source: computed by the author (2019)

Finally, the overall accuracy of 2003 and 2019 were 95.66 and 99.37 respectively (see Table28) this showed that there are high agreement between classified data and referenced data. Similarly, kappa coefficient results of the 2003 and 2019 satellite image classification were82.74 and94.69 respectively. These results found within0.81to 0.99, which is labeled as almost perfect agreement.

Table 19: Overall accuracy and kappa coefficient (2003 and 2019)

	2003	2019
Overall accuracy	0.9566	0.99375
Kappa coefficient	0.8274	0.9469

Source: computed by the author (2019)

4.1.3.6. Image Differencing

Image differencing is performed by subtracting the digital number (DN) value of one date for a given band from the DN value of the same pixel for the same band of another date (Macleod and Congaltan,1998).in the process of classification it needs to assign the appropriate ’from’ and ‘to’ identifiers.

Table 20: Change matrix of 2003 - 2019

	Final LULC (2019)					
	Classes	**Forest**	**Settlement**	**Bare land**	**Farm land**	**Total**
Initial (2003)	Forest	3697	2808.68	11147.36	3284.78	20937.84
	Settlement	8219.43	28237.16	165.95	8030.4	44652.94
	Bareland	1385.15	4198.59	764.79	1656.97	7296.44
	Farm land	6475.82	36020.13	411.26	14080.23	56987.44
	Total	**19777.4**	**71115.61**	**12078.25**	**26903.43**	**129874.69**
	Class Change	-1160.44	26462.67	4781.81	-30084.01	

Source: computed by the author (2019)

According to Table 28 above forest covers between 2003 to 2019 years lost 1160.44ha and bare land gain 4781.81 ha. Similarly, 26462.67ha converted to settlement from other land use land cover and 30084.01ha converted from farm land to other land use land cover.

4.1.4. Identification of Risk Area of Modjo River contamination and its effect in the catchment area.

4.1.4.1. Parameters for Risk area Identification in the Watershed

Identification of risk area is essential for the effective implementation of decision-making. Risk area in a watershed on the other hand those areas that are either source of priority pollutants exist. Based on these the environmental, physical and socioeconomic factors are identified. These are: proximity to Road Network, proximity to Stream Network, Slope, LULC, population density, Geology, Topography, and Soil are contributing factors in this study used for identifying risk area of Modjo river contamination.

4.1.4.1.1. Topography

Topography is one of the determining factors for water pollution risk area identification. The lowest area is more affected by river pollution impact than the highest because due to its topographical characteristics pollutants run off from highest topographical areas and store in this area the area having high pollution loads. Due to this, the area with the topography range between 1606 to 2064m was taken as high risk. Whereas the area found between 2256 to 3026m are low risk due to its topographical structure. The analysis is based on the standards formulated by Fataei et al., (2015).

Table 21: Topography risk class and areal coverage

Topography class	Risk Ranges	Rank	Area(ha)	Percentage of area (%)
1606-1869	Very high Risk	5	1275.24	0.97
1869-2064	high Risk	4	15168.9	11.67
2064-2256	Moderately Risk	3	28940.51	22.28
2256-3026	low Risk	2	59729.61	46
>3026	Very low Risk	1	24760.42	19.08
Total			**129874.6**	**100**

Source: computed by the author (2019)

Based on the above Table29 during reclassification phase the highest rank (5) was given for Topography ranges from 1606 to 1869m due to its flat and suitable for concentration of pollutants. Whereas the least rank (1) was given in elevation ranges to >3026m relatively due to its topographic condition pollutants are not concentrate in this area. The result of the analysis reveals that 1275.24ha (0.97%) of the study area is taken as very high Risk areas for Modjo river pollution. On the other hand15168.9ha (11.67%) of the area were high risk while 28940.51ha (22.28%) of the area were moderately risk and 59729.61ha (46%) of the study area were low risk and 24760.42 ha (19.08%) of the study area were very low risk for Modjo river pollution. The risk classes of Topography are clearly shown in the following (figure 29).

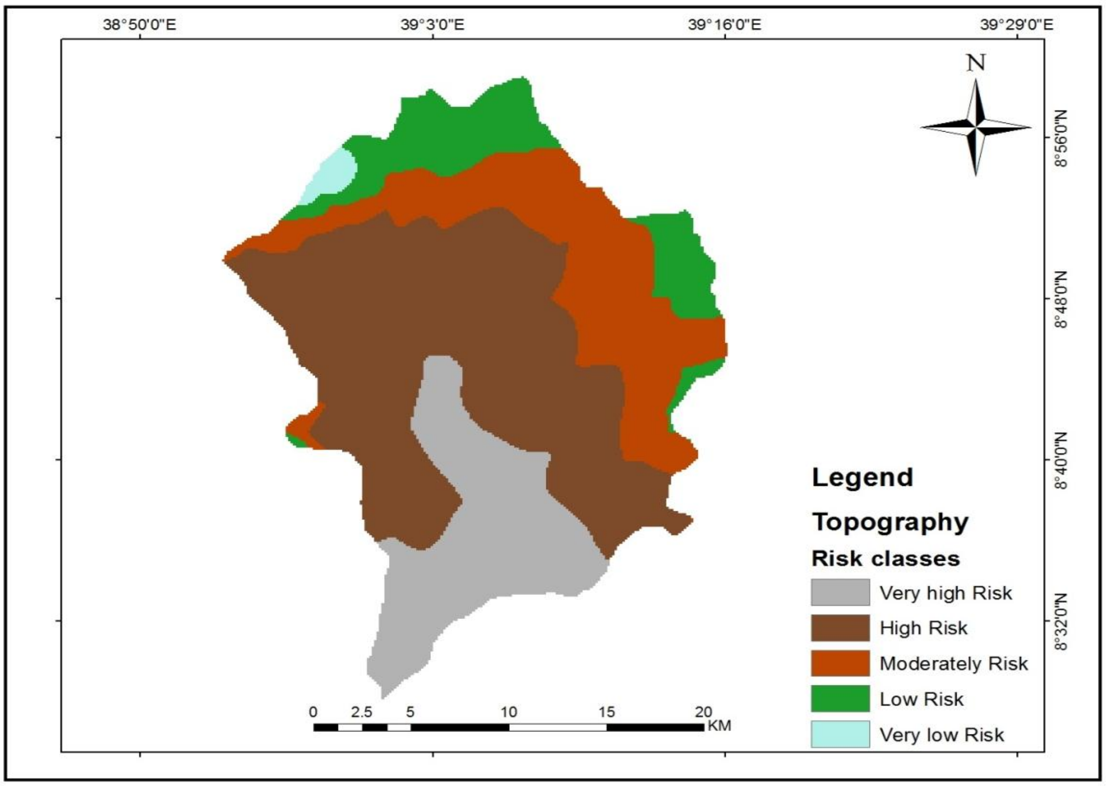

Figure 22: Topography risk class map
Source: computed by the author (2019)

4.1.4.1.2. Slope

The slopes were reclassified into four classes the area with highest slope ranges 20-25 were considered as low risk whereas the area with the lowest slope ranges 0-10 were taken as high risk for river pollution. As mentioned above the standard used by Fataei et al., (2015) was the base of categorizing slopes according to its risk class. During slope reclassification process the highest value (5) was assigned to gentle slope due to its high pollutant loads whereas the lowest value (1) was assigned to steep slopes due to its steepness high runoff and there is no pollution load. The areal coverage and risk class of the study area are depicted in the following Table and figures.

Table 22: Slope risk class and areal coverage

Slope class	Risk Ranges	Value	Area (ha)	Percentage (%)
0-10	High risk	4	113938.25	87.75
10 -15	Moderate risk	3	12700.11	9.77
15 -20	Low risk	2	2379.55	1.82
20-25	Very low risk	1	856.68	0.66
Total			**129874.59**	**100**

Source: computed by the author (2019)

Based on the above Table30 majority of the study area falls under the slope class of 0-10 covering113938.25ha (87.75%) is takenas high riskarea for Modjo river pollution. On the other hand12700.11ha (9.77%) were moderately risk while 2379.55ha (1.82%) and 856.68ha (0.66%) of the study area are low and very low risk for Modjo river pollution. The risk classes of slope are shown in below figure30.

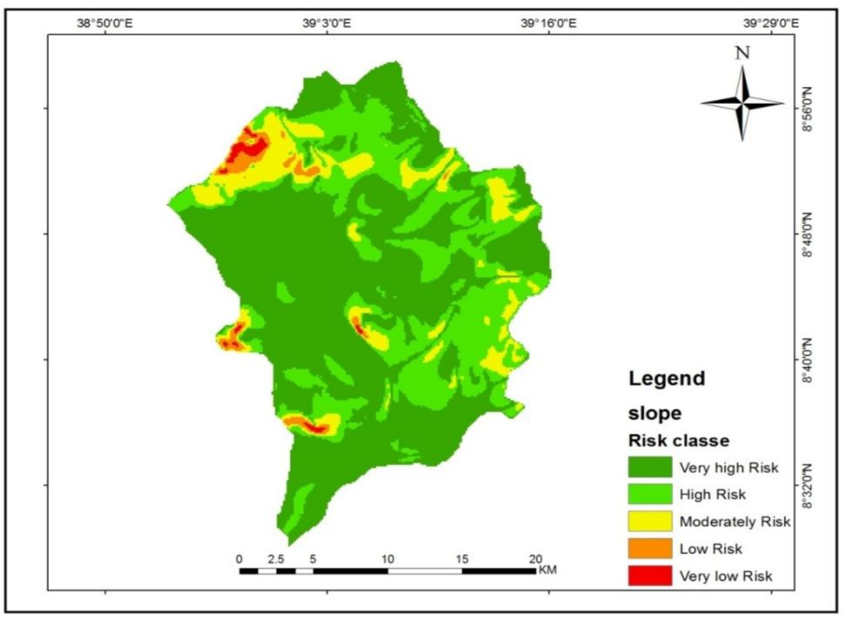

Figure 23: Slope risk class map
Source: computed by the author (2019)

4.1.4.1.3. Soil

To evaluate soil risk level of the study area for river pollution the soils were reclassified into five classes.During soil reclassification process the highest value (5) was assigned to Luvic phaeozems soil types due to its high water storage capacity due to this it could be a potential source of surface and ground water contamination whereas, the lowest value (1) was assigned toOrthic luvisols soil types due to low water holding capacity. Therefore, the areal coverage and risk class of the study area are showed in (Table and figure) as follow.

Table 23: Soil risk class and areal coverage

Soil class	Level of Risk	Rank	Area(ha)	Percentage of total area%
Luvic phaeozems	Very high risk	5	8949.49	6.88
Pellic vertisols	High risk	4	69380.82	53.44
Chromic luvisols	Moderately Risk	3	11032.9	8.47
Vertic cambisols	Low Risk	2	37987.9	29.25
Orthic luvisols	Very low risk	1	2523.76	1.96
Total			**129874.03**	**100**

Source: computed by the author (2019)

According to Table31 above based on their risk or susceptibility to impact soil type of the study area are reclassified on Luvic phaeozems and Pellic vertisols with an area cover 8933.04ha and 69380.62ha are identified as high risk area and soil type Chromic luvisols are considered as moderately risk with an area cover 9863.82ha and Vertic cambisols, Orthic luvisols soil are considered as low risk with an area coverage 37971.45ha and 1019.25ha.

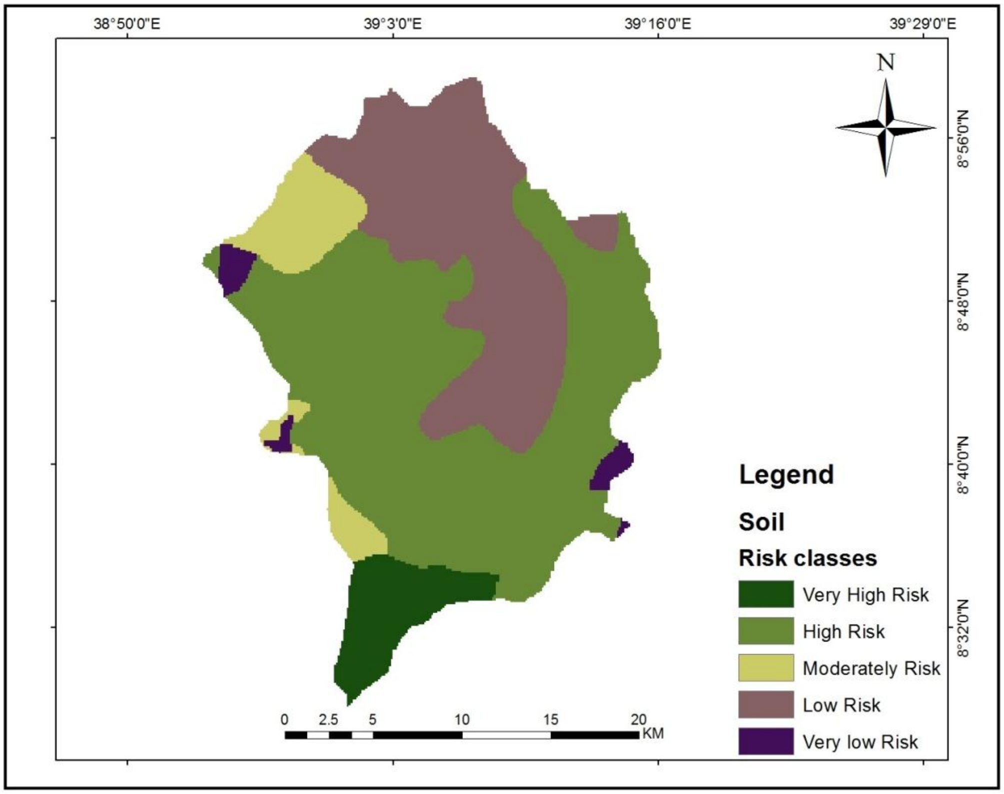

Figure 24: Soilrisk class map
Source: computed by the author (2019)

4.1.4.1.4. Land use/Land cover

The land use land cover of the study area was rank for river pollution risk area identification based on (Midatana et al 2018) standards. Accordingly, settlement, forest, farm land, and bare land are considered as very high risk, high risk, moderately risk and low risk. Duringreclassification in this phase the highest rank (4) was given for settlement because most of the settlements are existing close to polluted Modjo River and use the river for different purposes due to the contamination of the River susceptible for different health and water related problems The least rank(1) was given for bare lands.

Table 24: Land use /land cover risk class and areal coverage

LULC Class	Level of risk	rank	Area(ha)	Percentage of total area%
Farmland	Moderately risk	2	81083.08	11
Settlement	Very High Risk	4	26213.47	8
forest	high Risk	3	19119.25	34
Bare land	Low Risk	1	12078.25	2

Source: computed by the author (2019)

According to above Table32 describe that based on their susceptibility to polluted Modjo river settlement are identified as very high risk area with an area cover 26213.47ha and forest are also considered as high risk with an area cover 19119.25ha.Because most the forests existing on the river bank due to the contamination of Modjo River it becomes to destroy and decreased in amount and finally changes to bare lands. Farmland is considered as moderately risk area with an area covered81083.08ha. Finally, barelands are identified as low risk areas with an area covered 12078.25ha.

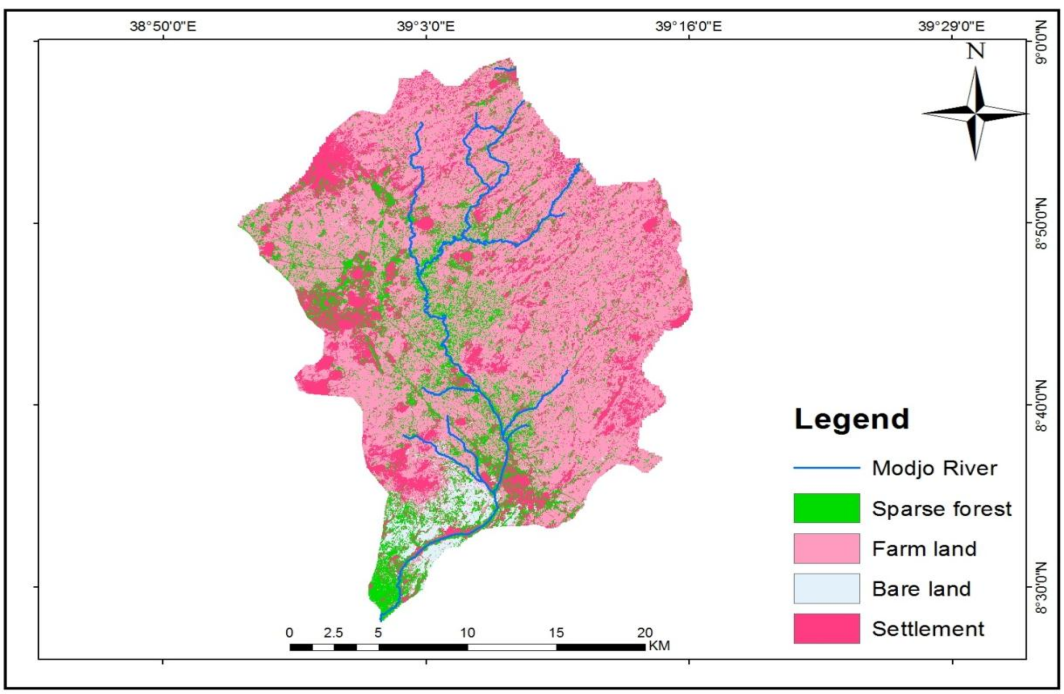

Figure 25: **Land use /land cover risk class map**
Source: computed by the author (2019)

4.1.4.1.5. Stream Network

Proximity from stream to river is one of the vital parameters in the identification of risk area for river pollution impacts due to their inextricably and reciprocally connectivity to River. Based on Fataei et al., 2015 standard accordingly, five different zones were specified: in which buffer from river within >9000m distance is low risk and within distance 0-1000m is high risk area. The stream networks close to river is high risk due to having high connectivity to polluted river on the other hand streams far away from polluted river is considered as low risk therefore the following Table33and figure34were clearly depicted proximity analysis of the stream network in this study.

Table 25: Stream network risk class and areal coverage

Buffer Distance in meter	Risk class	rank	Area in (ha)	Area in %
0-1000	Very High risk	1	1229.70	0.94
1000-3000	High risk	2	6002.93	4.63
3000-5000	Moderate risk	3	16186.17	12.46
5000-7000	Low risk	4	38742.48	29.96
>9000	Very low risk	5	67464.62	52.01
Total			12 9874.7	100

Source: computed by the author (2019)

Based on the above (Table33) areas close proximity to the river is more risk for Modjo river pollution impact. During the reclassification process, the highest risk rank (5) was assigned to areas within a buffer distance between 0 to1000m. Whereas the lowest score(1) was assigned to areas >9000m buffer distance from the rivers for their low connectivity to the river. Within a buffer distance between3000to5000m and 5000to7000m were under moderately and low risk class respectively.

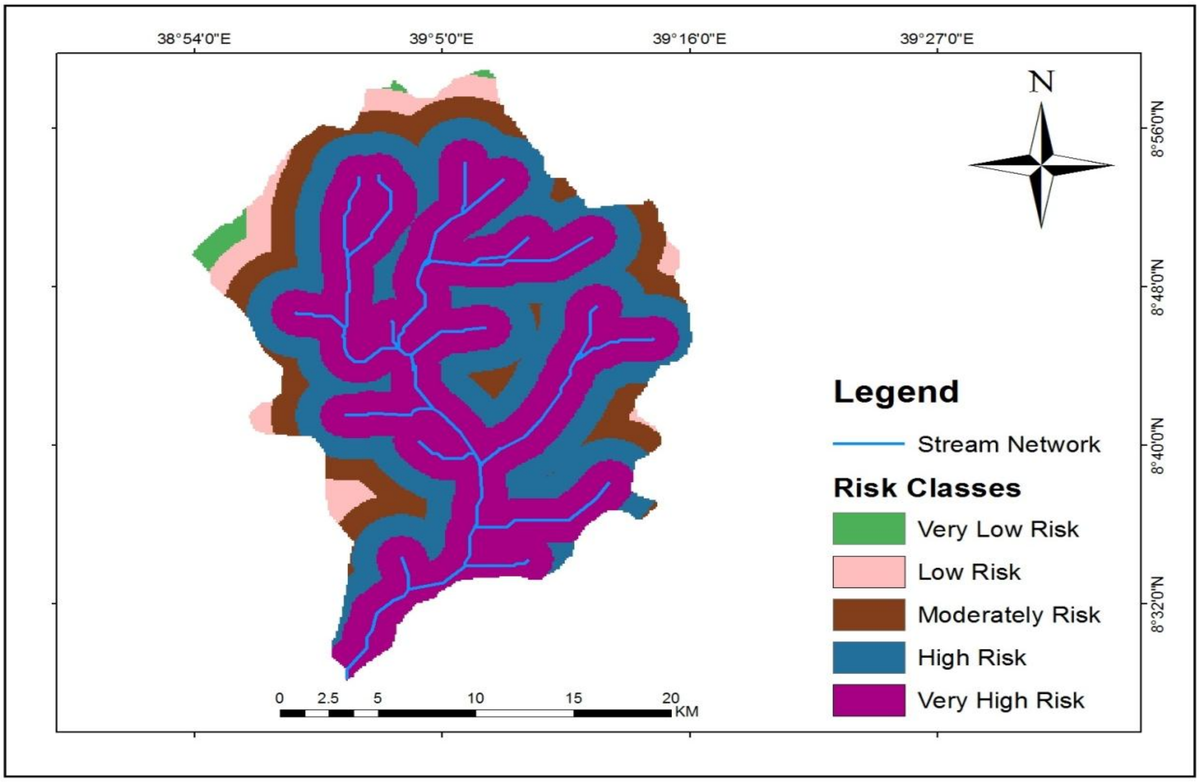

Figure 26: Stream Network risk class map
Source: computed by the author(2019)

4.1.4.1.6. Road Network

Road is one of the criteria that should be considered in identifying risk area of river pollution. Because roads close to pollution may cause public health problem (Sener et al., 2011).Based on this the road network of the study area classified into five different zones were specified: very high risk, high risk, moderately risk, low risk and very low risk based on Fataei et al., (2015)standards. Therefore the following table and figure were clearly depicted proximity analysis of the road network.

Table 26: Road Network risk class and areal coverage

Distance in meter	Risk ranges	value	Area(ha)	% of total area
0-2000	Very high risk	1	46429.02	35.76
2000-4000	High Risk	2	35507.79	27.34
4000-7000	Moderate Risk	3	25647.39	19.75
7000-9000	Low Risk	4	14771.16	11.37
>9000	Very low Risk	5	7519.35	5.78
Total			12,9874.74	100

Source: computed by the author (2019)

According to the above table the road network within 0-2000 to 4000m from the polluted river are under high risk and the area within distance from4000 to7000m are considered as moderately risk and within distance from 7000 to 9000m are considered as low risk areas. This means the roadnetwork which is close to the polluted river ismore vulnerable to impacts. However most of the roads in the study area are located within below 500m from polluted Modjo River so this make road network as one of the criteria for identify risk area.

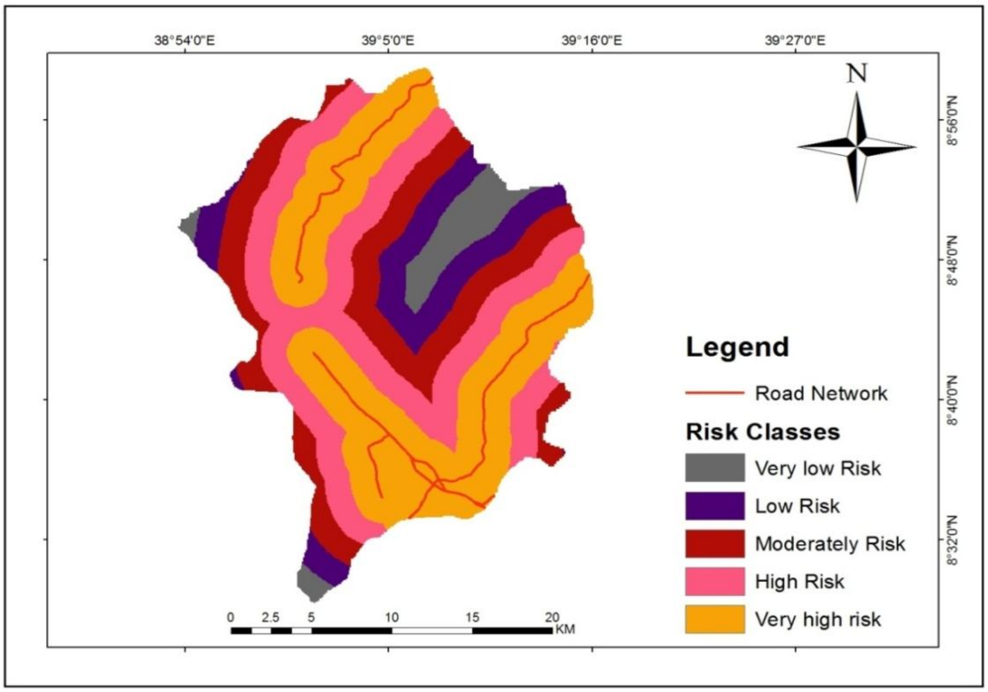

Figure 27: Road Network risk class map

Source: computed by the author (2019)

4.1.4.1.7. Population Density

Topography is one of environmental factors has strong influence on river flow direction of a given area that determining the concentration of pollutants. Based on this peoples living within lowest topography of the watershed is more susceptible for Modjo river pollution impact than peoples living within highest topography of the study area. For this study population data of three districts of the study area was extracted and buffer based on their topographical structure and distance from the river by using Midatana et al, (2018) standards. Accordingly, five different zones were specified: very high risk, high risk, moderately risk, low risk and very low risk. Therefore, the following table and figure were clearly depicted proximity analysis of population density.

Table 27: Population risk class and areal coverage

Distance in meter	Level of risky	rank	Area(ha)	% of total area
0-1500	Very high risk	5	79399.90	37.48
1500-3000	High risk	4	66164.11	31.23
3000-6000	Moderate risk	3	42537.77	20.08
6000-12000	Low risk	2	15213.23	7.18
>12000	Very low risk	1	8503.26	4.03

Source:computed by the author(2019)

Above Table 35 showed that the population density within 0 to1500m and 1500 to 3000m from the polluted river are under high risk and population living within distance from 3000 to 6000 m are considered as moderately risk while the population living within distance from6000-12000m and >12000m are considered as low risk.

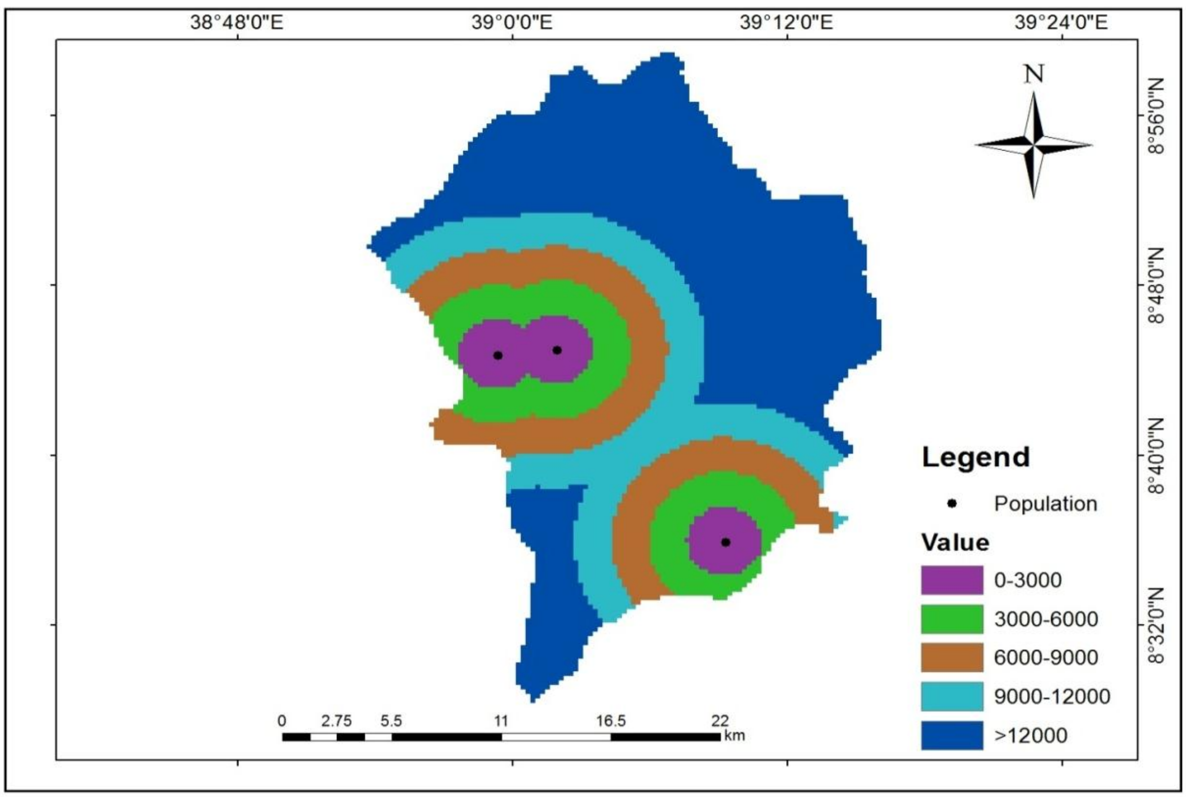

Figure 28: Population density risk class map
Source:computed by the author (2019)

4.1.4.1.8. Geology

Geology was considered as an important factor for risk area identification. Due to high contamination of this polluted River geology types and characteristics are important especially which is existing on the high pollution load area. Because based on characteristics each Geology types are different kinds of weathered, fracture, permeable and instable capacity for pollution. Accordingly geology of the study area is reclassify as highly risk, moderately risk and low risk based on their formation and pedogenesis of geology by using Midatana et al., 2018 standards. During reclassification in this phase, the highest rank (4) was given for undifferentiated unconsolidated sediments evaporities (2) was given for undifferentiated igneous rocks.

Table 28: Geology risk class and areal coverage

Geology class	Level of risk	rank	Area(ha)	Percentage
Undifferentiated unconsolidated sediments evaporities(e.g gypsum, trona,etc)	Very high risk	4	9655.56	7.43
Basic and ultra basic rocks e.g. basalt, alkali basal, nephelenite, gbbro and pyroclastic rock	Moderately risk	3	109614.6	84.49
Undifferentiated igneous rocks	Low risk	2	10535.49	8.11

Source: computed by the author (2019)

According to (Table 36), based on their susceptibility to pollution, in Modjo river the geology types of undifferentiated unconsolidated sediments evaporities are identified as very high risk area and cover an area of 9655.56ha(7.43%). Whereas, basic and ultra basic rocks are considered as moderately risk area with area coverage of 109614.6ha (84.49%) finally, undifferentiated igneous rocks considered as low risk.

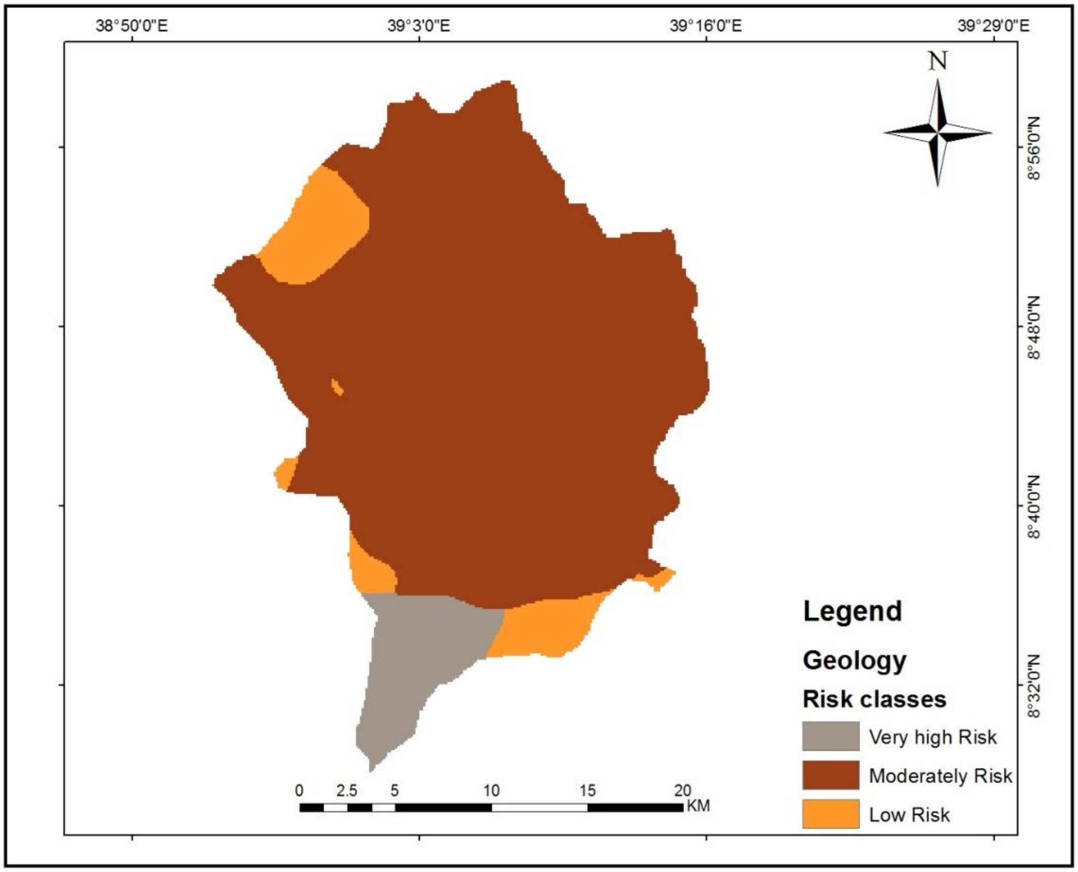

Figure 29: **Reclassified map of Geology**
Source: computed by the author(2019)

4.1.4.2. Weighted Overlay Analysis for Risk Area Identification and Multi Criteria Evaluation

4.1.4.2.1. Results of Pair wise Comparison Matrices

Risk area identification is the process by which river pollution risk area was selected through actual application of multi criteria evaluation of different factors that determines high risk area screening. In the present study, eight factor maps were produced and reclassified according to their degree of significance they have for identifying risk area for Modjo river pollution. The above eight factor maps prioritized in their descending order as follows :(Topography, slope, Soil, Land use land cover, Stream Network, Road Network, Geology and Population density).after prioritizing all the factor maps according to their relative importance, the task of assigning weight for each parameter was performed outside GIS on IDRISI decision wizard software. The following Weight-AHP weight derivation in (Table37) clearly indicates the influences of each factor.

Table 29: pair wise comparison matrix in IDRISI software

Reclassified map layers	Topography	Slope	LULC	Soil	Road network	Stream network	Population density	Geology
Topography	1							
Slope	0.5	1						
Soil	0.3	0.5	1					
LULC	0.25	0.3	0.5	1				
Stream network	0.2	0.25	0.3	0.5	1			
Geology	0.16	0.2	0.25	0.3	0.5	1		
Road Network	0.14	0.16	0.2	0.25	0.3	0.5	1	
Population Density	0.125	0.14	0.16	0.2	0.25	0.3	0.5	1

Source: computed by the author (2019)

Based on the above pair wise comparison (Table 37), the soil is less moderate important than Topography whereas LULC is strongly less important than the Slope and Topography like LULC, Stream Network is also strong less important than Topography and slope, but moderate less important than a soil. In other hand, Geology is very strong less important than Topography and slope as well as very moderate less important than a soil, but moderate less important than stream network and LULC. At the end, road network and population density is extremely less important than Topography and slope, but very strong less important than a soil. It is also strongly less important than LULC andstream network but moderate less important than geology.

The diagonal cells in the matrix contain a number1 because the variables were compared with themselves.Generally,in the above matrix only the lower left trianglehalf was evaluated because the upper right was symmetrically identical and the cells in the matrix were indicates the evaluation of each pair of comparisons. The Eigen vector of weight generated in the IDRISI software module was used to produce a relative weight for all eight factor maps that was used to control their influence in weighted overlay tool in ARCGIS Environments. As indicated in the following (Table38), this module produced a set of weights for each parameter that sum 1 which was used as input for multi criteria evaluation.

Table 30: Eigenvector of factor map weights

No	Factor maps	Eigenvector weight	Weight in %	Consistency ratio
1	Topography	0.2998	29.98	
2	Slope	0.2350	23.50	
3	Soil	0.1625	16.25	
4	LULC	0.1112	11.12	0.07
5	Stream Network	0.0821	8.21	
6	Geology	0.0759	7.59	
7	Road Network	0.0305	3.05	
8	Population density	0.0330	3.30	

Source: computed by the author (2019)

The above (Table 38) consistency ratio of Eigen vector weight shows how each individual factor rating would have to be changed if they were to be perfectly consistent with the best-fit weightings achieved. According to Saaty, (2008) if consistency ratio is less than 0.1the judgment is within the consistency limit and its value were consistent and acceptable but, when its value is greater than 0.1,the judgment is out of the acceptable limit and should be reconsidered again to make a consistent rating between the factors that considered in the study. Therefore, the consistency ratio in the current study was 0.07 which was an acceptable one.

As indicated in the above Eigen vector weight, Topography is the most important determinant factor for river pollution risk area identification with Eigen vector weight of 29.98%, which was followed by slope, and soil with an Eigen vector weight of 23.50% and16.25%respectively. Whereas the other remaining factors that were employed in this study includes LULC, stream network, Geology, road network, and population density hold11.12%, 8.21%, 7.59,3.05,3.30of Eigen vector weights respectively.

4.1.4.2.2. Results of weight overlay

In the current study, all the weighted and standardized criteria that used in the analysis were combined together with weighted overlay tools to generate a final risk area map of the watershed.

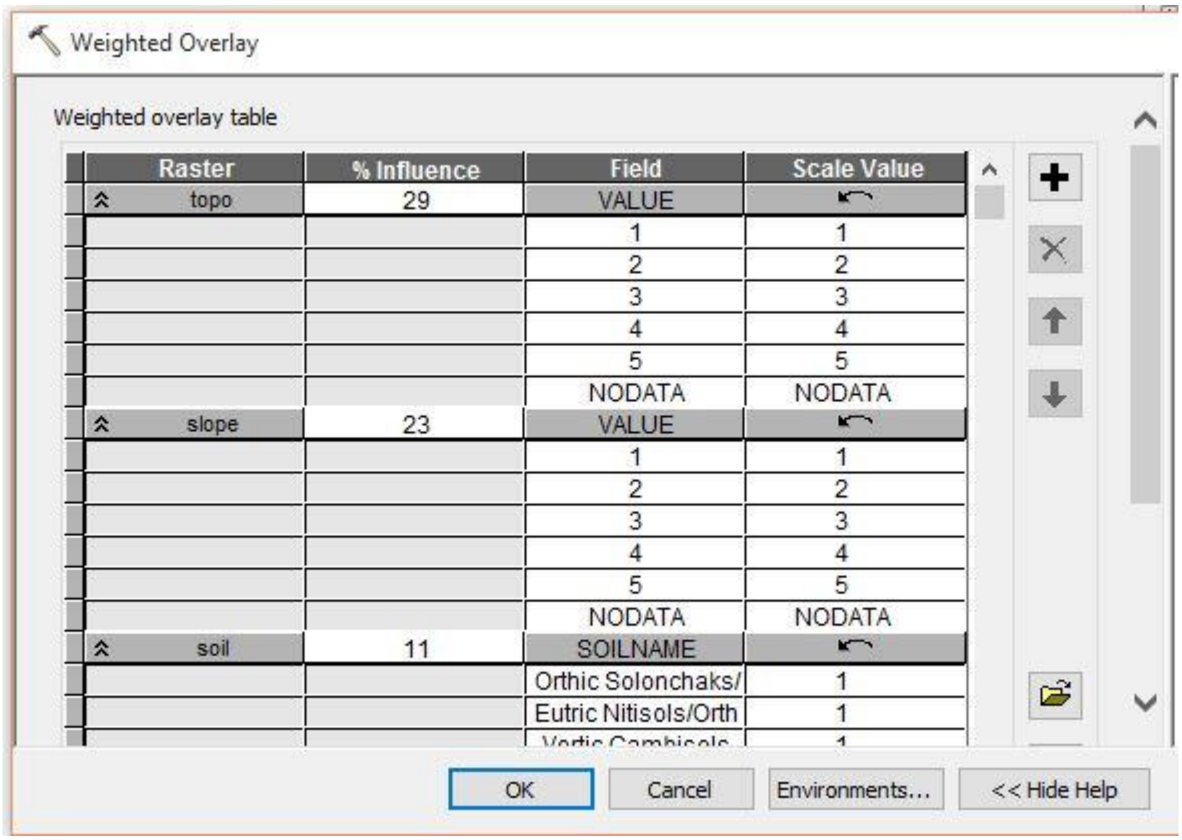

Figure 30: weighted overlay tool in ARCGIS environment

The following (Table39) clearly indicates risk classes and percentage shares of final weighted overlay map of the watershed.

Table 31: Weighted overlay results for each risk class

Risk range	Rank	Area(ha)	Percent of total Area (%)
Very high risk	5(Red)	12855.56	9.48%
Moderate risk	4(Green)	105597.3	82.14%
Very low risk	3(Yellow)	11421.14	8.38%
Total		**129874**	**100**

Source: computed by the author (2019)

According to the results obtained from weighted overlay risk class (Table39) an area of 12855.56ha (9.48%) was found to be in a high risk class for Modjo river pollution. Similarly, all environmental, physical and socio economic criteria used in current study suggest the pollution has highlyinfluenced the study area. Thehigh pollution load of the river due to the presence of many industries in the watershed is the main factor. This is also supported by laboratory analysis result from water samples taken from the river. The results of all the parameters show value above the permissible limits of (WHO, 2011 and EEPA, 2003) standards due to this the area fall under very high riskof water pollution.

Meanwhile, an area about 105597.3ha(82.14%) was classified as moderately risk area for river pollution and lays all most all parts of the watershed excepts some extreme part of southern,southeastern, central northern and some northwestern part of the watershed. The areas were also characterized by less pollution loads than the areas fall under high risk. In other hand, the area with 11421.14ha (8.38%) of the watershed was found as very low risk for river pollution impacts.

The largest portions of this area located in the northern and northwestern part of the watershed. The risk map of the watershed (Figure38) clearly shows that the largest area has under moderately risk for Modjo river pollution impact.

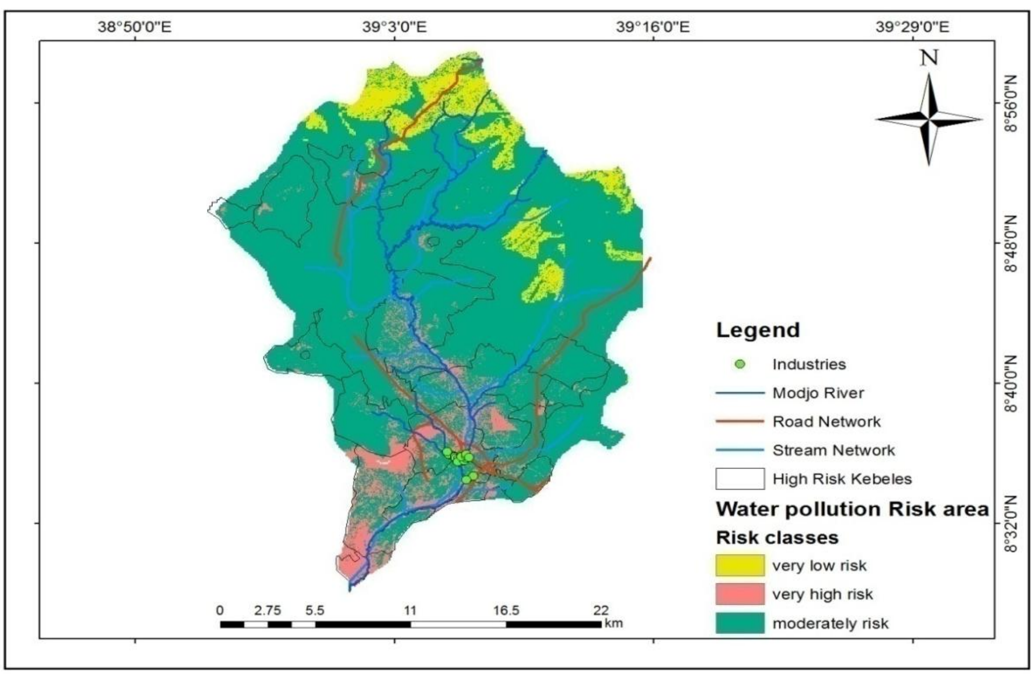

Figure 31: Weighted overlay of risk area map
Source: computed by the author (2019)

4.1.4.2.3. Thematic Maps of Highly Risk kebeles

Thematic map is a type of map that is designed to show the distribution of the highly risk kebeles in the watershed that fulfilled high influence of all criteria that was selected for the current study. As shown in the above (Figure38), weighted overlay of risk area map contains all risk classes,namely highly risk,moderately risk and low risk area for Modjo river pollution impact of the watershed. Therefore, it is essential to show only highly risk kebeles of the watershed to take a reasonable decision for minimize risks on the life of human,livestock and Environment in the study area. In order to produce the thematic map of the selected risk kebeles in the study area, the raster map of weighted overlay result was converted into polygon by using the conversion tool in ARCGIS environment. After the conversion process, the shape file of highly risk kebeles was selected and exported in ARCGIS software to generate the final thematic map of highly risk kebeles as shown in the following (Figure39).

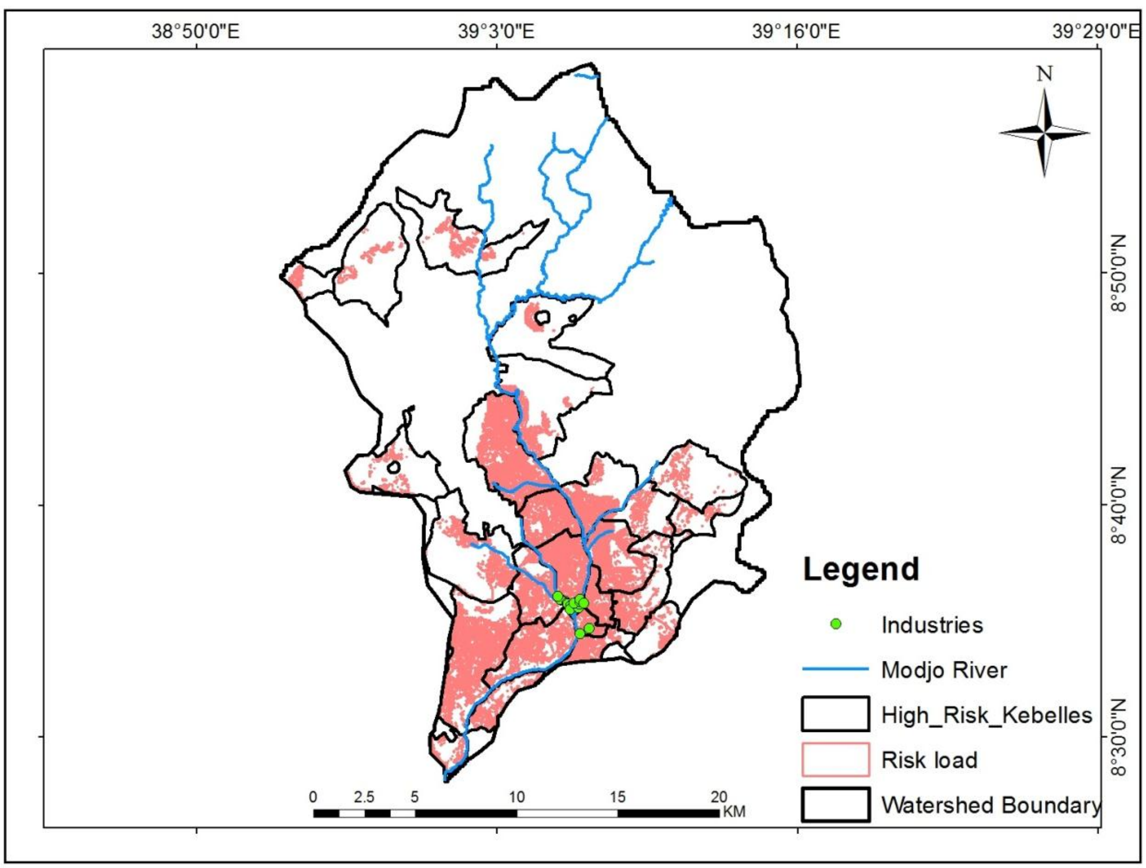

Figure 32: Thematic map of highly risk kebeles
Source: computed by the author (2019)

Figure 39 above showed that from total 60 kebeles of watershed boundary about 23 kebeles are fall under high risk of Modjo River pollution impacts for each kebeles its areal coverage in Hectare and percentage is shown in Table40 Below.

Table 32: High risk Kebeles and areal coverage

Kebeles Name	Area(ha)	Percentage (%)
Jalo chancho	4217.66	8.19
Gobo saye	3919.76	7.61
Katila	3759.96	7.30
Denkaka	3634.80	7.06
Yerer selase	3350.37	6.51
Hidi	3277.62	6.36
Godino	3262.23	6.33
Gerbicha	2529.49	4.91
Dekabora Kara	2453.59	4.76
Kolbe Gode	2322.83	4.51
Taafi Abo	2240.16	4.35
Jegola Arfeta	2181.83	4.23
Jirmi Enslale	2097.01	4.07
Momo Shoke	1750.22	3.40
Shera Dibandiba	1682.98	3.27
Biyu Bisqe	1556.74	3.02
Birmaji Tulu Rea	1633.44	3.17
Todedi Ledima	1164.16	2.26
Muda Senkele	1052.68	2.04
Kara finchawa	1041.04	2.02
Gogecha	809.97	1.57
Gongo	673.17	1.30

Source: computed by author from high riskkebele maps

As the above Table 40 showed that from 60 kebeles of watershed about 23 kebeles are fall under high risk the main cause for this one those kebeles are existing on the area most of the industries are there, second topographical structure of those kebeles are susceptible for concentration of pollutants finally influence of factors determine for identified risk area is high.

Due to this the above listed 23 kebeles from total 60 kebeles of watershed fall under high risk for Modjo river pollution impacts.

4.2. Discussion

4.2.1. Extent of Modjo river pollution in the watershed

The extent of observed parameters showed that the value of the parameters increased (reach above the permissible limits) at the downstream part of the watershed. In all samples ten parameters measured and reach above the permissible limit of discharge. DO, BOD, COD, pH, Pb, Cd, Cr were observed in laboratory while the others EC, T^o and turbidity were onsite observed. In this context Islam et al., (2011) has found BOD_5, COD, and T^o values of 573.89mg/l,1223.33mg/l,1123.11mg/l and 5022^oC respectively, from samples taken from textile industry effluents in Gazipur and Narayanganj cities in Bangladesh.

likewise the results of a study conducted by Siyanbola et al.,(2011) on effluents from five textile industries in Nigeria shows high concentration of $BOD_{5,}$COD, and $T^{o,}$ between 340mg/l and 560mg/l for BOD_5, between 615mg/l and 1245mg/l for COD. The measured value of temperature in waste water discharge from textile in most cases falls well within the national standard of their respective countries. In our study, however an exceptionally high BOD and COD were measured in Modjo River. This is nearly double the WHO and EEPA permissible limits of the maximum BOD and COD value.

Another important pollutant identified in the sampled point was T^o, EC, Turbidity, DO, pH, Pb, Cd and Cr where 23.8^oC to 26.3^oC,683 to 7024, 18 to 107, 7.3mg/l to 0.18mg/l, 0.013 to 0.054, 0.0001 to 0.0017and 0.04 to 0.12 were found in the sample taken from Modjo River respectively. The main cause for the presence of these pollutants in large quantities is attributed to the industrial waste discharge to the river due to use organic material as raw materials and absence of waste treatment or low quality of waste treatment techniques used.

These cause implications on the health of human, livestock and environment. According to Dirriba et al., (2014) the presence of pollutants in large concentration is attributed to industrial waste discharges use organic and inorganic materials.

4.2.2. Impact of Modjo River Pollution on Socio economic Activity and Environment

According to the results obtained from socio economic data and satellite image residents who live close to the polluted river and downstream part of the watershed were more affected than those who live further away from polluted river. This is due to the existence of high concentration of pollutants in the area.Similarly According to kant, (2012) high concentration of pollutants cause the extinction of important microorganisms and implication on the health of human, livestock and environment. The environmental impact of high BOD_5 in waste water is associated with the removal of dissolved oxygen(DO) which is central for aquatic ecosystems. The amount of DO available in water is directly affected by the amount of BOD loads in waste discharge.

High concentration of BOD could create an ideal environment for the growth of microorganisms that survive by decomposing the organic matter using DO. Thus at higher concentration BOD remove more DO that are equally required for the survival of other aquatic life mainly fish and other aerobic organisms that will be threatened in such circumstances (Islam et al.,2011;prabu et al.,2008). Hence, the existence of high BOD value and removal of DO value has a destructive effect on aquatic biodiversity by reducing the metabolism.COD was another pollutant found in large concentrations in the sampled area. The main problem related to high COD concentration is that it depletes available dissolved oxygen.

In this environment anaerobic microorganisms use DO to oxidize inorganic loads in the water. The concentrations of all observed parameters above the permissible limits have environmental implication in the study area. According to the results obtained from socio economic data residents who live close to the river and those who live in downstream part of the watershed were more affected than those who live farther away from Modjo River. The high levels of contamination in river with different chemicals are considered as factors that contribute to human and livestock health problems. This produce multiple direct and indirect economic costs by reducing agricultural production, by increasing cost of drinkable water and health treatment.

4.2.3. Identify risk area of Modjo River contamination effect in the catchment area

The downstream and southeast part of the watershed is risky for Modjo river pollution impact. This is mainly due to the influence of various environmental, physical and socio economic factors. To this effect risk area map of the study area was generated based on the influence of parameters such as Topography, slope, soil, LULC, Road Network, Stream Network, Geology and population density (Fataei et al., 2015; Midatana et al., 2018).The weighted overlay result showed the highly risk area for Modjo River pollution impact and from 60 kebeles of the watershed about 23 kebeles fall under high risk. As Midatana et al., 2018 reported that lowland areas are susceptible for pollution loads.

CHAPTER FIVE

5. Conclusions and recommendations

This chapter intends to present an overall conclusion and recommendation of the study. In conclusion,parts the results are analyzed in line with the variables incorporate in the result and then in second part recommendations are made here with to draw the attention of decision maker.

5.1. Conclusions

Ethiopia is one of the least developed countries and agriculture is the backbone of its national economy. The industrial sector is in its infancy, accounting for less than 5% of the workforce and contributing less than 13% to the national GDP. Since 2003, Modjo watershed has undergone rapid industrialization process that involved the rapid flow of investors. The results of this study revealed that the concentration of some physico-chemical parameter (BOD, COD, turbidity, EC, pH, Cd, Cr is higher than the permissible limits of WHO, 2011 and EEPA standards. The concentrations of other parameter however DO below the permissible limit. Due to the concentration of heavy metals and other chemicals that exceed by far normal ranges the river has cause Environmental implications by damage the aquatic biodiversity.

Modjo River has negatively affecting the livelihood of residents in many ways. Since the settlers in the catchment areas have no other option and highly depend on this river for their livelihood activity. Most of the people are utilized for animal watering, washing, home consumption, irrigation and other purpose. That is why, even though they know that the river is polluted and have hazardous health implication they went on utilizing this river for various purposes. Waterwashes and water borne diseases such as typhoid,diarrhea,cholera and rashes on skin are apparent in the catchment areas.

They are exposed to additional medical expenses and have negative effect on the productivity of labor force. Due to the continuations of acute water related infections in the study area households are forced to allocate their larger share of income for the prevention of such disease. These cases are negatively affecting the productivity. The livestock also back bone of the rural economy exposed to death, rapid weight loss, and different range of skin disease due to drinking from contaminated Modjo river water. Consequently, these produce direct and indirect economic costs on the residents of the study area.

This is due to enormously decrease the marketability of the product. In this regard, the problem is long running because income and life loss it affects negatively the livelihood of the communities. The downstream part of the watershed is fall under very high risk for Modjo river pollution impact.The largest portion of watershed is falling under moderately risk area.

However, the industries still discharge their wastes into the river by despite the implementation of Ethiopian Industrial Policy which is a framework for industrial activities. This is due to lack of law enforcement and lack of coordination but the issue is an alarming for environmentalist and decision maker to implement action based work.

5.2. Recommendations

- The study has assessed the environmental impact of Modjo River pollution. Based on the findings of this study the following recommendations are put forwarded to prevent further water pollution of Modjo River.

- Tons of untreated industrial wastes are frequently flowing into the river which is polluting the water. Therefore, the concerned bodies should strictly enforce on all industries to install facilities and effectively treat waste water. Industries and other factories, which have built up on the bank of the river, should be stopped and evicted immediately.

- Pollution free technology should be used to all industries. People should be more aware about the danger of water pollution and the importance of healthy environment.

- The existing environmental protection policy of the country should be implemented by the government (at federal and local levels)and there should be proper review ofthe weaknesses of the existing policies in term of implementation drawbacks of thepolicy guideline for managing a sustainable environment for the Modjo watershed and beyond.

- The decision makers at all levels of government should be able to use the risk area map identified by this study and prepare action plans for immediate, short term, medium and long-term plan regarding all kinds of existing and future developments within the watershed.

- The industries, which lie within the high risk and moderate risk area, are strongly recommendedto perform their duties of establishing waste treatment facilities.

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APPENDIX I

Jimma University

College of Social Sciences and Humanities

Department of Geography and Environmental Studies

Questionnaire for Sample Household

Dear respondent:-

The main aim of this questionnaire is to collect data for master thesis entitledas Environmental Impact Assessment of Water Pollution: The Case of Modjo Watershed, Oromiya Regional State, Ethiopia'. Dear respondents, you are expected to provide genuine, accurate and balanced information. Your information is highly valuable for the success of this study. Therefore, the researcher is very much grateful for the sacrifice you pay to this end and the information gathered will be highly confidential and will be only for the purpose of this research alone.

Please note that:-

- ✓ There is no need to write your name
- ✓ Each question are its instruction to follow

Thank you very much in advance!

Part I: Respondentbackground information

Note: Circle the answer that meets your choice

1. KebeleA) Jalo chancho B) MudaSenkele C) Tafi abo D) GongoE) Goditigoro
2. Sex--- A) Male B) Female
3. Age---- A) 20-29 B) 30-39 C) 40-49 D) 50-59 E) 60 and above
4. Marital status-- A) Single B) Married C) Divorced D) Widowed
5. Level of Education-A)Illiterate B) Read and write C) Primary First Cycle (1-4) D) Primary Second Cycle (5-8) E) Secondary First Cycle (9-10) F) Secondary Second Cycle (11-12)G) Tertiary (college and university)
6. Family size including household head (in number):________________
7. How much it takes to reach at main river course from your home in walk? _______minutes
8. How often did you live in this area? _____________Years

Part II.Impact of Modjo river pollution on communities'livelihood

9. Do you think that Modjo river pollution have effect on community livelihood?

A,yes B,No

10. If your answer is yes for question number 9 which type of effect?

11. Do you have livestock?

A) Yes B) No

12. What is the main source of water for livestock?

A, River/Stream B, pond water C, Tap water

13. If your answer is yes for question No.9 please fill the following table.

Type of livestock	Number of livestock you owned currently	Number of livestock effected and/or died by water borne problems in last 5 years	Modjo river is source of drinking water	
			Yes	No
Cow				
Oxen				
Heifer				
Calf				
Goat				
Sheep				
Horse				
Donkey				
Chicken				
Other				

14. What is the source of water for domestic uses?

A, River/stream B, pond water C, tap water

15. Does ModjoRiverserve for your consumption purpose?

A) Yes B) No

16. If your answer is yes for question No.15, for what purpose? (Tick any utilization)

No.	Consumptive uses of Modjo River	Yes	No
1	For clothes		
2	For shower		
3	For potting (drinking, food preparation etc. at home)		
4	For watering vegetables		
5	Other (specify):		

17. Have you and/or any of your family members ever been suffered from water borne health complication?

A) Yes B) No

18. If your answer is yes for question No. 17, which age groups are more victims?

No.	Sex of victim	Age group (in years)					
		<5	5-10	11-20	21-35	35-65	65+
1							
2							
3							
4							
5							
6							
7							

19. What is the cause for the pollution of Modjo River?

A, industrial waste B, municipal waste, C, domestic waste D, if any other

20. If your answer is A for question number 19 what type of effects?

PartIV:Impact of Modjo river pollution on the Ecological

21. In your stay in this area, how do you recognize river side vegetation cover?

A) DecreaseB) increaseC) no change

22. Have you ever own trees around river side?

Yes No

23. How do you explain its amount in the last -----years?

A) Decrease B) increase C) no change

24. If decreased, what causes for its diminishing?

25. If decreased, how much of it is gone? _______in hectares?

APPENDIX.II

College of Social sciences and Humanities
Department of Geography and Environmental Study
Interview Questions for key informants

Dear respondent:-

The main aim of this questionnaire is to collect data as input for the study titled Environmental impact Assessment of water pollution: the case of Modjo watershed, Oromiya Regional state, Central Ethiopia. The purpose is to qualify the requirement for awarding the masters of (MSc) Degree at JimmaUniversity. Dear respondents, you are expected to provide genuine, accurate and balanced information with respect to Environmental Impact and Water Pollution. Your accurate information is highly valuable as it determines the success of this study. Therefore, the researcher is very much grateful for the sacrifice you pay to this end and the information gathered will be highly confidential and will be only for the purpose of this research.

Thank you!!

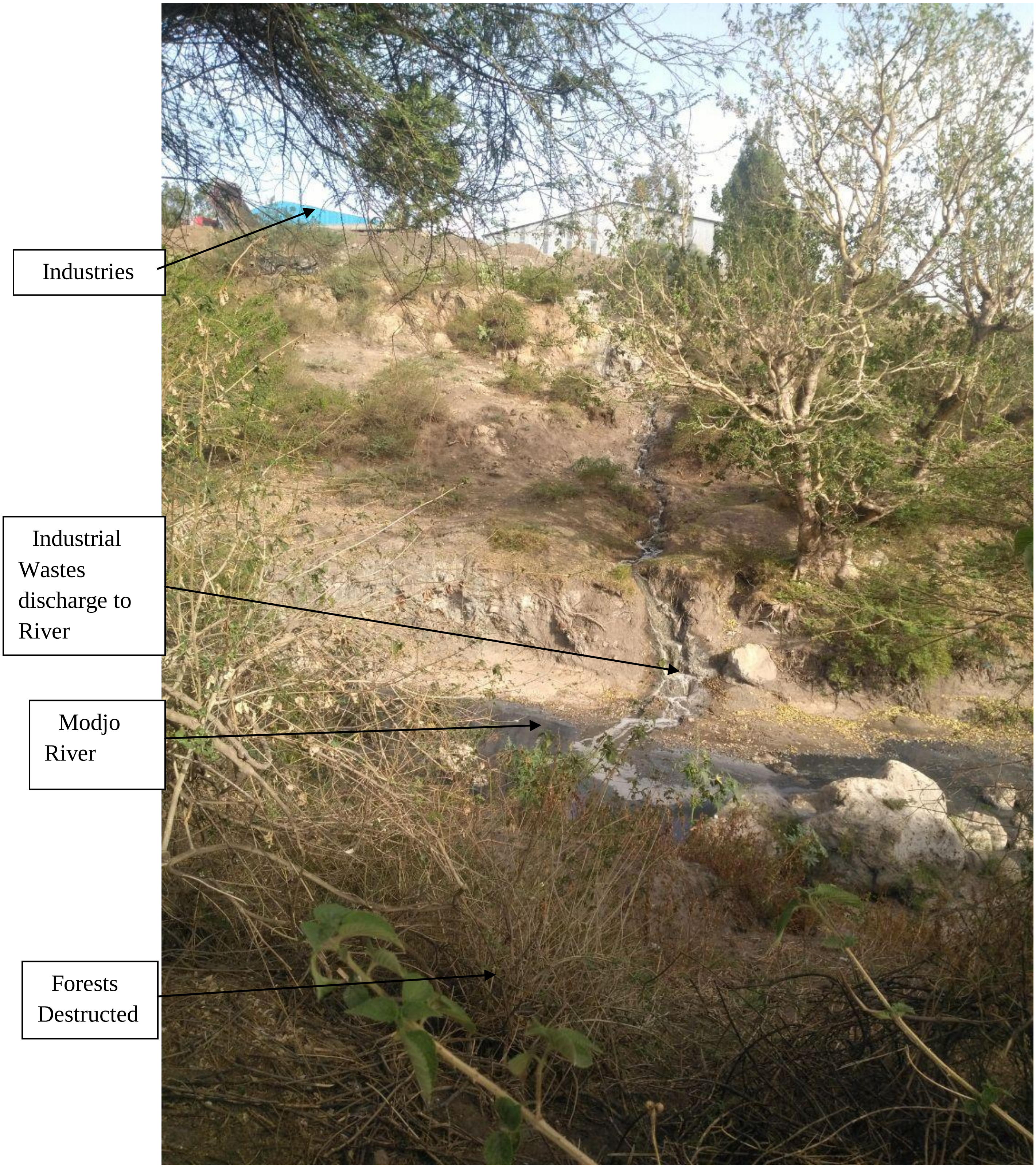
Part I: - Background of Respondent

2. Kebele---------------------
3. Sex------------------------
4. Age-------------------------
5. Level of education---------------
6. Occupation---------------------------
7. Your position in this organization-------------------
8. Year of services in this organization-----------------
9. Year of living in this area-----------------------------

Part II:-interviews about Modjo river pollution

10. How do you evaluate the quality of Modjo River in the last _____years?
11. What do you think are the factors that contributed for the pollution of Modjo River?
12. Is there any link between health problem livestock/human and Modjo river pollution?
13. What is your view about the negative impact of Modjo river pollution on socio- economic and environmental condition?
14. Are there anyworks doneto minimize the challenge faced as a result of Modjo river pollution?
15. If not what are the recommendations you propose for the challenges faced as a result of Modjo river pollution?

APPENDIX III



Industrial wastes discharge to Modjo River

This is Modjo River water imagine how it change from colorless to black this show how far the river is polluted