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SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULITY OF CIVIL AND ENVIRONMNTAL ENGINNERING

DEPARTEMENT OF WATER SUPPLY AND ENVIRONMENTAL ENGINEERING

MASTERS PROGRAM IN ENVIRONMENTAL ENGINEERING

CHARACTERIZING POTENTIAL BACTERIA SOURCES AND QUANTIFYING FECAL COLIFORM LOADS FOR THE GILGEL GIBE WATERSHED USING BACTERIA SOURCE LOAD CALCULATOR TOOL

BY: TEKLU MENGESHA TERFASSA

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MARCH, 2020

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ABSTRACT

Bacteria and water are crucial natural resources used in the activities of sustaining lives. However, indecorous management of livestock manures, human excreta, and pet's feces, were the main sources of fecal coliform bacteria, which can degrade water quality and quantity. These bacteria have momentous role in the cause of waterborne out breaks and changes natural water characteristics through direct dumping of fecal matters in streams and urban and rural storm water runoff. Quantifying and testing of these bacteria in the water bodies was complex, time consuming, and costly. Because of this fact, characterizing potential bacteria sources and quantifying fecal coliform bacteria loads using Bacteria source load calculator is the easiest and cheapest way at watershed level. There is no study in Ethiopia, particularly in Jimma Zone that depicts bacterial source characterization and quantification of fecal coliform bacteria load using BSLC, so that study aims to characterize potential bacteria sources and quantify fecal coliform bacteria loads to Gilgel Gibe watershed using BSLC tool.

Different combination of software's were used; ArcGIS version 10.3, SWAT, origin pro 2016, and BSLC. ArcGIS was used in characterizing of farm and land use and SWAT was used for watershed delineation of the study area. BSLC is used to calculate monthly bacteria land loading & hourly bacterial instream loading through externally generated available input data and literature reference values. 30m×30m Resolution of DEM, land cover land use data, and five consecutive years (2013-2017) of livestock, human, and pet's population data collected from study area watershed districts of livestock & fishery development office was also used.

The current study showed that, the uppermost fecal coliform bacteria source recognized in the study area was cattle's which accounts (92.7%) 3.42E+18 cfu /year/ animal unit, followed by sheep (3.9%) 1.43377E+17 *cfu* and *the* least contributing animal was horse (0.3%) 1.91E+16 *cfu. Of the total fecal coliform bacteria (96.5%) 3.58E+18 cfu were loaded to pasture land and the least portion (0.51%) 1.19E+16 cfu were directly deposited to water bodies. The current study concludes that fecal coliform bacterial load is an alarming for nearby surface water. Water quality modeling with laboratory diagnosis has to be done to identify specific species and amounts of instream fecal coliform loads, finally best watershed management shall be required.*

Key words: ArcGIS, BSLC, fecal coliform bacteria, SWAT, Watershed.

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ACRONYMS

AWD	Acute Watery Diarrhea
BMP	Best Management Practice
BSLC	Bacteria Source Load Calculator
CFU	Colony Forming Unit
CWA	Clean Water Act
DEM	Digital Elevation Model
EPA	Environmental Protection Agency
FIO	Fecal Indicator Organisms
GIS	Geographic Information System
HRU	Hydrologic Response Unit
NMSA	National Metrological Service Agency
NPS	Non-point Sources
PS	Point Sources
SWAT	Soil and Water Analysis Tool
TMDL	Total Maximum Daily Load
USEPA	United State of Environmental Protection Agencies
VBA	Visual Basic for Application
WBDO	Waste Borne Disease out Break
WPPs	Watershed Protection Plans
WQC	Water Quality Criteria
WQS	Water Quality Standard

CHAPTER ONE

INTRODUCTION

1.1 Background

Bacteria and water are crucial natural resources used in the activities of sustaining lives. However, Some of bacteria that accounts about 10 percent are harmful (pathogens), and they are the single most frequent cause of water impairment worldwide (1). Due to this, high levels of fecal coliform bacteria transported to the water sources and directly dumped in to water sources can affect the public health, economy, and environmental quality. Fecal coliform bacteria are the indicators of pathogenic bacteria mostly found in the intestine of warm blooded animals and waterfowls, excreted through their fecal matters, and can grow at higher temperature (2). Thus, they brought to aquatic environment through the release of wastewater effluents, urban and rural storm water, inadequate sanitary facilities, soil leaching, illegal connection of septic system to water sources, waste water discharge point, runoff from livestock housing, runoff through soil from agricultural and pasture land that receive manure application, runoff of wildlife dropping, and direct deposition of feces by livestock's, wildlife, and waterfowls (3).

Likewise, water is a truly a unique gift of natural resources used for sustaining all forms of life, habitat for a wide range of microorganism, used for food production, economic development, agriculture, hydro-power generation, livestock production, industrial activities, forestry, fisheries, recreational activities (4). All these properties impart to water its great utility for all forms of life. For this facts, safe water is a precondition for health and development and a basic human right, yet it is still denied to hundreds of millions of people throughout the developing nations (2). Contrariwise, different anthropogenic and natural water pollution sources directly discharged to the water bodies without any treatment elevates instream fecal coliform and other pathogenic bacteria which reduces fresh water quality and quantity, causes waterborne diseases outbreaks, disturbing health of aquatic ecosystem, and affecting human health or even death (5).

Globally, some 2 million tons of wastes per day are disposed of within receiving waters without any treatments (6). As a result, over 7800 segments of rivers are impaired with pathogenic bacteria, the availability of safe freshwater is on the decline, and its quality is under pressure globally. This requires the development of bacterial total maximum daily load to meet water quality standard of bacteria (7). In the United states alone, next to siltation, fecal coliform bacteria are reported to be the most widespread cause of water quality impairment (8). The main sources of nation's water pollutants were insanitary waste management operations, combined sewer overflows, inadequately treated sewage, faulty or leaky septic systems, and runoff from urban and rural areas, fecal matters of pets, farm animals, waterfowl, and wildlife (3). The human sanitary risk linked to the presence of pathogens from these sources depends on the use of the water for drinking, recreational activities, bathing, irrigation, and shellfish harvesting and on the pathogen concentration in water (9).

Like water pollution with nutrients, sediments, and toxic, water pollution by microbial pathogens can also cause by point and non-point sources (10). Point source pollution normally results from direct entry of wastes into the water supply and it is easier to identify and control, whereas, the non-point source is more complex and difficult to manage, because the source of bacterial pollution in stream originated from various sources; and the effective treatment and control normally demand a more comprehensive solution that usually necessitates the consideration of many watershed or basin factors including site-specific soil characteristics, hydro-logic parameters, and climatic conditions (11).

In developing countries, enormous agricultural activities, urbanization, and industrialization are the main factors that reduce the fresh water resources. Resulting of agricultural activities discharge carries large amounts of pesticides and contaminants from domestic animals' faeces. Urbanization degrades streams and rivers and contributes to decreased ecological health in watersheds. Urban rivers have always been the recipient of sewage water from various sources that have different kinds of the domestic, agricultural, and industrial wastes (12).

Giardia, Cryptosporidium, Norovirus, Escherichia coli O157:H7, Campylobacter, and Legionella are the etiologic agents of fecal-origins identified as the responsible for most WBDOs. Globally waterborne diseases cause about 6, 000 deaths every day which is caused by microbial pathogens that are often present in human and animal fecal matter .To manage these risks the knowledge of fecal pathogenic sources characterization with its path way in to aquatic environment need to be understood and quantitatively described. This highlighted the need to enhance strategies that minimize human exposure to pathogens in drinking water supplies and prevents the deterioration of water quality of any sources (13).

The quantity of faecal contamination sources and associated pathogens existing within a watershed area and in streams are dependent on kinds of land use or land management systems followed by human activities such as urbanization, population growth and different types of waste management systems. Despite the many potential source of release of pathogenic organisms in to the environment, agricultural practices that utilizes animal manure contaminated with pathogenic or parasitic organisms, appears to be the major contributors to watershed contaminations. The animal feeding operations have been cited as one of the agricultural activities that can adversely impact environmental and public health (14).

Drinking water quality can be evaluated on chemical, microbial and radiological aspects. Microbial water quality parameter is the most essential one and it is done through detecting and modeling pathogenic indicators such as total coliform, fecal coliforms, *Escherichia coli*, *Enterococci*, and Protozoan human pathogens such as *Cryptosporidium* spp. and *Giardia lamblia*. Even though animal manure can be considered a beneficial fertilizers and soil amendment, high rate of land applied raw manure increases the risk of surface or ground water contamination both from excess nutrients and pathogenic organisms including *Cryptosporidium*, *Salmonella*, *Escherichia Coli 0157:H7*, etc. unfortunately current technologies are not adequate for handling large scale treatment processes for stabilizing human pathogens in animal manure before application to agricultural land. Therefore; modeling capabilities should be extended to account for individual and cumulative impacts of various pollutants and pollutant sources on watershed and basin impairment (15).

The pathogen load to the water body from different contamination sources varies strongly with time, often due to the prevalence of the disease in the population. Under epidemic conditions, pathogens are excreted from many more human or animal hosts than under endemic conditions. An increased pathogen load, which enters the water source with wastewater discharges or surface runoff, implies higher pressure on water treatment and, as a result, increased risk of waterborne infections (16).

1.2 Statement of the Problem

Water source pollution due to fecal and others pollutants remains the most challenging issue that faced many countries on the global scale. Most of fecal pollution of water sources comes from improperly management of fecal matters of all warm blooded animals including humans and waterfowls. Fecal coliform bacteria and others disease causing organisms are present primarily in the feces of warm blooded animals and seriously hazards to human health and aquatic environments. However, the health impacts of using untreated livestock's manure as fertilizers were remaining poorly understood and inadequately addressed in the literature. In developing countries, untreated livestock manures, pet feces, human excreta, and others pollutants were poorly managed and directly damped in to the surrounding water sources prior to treatment which was seriously affect the quality as well the quantity of water, causes water borne diseases outbreak, causes loss of biodiversity, and affects the health of aquatic environments. Even in developed countries, were municipal wastewater treatment and management of agricultural wastes is more practical, faecal contamination of waters sources for drinking, recreation and rearing of shellfish still contributes to outbreaks of infectious disease. Generally, in all highly developed and developing countries, huge amount of wastes specifically fecal origin is released directly to the environment without adequate treatment. Thus, it has detrimental impacts on human health, economic productivity, the quality of ambient freshwater resources, and ecosystems (17).

Globally, due to water pollution with fecal matters, annual death of five million people or daily death of 6, 000 people from water-borne diseases is recorded , ecosystem dysfunction & loss of biodiversity is appeared ,marine ecosystems, surface water, and ground water is contaminated from land-based activities due to organic or inorganic sources of pollutants (13). Diarrheal diseases account for 1 in 9 child deaths worldwide, making diarrhea the second leading cause of death among children under the age of five years (18).

In developing country, the burden of gastrointestinal disease, much of which is waterborne, is already massive and estimated at greater than 26 billion cases per year due to water pollution with fecal matters (19). Diarrhea diseases due to unsafe drinking water, inadequate availability of water for hygiene, and lack of access to sanitation such as mismanagement of livestock and pets wastes, open defecation and inadequate usage of latrine remain a leading cause of illness and death. Recently, almost all rivers are sink that collects any type of wastes from neighboring watersheds and serves as dump yards for wastes leading to disturbing and destroying ecosystem in general, and human and aquatic health in particular. According to world health organization report about 2.2 million people and an estimated 801,000 children younger than 5 years of age die from diarrhea every year. A significant number of deaths are due to a single type of bacteria, *Shigella*, which causes dysentery or bloody diarrhea (20). These potential sources of pollutants affect the quantity and quality of water sources and influence human life, society stability and economy development directly as well indirectly (21).

In Ethiopia in general and in Gilgel Gibe watershed in particular, there is scarcity of literatures that pointed the levels of fecal coliform bacteria in streams or rivers and its loads at watershed levels. Rivers are not protected from any pollutants, rather than they are used as the final disposal of all wastes which was the leading cause of waterborne diseases. The status of livestock's population waste management system, inadequate management of pets and human feces, and practicing of open defecation can lead to river impairment, and it can affects aquatic environments and human health. Gilgel Gibe rivers and its tributaries was the only sources of water for drinking, irrigation, recreation, agricultural product processing, shellfish production, fishing, bathing, swimming, and domestic use for the surrounding communities. These communities' uses contaminated water sources by fecal matters and other wastes. As a result, the burden of water borne, and others water related diseases can affects the entire population of the study area. Besides, since the study area catchments receive intense seasonal rainfall resulting in high surface runoff, pathogenic microorganisms, sediments, nutrients and others associated pollutants can transported to the surrounding water bodies and can cause water pollution. Therefore, the magnitude of fecal matter pollutants loaded in to land surface and transported to the surrounding river by run-off and others mechanisms become a serious concern for planning and design of watershed management and water quality modelling.

1.3 Research Questions

The research questions were:

i. What are the main sources of fecal coliform bacteria in the study area watershed?

ii. How many fecal coliform bacteria are loaded in to Gilgel Gibe watershed?

iii. Which area and sources are significantly contributing high fecal coliform bacteria load?

1.4 Objectives of the study

1.4.1 General Objective

The general objective of this study is to characterize potential fecal coliform bacteria sources and quantify fecal coliform bacteria loads in the Gilgel Gibe watershed by using BSLC tool.

1.4.2 Specific Objectives

The specific objectives of the study were:

i. To characterize sources of fecal coliform bacteria in the study area.

ii. To quantify fecal coliform bacteria loads contributed by various sources in the watershed.

iii. To identify the area and sources that contributes high fecal coliform bacteria load.

1.5 Limitation of the Study

As a research behavior, no research is terminated without limitation, but the researcher ought to have indicated the limitation encountered on his works to be resolved by concerned body or other researcher based on its requisite. In the manner of this idea, the result of this research is limited to insufficiency of some necessary data in the context of our countries, such as manure production rates of different types of livestock population based on their weight and nutritional status, numbers of wildlife population, numbers of water fowl and other bird's population, and measured pathogenic bacteria data of different sources. Besides, there are scarce references of pathogenic bacteria loads on the surface land and total maximum daily loads of pathogenic bacteria was not studied and not listed as impaired in Ethiopia Rivers.

There are also several known limiting assumptions of bacteria source load calculator tool. These includes: sheep, goats, and horses do not spend significant time in confinement; The amount of time spent by cattle in loafing lots is constant throughout the year; Wildlife do not defecate in residential areas; and high-density residential land uses have only sewered communities; all non-sewered communities occur on low density residential land uses; and only cattle and wildlife defecate in streams.

1.6 Scope of the Study

Geographically, the study area was bounded to five districts of Gilgel Gibe catchment watersheds (Dedo, Qarsa, Omo Nadda, Tiro Afata and Sokoru) which is located in the southwestern part of Ethiopia in Jimma zone, Oromiya region situated within Omo-Gibe basin. This study was circumscribed to characterize potential fecal coliform bacteria sources and fecal indicator bacteria loads in the expressed districts watershed based on available input data of sources of bacteria using bacteria source load calculator tool and filed visit.

1.7 Significance of the Study

Intelligibly, this study is organized to characterize fecal coliform bacteria sources and quantify coliform bacteria loads of fecal origin using bacteria source load calculator tool approach to address the severity of water sources impairment from non-point sources in general and point sources in particular in Gilgel Gibe watershed. In this regard, it builds to differentiate main sources of fecal coliform bacteria used in watershed management plans and to calculate fecal coliform bacteria load used for water quality modelling.

Overall, the findings from this study suggest that water quality modeling incorporating BSLC has the potential to significantly improve predictions of pathogenic bacteria of feco-oral routes. Clearly, the findings reported here have significant implications in improving total maximum daily load allocation and remediation plans. Moreover, it submits well for the future of total maximum daily load management in that it provides a more influential and cost effective basis for policy makers to decide on effective management strategies that incorporate acceptable risk, allowable loading and land use that is compatible with unimpaired receiving waters.

1.8 Rationale of the Study

Ethiopia has great potential of both surface and ground water resources that result in to having many tributary rivers. Many large rivers that originated from Ethiopian highlands and flow to the surrounding countries makes Ethiopia as a water tower of east Africa (22). Contrariwise, all water sources in Ethiopia are used as a final disposal of any wastes. As a result all rivers found in Ethiopia is not free from any types of pollutants and all people live in Ethiopia did not gets safe and adequate water supplies. All rivers are not protected from the entrance of any pollutants and also all rivers are not checked for impairment. The quantity as well the quality of water is under question. In developed and developing world, over one billion people have no access to safe drinking water. Waterborne diseases cause about 6, 000 deaths every day in the world. Control of water pollution has reached primary importance in developed and a number of developing countries. The prevention of pollution at source, the precautionary principle and the prior licensing of wastewater discharges by competent authorities have become key elements of successful policies for preventing, controlling and reducing inputs of hazardous substances, nutrients and other water pollutants from point sources into aquatic ecosystems. Potential pollution sources that pose threats to drinking water are open field defecation, animal wastes, plants, economic activities (agricultural, industrial and businesses) and even wastes from residential areas as well as transportation systems. Any water sources, especially older water supply systems, hand dug wells; spring-fed systems (including treatment plants, reservoirs, pressure breaks, pipe networks, and delivery points) are vulnerable to such contamination. Another way by which pollution reaches and enters a water supply is through inundation or infiltration by flood waters. Flood waters commonly contain high levels of contaminants.

The quality of drinking-water is a powerful environmental determinant of health. Assurance of drinking-water quality has been a pillar of primary prevention for more than 150 years and continues to be the foundation for the prevention and control of waterborne diseases. Water can and does serve as a medium for disease transmission in countries on all continents; all are affected, from the poorest to the wealthiest. The most predominant waterborne disease, diarrhea, has an estimated annual incidence of 4,600 million episodes and causes 2.2 million deaths every year. In terms of global burden of disease, diarrhea ranks second after respiratory infections. Children under five years of age are most affected: some 1.33 million die each year of diarrhea, representing 15% of overall mortality in that age group. More than 50 member states continue to report cases of AWD every year (23).

CHAPTER TWO

LITERATURE RIVEW

2.1 Introduction

Any types of pollutants that degrade water quality and quantity comes from surrounding watersheds through runoff, infiltration, and direct dumped to water sources. These pollutants leads to water bodies as “impaired” , means water bodies in violation of water quality standards or water bodies that do not meet water quality standards due to elevated amount of contaminants such as Nitrate, Phosphors, and microbial organisms such as bacteria, virus, and protozoa (24). In most developed countries the status of different types pollutant load in any rivers were checked every two years whether it receives above the normal range and they classified as “Impaired” if it does not meet water quality standards and mitigates the pollutant sources. In the United States, the Environmental Protection Agencies Watershed Branch is the national program manager for Clean Water Act Section 303(d) which classifies water bodies that do not meet water quality standards as "impaired," and requires development of TMDLs to bring impaired waters into compliance with water quality standards. These includes; identifying the sources of the pollutants causing water quality impairments, quantifying the pollutant contribution from each point and non-point source pollution, and determining of the pollutant reduction from each source required to meet applicable state water quality standards (25).

2.2 Theoretical Review

There are a lot of computer based software used in characterization of source and load of pollutants particularly fecal coliform bacteria at watershed level. Of these, BSLC tool is the one which is developed by biological engineering and used by the Center for TMDL and Watershed Studies at Virginia Technology. It was developed by using Visual Basic for Applications (VBA) in Microsoft Excel and designed to organize and process the bacterial inputs needed to develop a TMDL to address a bacterial impairment. collecting or inventorying bacterial sources such as livestock, wildlife, humans, and pets; estimating loads generated from these sources; distributing estimated loads to the land as a function of land use and source type; and generating bacterial load input parameters for watershed scale simulation models is accomplished externally in animal worksheet, farm and land use sheet, and human activity work sheet of BSLC tool. This process is critical processes to characterize bacteria sources and to automate the creation of input files for water quality modeling. Therefore, BSLC uses these externally generated inputs to calculate monthly land surface and hourly direct NPS bacterial loads. These loadings are available as outputs from the BSLC and can be used to generate input for watershed scale simulation programs (25).

2.3 Indicator Bacteria

Fecal coliform bacteria are one of indicator bacteria that originated specifically from the intestinal tracts of warm- blooded animals. Feces of humans, domestic animals, wildlife, and waterfowls are the main sources of fecal coliform bacteria. These pathogens brought to aquatic environment through the release of wastewater effluents, urban and rural storm water, inadequate sanitary facilities, soil leaching, wastewater treatment facility discharge point, runoff from livestock housing, runoff through soil from agricultural and pasture land that receive manure application, runoff of wildlife dropping (1).

Beside of pathogenic bacteria is the most common water body impairment in both developed and developing worlds, Accurately assessing watershed pollutant loads for the development of a total maximum daily load (TMDL) and watershed protection plan (WPP) is difficult because of un availability of insufficient water quality monitoring data . In developed countries, A WPP is a stakeholder-driven process to restore or protect the water quality of a specific water body. The development of bacteria WPPs and TMDLs can be delayed because of the scarce availability of measured bacterial concentrations. Bacterial impairment is usually assessed by measuring the actual concentration of an indicator organism. When the geometric mean concentration of the indicator organism exceeds the regulatory standards, the water body is considered impaired because of fecal contamination (26).

Direct testing for pathogens in stream is very expensive and impractical, because pathogens are rarely found in water bodies. Instead, monitoring for pathogens uses “indicator”, which includes fecal coliform, total coliform, enterococci, and fecal streptococci and they are easier to identify in the environment and are associated with other pathogens known to be harmful to human health. Fecal coliform bacteria (*E. coli O157:H7, Campylobacter jejuni* and *Cryptosporidium parvum*), have been used for decades as indicator of fecal origins. A bacterial species to be considered a good indicator of fecal pollution must adhere to high densities in feces far exceeding pathogen levels, no other environmental source except the feces of warm blooded animals. There is a positive correlation between the indicator and fecal contamination and between the indicator and waters contaminated with feces. Fecal coliform especially E. coli possess most of these traits and it has been suggested as the fecal pollution indicator of choice (27).

The main origin of these organisms was feces of all warm blooded animalss including humans. Not all fecal coliform bacteria are pathogens, but their presence in water sources indicates feco-oral contamination that can elevate the concentration of organisms in water bodies. These Fecal indicator organisms and other sources of pollutants when detected in higher concentrations threatens both human and environmental health, and plays a significant global role in informing regulators and environmental managers of levels of fecal pollution and hygienic status of water resources.

In water pollution control and water quality monitoring, specific disease-producing organisms (pathogenic) are not easily identified. The detection and enumeration of all pathogenic microorganisms potentially present in aquatic environment is impossible due to the large diversity of the pathogens, the low abundance of each species and the absence of standardized and low-cost methods for the detection of each of them. Thus, for routine monitoring, FIB is usually enumerated to evaluate the level of microbial water contamination. The abundance of this FIB is supposed to be correlated with the density of pathogenic microorganisms from faecal origin and is thus an indication of the sanitary risk associated with the various water utilizations, and total coliforms and faecal Coliform bacteria (thermotolerant) coliforms were the main organisms used as bacterial indicators (3).

2.4 Sources of Fecal Coliform Bacteria

Livestock agriculture is one of the major sources of pathogenic microorganisms in surface and ground water systems (28). Feces of warm-blooded animals such as people, livestock, and pets contain high fecal coliform concentration (29). The numbers of livestock population and the amount of wastes/feces/ they excrete determines the amount of fecal coliform bacteria concentration generated and loaded to the watershed. Unless these wastes undergo treatment, high amount of fecal coliform bacteria present in these wastes transported to nearby surface water during rainfall events or in filtered to the ground water. The risk that pathogenic organisms pose to water sources are highly dependent on their path way and agricultural setting. Knowing of the factors that influence the pathogenic path way to the water bodies is needed to assess the risk of pathogenic contamination, and to develop control strategies to reduce pathogen mitigation. The majority of fecal bacteria load is originated from non-point sources which were mainly agricultural and includes manure deposited on pasture by livestock's. A significant bacterial load directly deposited feces in stream by livestock's is another point sources. High levels of fecal coliform from both sources which flows in the surrounding water bodies can affect the public health, economy, and environmental quality of a community (30).

Fecal bacteria concentrations vary widely among different sources. This variability may be due to animal age, feeding conditions, housing system, and manure management systems. The bacteria composition of the manure may be affected by the animal health, use of antibiotics or other inhibitory substances in the feed, environmental stresses on the animal, and the amount of cleaning and disinfection used in the livestock operations (31).

Agriculture such as crop production, feedlots (including concentrated animal feeding operations), grazing, manure runoff were the most wide spread source of pollution in the Nation's surveyed rivers, contributing to impairment of 25% of the surveyed river miles (32). In US, pathogenic bacteria are the leading cause of water bodies' impairment and agriculture is the primary sources of impairment as shown in Figure 2: (United States Environmental Protection Agency, 2000). Out of 93,000 Shoreline Rivers and streams in this country, 19% were assessed, and 39% of the assessed rivers and streams were impaired with pathogenic bacteria (33).

Agricultural and municipal pollution are closely linked to the hydrologic cycle. Wastewater that comes from industries, cities, towns and some agricultures such as big industrial livestock farms (e.g. pigs, poultry), slaughterhouses and intensive aquaculture farms and are health-damaging pollution. These types of pollutants sources (PS) discharged through a pipe or channel to the water bodies. Unless it is treated before discharging to the water bodies, they are highly impacts human, animals, and aquatic and marine ecosystems. Other types of pollution sources (NPS) which cannot be easily measured because of its diffuse nature are land-use activities, such as road construction, mine drainage, rainwater runoff from city streets (which is not collected in storm drains), from agriculture and from many rural villages, produce water pollution that does not come from any specific pipe or channel, but instead tends to be dispersed across the landscape. However, the pathways of these pollutant sources are: i) from soil solution to deep percolation and groundwater recharge; ii) from runoff, drainage water and floods to streams, rivers and estuaries; iii) from natural or human induced soil erosion to sediment-rich streams (34). Point and non-point sources with their water source pollution pathway are shown in Figure 1, and leading pollutants and sources impairing assessed rivers and streams in US are presented in Figure 2.

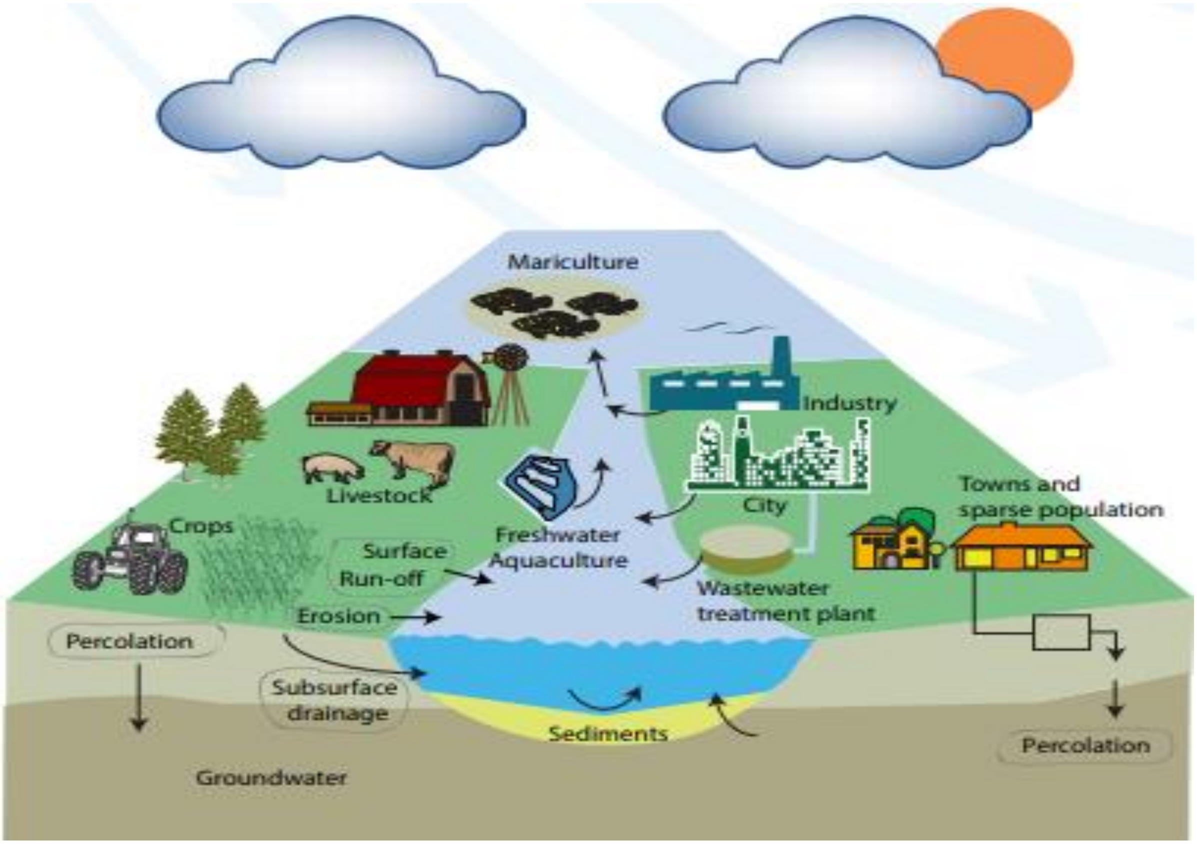

Figure 1 Point and Non-point sources of water pollution and pathways (34).

According to United States Environmental Protection Agency National Water Quality Inventory Report; Pollution from urban and agricultural land that is transported by precipitation and runoff (non-point source pollution) is the leading source of impairment. Siltation, nutrients, bacteria, and metals are among the top pollutants causing impairment, and Aquatic life, swimming, and fish consumption are among the top impaired uses. Across all waterbody types, the bottom line did not change significantly from 1996 to 1998 In terms of the nature of impairment (35).

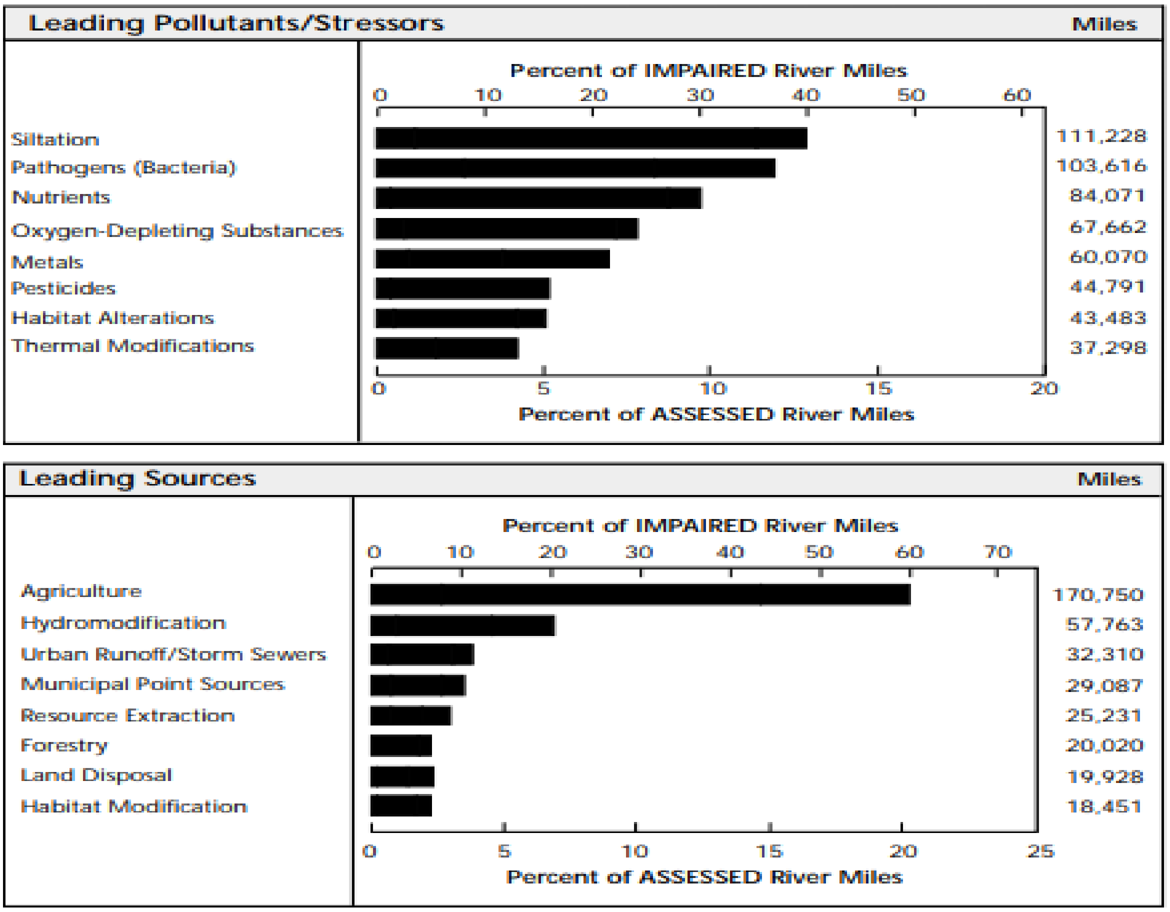

Figure 2 Leading pollutants and sources impairing assessed rivers and streams (34).

Fecal pollution of water bodies and other type of water pollution that pollute water bodies arises from agricultural watersheds or farm lands, residential areas, and direct deposition of feces by wildlife's and others domestic animals and waterfowls. Over all sources of water pollution may be grouped in to point and non-points. Point sources of pollution occurs when pollutant is discharged at specified sources such as a leaking pipe or a holding tank with a hole in it, polluted water leaving a factory, or garbage being dumped into a river, direct deposition of feces by wildlife, live stocks, and waterfowls, and illegal connection of septic system to the water sources, where as non-point sources are more common, and contributes more pollution to surface water than does point source pollution. This type of pollution is difficult to identify and may come from pesticides, fertilizers, or automobile fluids washed off the ground by a storm. Non-point source pollution comes from three main areas: urban-industrial, agricultural, and atmospheric sources (36).

The sources of bacteria contributing to stream impairment can be widespread and come from both urban and agricultural areas. In agricultural areas, grazing lands and animal feeding operations near streams are often recognized as sources of contamination. However, other studies have shown that elevated bacterial levels are associated across many agricultural practices. This is especially true where manure is applied to cropland. Various studies have indicated that urban areas may be a greater source of contamination. In urban areas, combined sewer overflow events, leaky sewer systems, storm water runoff, failed septic systems, and improper sanitary and storm sewer connections can be sources of contamination. Human inputs can come in the form of sanitary wastes from combined sewer outflows, waste treatment plant by passing and illegal connections to storm sewers (37).

Pathogenic bacteria and protozoa are potentially available from many different animal species in watersheds. Wildlife, pets and companion animals, agricultural animals, and humans are all possible sources of pathogens. In addition, urban development is often associated with an increase in bacteria in runoff (38).

Identification and characterization of zoonotic animal pathogens is one of the key steps in reducing potential human exposures via water and other routes (foods, air and soil). Various bacteria, viruses, and protozoa exist in apparently healthy animals, but upon transmission to humans these pathogens can cause illness and even death. Exposure of humans to these disease-causing pathogens of animal origin can occur via occupational exposure, water, food, air or soil (39). Some of the important sources and pathways for pathogen transmission to humans are shown in Figure 3.

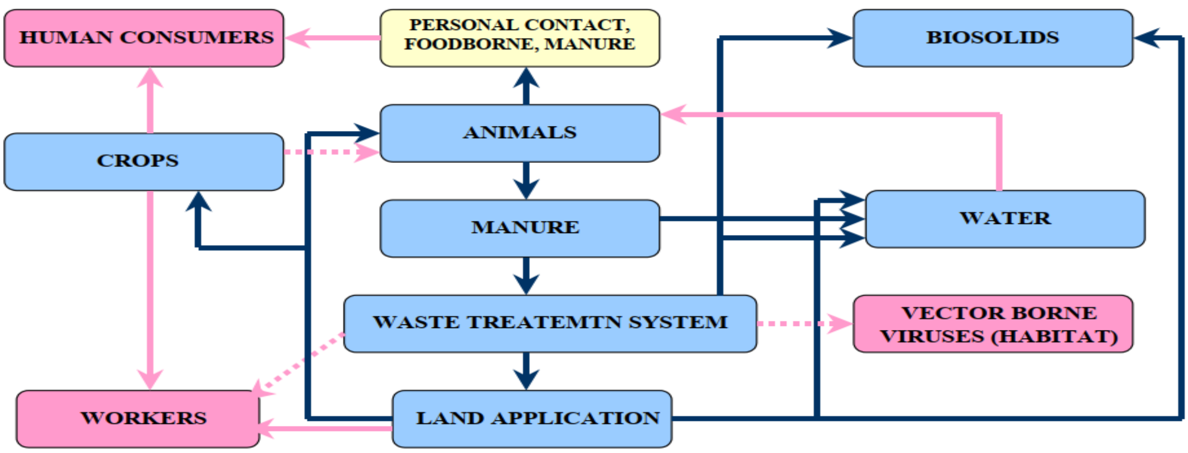

Figure 3 Sources and transmission pathways of pathogens to humans from animal agriculture (39).

2.5 Path Way of Fecal Coliform Bacteria to Water Body

Water plays a major role in mobilizing and transporting micro-organisms. Rainfall washes organisms from feces or vegetation surfaces and directs them into the soil or along the land surface and thus into surface water. Pathogenic bacteria path way in to water bodies include direct routes to surface waters (illicit septic systems connections, wastewater treatment facility discharge points, and urban storm water systems), spills or runoff from livestock housing or manure storage facilities, runoff or movement through soil from agricultural lands that receive manure applications, runoff of wildlife dropping, and direct deposition into waterways by wildlife or grazing animals (1).

Pathogenic bacteria and protozoa can come from many different animal sources in rural and suburban watersheds, including wildlife, pets, agricultural livestock, and humans. Urban development is also often associated with an increase in bacteria in storm water runoff and receiving waters. Exposure to pathogens can occur during swimming or other recreational activities through ingestion, inhalation, or direct contact with contaminated water. Shellfish from pathogen-impaired estuarine waters may pose a health risk to consumers (40). All possible pathogenic bacteria path way was presented in the Figure 4.

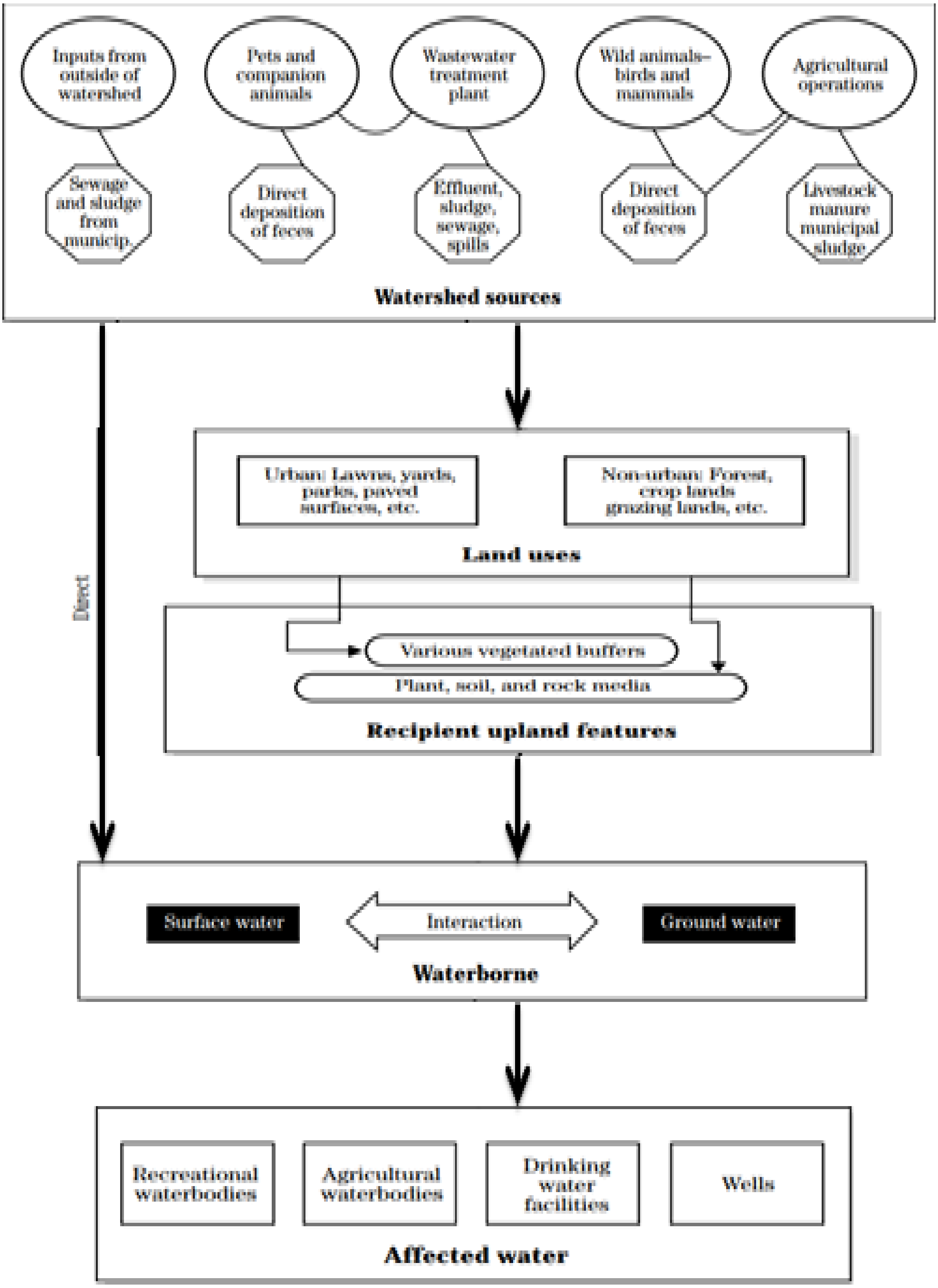

Figure 4 Potential pathways for waterborne pathogens from watersheds (38)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location of Study Area

The study area, the major tributary of the Great Gibe river, Gilgal Gibe basin, is positioned on the upstream of large Omo Gibe basin in the south-western part of Ethiopia, in Oromiya Regional National State at about 260 km of the capital city, Addis Ababa and 70 km north-east of Jimma. Seqa District Mountain is the starting point of Gilgel Gibe basin and crosses all the study area until it joins with great Gibe River. The study catchment covers an area of about 1152605 acres and has an altitude that varies between 1,096 and 3,259 m above sea level. Approximately it is located between 7° 22’ 72’’ and 7° 34’ 84’’ latitude N and between 37° 21’ 05’’ and 37° 28’ 80” longitude E. The bulk of the catchment is located in the south of Jimma Zone, which is one of the Zones of Oromiya Region National State. This zone is subdivided into Tiro Afata (major village is Dimtu), Omo Nadda (major village is Nada), Qarsa (major village is Sarbo) and Dedo (major village is Dedo), that cover part of the study area. The main town in the catchment is Jimma, located at an altitude of approximately 1,800 m above sea level. Gilgal Gibe is the main river of the catchment. The location map of the study area is shown in Figure 5.

3.2 Socio-economy of the Study Area

The dominant land use of the study area is mostly occupied by agriculture. Along the Gilgel Gibe River, the small amount of remaining riverine forest provides some habitat for wildlife and provides a source of fuel wood, building materials and other materials used for meeting a variety of domestic requirements. The agricultural landscape is dominated by small plots cultivated for the production of cereals, primarily maize, teff, sorghum and flax. The catchment is largely comprised of cultivated and grazing land. In the upper part of the catchment coffee based forest is common. Generally, a mixed farming system is common in the study area. Livestock, consisting mainly of zebu cattle, have access to plenty of water due to the presence of the Gilgel Gibe river, and to reasonable grazing areas. Traditional farming techniques are still used with the land is worked with animal traction scratch ploughs. Bee-keeping is commonly practiced, but at low technical inputs. As a general, the economy of the local population is based almost entirely on agriculture and livestock production, and the total populations of livestock’s are summarized in

Annex A. Commercial trade takes place primarily in local markets and this local trade exceeds the volume of trade and goods with other regions (41).

3.3 Topography and Soil Type of the Study Area

The basin is generally characterized by rouged topography and was heterogeneous, with upper plateaus that are cut by deep V-shaped valleys in the sides and flat river terraces around the Gilgel Gibe river in the center of the catchment and by high relief hills and mountains such as Geshe, Haro, Gabara, Ako, and Abalti with an average elevation of about 1,700 m above mean sea level. Nitisol and Vertisols are the two dominant soil types of the study area watershed. Other soil types such as Fluvisols, Acrisols, and planosols also present. The associations of Planosols and Vertisols are located on the river terraces in the lower landscape positions.

3.4 Climate

Like Ethiopia, Gilgel Gibe basin has a two-season tropical climate. The dry winter season occurs between October and April and the rainy season occurs between May and September. The study area has a wet climate and the average annual air temperature is 19.2°C with maximum temperature of 24.78 ^{0}C and minimum temperature of 11.58^0 C. The annual rainfall of the Gilgel Gibe catchment area varies from a minimum of 1,300 mm to a maximum of about 1,800 mm having an average of 1550 mm. Rainfall decreases throughout the catchment with a decrease in elevation. The average annual rainfall calculated over the whole Gilgel Gibe basin where it joins the Great Gibe River (1,359,080 acre) is 1,527 mm; over the Danaba catchment (1,044,020 acre) it is 1,535 mm; over the partial catchment between Asendabo and Danaba (320,002 acre) it is about 1,479 mm, and over the partial catchment area between Danaba and the Great Gibe river (315,059 acre) it is 1,429 mm. It appears that 60% of the total amount of annual rain fall occurs between June and September, 30 per cent from February to May, and only 10% between October to January. The seasonal rainfall distribution takes a uni-modal pattern with maximum during summer and minimum during winter, influenced by the inter-tropical convergence zone.

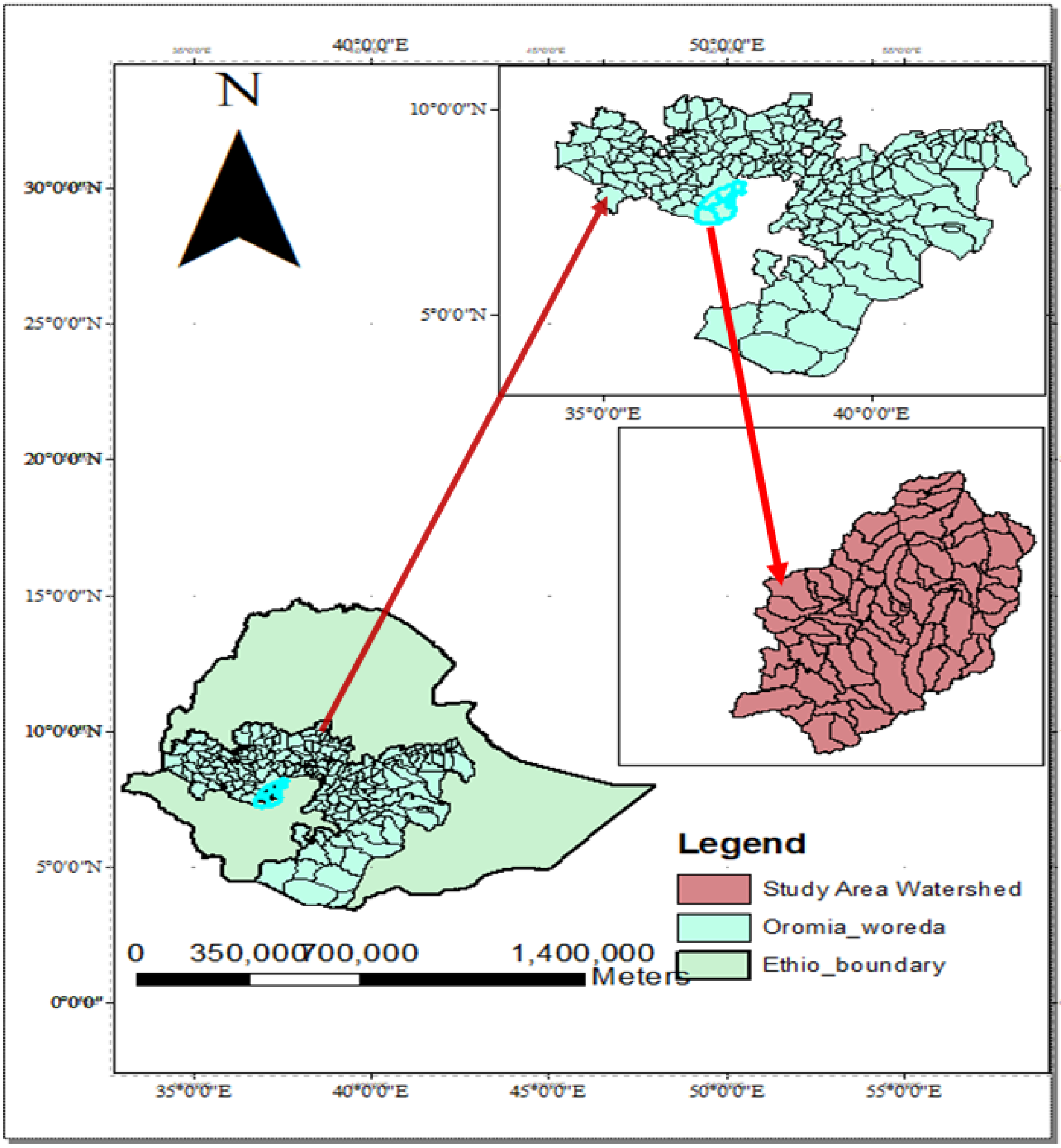

Figure 5 Location map of the study area

3.5 Research design

The study was followed a kind desktop longitudinal research design type to answer the study question and the defined objectives.

3.6 Soil and Water Assessment Tool (SWAT)

The Soil and Water Assessment Tool was created in the early 1990s by Dr. Jeff Arnold for the U.S. Department of Agriculture (USDA). The software is an interface to the Geographic Information System GIS, ArcGIS. Raster and vector files were main types of map files used for spatial data in SWAT (42).

A major model component of SWAT includes weather, hydrology, soil temperature and properties, plant growth, nutrients, pesticides, bacteria and pathogens, and land management. Topographic data and the elevation above sea level are entered into SWAT as a raster layer called

"Digital Elevation Model". This layer is assigning a height value to each cell in the grid. From the DEM, SWAT calculates the slope, delineation of the catchment, and the outline of the rivers and then categorizes' the cells into different slope classes defined by the user. In SWAT, a watershed is divided into multiple sub-watersheds, which are then further subdivided into hydrologic response units (HRUs) that consist of homogeneous land use, management, topographical, and soil characteristics. "Hydrological response units" (HRUs) are the base for the hydrological modeling and are derived from raster data on land use, soil type and slope. Each unique combination of land use, soil type and slope gives a setting (i.e. HRU) for the hydrology and transport of both water and microbial organisms (43).

3.6.1 SWAT Model Setup

The software works as a built in ArcMap 10.3 that provides a graphical user interface for the Soil and Water Assessment Tool. ArcSWAT version 2012 was used for watershed delineation of Gilgel Gibe river basin. Sub watershed configuration, which is the primary discretization scheme, was performed by importing Digital Elevation Model (DEM), a raster data set with the grid size fine resolution of 30mx30m from existing Omo basin DEM was used to define the watershed map (Figure 6). The DEM defines all topographical features in the study area, such as drainage patterns, slope length / gradient of the terrain and stream network parameters. From the DEM, SWAT calculates the delineation of the catchment and the outline of the rivers, the slope, and then categories' the cells into different slope classes. Three slope classes from 0 - 10%, 10 - 20% and > 20% was assigned.

The land use land cover data was clipped and projected to fit the DEM and soil data of the study area. In addition, the key land use types of the study area was identified and coded to match the SWAT land use database. For this study, Gilgel Gibe watershed is clustered in to five (5) sub watersheds namely; Sokoru, Omo Nadda, Dedo, Qarsa, and Tiro Afata. Potential loads are based on land use classification with regard to the distribution of non-point and point sources. Land use data of the study area identified in this manner were; Agricultural land-crops generic (AGRL), Range grass bush or pasture (RNGB), Forest mixed (FRST), and Residential- low density (URLD). Hence AGRL and FRST were the dominant land use land cover of the area.

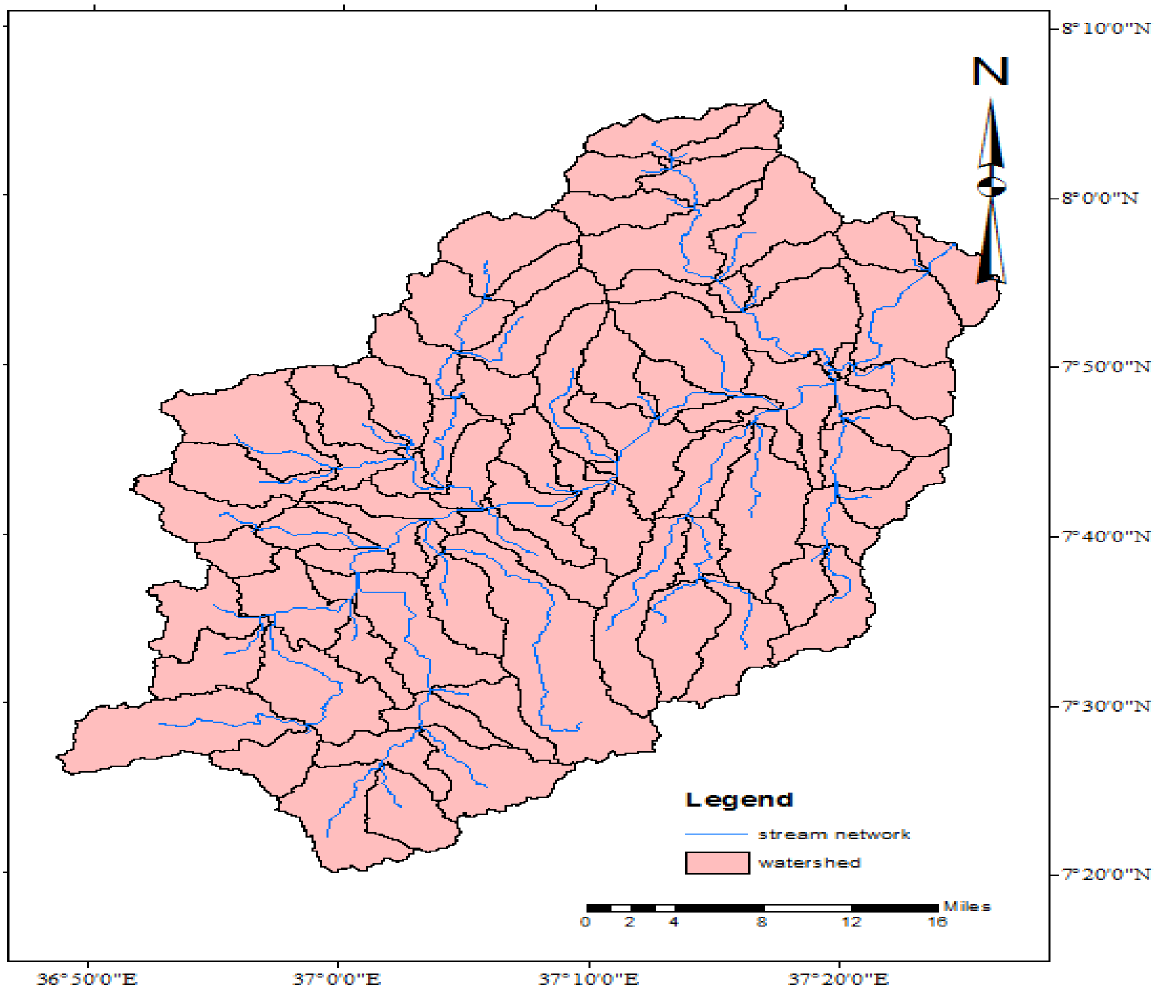

Figure 6 Map of study area watershed

3.7 Bacteria source Load Calculator Tool

Bacteria Source Load Calculator is Biological Systems Engineering (BSE) software tool developed by center for watershed studies at Virginia Technology (44). This software is aimed to assists in the bacteria source characterization, load allocation development process, and to automate the creation of input files for water quality modeling. It was developed using Visual Basic for Applications (VBA) in Microsoft Excel and macrons to perform a number of functions, and designed to simplify the complex and time-consuming work involved in determining bacterial loadings. The program automates many of the characterization steps, while providing a high level of consistency in data development and processing. The BSLC is an especially useful tool for developing Total Maximum Daily Load (TMDL) studies, including the allocation scenario development process. The BSLC characterizes how the bacterial loads are spatially and temporally distributed, organizing and processing source data to calculate monthly land loadings and hourly stream loadings. Hourly direct deposit fecal coliform loading by cattle to streams were calculated for the percentage of pastures adjacent to streams where no fencing was present.

However, systematic process that BSLC uses were; inventorying bacterial sources (including livestock, wildlife, humans, and pets), estimating loads generated from these sources, distributing estimated loads to streams and land, as a function of source type and land use, and generating bacterial load input parameters for watershed-scale simulation models to simplify the complex and time consuming work involved in determining bacterial loadings for bacterial impairment analysis in USA (25).

Based on the source assessment and user-input land uses, BSLC calculates the amount of bacteria produced in different locations and on different land uses (e.g., livestock confinement, pasture, forest). Bacteria production deposited on the land surface were estimated on monthly basis to account for seasonal variability in livestock management and production practices, such as the fraction of time cattle spend in confinement, pastures, or streams (Table 1), the amount of manure production rate (Table 2), the amount manure held in storage and subsequently land applied, and spreading schedules for manure application, were considered on a monthly basis. Manure and application rates for both liquid and dry manures were based on application rates and timing guidelines specified by Virginia's Department of Conservation and Recreation nutrient management planning guidance(Annex D©).

Table 1 Time spent by cattle in confinement and in the stream

Months	Time spent in confinement		Time spent in stream (hours/day)
	Lactating cow (%)	Dry cow, heifer, and beef (%)	All types of cattle's
January	67	63	1
February	67	63	1
March	67	63	1
April	67	63	0.75
May	58	54	0.75
June	58	54	0
July	58	54	0
August	58	54	0
September	58	54	0
October	58	54	0
November	58	54	0.5
December	58	54	0.5

Table 2 Manure production rate reference value used in BSLC

Type of animal	Animal weight (kg)	Manure production rate (kg/animal/day)	References
Dry cow	635	52	Barth (1992)
Milk cow	635	52	Barth (1992)
Beef cattle	450	27	MWPS (1993)
Heifer	290	18.4	Barth (1992)
Sheep and goat	27-64	1.08	MWPS (1993)
Chicken layers	1.8	0.115	Barth (1992)
Chicken broilers	0.9	0.0765	Barth (1992)
Horse	450	-	Barth (1992)

3.8. Data Source and Type

As data is mandatory for better investigation, preparing of input data such as land use distribution and livestock, and human population with in the study area watershed is the critical part for BSLC tool Program in attaining fecal coliform bacterial source analysis. In addition, the program calculates bacterial loads based on animal numbers and default values for manure production rates (kg/day), bacteria production rates (*cfu*/animal-day), and, as appropriate, factors such as bacterial die-off rates and the fraction of time livestock are confined. Default values, assembled from scientific literature, the Natural Resources Conservation Service, the American Society of Agricultural Engineers (ASAE), and previously approved TMDLs, are contained in the BSLC in two reference value worksheets. The three input data sheets included in BSLC tool are an animal sheet, a farm and land use sheet, and a human activity sheet. The inputs from these three sheets are the only watershed-specific data that are required by the program for this study was mentioned accordingly.

3.8.1 Animal Data

As the inventory of livestock population is critical part of the input data in BSLC tool program, five consecutive years (2013 - 2017) livestock's population data were collected from each study watershed districts of Livestock and Fishery Development office (Table 3). This secondary data such as different types of cattle's, horses, donkeys, mules, sheep's, goats, and poultry are used as input for BSLC tool for the purpose of this study. The total number of livestock in the study watershed included only unconfined (pastures) fractions. The distribution of cattle populations in pasture area assumed as in Virginia, center personnel frequency, which is 0.18 head/acre. Mules and donkey are not included in the BSLC tool program; they are assumed as horses and added in the number of horses for the purpose of this study. In general, average of five years livestock population data used for this study was summarized in Annex A.

3.8.2 Land Use Data

Likewise, the second critical part of source characterization input data in BSLC tool is preparing farm and land use information of the study area watershed. This data is taken from land and Natural Resources management office of each district which was prepared by Geographical information system. In all watersheds, pasture lands are divided in to three parts to match with BSLC tool sheets. But, Livestock distribution in the pasture lands and stream access of pasture lands for cattle's populations were based on information gathered from surrounding communities and observation carried during filed visit. Residential one and two are assigned for Urban and Rural respectively. General information prepared in this manner for BSLC tool is summarized in Annex B.

3.8.3 Human Activities Data

This is the last data input sheet to characterize human and pets source loadings. The BSLC tool calculates the amount of bacteria available on residential land surface for loss in surface runoff based on the number of houses in different age categories, standard or user specified failure rate, the bacteria production per person, and the average number of peoples per house. To achieve this purpose, human activities data input worksheet categorizes the existing houses in to sewered and non-sewered houses to generate fecal bacteria loading from failed septic systems. Sewered house is categorized in to persons per sewered house and number of sewered houses. BSLC does not estimate any loads from people in sewered houses. Non-sewered house is again categorized in to persons per unsewered house and number of unsewered houses. The information or data entered in the persons per unsewered house is used to calculate the number of people not connected to a sewer network and will also be used in conjunction with house ages to determine the amount of human-defecated bacteria coming from failing septic systems and straight pipes, whereas the information entered in the number of unsewered houses is used determine the sub-watershed's pet population. Septic systems and straight pipes are categorized in to old, mid-age and newest to represent the failed septic system of un-sewered houses by age category. The BSLC computes the pet population based on an average number of pets per household. To characterize pet sources, a standard unit pet is assumed equivalent to one dog or several cats, and a rate of one standard unit pet per household is used by BSLC to calculate a total pet population for study area watersheds based on total number of both sewered and un sewered houses.

However, as a watershed is a very complex system that cannot be feasibly represented without some simplifying assumptions, BSLC incorporates many assumptions into its processing. Taking this idea in to consideration, some of input data's of human activities were rearranged based on the contexts of the study area watersheds. Thus, as effluents from improperly installed or poorly maintained septic systems that rises to the surface can be carried away with run off during storm events were represents potential sources of human bacteria with in watershed in BSLC tool , household contributing in water source pollution with potential sources of human bacteria through runoff during rainy seasons due to having no pit latrine, unimproved pit latrine, and filed pit latrine were assumed to be equivalent to unsewered houses with failed septic system. Accordingly, households having no pit latrine are assumed as oldest age septic system, households having unimproved pit latrine are assumed to mid-age, and households having filled pit latrine are assumed to newest septic system of unsewered houses. Similarly, households having improved pit latrine and water carriage latrine are assumed to sewered houses. Human activities input data (Annex E) organized in this manner is computed from five consecutive years hygiene and sanitation report of Jimma Zone Health Office.

3.8.4 BSLC Reference Values and Monthly Variables Data

This worksheet contains default values of BSLC tool program to calculate daily loading amounts for study area sub watersheds. These default values were derived from a variety of sources, including research literature and professionals judgment of subject-matter expertise. Detailed explanation is offered in (Annex D (a)-D (c)). Some values like detailed stream access acreage; failure rates for septic systems, time cattle's spent in the stream, etc were customized in to the study sub watersheds based on information gathered from expertise and source assessment carried out during filed visit, whereas the others reference values were taken as the default value. Bacterial loading rates are not consistent throughout the year, so the BSLC provides monthly default values to calculate loading amounts for study area sub-watersheds.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Sources of Fecal Coliform Bacteria in the Gilgel Gibe Catchment Watershed

The fecal coliform bacteria sources identified in the study area watersheds were vary widely, originating from both point and non-point sources. The major sources were agricultural non-point such as fecal matter (manure) from livestock production (cattle, mules, donkey, horses, sheep, and goats). These sources are categorized under agricultural discharges of land-applied animal manure by livestock populations. Other non-agricultural non-point sources such as inappropriate management of feces of wild animals (dog and cat), and human excreta were also identified. These are categorized under residential area of fecal coliform bacteria sources originated from open defecation, unimproved traditional latrine, and pet feces. All these sources are land deposited sources of fecal coliform bacteria, and then undergo die-off and must be transported by runoff during high rainfall events into the stream. Cattles were the highest fecal coliform bacteria sources in the study area watershed, whereas horses were the least fecal coliform bacteria sources of the study area. Following to cattle sheep's, humans, and pets were the second, third, and fourth sources of fecal coliform bacteria respectively (Table 3). Cattles directly depositing their feces during grazing period was identified as point sources in the study area watersheds. This type of sources of bacteria enters to the stream immediately without die-off and without the need for a rainfall event and highly polluted the water sources particularly surface water.

As indicated in Table 3 , different types of livestock's such as cattle's horses, mules, donkeys, goats, sheep's, dogs, cats, and humans were identified as the main sources of fecal coliform bacteria. Their numbers are varying in each watershed and projected from five years data collected from each study area watershed districts of livestock and fishery development offices.

Table 3 Sources of fecal coliform bacteria in Gilgel Gibe watershed (Secondary data of study area watershed livestock and fishery development office)

Sources of fecal coliform	Population by watershed					
	Sokoru	Omo Nadaa	Dedo	Qersa	Tiro Afata	Total
Livestock's						
Milk cow	11530	21929	14015	11500	19914	78888
Dry cow	11670	62144	14183	12347	20153	120497
Heifers	43929	105388	53392	45063	75862	323634
Beef cow	43196	103630	52502	44311	74596	318235
Total cattles	110325	293091	134092	113221	190525	841254
Horses	23	6829	15723	68	516	23159
Donkeys	207	13910	8385	473	629	23577
Mules	423	5863	8385	91	529	15291
Goate	666	4317	2067	674	996	8720
Ewes	1481	9595	4595	1553	2217	19441
Human activities						
House hold having improved latrines	26885	48355	33897	38188	26601	173926
House hold having un improved and without latrine	15426	26378	30513	13024	13031	98372
Pet populations						
Dog	6407	7552	6259	3319	1675	25212
Cat	15104	6565	5036	4427	1725	32857

4.2 Fecal Coliform bacteria loads

4.2.1 Instream loads of fecal coliform bacteria

Annual in stream fecal coliform bacteria loading were obtained only from cattle's for this study because of scarcity of input data. BSLC tool calculates hourly instream fecal coliform bacteria load based on cattle population and the time they spent in the stream. The load of fecal coliform bacteria was high during warmer months (January, February, and March), and almost nil during high rainy season. This is because of the river is highly full, cattle's keeps from entering the river. In this regard, instream annual fecal coliform bacteria load of dry cow, milk cow, heifers, and beef cow were 1.62E+15, 9.52E+14, 1.99E+15,and 7.3E+15 *cfu* respectively (Figures 7, 8, 9, and 10). The highest load was obtained from beef cow, whereas the least load was obtained from milk cow. This indicates dry cow, beef cow, and heifers spent their time in stream twice daily whereas milk cow spent once daily. Generally, annual instream total coliform bacteria obtained by cattle's were 1.186E+16 *cfu*. The loads also vary in each watershed based on the number of cattle's and areas of watersheds. However, annual in stream fecal coliform loading by cattle obtained in the Omo Naddaa, Tiro Afata, Qarsa, Dedo, and Sokoru watershed was 4.17E+15, 2.81E+15, 1.73E+15, 1.6E+15, and 1.54E+15 *cfu*/year/animal respectively, with highest stream load of fecal coliform bacteria in Omo Naada watershed and the least stream load of fecal coliform bacteria in Sokoru watershed (Figure 11).

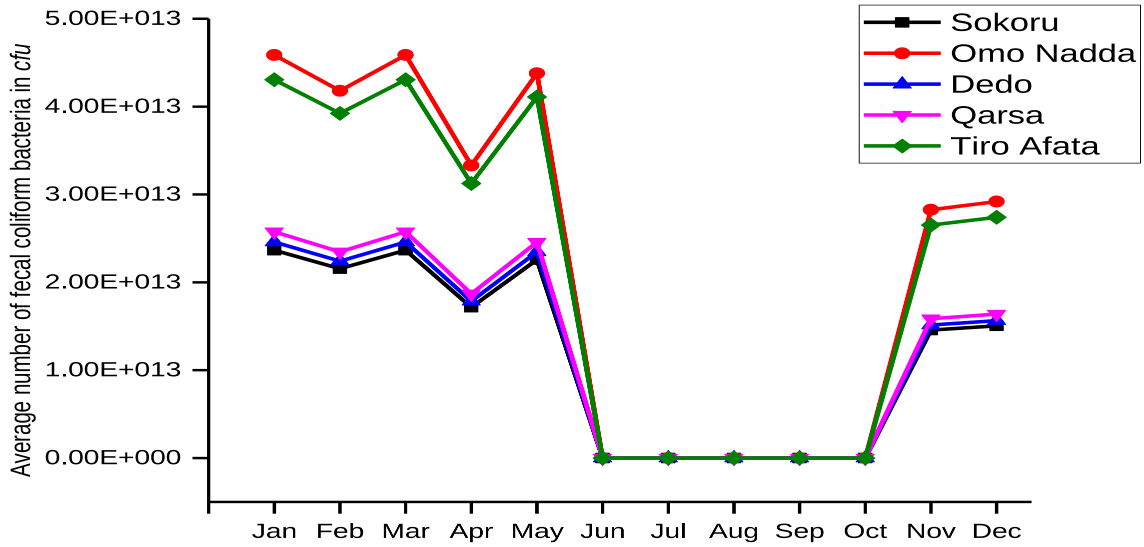

Figure 7 Average of five year fecal coliform bacteria loading to stream by milk cow

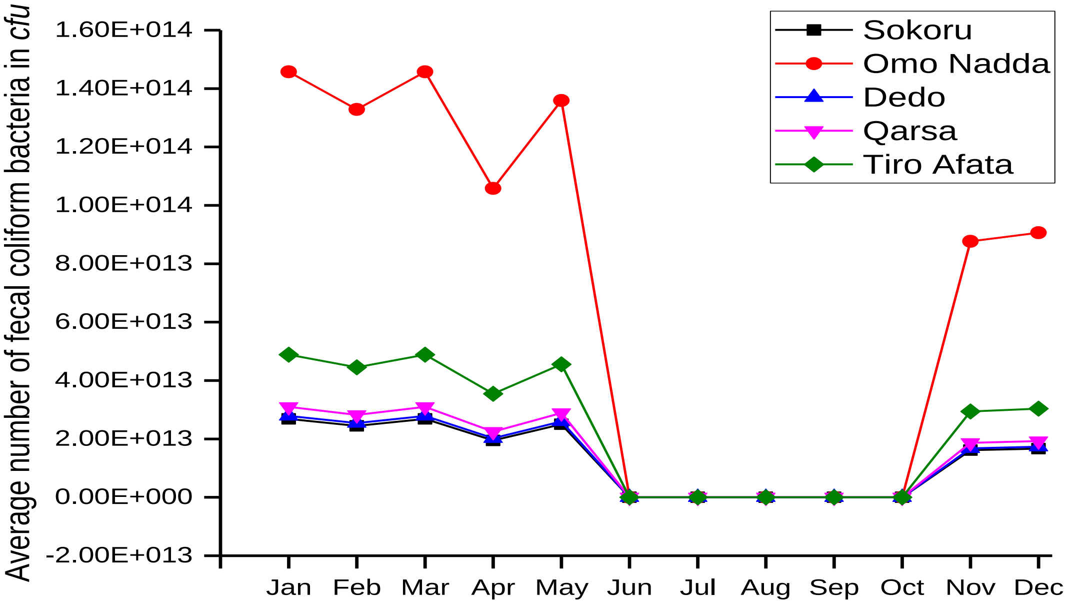

Figure 8 Average of five year fecal coliform bacteria loading to stream by dry cow

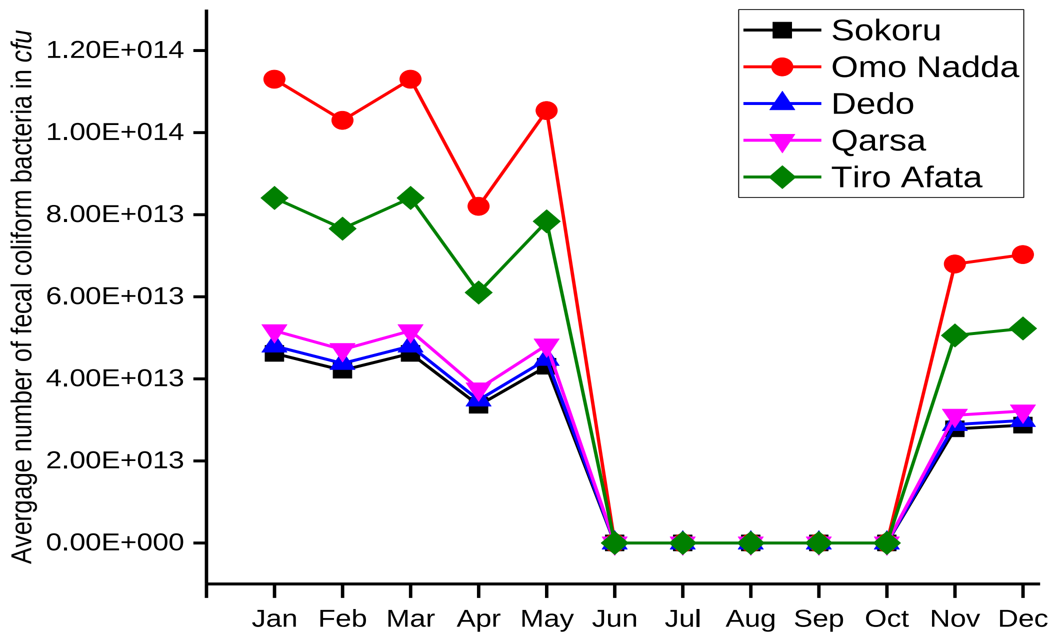

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Figure 9 Average of five year fecal coliform bacteria loading to stream by heifers

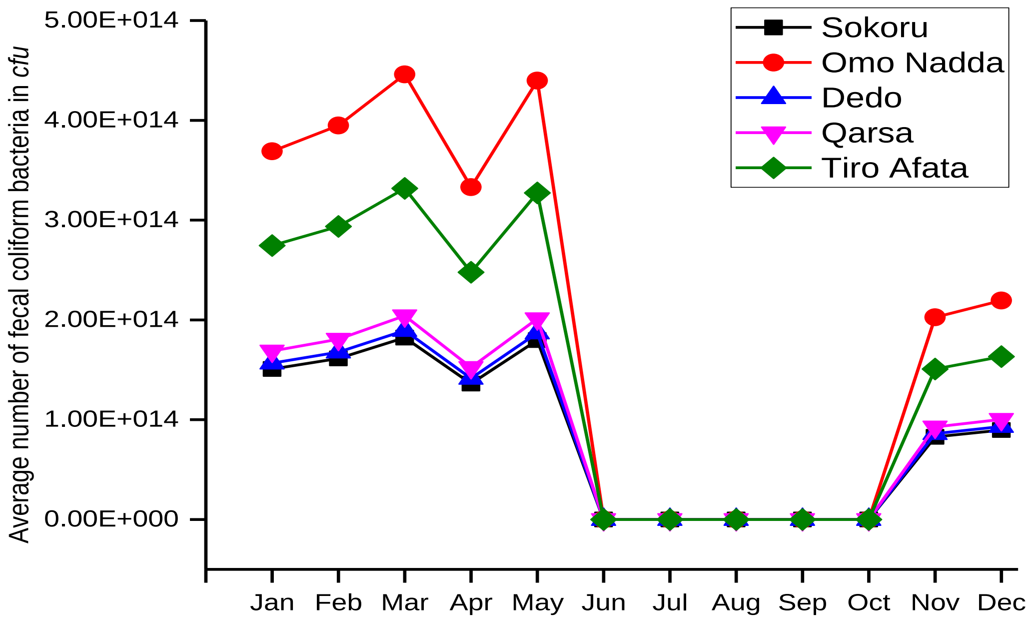

Figure 10 Average of five year fecal coliform bacteria loading to stream by beef cow

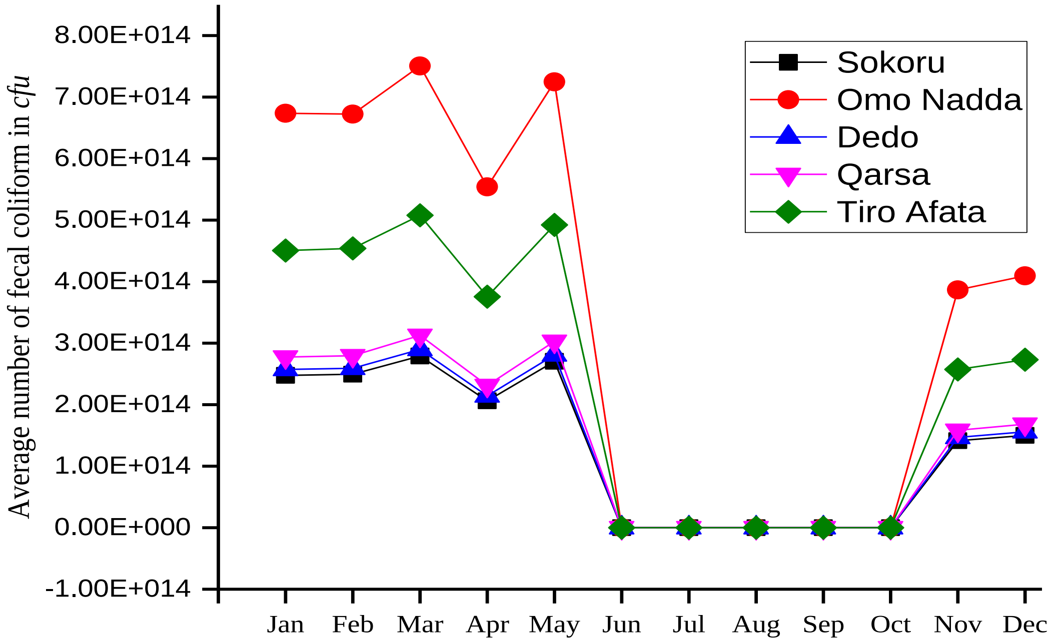

Figure 11 Summary of average of five year fecal coliform bacteria loading to stream by cattle

4.2.2 Pasture land loads of fecal coliform bacteria

BSLC tool calculated fecal coliform bacteria for all different livestock population in the study area watershed based on bacteria source load calculator tool default reference value. To generate fecal coliform bacteria in pasture land, the average of five years livestock population was calculated by Excel and inserted in to BSLC tool (Table 3). The occasion of fraction of time cattle spent in pasture, confinement, and instream was assumed in monthly available worksheet (Table 1).

The annual fecal coliform bacteria loads in the pasture land were obtained from all livestock population. The result obtained was varying in all study area watersheds because of the different numbers of livestock's population and different numbers of pasture land area. Monthly fecal coliform bacteria load was also vary in between cattle's, sheep's, and horses because of the different amount of wastes they generate and it may be due to the feeding habit (Annex F, G, & H). Fecal coliform bacteria load is high from May to September with very high at August and low during October to April with very low at February. For horse, mules, donkeys, goats, and sheep's (Figure 13 and 14) fecal coliform load was very low in February and with the same momentum for the rest of months due to feeding type and habits. Accordingly, the amount of annual Load of fecal coliform bacteria in the pasture land from cattle populations in the Sokoru, Omo Nadda , Dedo, Qarsa, and Tiro Afata watershed was 3.31E+17, 1.23E+18, 5.68E+17, 4.8E+17, and 8.07E+17 *cfu* respectively (Figure 12). In this regard, Omo Nadda watershed has the highest load of fecal coliform bacteria due to the highest population of cattle. Annual load of fecal coliform bacteria from horses in the Sokoru, Omo Nadda, Dedo, Qarsa, and Tiro Afata was 1E+14, 4.08E+15, 4.98E+15, 9.7E+13, and 2.57E+14 *cfu* respectively (Figure 13) with the highest in Dedo watershed and the least in Sokoru watershed. Annual Load of fecal coliform bacteria from sheep in the Sokoru, Omo Nadda, Dedo, Qarsa, and Tiro Afata was 2.1E+16, 4.08E+15, 6.51E+16, 2.18E+16, and 3.14E+16 *cfu* respectively (Figure 14) with the highest in Dedo watershed and the least in the Omo Nadda watershed. Generally, from the all study area watershed, Omo Nadda is the highest contribution of fecal coliform bacteria load of cattle and horse in pasture area. Whereas Dedo is the highest contribution of fecal coliform bacteria load from sheep and goats in pasture area.

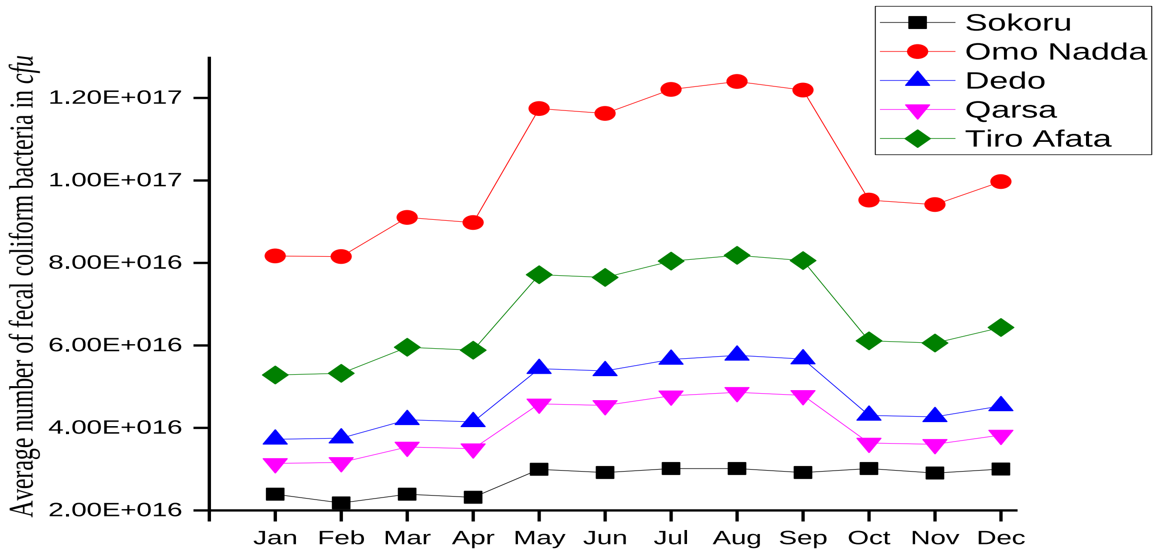

Figure 12 Annual fecal coliform loading on pasture by cattle

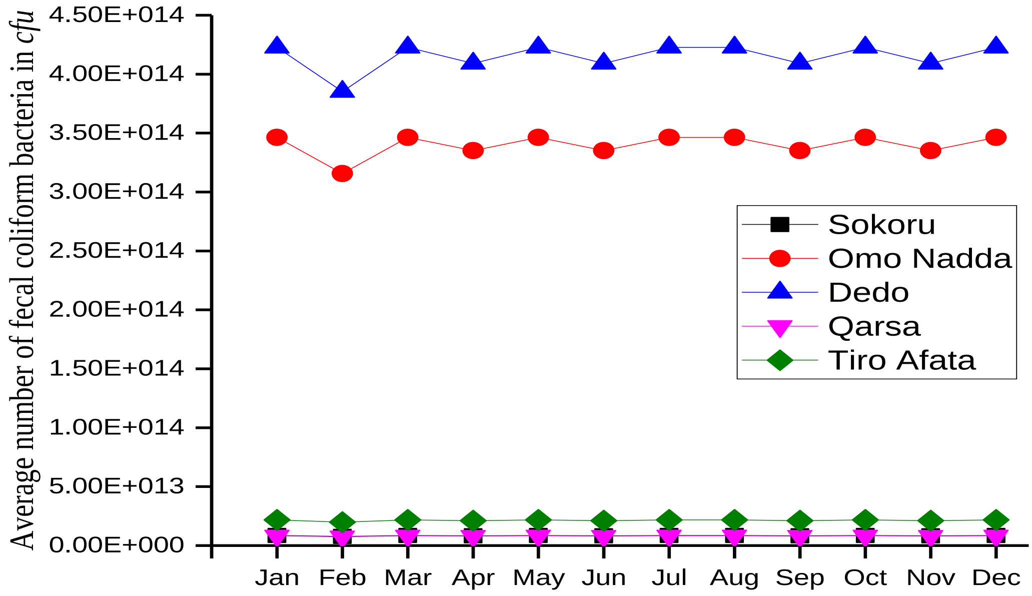

Figure 13 Annual fecal coliform loading on pasture by horses, mules, and donkeys

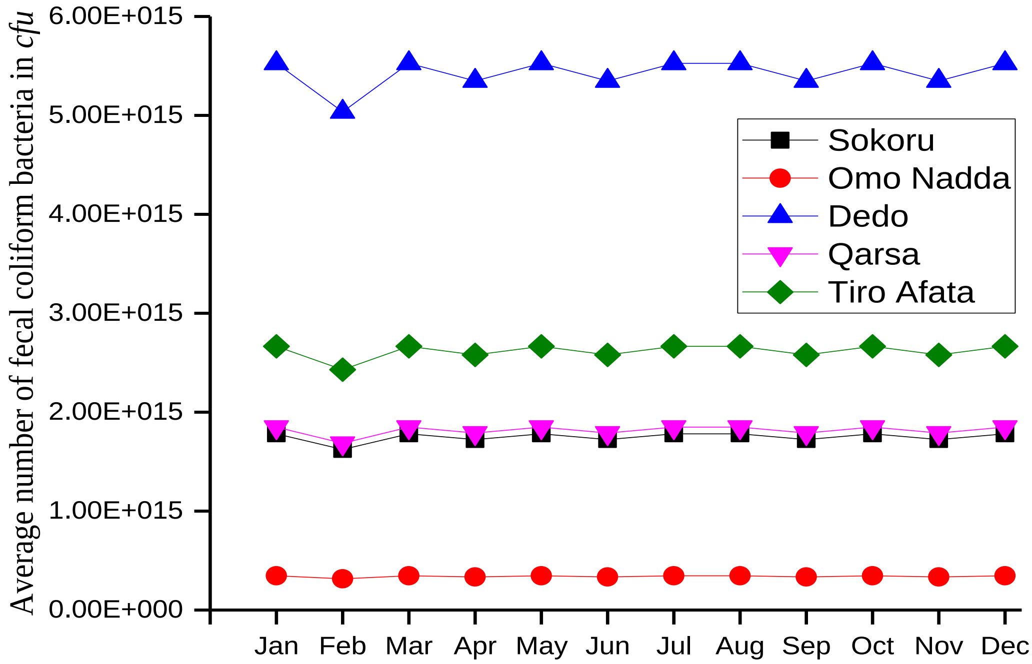

Figure 14 Annual fecal coliform loading on pasture by sheep and goat

4.2.3 Residential Area Loads of Fecal Coliform Bacteria

Fecal coliform bacteria loading to residential area was obtained from inappropriately managed human excreta and pets feces. Based on input data inserted in to BSLC tool, annual fecal coliform bacteria obtained from residential area were 1.17E+17*cfu*. As shown in Figure 17, annual fecal coliform bacteria generated from both pet population and human activities in Sokoru, Omo Nadda, Dedo, Qarsa, and Tiro Afata was 2.1E+16, 2.92E+16, 3.5E16, 1.67E+16, & 1.48E+16 cfu respectively. Loads of residential fecal coliform bacteria were varying in each study area watershed. This is because of the variation of pet's population and the coverage of improved latrine. The area having high coverage of improved latrine has low fecal coliform bacteria loads. Based on this finding Dedo watershed has high residential area fecal coliform bacteria loads (3.5E+16 cfu), whereas Tiro Afata has the least residential fecal coliform bacteria loads (1.48E+16 cfu). Annual fecal coliform bacteria generated from human activity in Sokoru, Omo Nadda, Dedo, Qarsa, and Tiro Afata was 1.41E+16, 1.69885E+16, 2.45E+16, 8.26E+15, and 8.29E+15 *cfu* respectively (Figure 15). The highest fecal coliform bacteria was obtained in Dedo watershed and the least fecal coliform was obtained from Qarsa watershed (Figure 15). The annual overall fecal coliform bacteria generated from human activity in all study area watershed was 7.21E+16 *cfu* (Table 4).The other fecal coliform bacteria generated in the residential area are from pet population (dogs & cats). Annual fecal coliform load generated from pet population Sokoru, Omo Nadda, Dedo, Qarsa, and Tiro Afata was 6.95E+15, 1.23E+16, 1.05E+16, 8.4E+15, and 6.5E+15 cfu respectively (Figure 16) and the overall fecal coliform bacteria generated from all study area watershed was 4.47E+16 *cfu* (Table 4). This load is highest in Omo Nada watershed and least in Tiro Afata watershed which accounts 1.23E+16, and 6.51E+15 *cfu* respectively (Table 4).

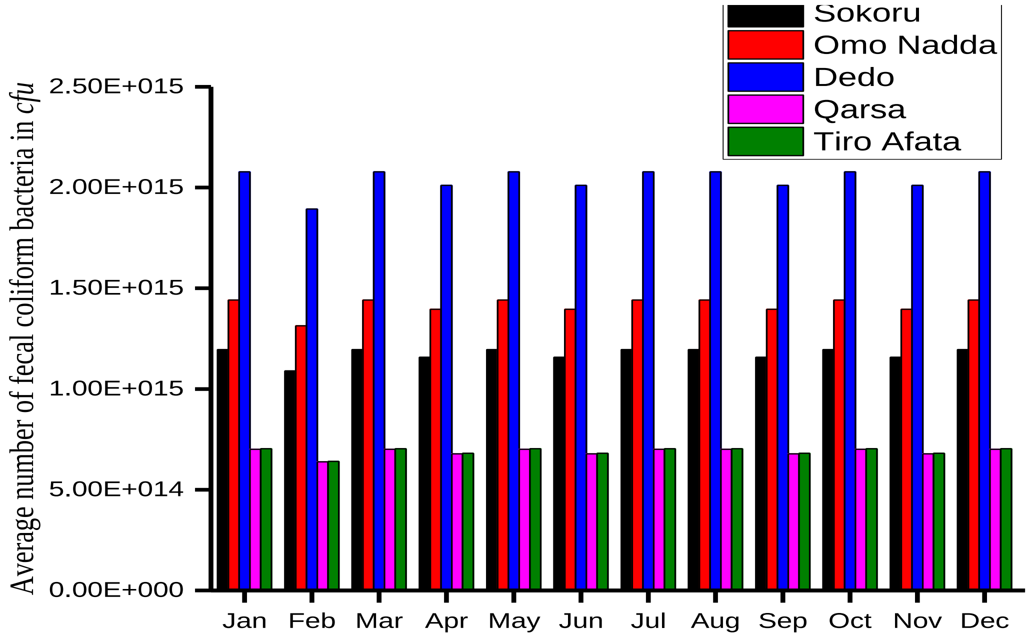

Figure 15 Fecal coliform loading on residential area from inappropriate management of human excreta

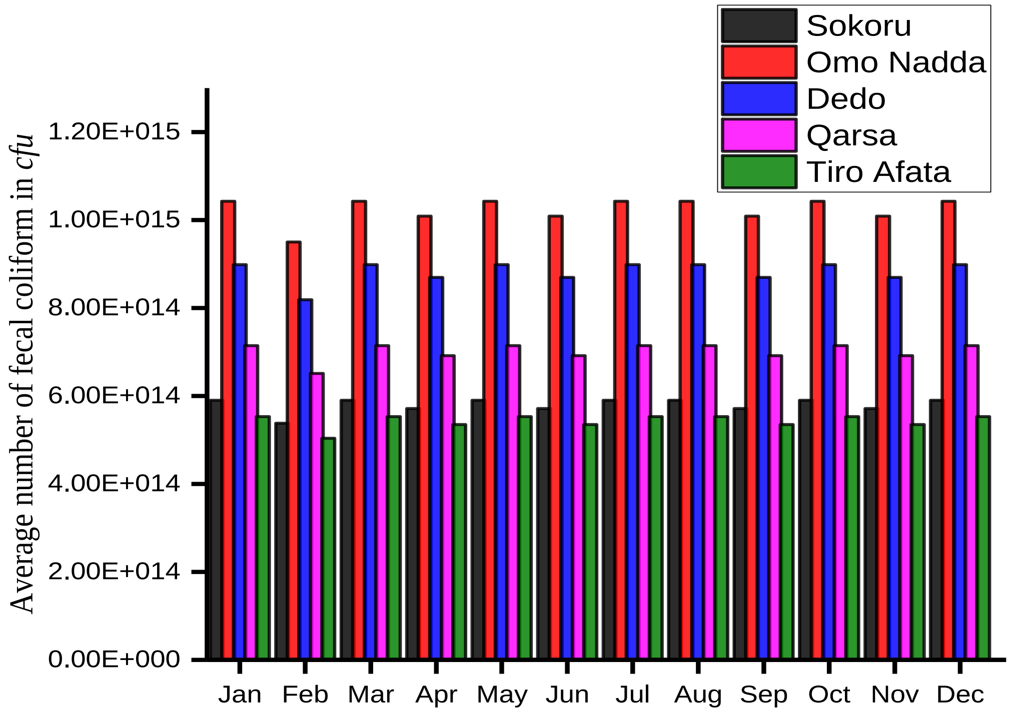

Figure 16 Fecal coliform bacteria generated in the residential area from pet population

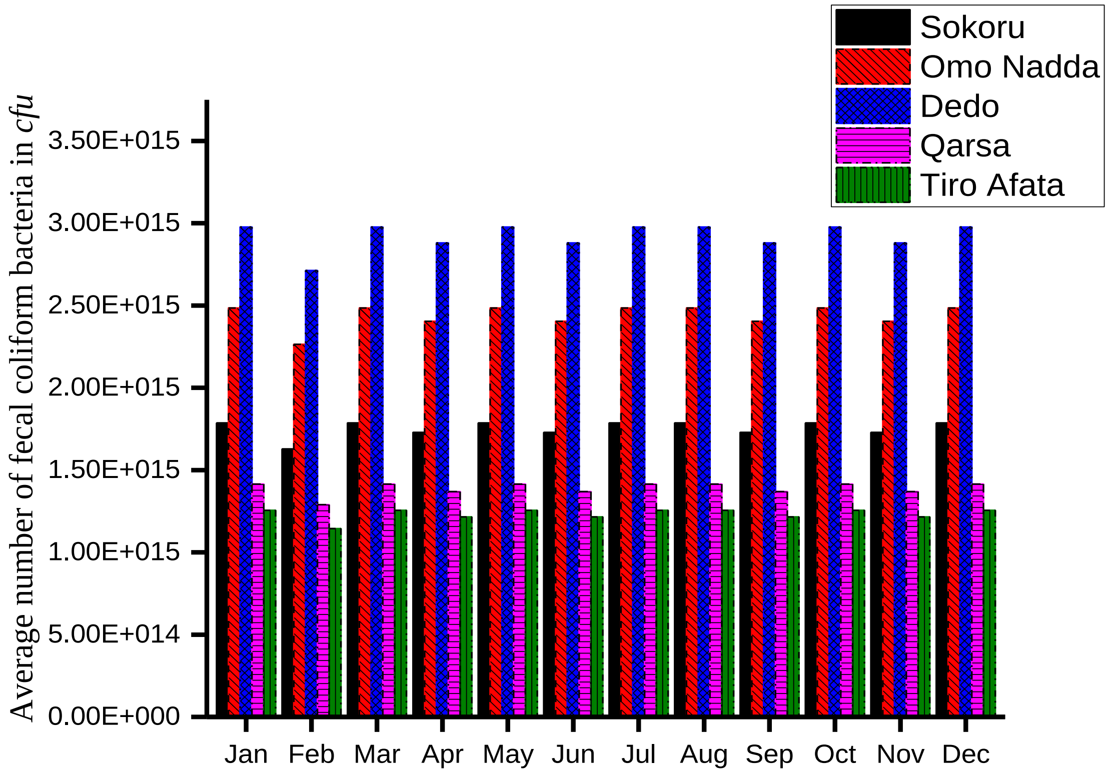

Figure 17 Summary of residential area fecal coliform bacteria load

4.2.4 Annual Fecal Coliform Loads From Different Sources In all Watershed Areas

Annual fecal coliform bacteria generated by BSLC from all sources in five study area watershed were 3.70E+18 *cfu*. Omo Nadda watershed has the highest (34.3%) fecal coliform bacteria concentration which accounts 1.27E+10 *cfu*. The second highest contribution of fecal coliform bacteria was generated from Tiro Afata watershed (23.1%), which accounts 8.56E+17 *cfu*. Dedo, Qarsa, and Sokoru watershed were the 3^{rd}, 4^{th}, and 5^{th} fecal coliform bacteria contribution which accounts 6.74E+17*cfu* (18.2%), 5.29E+17*cfu* (14.3%), and 3.73E+17*cfu* (10%) respectively (Table 4). The variation of fecal coliform bacteria contribution in the study area watershed was because of the difference number of livestock population. In addition to this, the variation of watershed area and latrine utilization coverage was also another factor for variation of fecal coliform bacteria in all study area watershed. According to this finding, cattle has high contribution of fecal coliform loads to the watershed which accounts 3.42E+18 cfu and Sheep and goats were the second highest contribution of fecal coliform loads which accounts 1.43E+17 cfu, whereas the least contribution of fecal coliform bacteria was obtained from horses which accounts 1.19E+16 cfu (Table 4).

Table 4 Annual fecal coliform bacteria load from all sources in the study area watershed

watersheds	Annual fecal coliform bacteria load per animal(*cfu/year)*							
	Pastue	Direct deposeted in stream		Pasture	Pasture	Residential		
	cattle	Cattle	Total Cattle	Sheep &Goate	Horse,Donky ,& Mule	pet(Dog & Cat)	Human	Grand total
Sokoro	3.30E+17	1.54E+15	3.32E+17	2.09E+16	1.00E+14	6.95E+15	1.40E+16	3.73E+17
Omo Nadaa	1.23E+18	4.17E+15	1.23E+18	4.08E+15	4.08E+15	1.23E+16	1.69E+16	1.27E+18
Dedo	5.68E+17	1.60E+15	5.70E+17	6.50E+16	4.98E+15	1.05E+16	2.44E+16	6.74E+17
Qersa	4.79E+17	1.73E+15	4.81E+17	2.17E+16	9.69E+15	8.40E+15	8.25E+15	5.29E+17
Tiro Afata	8.07E+17	2.81E+15	8.10E+17	3.14E+16	2.56E+14	6.50E+15	8.28E+15	8.56E+17
Total	3.41E+18	1.19E+16	3.43E+18	1.43E+17	1.91E+16	4.47E+16	7.18E+16	3.70E+18

4.3 Land Use and Soil Type

Land use and soil type were the critical part in the studying of pathogenic bacteria source and loads. Based on land use data obtained, four major land use groups were identified in the study area watersheds. These are; Agricultural land generic, pasture land, forest land, and residential land. Of the total land use area (1152605 Acre), the highest land use area is occupied by Agricultural land (65.6%). The second land use area is occupied by pasture land (15.3%). The others, 10.6 and 8.5% were occupied by forest and residential area respectively (Table 5). Agriculture is the main activities of the study area followed by high numbers of livestock population. The wastes generated from these livestock population were used for fertilizer without any treatment. During rainy season, these wastes and others fecal wastes were transported from crop and pasture land by runoff to Gilgel Gibe River. In addition, the pasture land area is not proportional to the numbers of livestock's populations as observed during filed visit (Annex J). As a result, most of the pasture type in all study sub watershed is overgrazing and this leads to repeat removal of plants/vegetation materials occurs without sufficient amount of time given for the pasture mass to regrow and microorganisms are easily transported by flood during rainy season especially from June to September. In all study area, most of pasture land is near to the river (Annex I) which has negative impact on the pollution of the surrounding river. In addition to this phenomenon, during hot season all the land area of sub watersheds were used for grazing livestock's which makes difficult to allocate bacteria loading on the type of land uses. Besides, Gilgel Gibe river is access to the entrance of livestock population for drinking purposes especially during dry season and car wash (Annex K) which have high impact on river pollution or contamination that leads to waterborne diseases outbreak and disturbances of aquatic environments.

Six soil types were identified. However, Nitisol and Vertisols are the two main dominant soil types of the study area watershed. Other types such as Fluvisols, Acrisols, vertisols, and planosols also present. The associations of Planosols and Vertisols are located on the river terraces in the lower landscape positions.

Table 5 land use classification of the study area

Sub-watershed	Land use in Acres and percent								Total Area
	Agericulture(Crop land)		Pasture		Forest		Residential		
	Acres	%	Acres	%	Acres	%	Acres	%	Acres
Sokoru	140954	65.5	13443	6.3	38650	18	21993	10.2	215040
Omo Nada	234071	68.1	87097	25.4	339	0.1	22037	6.4	343544
Dedo	159235	61.4	41694	16.1	33946	13.1	24395	9.4	259270
Qersa	150121	76.8	13591	7	14871	7.6	16842	8.6	195425
Tiro Afata	71824	51.6	20112	14.4	34570	24.8	12820	9.2	139326
Total	756205	65.6	175937	15.3	122376	10.6	98087	8.5	1152605

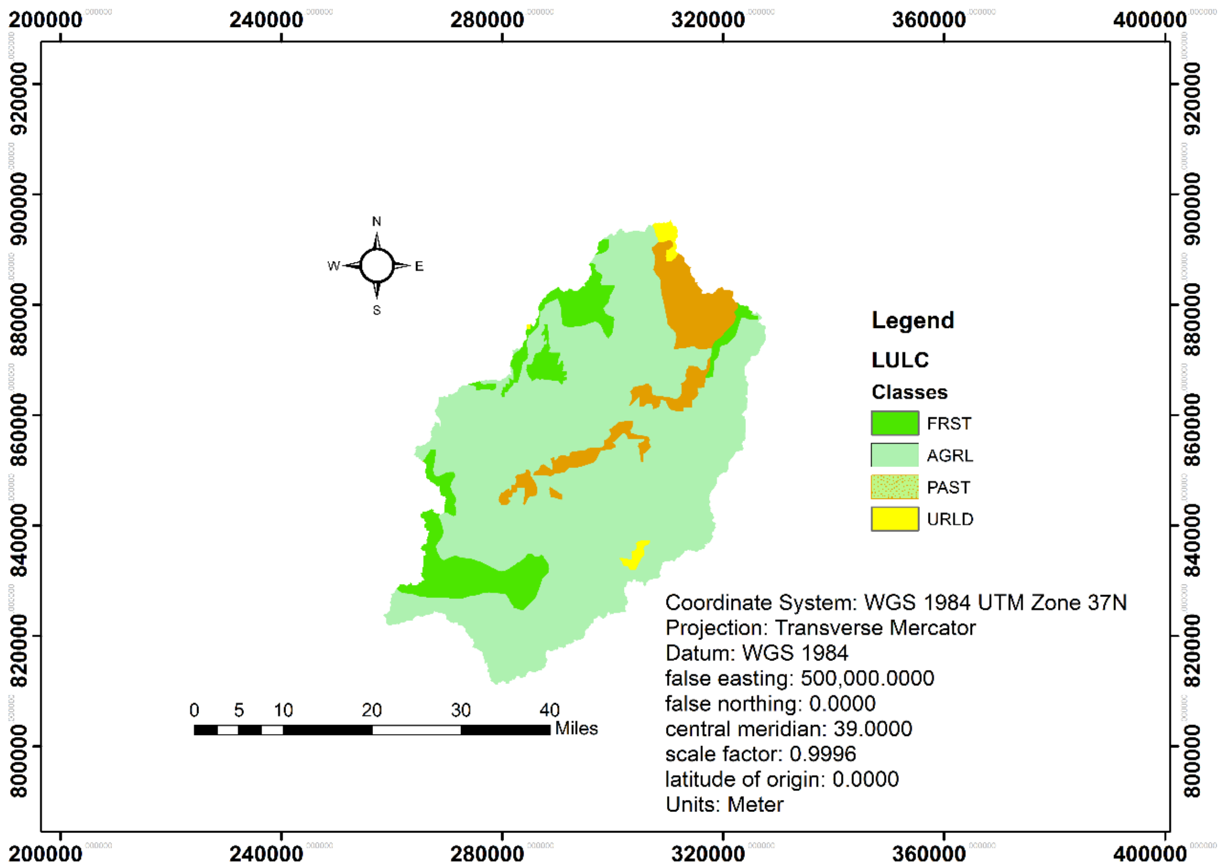

Figure 18 Land use land cover map of study area

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The BSLC methodology was applied for five watersheds (Dedo, Omo Nadda, Qarsa, Tiro Afata, and Sokoru) of Gilgel Gibe river based on perceived potential contributing sources and data availability to characterize potential sources and loads of fecal coliform bacteria. Representative sources of fecal coliform bacteria identified in all sub watersheds of the study catchments were all most all similar, which includes feces of livestock and improperly managed human excreta and domestic pet's feces. Bacteria source load calculator tool results indicated that the largest sources of fecal coliform in the study area were cattle and the least fecal coliform bacteria source was horses. Unfortunately BSLC is unable to reflect the true total potential fecal coliform loading of each sources from these watersheds because of the lack of data regarding wildlife and waterfowl's contributions makes it impossible to include all sources. The other thing is mules and donkeys are assumed as equivalent to horses in BSLC methodology. Scarcity of researches done on the livestock weights and manure production rate in Ethiopia can also affect the result. For this reason bacteria source characterization and quantification is computed between the existed bacteria input data and BSLC default value. The BSLC considered cattle was the highest potential contributor of fecal coliform bacteria load in all five watersheds. This suggests that BMPs implemented to reduce pollutant contributions from cattle will yield the largest load reductions as compared to management targeted at other contributors. The BSLC methodology was able to highlight both contributing sources of most concern and areas of highest concern, allowing more effective application of these BMPs. The BSLC methodology can be easily adapted and applied to watersheds to reflect stakeholder knowledge and concerns.

As the dominant sources of the study area population is depend up on agricultural activities mainly farming and livestock production; overgrazing, improperly management of animal wastes, practicing of open defecation, and improperly management of pets feces are the main sources of pollutants that can increase the load of fecal coliform bacteria and other types pollutants in to the stream through runoff during highly rain fall events and directly defecation in the stream by livestock population. The amount of fecal coliform bacteria obtained from this study threatens both human and environmental health. Basically the BSLC outputs is used as input for another water quality models that route the potential fecal coliform bacteria loads through the watershed using either surface runoff or through the soil to determine how much fecal coliform bacteria is reaching the stream. Surface runoff could be measured or modeled and, in combination with a digital elevation model (DEM), the path of the runoff from the land surface into the water body could be determined. Generally, bacteria source characterization and load allocation needs detail pollutant source input data, computer skills and detail knowledge of different bacteria sources characterization technologies, different bacteria water quality modeling, and multi-disciplinary fields to take sustainable action on the pollutant reduction from entering water sources.

5.2 Recommendations

The magnitude of fecal coliform bacteria loads to the watersheds threats to human health and aquatic environment. Unless it is controlled and monitored, the magnitude of pathogen-related water quality impairments drive the need to monitor for microbial pathogens and indicators in watershed programs. Because pathogens and many associated indicators are living organisms, monitoring provides challenges that differ from the demands of typical physical and chemical monitoring in point and nonpoint source plans. The generation of microorganisms from both domestic and wild animals, the transport of microbes through the environment, their survival or die-off in the environment, and sampling and analytical constraints all combine to require specific approaches to monitoring. As a general, the following points can be recommended based on the basis of the findings of this study:

1. Livestock agriculture is one of the major sources of fecal coliform bacteria in surface and ground water systems pollution in the study area. As a result, there has been an increasing need for the development of farm best management practices (BMPs) which minimize the risk of water contamination, especially with respect to human pathogens.
2. Emphases should be given in the improperly management and disposing system of pets feces and awareness on the health risk of pathogens present in the feces of pets should be properly delivered for the community.
3. Practicing of open defecation should have to be stopped and the properly utilization of latrine should be enhanced.
4. Pathogenic bacteria modeling to monitor rivers and streams impairment at watershed level should have to be planed and implemented.

5. Water quality modeling with laboratory diagnosis has to be done to identify specific species and amounts of instream fecal coliform loads of Gilgel Gibe river.
6. Fecal coliform bacteria sources data such as wildlife’s and waterfowls should be avail by concerned organization.
7. Gilgel Gibe river should be fenced or protected from the entrance of livestock population

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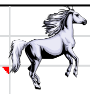
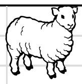
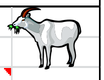
ANNEXES

Annex A Average of five years Animal data spreadsheets used in bacteria source load calculator

2005 EC													
													
	Cattle				Chickens			Turkeys					
	Dairy												
Subwatershed	M	D	H	Beef	Layers	Broilers	Broiler Breeders	Toms	Hens	Breeders	Horses	Ewes	Goats
Sekoru	11221	11265	43505	40935	49952	32107	17905	0	0	0	682	616	1436
Omonada	21342	59987	104371	98205	90463	58145	32425	0	0	0	27775	3989	9307
Dedo	13639	13691	52877	49753	45581	29297	16338	0	0	0	33898	1910	4456
Kersa	11192	11919	44628	41991	8721	5606	3128	0	0	0	660	623	1453
Tiroafata	19380	19454	75130	70691	43099	27702	15448	0	0	0	1747	921	2149
2006EC													
	Cattle				Chickens			Turkeys					
	Dairy												
Subwatershed	M	D	H	Beef	Layers	Broilers	Broiler Breeders	Toms	Hens	Breeders	Horses	Ewes	Goats
Sekoru	11937	11436	42652	41558	48498	32596	18402	0	0	0	692	626	1458
Omonada	22704	60901	102325	99701	87829	59030	33325	0	0	0	28192	4049	9447
Dedo	14510	13900	51840	50511	44254	29743	16791	0	0	0	34406	1939	4528
Kersa	11906	12101	43753	42631	8467	5692	3213	0	0	0	670	632	1748
Tiroafata	20617	19750	73657	71768	41844	28124	15877	0	0	0	1775	934	2188
2007EC													
	Cattle				Chickens			Turkeys					
	Dairy												
Subwatershed	M	D	H	Beef	Layers	Broilers	Broiler Breeders	Toms	Hens	Breeders	Horses	Ewes	Goats
Sekoru	11534	11670	43745	43745	51869	33261	18720	0	0	0	634	691	1493
Omonada	21936	62144	104948	104948	93934	60235	33901	0	0	0	25809	4481	9668
Dedo	14019	14183	53170	53170	47330	30350	17082	0	0	0	31498	2145	4629
Kersa	11504	12347	44874	44874	9056	5808	3268	0	0	0	613	700	1509
Tiroafata	19920	20153	75545	75545	44753	28698	16151	0	0	0	1623	1035	2232
2008EC													
	Cattle				Chickens			Turkeys					
	Dairy												
Subwatershed	M	D	H	Beef	Layers	Broilers	Broiler Breeders	Toms	Hens	Breeders	Horses	Ewes	Goats
Sekoru	11363	11554	44187	44187	48476	32292	18353	0	0	0	627	702	1515
Omonada	21612	61528	106008	106008	87789	58480	33236	0	0	0	25553	4548	9813
Dedo	13812	14043	53707	53707	44234	29466	16747	0	0	0	31186	2178	4698
Kersa	11334	12225	45328	45328	8463	5639	3204	0	0	0	607	710	1532
Tiroafata	19625	19954	76308	76308	41825	27862	15835	0	0	0	1607	1050	2266
2009EC													
	Cattle				Chickens			Turkeys					
	Dairy												
Subwatershed	M	D	H	Beef	Layers	Broilers	Broiler Breeders	Toms	Hens	Breeders	Horses	Ewes	Goats
Sekoru	11595	12424	45554	45554	44885	34911	19949	0	0	0	631	696	1504
Omonada	22053	66160	109287	109287	81286	63222	36127	0	0	0	25681	4515	9740
Dedo	14094	15100	55368	55368	40957	31856	18203	0	0	0	31342	2161	4663
Kersa	11565	13145	46730	46730	7836	6096	3483	0	0	0	610	705	1521
Tiroafata	20026	21456	78668	78668	38727	30121	17212	0	0	0	1615	1042	2249
Average of 2005-2009													
	Cattle				Chickens			Turkeys					
	Dairy												
Subwatershed	M	D	H	Beef	Layers	Broilers	Broiler Breeders	Toms	Hens	Breeders	Horses	Ewes	Goats
Sekoru	11530	11670	43929	43196	243680	33033	18666	0	0	0	653	666	1481
Omonada	21929	62144	105388	103630	441301	59822	33803	0	0	0	26602	4317	9595
Dedo	14015	14183	53392	52502	222356	30142	17032	0	0	0	32466	2067	4595
Kersa	11500	12347	45063	44311	42543	5768	3259	0	0	0	632	674	1553
Tiroafata	19914	20153	75862	74596	210248	28501	16105	0	0	0	1674	996	2217

Annex B Land use data used in BSLC

Subwatershed	Total Forest Acreage	Total Residential 1 Acreage	Total Residential 2 Acreage	Total Cropland Acreage	Total Pasture Acreage	Total Loafing Lot Acreage	Loafing Lot Time Dairy	Loafing Lot Time Beef	Pasture 1 Fraction of Total	Pasture 2 Fraction of Total	Pasture 3 Fraction of Total	Stream Access Pasture 1	Stream Access Pasture 2	Stream Access Pasture 3	Straight Pipes
Sokoru	21258	605	11491	77525	7394	0	0	0	0.3	0.5	0.2	0.55	0.6	0.9	0
Omo Nada	20368	661	12561	140443	52258	0	0	0	0.3	0.35	0.35	0.5	0.85	0.9	0
Dedo	11157	488	9270	63694	16678	0	0	0	0.35	0.25	0.4	0.75	0.5	0.35	0
Qarsa	13384	761	14396	135109	12232	0	0	0	0.45	0.2	0.35	0.75	0.75	0.65	0
Tiro Afata	29385	872	10025	61050	17095	0	0	0	0.5	0.25	0.25	0.65	0.65	0.75	0

Annex C Monthly variable input data sheet used in BSLC

	January	February	March	April	May	June	July	August	September	October	November	December
Fraction of time in a day spent by Milk Cows in confinement												
Sokoru	0.67	0.67	0.67	0.67	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Omo Nadda	0.67	0.67	0.67	0.67	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Dedo	0.67	0.67	0.67	0.67	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Qarsa	0.67	0.67	0.67	0.67	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Tiroaf Ata	0.67	0.67	0.67	0.67	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Fraction of time in a day spent by Dry Cows in confinement												
Sokoru	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Omo Nadda	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Dedo	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Qarsa	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Tiroaf Ata	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Fraction of time in a day spent by Heifers in confinement												
Sokoru	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Omo Nadda	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Dedo	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Qarsa	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Tiroaf Ata	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Fraction of time in a day spent by Beef Cows in confinement												
Sokoru	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Omo Nadda	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Dedo	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Qarsa	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Tiroaf Ata	0.63	0.63	0.63	0.63	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Fraction of time in a day spent by Sheep and Goats in confinement - UNDER CONSTRUCTION												
Sokoru	0	0	0	0	0	0	0	0	0	0	0	0
Omo Nadda	0	0	0	0	0	0	0	0	0	0	0	0
Dedo	0	0	0	0	0	0	0	0	0	0	0	0
Qarsa	0	0	0	0	0	0	0	0	0	0	0	0
Tiroaf Ata	0	0	0	0	0	0	0	0	0	0	0	0
Application Schedule for liquid dairy manure (sum of numbers in one row should equal 1)												
Sokoru	0	0	0	0	0	0.25	0.25	0.25	0.25	0	0	0
Omo Nadda	0	0	0	0	0	0.25	0.25	0.25	0.25	0	0	0
Dedo	0	0	0	0	0	0.25	0.25	0.25	0.25	0	0	0
Qarsa	0	0	0	0	0	0.25	0.25	0.25	0.25	0	0	0
Tiroaf Ata	0	0	0	0	0	0.25	0.25	0.25	0.25	0	0	0
Application Schedule for solid cattle manure (sum of numbers in one row should equal 1)												
Sokoru	0.125	0.05	0.25	0.2	0.05	0	0	0	0	0.1	0.1	0.125
Omo Nadda	0.125	0.05	0.25	0.2	0.05	0	0	0	0	0.1	0.1	0.125
Dedo	0.125	0.05	0.25	0.2	0.05	0	0	0	0	0.1	0.1	0.125
Qarsa	0.125	0.05	0.25	0.2	0.05	0	0	0	0	0.1	0.1	0.125
Tiroaf Ata	0.125	0.05	0.25	0.2	0.05	0	0	0	0	0.1	0.1	0.125
Application Schedule for poultry litter (sum of numbers in one row should equal 1)												
Sokoru	0	0.05	0.25	0.2	0.05	0.05	0.05	0.05	0.1	0.1	0.1	0
Omo Nadda	0	0.05	0.25	0.2	0.05	0.05	0.05	0.05	0.1	0.1	0.1	0
Dedo	0	0.05	0.25	0.2	0.05	0.05	0.05	0.05	0.1	0.1	0.1	0
Qarsa	0	0.05	0.25	0.2	0.05	0.05	0.05	0.05	0.1	0.1	0.1	0
Tiroaf Ata	0	0.05	0.25	0.2	0.05	0.05	0.05	0.05	0.1	0.1	0.1	0
Hours Each Day Spent by Animals (cows, sheep, goats) in a Stream												
Sokoru	1	1	1	0.75	0.75	0	0	0	0	0	0.5	0.5
Omo Nadda	1	1	1	0.75	0.75	0	0	0	0	0	0.5	0.5
Dedo	1	1	1	0.75	0.75	0	0	0	0	0	0.5	0.5
Qarsa	1	1	1	0.75	0.75	0	0	0	0	0	0.5	0.5
Tiroaf Ata	1	1	1	0.75	0.75	0	0	0	0	0	0.5	0.5
Beef Number: 1000 lb Animal Units per Cow-Calf Pair Throughout the Year for Beef Operations												
Sokoru	1.15	1.35	1.39	1.43	1.47	1.51	1.55	1.59	1.63	1	1.05	1.1
Omo Nadda	1.15	1.35	1.39	1.43	1.47	1.51	1.55	1.59	1.63	1	1.05	1.1
Dedo	1.15	1.35	1.39	1.43	1.47	1.51	1.55	1.59	1.63	1	1.05	1.1
Qarsa	1.15	1.35	1.39	1.43	1.47	1.51	1.55	1.59	1.63	1	1.05	1.1
Tiroaf Ata	1.15	1.35	1.39	1.43	1.47	1.51	1.55	1.59	1.63	1	1.05	1.1

Annex D (a) Reference values used in BSLC

Dairy Cow Parameters		Sokoru	Omo Nada	Dedo	Qarsa	Tiro Afata	Units	Source
Weight of milk or dry cow		1400	1400	1400	1400	1400	lbs	MWPS, 1993
Weight of heifer		640	640	640	640	640	lbs	based on weighted average young cow weight MWPS, 1993
Manure production by heifers		40.7	40.7	40.7	40.7	40.7	lbs/day	for 640 lb heifer in Barth, 1992
Ratio of dairy cows on:	Pasture 1	1.2	2.3	1.3	0.3	0.6	ratio	customize to your watershed
	Pasture 2	0.9	0.3	1	1.1	1.6	ratio	customize to your watershed
	Pasture 3	1	1	1	1	1	ratio	customize to your watershed
Fraction of cows defecating in stream as compared to the cows that are in/around streams (dairy)		0.3	0.3	0.3	0.3	0.3	ratio	best professional judgment
Fecal coliform production by milk or dry cow		2.50E+10	2.50E+10	2.50E+10	2.50E+10	2.50E+10	total cfu/day-animal	Yagow, 2001; ASAE Standards, 1998; Geldreich, 1978
Manure excreted by milk or dry cow		115	115	115	115	115	lb/day-animal	for 1400 lb dry cow in Barth, 1992
Liquid manure produced by confined milk cows		17	17	17	17	17	gal/day-animal	for 1400 lb cow, manure included, in Barth 1992
Fraction of fecal coliform produced per milk cow lost in milk parlor wash-off		0.025	0.025	0.025	0.025	0.025	ratio	best professional judgment
Die-off coefficient for liquid manure		0.375	0.375	0.375	0.375	0.375	1/day	DeGuise, 2002
Die-off coefficient for solid manure pile		0.05	0.05	0.05	0.05	0.05	1/day	DeGuise, 2002
Survival factor for liquid manure		0.0345	0.0345	0.0345	0.0345	0.0345	factor	based on die-off reported in Crane and Moore, 1986
Survival factor for solid manure		0.068	0.068	0.068	0.068	0.068	factor	based on die-off reported in Crane and Moore, 1986
Beef Cow Parameters								
Average weight of beef cow		1000	1000	1000	1000	1000	lb	average of ASAE Standards, 1998 and MWPS, 1993
Fecal coliform production by 1000-lb beef cow		3.30E+10	3.30E+10	3.30E+10	3.30E+10	3.30E+10	total cfu/day-animal	Yagow, 2001; ASAE Standards, 1998; Geldreich, 1978
Ratio of beef cattle on:	Pasture 1	1.2	2.3	1.3	0.3	0.6	ratio	Assumed to be 4:2:1 based on information gathered from
	Pasture 2	0.9	0.3	1	1.1	1.6	ratio	beef extension specialists at Virginia Tech.
	Pasture 3	1	1	1	1	1	ratio	
Manure excreted by beef cow		60	60	60	60	60	lb/day-animal	MWPS, 1993 for 1000lb cow
Fraction of cows defecating in stream as compared to the cows that are in/around streams (beef)		0.3	0.3	0.3	0.3	0.3	ratio	best professional judgment

Annex D (b) Reference values used in BSLC

Sheep and Goat Parameters	Sokoru	Omo Nada	Dedo	Qarsa	Tiro Afata	Units	Source
Ewe Weight	60	60	60	60	60	lbs	ASAE Standards, 1998
Lamb Weight	30	30	30	30	30	lbs	best professional judgment - 1/2 weight of ewes
Goat Weight	140	140	140	140	140	lbs	ASAE Standards, 1998
How many lambs should be associated with each ewe?	2	2	2	2	2	lambs/ewe	ewes are bred for twins (Ensminger and Parker, 1986, p. 356)
Ratio of sheep and goats on: Pasture 1	1.2	2.3	1.3	0.3	0.6	ratio	customize to your watershed
Pasture 2	0.9	0.3	1	1.1	1.6	ratio	customize to your watershed
Pasture 3	1	1	1	1	1	ratio	customize to your watershed
Fraction of sheep defecating in stream as compared to the sheep that are in/around streams	0	0	0	0	0	ratio	best professional judgment/customize to your watershed
Fecal coliform production by 60-lb sheep	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	total cfu/day-animal	ASAE Standards, 1998
Manure excreted by sheep	2.4	2.4	2.4	2.4	2.4	lb/day-animal	ASAE Standards, 1998
Horse Parameter							
Fecal coliform production by 1000-lb horse	4.20E+08	4.20E+08	4.20E+08	4.20E+08	4.20E+08	total cfu/day-animal	ASAE Standards, 1998
Ratio of horses on: Pasture 1	1.2	2.3	1.3	0.3	0.6	ratio	customize to your watershed
Pasture 2	0.9	0.3	1	1.1	1.6	ratio	customize to your watershed
Pasture 3	1	1	1	1	1	ratio	customize to your watershed
Fraction of horses defecating in stream as compared to the horses that are in/around streams	0	0	0	0	0	ratio	customize to your watershed
Poultry Parameters							
Length of layer cycle (including down time)	336	336	336	336	336	days	observations in Valley Region of Virginia: customize
Length of broiler cycle (including down time)	56	56	56	56	56	days	based on 6 cycles/yr (VADCR, 1993)
Length of turkey cycle (including down time)	70	70	70	70	70	days	based on 4 cycles/yr (VADCR, 1993); note that if hens are used, there are 5 cycles/yr and 16 lb/bird/cycle so mathematics work out the same
Manure production by layers	0.256	0.256	0.256	0.256	0.256	lb/day-bird	ASAE Standards, 1998
Manure production by broilers	0.168	0.168	0.168	0.168	0.168	lb/day-bird	ASAE Standards, 1998
Manure production by turkeys	0.705	0.705	0.705	0.705	0.705	lb/day-bird	ASAE Standards, 1998
Fecal coliform production by layers	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	cfu/day-bird	ASAE Standards, 1998
Fecal coliform production by broilers	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	cfu/day-bird	best professional judgment - based on relative manure production by layers and broilers
Fecal coliform production by turkeys	9.30E+07	9.30E+07	9.30E+07	9.30E+07	9.30E+07	cfu/day-bird	ASAE Standards, 1998
Layer litter produced	30	30	30	30	30	lb/cycle-bird	Early estimate (circa 2000) for Virginia: customize
Broiler litter produced	2.6	2.6	2.6	2.6	2.6	lb/cycle-bird	VADCR, 1993, pg 6-16
Turkey litter produced	18	18	18	18	18	lb/cycle-bird	VADCR, 1993, pg 6-16
Occupancy Factor for layers	0.958	0.958	0.958	0.958	0.958	ratio	These three occupancy factors are based on localized
Occupancy Factor for broilers	0.787	0.787	0.787	0.787	0.787	ratio	observations in the Valley Region of Virginia and should
Occupancy Factor for turkeys	0.865	0.865	0.865	0.865	0.865	ratio	be customized to your watershed
Die-off coefficient for poultry litter	0.035	0.035	0.035	0.035	0.035	1/day	DeGuise, 2002
Survival Factor for poultry litter	0.099	0.099	0.099	0.099	0.099	factor	based on die-off reported in Crane and Moore, 1986

Annex D (C) Reference values used in BSLC

Human Activities parameter	Sokoru	Omo Nada	Dedo	Qarsa	Tiro Afata	Units	Source
Human fecal coliform production	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09	total cfu/day-animal	Geldreich, 1978
Pets per sewered household	1	1	1	1	1		HSUS, 2011 - assuming one dog is equal to two cats
Pets per unsewered household	1	1	1	1	1		HSUS, 2011 - assuming one dog is equal to two cats
Pet fecal coliform production	4.50E+08	4.50E+08	4.50E+08	4.50E+08	4.50E+08	total cfu/day-animal	Geldreich, 1978
Failure rate of 'old' septic systems	0.15	0.17	0.24	0.08	0.09	fraction	Failure rates of septic systems are based on expert opinion
Failure rate of 'mid-age' septic systems	0.38	0.23	0.27	0.26	0.25	fraction	of septic system specialists at Virginia Tech and should
Failure rate of 'new' septic systems	0.16	0.1	0.11	0.11	0.11	fraction	be customized to your watershed
Tillage and Application Activities							
Fraction of time in a year that liquid manure is applied to cropland	0.33	0.33	0.33	0.33	0.33	fraction	customize to your watershed
Fraction of time in a year that solid manure (cattle and poultry) is applied to cropland	0.67	0.67	0.67	0.67	0.67	fraction	customize to your watershed
Fecal coliform available from tilled-in waste	0.1	0.1	0.1	0.1	0.1	fraction	best professional judgment
Fraction of 10 year rotation during which the land is in a no-till crop (e.g., hay)	0.571	0.571	0.571	0.571	0.571	fraction	customize to your watershed
Application rate of solid manure (cattle) to cropland	24000	24000	24000	24000	24000	lb/ac-yr	customize to your watershed
Application rate of solid manure (cattle) to pasture 1	24000	24000	24000	24000	24000	lb/ac-yr	customize to your watershed
Application rate of solid manure (cattle) to pasture 2	24000	24000	24000	24000	24000	lb/ac-yr	customize to your watershed
Application rate of solid manure (cattle) to pasture 3	24000	24000	24000	24000	24000	lb/ac-yr	customize to your watershed
Application rate of liquid dairy manure to crops	6600	6600	6600	6600	6600	gal/ac-yr	customize to your watershed
Application rate of liquid dairy manure to pasture 1	3900	3900	3900	3900	3900	gal/ac-yr	customize to your watershed
Application rate of liquid dairy manure to pasture 2	3900	3900	3900	3900	3900	gal/ac-yr	customize to your watershed
Application rate of liquid dairy manure to pasture 3	3900	3900	3900	3900	3900	gal/ac-yr	customize to your watershed
Application rate of poultry manure to cropland	6000	6000	6000	6000	6000	lb/ac-yr	customize to your watershed
Application rate of poultry manure to pasture 1	6000	6000	6000	6000	6000	lb/ac-yr	customize to your watershed
Application rate of poultry manure to pasture 2	6000	6000	6000	6000	6000	lb/ac-yr	customize to your watershed
Application rate of poultry manure to pasture 3	6000	6000	6000	6000	6000	lb/ac-yr	customize to your watershed

Annex E Five years human activities input data used in BSLC

2005EC										
	Persons/	Persons/	Number	Number	Septic Systems			Straight Pipes		
Subwatershed	Unsewer	Sewered	Unsewer	Sewered	oldest	mid-age	newest	oldest	mid-age	newest
Dedo	4.8	4.8	42594	25901	16438	18309	7847	0	0	0
Omonada	4.8	4.8	30001	30500	10285	13801	5915	0	0	0
Kersa	4.8	4.8	17980	22398	3230	10325	4425	0	0	0
Sekoru	4.8	4.8	23136	10370	5026	12677	5433	0	0	0
Tiroafata	4.8	4.8	14224	17916	2893	7932	3399	0	0	0
2006EC										
	Persons/	Persons/	Number	Number	Septic Systems			Straight Pipes		
Subwatershed	Unsewer	Sewered	Unsewer	Sewered	oldest	mid-age	newest	oldest	mid-age	newest
Dedo	4.8	4.8	35183	36954	14108	16753	4322	0	0	0
Omonada	4.8	4.8	25767	38576	9969	11246	4552	0	0	0
Kersa	4.8	4.8	13612	28960	2911	7901	2800	0	0	0
Sekoru	4.8	4.8	13034	22057	4486	6556	1992	0	0	0
Tiroafata	4.8	4.8	13429	21113	2648	7861	2920	0	0	0
2007EC										
	Persons/	Persons/	Number	Number	Septic Systems			Straight Pipes		
Subwatershed	Unsewer	Sewered	Unsewer	Sewered	oldest	mid-age	newest	oldest	mid-age	newest
Dedo	4.8	4.8	29537	47008	13384	10484	5669	0	0	0
Omonada	4.8	4.8	25335	40570	9632	10865	4838	0	0	0
Kersa	4.8	4.8	11700	32277	2135	6021	3544	0	0	0
Sekoru	4.8	4.8	13579	23474	4257	6002	3320	0	0	0
Tiroafata	4.8	4.8	13330	22440	2380	7350	3600	0	0	0
2008EC										
	Persons/	Persons/	Number	Number	Septic Systems			Straight Pipes		
Subwatershed	Unsewer	Sewered	Unsewer	Sewered	oldest	mid-age	newest	oldest	mid-age	newest
Dedo	4.8	4.8	26303	50060	12982	7178	6143	0	0	0
Omonada	4.8	4.8	25356	40590	9232	10538	5586	0	0	0
Kersa	4.8	4.8	11296	32560	2193	5359	3744	0	0	0
Sekoru	4.8	4.8	12920	23544	4011	5827	3082	0	0	0
Tiroafata	4.8	4.8	11807	23106	2095	6564	3148	0	0	0
2009EC										
	Persons/	Persons/	Number	Number	Septic Systems			Straight Pipes		
Subwatershed	Unsewer	Sewered	Unsewer	Sewered	oldest	mid-age	newest	oldest	mid-age	newest
Dedo	4.8	4.8	18948	9561	13161	3645	2142	0	0	0
Omonada	4.8	4.8	25429	91540	13565	10082	1782	0	0	0
Kersa	4.8	4.8	10530	74743	4827	4188	1515	0	0	0
Sekoru	4.8	4.8	14461	54980	5761	5228	3472	0	0	0
Tiroafata	4.8	4.8	12363	48429	3796	5455	3112	0	0	0
Average of 2005-2009EC										
	Persons/	Persons/	Number	Number	Septic Systems			Straight Pipes		
Subwatershed	Unsewer	Sewered	Unsewer	Sewered	oldest	mid-age	newest	oldest	mid-age	newest
Dedo	4.8	4.8	30513	33897	14015	11274	5225	0	0	0
Omonada	4.8	4.8	26378	48355	10537	11306	4535	0	0	0
Kersa	4.8	4.8	13024	38188	3059	6759	3206	0	0	0
Sekoru	4.8	4.8	15426	26885	4708	7258	3460	0	0	0
Tiroafata	4.8	4.8	13031	26601	2762	7032	3236	0	0	0

Annex F Annual fecal coliform bacteria load in pasture land by cattle

Months	Sokoru	Omo Nada	Dedo	Qarsa	Tiro Afata	Total
January	2.39139E+16	8.16781E+16	3.72465E+16	3.13994E+16	5.28364E+16	2.27074E+17
February	2.17925E+16	8.15231E+16	3.75394E+16	3.16441E+16	5.3252E+16	2.25751E+17
March	2.39139E+16	9.10151E+16	4.19831E+16	3.53895E+16	5.95556E+16	2.51857E+17
April	2.31893E+16	8.97698E+16	4.14643E+16	3.49685E+16	5.88434E+16	2.48235E+17
May	2.99638E+16	1.17429E+17	5.43569E+16	4.58382E+16	7.71396E+16	3.24727E+17
June	2.91727E+16	1.1623E+17	5.38318E+16	4.54599E+16	7.64865E+16	3.21181E+17
July	3.01451E+16	1.22055E+17	5.66144E+16	4.78093E+16	8.04401E+16	3.37064E+17
August	3.01451E+16	1.24006E+17	5.76027E+16	4.86434E+16	8.18443E+16	3.42241E+17
September	2.91727E+16	1.21893E+17	5.67009E+16	4.78814E+16	8.0563E+16	3.36211E+17
October	3.01451E+16	9.52337E+16	4.30259E+16	3.63408E+16	6.11333E+16	2.65879E+17
November	2.90557E+16	9.41347E+16	4.26865E+16	3.60191E+16	6.06025E+16	2.62499E+17
December	3.00242E+16	9.97009E+16	4.53405E+16	3.82578E+16	6.43704E+16	2.77694E+17
Annual/Year/	3.30634E+17	1.23467E+18	5.68393E+17	4.79652E+17	8.07067E+17	3.42041E+18

A**nnex G Annual** fecal coliform bacteria load in pasture land by horse, mules, & donkeys

Months	Sokoru	Omo Nada	Dedo	Qarsa	Tiro Afata	Total
January	8.50206E+12	3.46358E+14	4.22707E+14	8.22864E+12	2.17955E+13	8.07592E+14
February	7.74785E+12	3.15633E+14	3.85209E+14	7.49868E+12	1.9862E+13	7.3595E+14
March	8.50206E+12	3.46358E+14	4.22707E+14	8.22864E+12	2.17955E+13	8.07592E+14
April	8.2278E+12	3.35185E+14	4.09072E+14	7.9632E+12	2.10924E+13	7.8154E+14
May	8.50206E+12	3.46358E+14	4.22707E+14	8.22864E+12	2.17955E+13	8.07592E+14
June	8.2278E+12	3.35185E+14	4.09072E+14	7.9632E+12	2.10924E+13	7.8154E+14
July	8.50206E+12	3.46358E+14	4.22707E+14	8.22864E+12	2.17955E+13	8.07592E+14
August	8.50206E+12	3.46358E+14	4.22707E+14	8.22864E+12	2.17955E+13	8.07592E+14
September	8.2278E+12	3.35185E+14	4.09072E+14	7.9632E+12	2.10924E+13	7.8154E+14
October	8.50206E+12	3.46358E+14	4.22707E+14	8.22864E+12	2.17955E+13	8.07592E+14
November	8.2278E+12	3.35185E+14	4.09072E+14	7.9632E+12	2.10924E+13	7.8154E+14
December	8.50206E+12	3.46358E+14	4.22707E+14	8.22864E+12	2.17955E+13	8.07592E+14
Annual/Year/	1.00173E+14	4.08088E+15	4.98045E+15	9.6952E+13	2.568E+14	9.51525E+15

Annex H Annual fecal coliform bacteria load in pasture land by sheep & goat

Months	Sokoru	Omo Nada	Dedo	Qarsa	Tiro Afata	Total
January	1.78114E+15	3.46358E+14	5.52643E+15	1.84958E+15	2.66538E+15	1.21689E+16
February	1.62313E+15	3.15633E+14	5.03618E+15	1.68551E+15	2.42894E+15	1.10894E+16
March	1.78114E+15	3.46358E+14	5.52643E+15	1.84958E+15	2.66538E+15	1.21689E+16
April	1.72368E+15	3.35185E+14	5.34816E+15	1.78992E+15	2.5794E+15	1.17763E+16
May	1.78114E+15	3.46358E+14	5.52643E+15	1.84958E+15	2.66538E+15	1.21689E+16
June	1.72368E+15	3.35185E+14	5.34816E+15	1.78992E+15	2.5794E+15	1.17763E+16
July	1.78114E+15	3.46358E+14	5.52643E+15	1.84958E+15	2.66538E+15	1.21689E+16
August	1.78114E+15	3.46358E+14	5.52643E+15	1.84958E+15	2.66538E+15	1.21689E+16
September	1.72368E+15	3.35185E+14	5.34816E+15	1.78992E+15	2.5794E+15	1.17763E+16
October	1.78114E+15	3.46358E+14	5.52643E+15	1.84958E+15	2.66538E+15	1.21689E+16
November	1.72368E+15	3.35185E+14	5.34816E+15	1.78992E+15	2.5794E+15	1.17763E+16
December	1.78114E+15	3.46358E+14	5.52643E+15	1.84958E+15	2.66538E+15	1.21689E+16
Annual/Year/	2.09858E+16	4.08088E+15	6.51138E+16	2.17923E+16	3.14042E+16	1.43377E+17

Annex I Sample photo shows livestock grazing area near river in Tiro Afata watershed

Annex J Sample photo shows overgrazing pasture land taken from Qarsa and Tiro Afata watershed

Annex K Sample photo shows instream defecation by cattle and car washing in Omo Nadda and Tiro Afata watershed