JIMMA UNIVERSITY, SCHOOL OF GRADUATE STUDIES

IMPACTS OF WATERSHED MANAGEMENT PRACTICES ON THE GILGEL GIBE I RESERVOIR AND ITS TRIBUTARIES, SOUTHWEST ETHIOPIA

A PhD DISSERTATION SUBMITTED TO THE SCHOOL OF GRADUTE STUDIES, JIMMA UNIVERSITY, ETHIOPIA FOR THE FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PhD) IN APPLIED ECOLOGY

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DEDICATION

This work is dedicated to the memory of my father, who passed away during my PhD study. He is the one who laid the foundation and gave encouragement for my education.

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ABBREVIATIONS

APHA	American Public Health Association
BOD_5	Five Days Biochemical Oxygen Demand
DEM	Digital Elevation Model
DO	Dissolved Oxygen
EC	Electrical conductivity
GPS	Geographic Positioning System
KAP	knowledge Attitudes and Practices
NTU	Nephelometric Turbidity Unit
OLI	Operational Land Imager
SRP	Soluble Reactive Phosphorus
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSItsr	Trophic State Index for tropical/subtropical reservoirs
TSS	Total Suspended Solids
WT	Water Temperature

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SUMMARY

Water plays a crucial role in achieving socio-economic development and it is the primary medium through which people, ecosystem and economy most likely experience the different impacts caused by natural and human changes. In developing countries, surface water deterioration is the most critical and severe water quality problems that remain unsolved due to poor land-use and land cover changes and population growth. Many challenges have been encountered by the continent of Africa in its endeavours to meet the needs of the development agenda of each country including agriculture, industry, energy and environmental requirements. These challenges will increase pressure on water quality (as a result of pollution from development activities) and quantity (due to development imperatives) of water. Reservoirs and rivers are among the main surface water resources. Reservoirs are an important component of infrastructure expansion and are considered as “green” energy source. Ethiopia, has particularly been experiencing development and undertaking large dam construction projects as part of a movement to improve quality of life for its people. But water quality has become an issue of concern because of the rapid increase in population and subsequent landuse changes within a given watershed. Such conditions limit the ability of a given water body to deliver its effective ecosystem service. Lakes and reservoirs are particularly susceptible to the negative impacts of eutrophication because of their complex dynamics, relatively longer water residence time and their role as an integrating sink for pollutants from their drainage basins. Water quality issues that have been observed influencing Ethiopian reservoirs include not only inorganic and toxic chemical compounds but also organic matter and excess nutrients. High sediment loads as well as chemicals and nutrients in runoff from agricultural land, manufacturing and other related sources have been observed impacting Ethiopian reservoirs.

In the Gilgel Gibe I Reservoir, various physical and chemical impairments of water quality occur as water from the tributaries in the watershed that flow into the reservoir carry various impurities.. Water quality issues require long-term watershed planning and management in order to protect the resources for future generations. On a watershed, scale evaluation of spatial and temporal variations in the water qualities of tributaries is crucial to characterize the physical and chemical aspects of aquatic environments. This will help to inhibit further loss of resource and biological diversity in the aquatic system. Temporal and Spatial changes have not been considered in studies so far. Morever, the influences of changing catchment characteristics in relation to the limnological aspects of the tributaries have not been well recognized. This study attempted to relate the spatial and temporal patterns of water quality

variables with underlying causes of pollution such as landuse land cover change. The vertical variability of reservoir water physicochemical parameters was determined at four different depths (surface, 5m, 10m and 15m). Covering this knowledge gap would help to regulate the health status of aquatic ecosystem, support sustainable and economical benefit of the local community; inform management strategies for other similar reservoirs.

Specifically, this study aimed to

1) Quantify spatiotemporal variation of water quality parameters within the reservoir
2) Assess the depth profile of water physicochemical parameters and the reservoir trophic status
3) Estimate the influence of various landuse types on the water quality of tributaries in the watershed of Gilgel Gibe I Reservoir and determine the distribution of nutrients in the major tributaries of Gilgel Gibe catchment.

Five sampling sites within the reservoir water system, twelve sampling sites from four tributary system (three from each tributary), and twenty-four sampling sites (six on each tributary) along the tributary system were selected for the analysis of water physicochemical parameters and to determine sediment load. The water quality of the reservoir and its tributaries were also analysed on site and in the laboratory following the standard protocols. Trophic state index was used to determine the trophic status of the reservoir. Different landuse classes were categorized to estimate their influence on the water quality of feeding tributaries to the reservoir. Turbidity, suspended solid, TP, SRP and nitrate concentration of tributaries was computed to assess the distributiob of nutrient in different river system.

Spatially (within the reservoir), EC, SRP, TDS and TSS have showed significant difference in wet season while during the dry season, EC, TDS, and turbidity showed significant difference (Kruskal-Wallis test, $P < 0.05$). Seasonal variation of the reservoir water quality parameters like EC, pH, BOD_5 TP, TN, NO_3^-, TDS and TSS were all significantly different among seasons (Mann -Whitney U test, $p < 0.01$). Depth study results showed that except for TDS, TP and SRP the rest indicated statistically significant difference at $p < 0.05$ level. Temperature, pH and DO decreased as the depth increased. The trophic state index for tropical / subtropical reservoir (TSItsr) categorized the reservoir as eutrophic water body. Based on landuse type (spatially) water quality parameters of tributaries such as DO, temperature, BOD_5, TP, SRP, TN, turbidity, TDS and TSS showed significant difference in wet season. During the dry season, DO, temperature and BOD_5 showed significant difference. Seasonally, tributaries water quality parameters excluding DO, EC, and TP and the rest showed significant difference. Overall, high nutrient concentrations suggest eutrophic conditions, likely due to high nutrient loading from the watershed. The discharge of greatest concentration of chemicals from agricultural landuse caused eutrophication and pollution of water bodies hence watersheds with such landuse types needs emphasis and priorities for management/conservation as first course of action. Assessment of tributaries water quality for TSS and turbidity level showed a good positive correlation. The information gained from this relationship identified that Nedhi and Yedi rivers are most likely impaired by suspended solids. Understanding community's watershed conservation and managements helps to implement necessary interventions to minimize environmental threats. It was suggested that

A) Identifying the sub-watershed for conservation priority and proper landuse management
B) Selecting the type of soil conservation measures to be implemented, maintaining riparian buffer zone along the river, stream channels and around the reservoir
C) Further discussion with local elders to set and enforce traditional conservation laws are crucial.

1

1. GENERAL INTRODUCTION

1. BACKGROUND

Water resources have been developed to benefit mankind in several aspects. Reservoirs are among water bodies that have multiple advantages. They are commonly an enlarged water bodies either natural or artificial including lakes, ponds, or impoundments. Most reservoirs are constructed by building a dam across valleyes, or by using natural or artificial depressions across rivers (Eslamian et al., 2018). Dams control the amount of water that can flow out from the reservoir. Watershed is defined as any surface area that drains water, sediment and dissolved materials to a common receiving body or outlet including reservoirs (Wolka, 2012). The size of watershed varies from the largest river basins to just acres or less (O'Keefe et al. 2012). It is the basic building block for land and water planning (Darghouth et al. 2008). It is not only a hydrological component but also a socio-economic and socio-political entity that inquire planning and implementing resources (Reddy et al., 2017). The construction of dams to create reservoirs provide ecological and economic importance. Among the most common application areas of reservoirs include irrigation, industry, hydroelectric power, flood control, and navigation.

Reservoirs of many countries including Ethiopia are adversely affected due to anthropogenic activities or natural processes such as high rate of sedimentation, climatic change, for example, seasonal variation impacts of flooding and drought. Global climate change due the increase in air temperature and changes in the precipitation patterns affects intensity and duration of rainfall, discharge volume of rivers and evaporation rate of reservoirs (Jahandideh-Tehrani et al., 2014). The most important challenges of reservoirs are accumulation of excess sediment (Lee et al., 2009) as well as threatening factors, such as land use pattern, application of agricultural chemicals, rural and urban settlement, industrial development (Granit and Lindstrom, 2009; Mustapha, 2008). Moreover, the characteristics of water in the tributaries of reservoirs could be an indicator of impacts upon reservoir systems (Holdren et al., 2001; Miranda, 2008). Effectiveness of aquatic systems to provide its full function depends largely on activities underway in the watershed catchment and land use/land cover changes (LULC) (Ahearn et al., 2005; Mustapha, 2009a). Accordingly, alterations in the watershed can affect water quality of reservoirs (Mustapha, 2009a). Understanding the relationship between land use and water quality is helpful in identifying major threats of water bodies, helping to plan for effective water quality management by minimize pollution loads (Abler et al. 2002).

General introduction

1.1 Watershed landuse/land cover and surface water quality

Land use refers to humans' activities on the land, for example, recreation, wildlife habitat or agriculture, and is generally inferred based on the cover. It denotes the physical and biotic character of the land surface. Whereas land use land cover change represents the dynamic relations between human activities and the physical environment (Shi et al., 2010). Human activities affect not only the hydrological conditions, but also the ecological, and geochemical processes like change in the chemical composition of rocks and minerals (Wan et al., 2014).

Landscape constituents land use, which has a vital role in generating pollution (Giri and Qiu 2016). Land use change is critical environmental problem that can induce enhanced erosion and intensified sediment yields (Ramos-Scharron and Macdonald, 2007). It can have both positive and negative impacts on water resources (Namugize et al. 2018).The process of land use changes alter the surface characteristics of watersheds that affect the quality and quantity of runoff. A range of natural and anthropogenic factors alters farming systems, overgrazing, abstraction of water, and deforestation (Vandas et al 2002; Darghouth et al. 2008). For instance, agro food-processing industries and aquaculture practices were recognised as source of organic pollution in freshwater, altering nutrient load that can lead to eutrophication and ecosystem damage as a result of changes in watershed (Ongley 1996; Moss 2008). Therefore, deterioration of surface water resources is a function of internal and external interactions between ecosystem components, principally, land use changes (Mirhosseini et al 2018).

Water quality is a term used to describe the chemical, physical, and biological characteristics of water, usually with respect to its suitability for a particular purpose (Carr and Neary 2008). Water quality plays a central role in all aspects of living organisms on the earth, attracting the attention of a broad range of scientists, researchers, and water resource managers (Camara, et al. 2019), and it varies according to location, time, weather, and sources of pollution (Vörösmarty et al. 2005; Giri and Qiu 2016).

The effect of land use changes on water quality can be studied by evaluating relationships between water quality and land use indicators (Tu 2011). These relations have often been investigated with respect to measures of improving water quality (Meals et al., 2009; Volk et al., 2009). It is known, most often that, the higher land use types are related to higher concentrations of water pollution, whereas intact areas such as natural forest areas are related to good water qualities. Many studies have shown that there are significant correlations between land use and water quality indicators (Baker 2003; Buck et al. 2004; Li et al. 2008;

Tong and Chen 2002; Randhir and Hawes, 2012). Therefore, there is growing interest to sustain the structure and function of watersheds to improve their role in supporting human populations while simultaneously maintaining ecosystem needs

1.2 Watershed management and conservation

Watershed management is the application of a set of resource management practices with the aim of confirming water quality while sustaining the ecosystem (Tomer, 2004). Therefore, it is the combined use of resources like, water, vegetation and land, in a geographically separated drainage area for the benefit of inhabitants and in harmony with the environment (Gerd and Brigitta 2004). Watershed offers vital role in reducing undesirable downstream or groundwater influences. This integrated way of watershed management combines measures that improve or conserve the ecosystem services and functions in the watershed; increase land productivity and resource efficiency; and improve or diversify people's livelihoods and incomes (FAO 2017).

Watershed management and catchment scale studies have become increasingly more important in determining the impact of human development on water quality both within the watershed as well as in receiving waters (Sliva and Williams 2001). Watersheds can cover areas of any size, and attention must be paid to what is being described in any given setting (Kerr 2007). The management unit covering from micro-watershed (0.05-0.50 km^2) to basin (1,000-10,000 km^2) where the micro-watershed as the successful project intervention unit with participatory planning: best management practices (BMPs); and site design (Darghouth et al. 2008) whereas the basin inquire basin planning; stakeholder management; policy, legal framework and stakeholders incentives. In general, watershed management should rely on participation of the population in planning, utilization and monitoring stages, thus it can support building of democratic structures suitable for providing framework for the utilization of traditional social structures and traditional knowledge for development (Gerd and Brigitta 2004).

Watershed controls several mechanisms of functioning of lakes and reservoirs (Jørgensen et al. 2013), and its performance can be disturbed directly or indirectly due to different factors, soil erosion (Durga Rao and Kumar 2004), watershed slope, intensity of development (Goff and Gentry 2006), vegetation cover, landscape, vicinity to water courses and soil (Chowdary et al 2013). Numerous socio-economic pressures together with pollution and scarcity of water, land degradation are problems that encountered watersheds in tropical regions (Firdaus et al. 2014). Severe soil erosion mainly due to steep terrain, poor surface cover, intensive cultivation, population and livestock pressure is common problems experienced in Ethiopia (Admassu et al. 2008). The Gilgel Gibe watershed is one in East Africa, Ethiopia, affected by landslides and caused an estimated 1 million m^3 slope material displacement, which corresponds to a mean displaced volume of 50 ton/ ha/ year in the last 20 years (Broothaerts et al 2012).

1.3 Surface water resources in Africa

Freshwater is the most vital natural resource for human beings and required in abundance for drinking, agriculture, and all forms of socio-economic development (Awange et al. 2013). Of the global freshwater resources, Africa shares about 10 percent and the distribution of this resource is uneven. The continent suffers from unstable rainfall regimes in the world (Mwanza 2005). Africa has 17 rivers with catchment areas greater than 100 000 km^2, and also has more than 160 lakes larger than 27 km^2, most of which are located in the equatorial region and sub-humid East African Highlands within the Rift Valley (Mwanza 2005). Fourteen countries in Africa are already experiencing water stress; another eleven countries are expected to join them by 2025. Due to societal demand for diverse uses, nearly all the major African rivers have been dammed for the purpose of reservoirs (Mustapha 2011). Africa only had 18 reservoirs out of collected 71 waterbodies (Kolding and Van 2006). Most of African reservoirs are shallow usually filled up with water in the rainy season (Mustapha, 2009b), but they show reduction during the dry season as a result of evaporation, sedimentation and water extraction (Geraldes & Boavida, 2005; Mustapha, 2009a; Dalu et al. 2012).

Pollution of water resources is a great anxiety for countries depending on hydropower generation that require consistent water throughout wet and dry seasons because of the threats to both the environment as well as availability of freshwater (Odada, 2013). In Eastern Africa, studies of surface water indicated that surface water found among highly threatened ecosystem with various factors (Stave et al., 2003; Negussie et al., 2011; Degefu et al., 2013;; McLennan and Plumptre, 2012; Asfaha et al., 2016). Among the main threats to water quality in Africa today are resulting in eutrophication and proliferation of invasive aquatic plants (Mwanza 2005). These impacts will significantly deplete available resources, destruct aquatic life and increase water scarcity.

1.3.1 Surface water resources in Ethiopia

Surface water accommodates a broad spectrum of different life forms, which additionally provides a broad variety of valuable goods and services to human beings (Dudgeon et al., 2006). However, human activities have been increasingly threatening ecosystems, directly and indirectly (Kensa, 2012), because surface water ecosystems change with increasing levels of human development. Consequently, accelerated pollution and eutrophication of surface water due to human activities are common phenomenon (Melaku et al., 2007).

Ethiopia is located between latitudes of 3.8°N to 14.5°N and longitudes of 33°E to 48°E with an area of about 1.12 million km^2. The varied topography of the country shows extreme changes in altitude with its lowest point at about 120 meters below sea level (Kobat Sink Afar depression) and its highest point about 4620 meters above sea level (Ras Dashen) (ENMA 2014). Ethiopia is endowed with substantial amounts of water resources and considered as 'Water Tower of East Africa' but no rivers flow into Ethiopia from neighbouring countries (Negash 2012). From rivers originated from Ethiopia, only 3% remains within the country, whereas the rest 97% is lost in runoff to the lowlands of neighbouring countries (Table 1.1) (UNESCO 2004).

Ethiopia has 12 river basins (Fig. 1.1) with estimated surface water resource potential of 123 bm^3 (Baro Akobo, Abbay, Tekeze and Omo Ghibe contribute 80% - 90%) (MoWIE 2013; FAO 2016). The river basins form four major drainage systems are:

1) The **Nile basin** (including **Abbay** or **Blue Nile**, **Baro-Akobo**, **Setit-Tekeze/Atbara** and **Mereb**) covers 33% of the country and drains the northern and central parts westwards
2) The **Rift Valley** (including **Awash**, **Denakil**, **Omo-Gibe** and **Central Lakes**) covers 28% of the country and consists of a group of independent interior basins extending from Djibouti in the north to the United Republic of Tanzania in the south, with nearly half of its total area being located in Ethiopia
3) The **Shebelli-Juba** basin (including **Wabi-Shebelle** and **Genale-Dawa**) covers 33% of the country and drains the southeastern mountains towards Somalia and the Indian Ocean
4) The **North-East** Coast (including the **Ogaden** and Gulf of Aden basins) covers 6% of the country.

The distribution of Ethiopia's water resources is characterised by very high spatial and temporal variability. In fact, it is believed to support the wealth of flora and fauna including many endemic plant and animal species (Getahun and Melanie, 1998; IBC, 2009). It is considered as important hotspot area for biodiversity conservation (Bezabih and Mosissa, 2017) that can provide great national and international importance (IBC, 2009; Friis et al., 2010). The western part of Ethiopia with the largest water endowment (roughly 85% of country's water) includes the four basins: Abbay (Blue Nile), Baro–Akobo (Sobat), Omo–Ghibe and Tekeze (Atbara), which is also with relatively high rainfall. The remaining eight basins in the central and eastern parts of the country face water shortages (Negash 2012).

As mentioned in Table 1.1, eight (8) of which are river basins; one (1) lake basin; and remaining three (3) are dry basins, with no or insignificant flow out of the drainage system (Birhanu et al. 2014). Despite these resources, droughts and floods are common water resource challenges, with significant events every 3–5 years in Ethiopia. Drought contributes to land degradation and causes crops to fail and livestock to perish (World Bank 2006). Rainfall is generally erratic and irregular, the fluctuation of the rainfall is closely related to the occurrence of the El Niño Southern Oscillation (ENSO) that occurs on a 2–7 year cycles. Physiographic variations create a large difference in meteorological and hydrological condition both by time and space (ENMA 2014). This spatial and temporal variability of water resources restricts development, poses important management challenges, and tilts distribution (Pascual-Ferrer et al. 2014). Ecosystems are suffering due to intensified influences caused by broad range of anthropogenic activities (Gebrehaweria et al., 2016). Water resource availability and demand is also affected by increasing population towns and rural areas, resulting in substantial natural and socio-economic changes (Desta, 2005; MOWIE 2013; Mosello, et al. 2015).

The complex and variable aquatic systems need appropriate assessment for the sustainable water resources development. Assessing and understanding the interactions among physical habitat features, water chemistry, their biota and riparian ecosystem are essential to the conservation of surface water ecosystem (Bonanno and Giudice, 2010; Cockburn et al., 2016). Moreover, water resource management from the local to global scale needs reliable information of surface water quality to offer proper attention in conservation development (Aguiar et al., 2009; Darwall et al., 2011).

Table 1.1 Physical characteristics, flow direction and terminal of major river and lake basins of Ethiopia

No	Basin name	Type	Source	Altitude at source (masl)	Terminal	Altitude at terminal/border (masl)	Flow direction	Area (km^2)	Water Resource	
									Billion m^3	Lt/sec/km^2
1	Abbay	R	Sekela, West Gojam	2,000	Sudan border	500	West (Nile)	199,912	54.40	8.63
2	Awash	R	Ginchi	3,000	Terminal lakes	250	Northeast	110,000	4.90	1.41
3	Aysha	D	–	–	Djibouti border	400	No flow	2,223	0.00	0.00
4	Baro - Akobo	R	Illubabor	3,000	Sudan border	395	West (Nile)	75,912	23.23	9.70
5	Dinakle	D	–	–	Kobar sink	160	No flow	64,380	0.86	0.42
6	Genale - Dawa	R	Bale Mountains	4,300	Somali border	180	East	172,259	6.00	1.10
7	Mereb	R	Zalanbessa	2,500	Eritrean border	900	West (Nile)	77,120	0.72	3.87
8	Ogaden	D	–	–	Somali border	400	No Flow	79,000	0.00	0.00
9	Omo-Gibe	R	Ambo	2,800	Rudolph lake	350	South (Nile)	52,000	16.6	6.66
10	Rift valley lakes	L	Arsi Mountains	4,193	Sudanese border	550	South	5,900	5.64	3.44
11	Tekeze	R	Lasta/Gidan	3,500	Chew Bahir	300	West (Nile)	82,350	8.20	3.16
12	Wabisheble	R	Bale	4,000	Somali border	200	East	202,220	3.40	0.53

R=river basin, L=lake basin, D=dry basin

Source: Negash, 2012

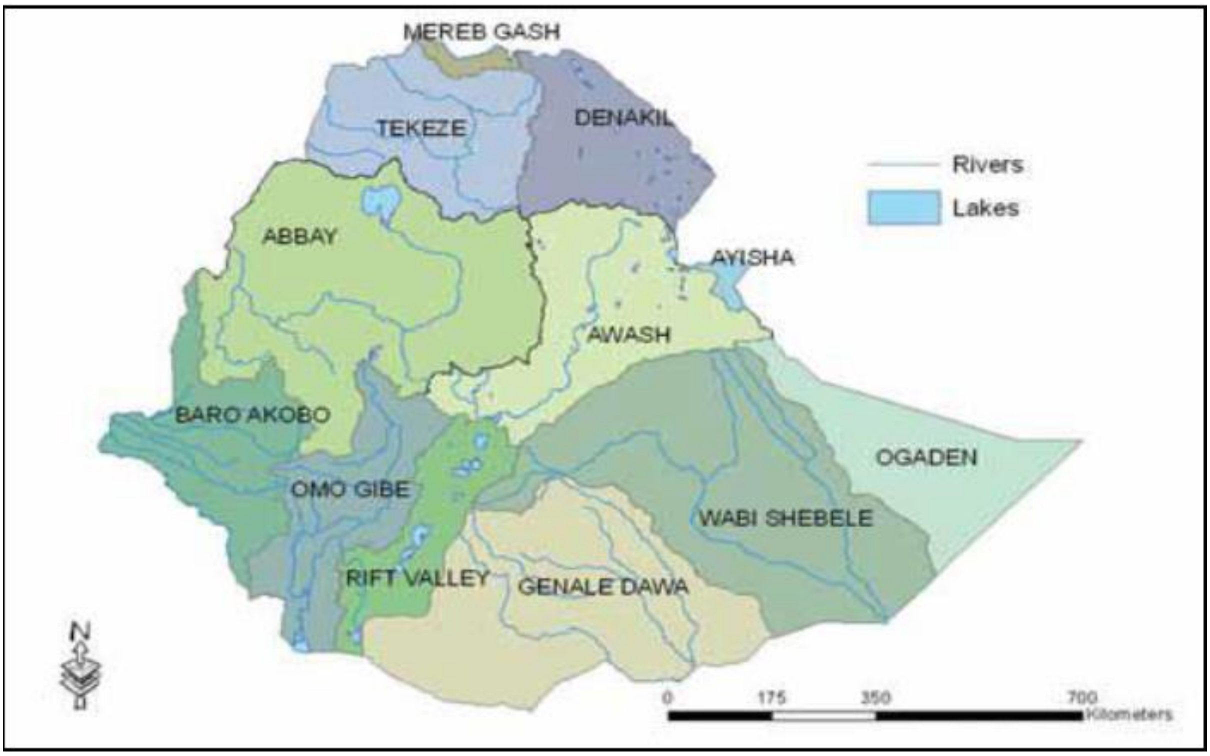

Figure 1.1 River basins of Ethiopia

Source: Negash, 2012

1.4 Reservoir ecology

Reservoir has different fundamental boundaries (air/surface-water, sediment-water, and organism-water interface). The interactions of substances and elements between boundaries characterize the daily and seasonal cycles of physical, chemical, and biological events in aquatic ecosystems (Carr and Neary 2008; Jørgensen et al. 2013). Reservoirs have several important biological communities that interact in food webs, and are considered as an intermediate between a river and a lake. Consequently, limnological characteristics of this hybrid system have great interest to ecologists and researchers because the different zones of the reservoir showed different unique features in its physicochemical and biological characteristics (Banerjee et al. 2017). Though, in many cases, reservoirs have provided profits for a range of beneficiaries, at the same time, they have negative effect on people and the environment (Bergkamp et al 2000). For example, as water is blocked, it affects downstream life by reducing water quality, land becomes less fertile, reduce biodiversity and cause extinction hence both people and ecosystem would be impaired (Manatunge et al., 2008).

1.4.1 Functions of reservoirs

Reservoirs are constructed and operated to meet human needs in the generation of energy, irrigatation, flood control, and supply of drinking water (Bergkamp et al. 2000). Various other purposes includes ecological balance prevention and local recreation centers (Nestmann & Stelzer 2007). In addition, aquatic biodiversity and fishing are often regarded as secondary uses (Gunkel et al., 2015). Worldwide, 20% of cultivated land is via irrigatation, accounting 75% of world water consumption that produce 33% of the food supply. The other basic function of a reservoir is to provide detention of flood runoff (Nestmann & Stelzer 2007).

Globally, hydropower generation attributable to hydroelectric schemes estimated to be 20% and about 35,000 large reservoirs worldwide are used for these purposes (White, 2010). The main source of renewable energy contributes about 85% of global renewable electricity (Lessa et al., 2015). It is estimated that global demand for energy will increase by 30% in the year 2040, requiring a boost in global power production (IEA 2016). Tropical reservoirs are very important for hydropower, flow regulation and inundation control (Gunkel et al., 2015). Particularly, in developing countries where poverty is in place and low cost food production is required, reservoirs are suitable places for fish production as an alternative livelihood (Kaggwa et al 2011).

Many reservoirs failed to perform their designed functions because much of their original active storage volumes have been filled by sediments (Ijam and AI-Mahamid 2012). Ethiopia has a vast hydropower potential, estimated to be about 30,000 MW with a total potential of 159 TWh/year and undertaking massive hydropower development activities in different river systems (Tufa 2013).

Dams have traditionally ensured availability of water for human supply and irrigation in periods of scarce rainfall and river flow declines (IHA 2013; Polimon 2015), roughly 30% to 40% of irrigated areas world-wide (271 million hectares) obtain their water from reservoirs (Nestmann & Stelzer 2007). They may generate revenue from export earnings from direct sales of electric power, cash crops and are a vital part of the economy of many nations (Cooke et al., 2005). Rural populations often depend on reservoirs for domestic and livestock water supplies. Besides, reservoirs are an important system that supplies fisheries that contribute significant to their economies for the riparian communities (Tundisi and Tundisi 2011; Akongyuure et al., 2017).

1.4.2 Major threats of reservoirs in Ethiopia

Worldwide loss of storage capacity in surface water reservoirs due to sedimentation is higher than the increase in storage volume achieved through construction of new reservoirs with estimated 0.5 % and 1% per year (White, 2010). Sediments from agricultural sources that are trapped behind world's dams account for approximately 50 billion tons every year (McCartney, et al., 2000). Every year, there is loss of significant portion of storage capacities in formerly created reservoirs owing to sedimentation, in reservoirs of Ethiopian. Reservoir capacities were observed being filled with sediment less than five years (Siyam et al., 2005; Haregeweyn, et al., 2012; Tufa 2013). Understanding the physico-chemical characteristics is helpful to determine the healthy status of any aquatic ecosystem (Venkatesharaju et al., 2010). For example, assessment of suspended sediment plays a significant part of water quality degradation in transporting organic and inorganic elements from land to the aquatic system and a good indicator of pollution (Laubel 2004). Reservoir sedimentation is a severe problem caused due to soil erosion occurs in the catchment areas of the reservoirs (Ninija Merina et al., 2016). A study from sedimentation of nine reservoirs in the Amhara Region showed reduction of 7 ha of irrigable land on average from 1997 – 2018 per year. This implies about 1.887 MCM sediment will be accumulated in all reservoirs displacing equal volumes of irrigation water (Genet 2013).

1.4.3 Seasonal and spatial variability of water quality

Pollution of surface water with toxic chemicals including rivers and lakes are of great environmental concern worldwide (Ouyang et al 2006). The spatial difference in water quality can also be influenced with point and non-point sources of pollutants (Anderson 2002). Most pollutants are persistent and non-biodegradable that can harm the environment for longer times (Cooke et al., 2005). Because of natural factors like climate and topography, spatial and seasonal variations of inflowing river water and hydraulic residence time are regularly influenced the physicochemical properties of surface water (Gikas 2009; Bogdał et al., 2016; Liu et al., 2016). The seasonal pattern of surface water quality features, especially nutrients and suspended solids, are linked to the seasonality of agricultural production (Poudel et al., 2013) which may release residues of organic and inorganic compounds through storm water runoff. Seasonal changes of surface water quality are used to understand temporal variations of pollution caused by natural or anthropogenic inputs from point and non-point sources

(Ouyang et al., 2006; Fan et al., 2012). Therefore, understanding of water quality variations and their driving factors is a critical topic for water quality management (Li et al., 2016).

1.5 Statement of the problem

The construction of dam for hydropower (electricity), irrigation, domestic water supply and flood control is not a recent practice (Bird and Wallace, 2001). Gilgel Gibe I Reservoir is among the reservoirs that provide multiple functions in Ethiopia. Reconnaissance survey of this study has initiated this work due to the various anthropogenic activities (farming inside the buffer zone), the location of tributaries in relation to land use characterstics and natural factors (steep slopes) occurring in the area. Seasonality in connection with spatial variability has effect in its water quality. Assessing water quality parameters associated with spatiotemporal change is a major concern to avoid impairment of water body. Differet events like erosion, landslides etc are frequently occurred due to land use land cover change in the watershed.

In the study area, the land use/land cover changes due to agricultural activity and settlement associated with landslide leave the soil vulnerable to erosion, aggravating non-point source pollutants. Once erosion occured, the sediment tsarted to move down joining the tributaries, ending up with sediment accumulation to the reservoir due to the very low velocity in reservoirs (Ninija Merina et al., 2016). Gilgel Gibe I has also challenged with similar problems, water quality degradation and complete disappearance of the water body. Sedimentation consumes the reservoir volume, which is designed to carry water and later requires high amount of cost to solve this problem. According to World Commission on Dams (2000), if no preventive measures are taken, one quarter of all dams would lose their storage due to sedimentation in the next 25 to 50 years. With several combined factors, freshwater is expected to become the most limiting resource in many parts of the world in the near future (Gleick, 2000).

Watershed management is effective for mitigating erosion on slopy lands, stabilizing landscapes, providing clean water, stabilizing and improving agrarian production systems. In addition, its sustainability is affected by the inhabitants' knowledge, attitude and practice. The process of management needs involvement of residents for wise utilization and conservation of resource for their benefit. Therefore, the impairment of reservoir and tributaries water quality calls for the active involvement of farmers' in watershed.

Previous studies in the study area did not address the afromentioned challenges as well as the link of spatial and temporal variability of land use change characteristics in catchments with the water quality parameters of reservoir and tributaries are limited (Broothaerts et al. 2012;

Van Daele 2011; Ambelu et al.2013; Mertens 2014; Takala 2016 and Legese 2018). Importance of Gilgel Gibe I reservoir and its tributaries water quality, as fresh water resources, was not assessed. Therefore, due to the above mentioned research problems, assessment of water quality and management practices are necessary to be evaluated.

1.7 Conceptual framework of the study

The conceptual framework of this study precisely describes the possible factors that should be considered for the sustainable aquatic ecosystem functioning. These features include natural (climate change) and human effect (landuse change, deforestation etc.) parameters. Watershed ecosystem plays vital role in improving water quality and aquatic biodiversity in cases when well managed. If watershed management practices are not well managed, water quality and quantity of freshwater resources (reservoir, river water etc.), will be significantly influenced. This urgently demands alleviation of the problems through inspection of spatiotemporal water quality, assessing land use classes in relation to water quality. Fig. 1.2 entails the detail schematic feature of conceptual framework. The outcome of water quality provides clues the way for watershed planning and management in order to protect the resources for future.

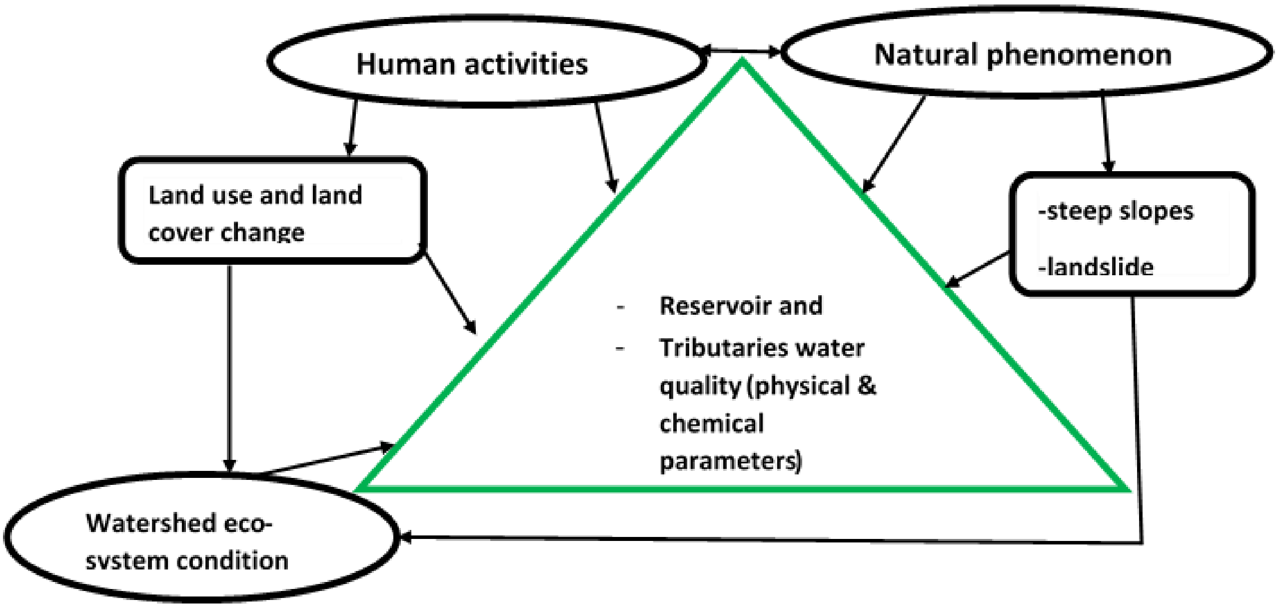

Figure 1. 2 Schematic presentation of the conceptual framework of the thesis

1.8 Significance of the study

This work is important in providing overall picture and baseline data with regard to spatial and temporal variations in water qualities of Gilgel Gibe Reservoir and its tributaries in relation to the effect of watershed land use. This also have implication for the management practices, farmers' knowledge, attitude and practices in conserving the watershed. The examination of water quality parameters will be used to forward monitoring and mitigation strategies for planners and natural resource managers in order to propose suitable measures for sustainable management. In addition, stakeholders' including the local community may get awareness about the devastating effects of anthropogenic activities on surface water. The study also fill some research gaps associated with the influences and characteristics of catchment in relation to the spatial and temporal limnological aspects of water quality which are not considered by earlier investigators in and around the Gilgel Gibe I Reservoir. It is also important for undertaking similar researches in other surface waters in other similar aquatic systems. The output of this study is used to recommend the appropriate prevention and conservation options and / or methods for reservoir water quality and watersheds in Ethiopia.

1.9 Objective of the study

1.9.1 General objective

The main objective of the study is to investigate water quality parameters and effect of watershed management practices on Gilgel Gibe I Reservoir.

1.9.2 Specific objectives

To assess the spatiotemporal change of physicochemical water quality parameters within the Gilgel Gibe I Reservoir.

To evaluate the vertical variability of reservoir water quality and trophic state

To categorize the different land uses classes and estimate their spatial and temporal influence on the tributary water quality.

1.10 Research hypothesis

The main research hypothesis includes

- Watershed land use and land cover change causes degradation of tributaries water quality
- Spatial and seasonal variability affect the reservoir water quality

These changes are likely to have a negative impact not only for the water quality of the reservoir and tributaries but also affect the whole life dependent on it. The output (information) can help to promote protection and improvement of the entire ecosystem of the Gilgel Gibe watershed ecosystem.

2

2. SEASONAL AND SPATIAL VARIATION IN WATER QUALITY OF GILGELGIBE I RESERVOIR

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2.1 INTRODUCTION

Reservoirs are artificial water bodies that have economic and ecological importance (Wetzel 2001). They play a pivotal role in freshwater resource accessibility in many regions throughout the world. Although many reservoirs were initially constructed with a single purpose (e.g., production of hydroelectric power), they commonly evolve towards provision of a multitude of services (Jorgensen et al. 2005). Reservoirs provide important ecological services (Atobatele and Ugwumba 2008), serving as rich ecological habitats (Menetrey et al. 2005) and hotspots of biodiversity, supporting abundant as well as unique and rare species (Williams 2003). Furthermore, reservoirs have diverse social and economic values like water management and serve as a source or sink for heat, sediments, and solutes that can cause severe effects far downstream from the dam (Wetzel 2001). Similarly, in Ethiopia, reservoirs often provide rural communities with an important source of dietary protein, consumable water for people and domesticated animals, irrigation water for horticulture, and income from fishing and eco-tourism (FAO 2008; Ndebele-Murisa et al. 2010).

Ethiopia, like many countries experiencing development, is undertaking large dam construction projects, primarily for the purpose of electric power generation and integrated irrigation development. The reservoirs are an important component of infrastructure expansion, as a part of a movement to improve quality of life for people in the region. Ethiopia has 12 major river basins, 12 large lakes (Berhanu et al. 2014) and numerous smaller ponds, lakes, rivers, reservoirs and wetlands, particularly in the central, western and south western parts of the country (Awulachew et al. 2007; Tessema et al. 2014). The major lakes and reservoirs cover 7,334 km^2 and 275 km^2 respectively (FAO 2003), and are distributed throughout the country.

Reservoirs are vulnerable to water quality deterioration, because of the nature of their formation by damming of rivers to contain and accumulate surface water and the associated particulate and dissolved chemicals. Tropical reservoirs in regions undergoing economic development are particularly vulnerable, because increasing human activities in the reservoir’s watershed can lead to nutrient loading and eutrophication (Chapman 1996).

In Ethiopia for example, rapidly increasing population levels and subsequent landuse changes (e.g., deforestation, agriculture) within a given watershed can result in degradation of reservoir water quality (Ebisa 2010). High sediment loads as well as chemicals and nutrients in runoff from agricultural land, manufacturing and other related sources have been observed impacting

Ethiopian reservoirs (Wolancho 2012). As a consequence, physical and chemical water quality degradation is among the most prevalent problems in Ethiopia (UNESCO 2004), and watershed activities may limit the ability of a given reservoir to deliver its effective functions (Mustapha 2009a).

The Gilgel Gibe I Reservoiris one of the five major reservoirs in Ethiopia. Beside its primary purpose which is power generation, this 54 km^2 reservoir now provides food (fish) and a source of income, acts as a research and educational area, a source of water for the local residents, and a source of water for cattle during the dry season. In order to maintain the multiple uses of the reservoir, not only water availability, but water quality has taken on high importance. Water quality has become a topic of concern due to the many diverse uses of the reservoir (Chapman 1996; Jorgensen et al. 2005), particularly as actual and potential sources of food. Thus it is a logical choice for a case study due to its economic and ecological significance and its vulnerability to pollution.

Reliable information on water quality is imperative to manage reservoirs sustainably, and to prevent and control water pollution. Because of its importance to the local community and its role as water source for Gilgel Gibe II and III hydroelectric power stations, Gilgel Gibe I Reservoir is a clear candidate for water quality research to inform natural resource managers and policy makers. Yet, currently there is little known about the spatial and seasonal water physicochemical quality characteristics in the reservoir. Although case studies have been conducted in the reservoir (Devi et al. 2008; Yewhalaw et al. 2009; Broothaerts et al.2012; Ambelu et al. 2013), they have been limited in time and space, covering only the dry season and ignoring within-reservoir spatial variation, which may be important. Spatial and temporal variation in water quality is to be expected due to variation in edaphic factors, climatic conditions, source of water, land use type, seasonal hydrology, and density of fish stock (Aladesanmi et al. 2014).

This spatio-temporal variation is known to be important for biological diversity and for the provision of resources from aquatic ecosystems (Venkatesharaju et al. 2010). Filling this knowledge gap will help regulate the health of this aquatic ecosystem, will support sustainable and economically beneficial use of resources by the local community (Makhlough 2008), and will inform management strategies for other similar reservoirs.

The goal of this study is to assess the spatio-temporal variation of physicochemical water quality parameters within the Gilgel Gibe I Reservoir. And hypothesizing that during the dry season when the input of water is low, most water quality chemical parameters would have higher concentrations (as compared to the wet season) due to resuspension, absence of dilution, and increased evaporation. We also hypothesized that water quality would vary spatially throughout the reservoir, with the highest concentrations of terrestrially derived pollutants (like TN and TP) found near the mouths of the largest tributaries, which serve as the main sources.

2.2 MATERIALS AND METHODS

2.2.1 Study area

The selection of the study area was based on its importance for power generation, its economic importance to the local community, and its accessibility. The reservoir was built on the Gilgel Gibe River in 1998, with a primary purpose of hydroelectric power production. The reservoir is characterized by a large 40m high dam, with a storage capacity of 839 Mm^3 covering more than 54 km^2 of land at its full supply level and with a conveyance system of tunnels and an underground power house consisting of three 61.3 MW generating units (EEPCO 2011). The site began operation in 2004 and is currently generating 184MW at its full capacity, with annual average flow of 50.4 m^3/s, reservoir live storage of 657 million m^3, and reservoir dead storage of 182 million m^3. The reservoir receives water from the surrounding tributaries, namely the Nadaguda, Nedi, Yedi and Gilgel Gibe rivers. The total catchment area is 4,225 km^2, and the watershed is highly agricultural, serving as an important food source for the region (Wakjira et al. 2016).

The Gilgel Gibe I Reservoir is situated in the Gibe - Omo River Basin in Oromiya regional state of Jimma zone, 260 km southwest of Addis Ababa (Fig.2.1). The climate of the study area is classified as tropical humid and belongs to the high altitude cool tropic area of the country. There is unimodal pattern of seasonal rainfall distribution where up to 60% of the rainfall falling during the rainy season (Demissie et al. 2013). According to unpublished data of Ethiopian National Meteorological Agency, from the year 1968 - 2015 the average annual rainfall in Jimma stations was 243mm and minimum (43mm) recorded in August and December, respectively. The maximum mean monthly rainfall (287mm) was occurred during June. In terms of the rainfall variability of the country by river basins, the West-flowing rivers (Abay, Baro-Akobo, Omo-Gibe, and Tekeze) receive much rainfall (Berhanu et al. 2014).

Based on Ethiopian National Meteorological Agency, from the year 2005/6 – 2014/15 the minimum reservoir water level was 1654 m.a.s.l and the maximum was 1671.2 m.a.s.l., with maximum and minimum depths of 35m and 2m, respectively, and an average depth of 20m.

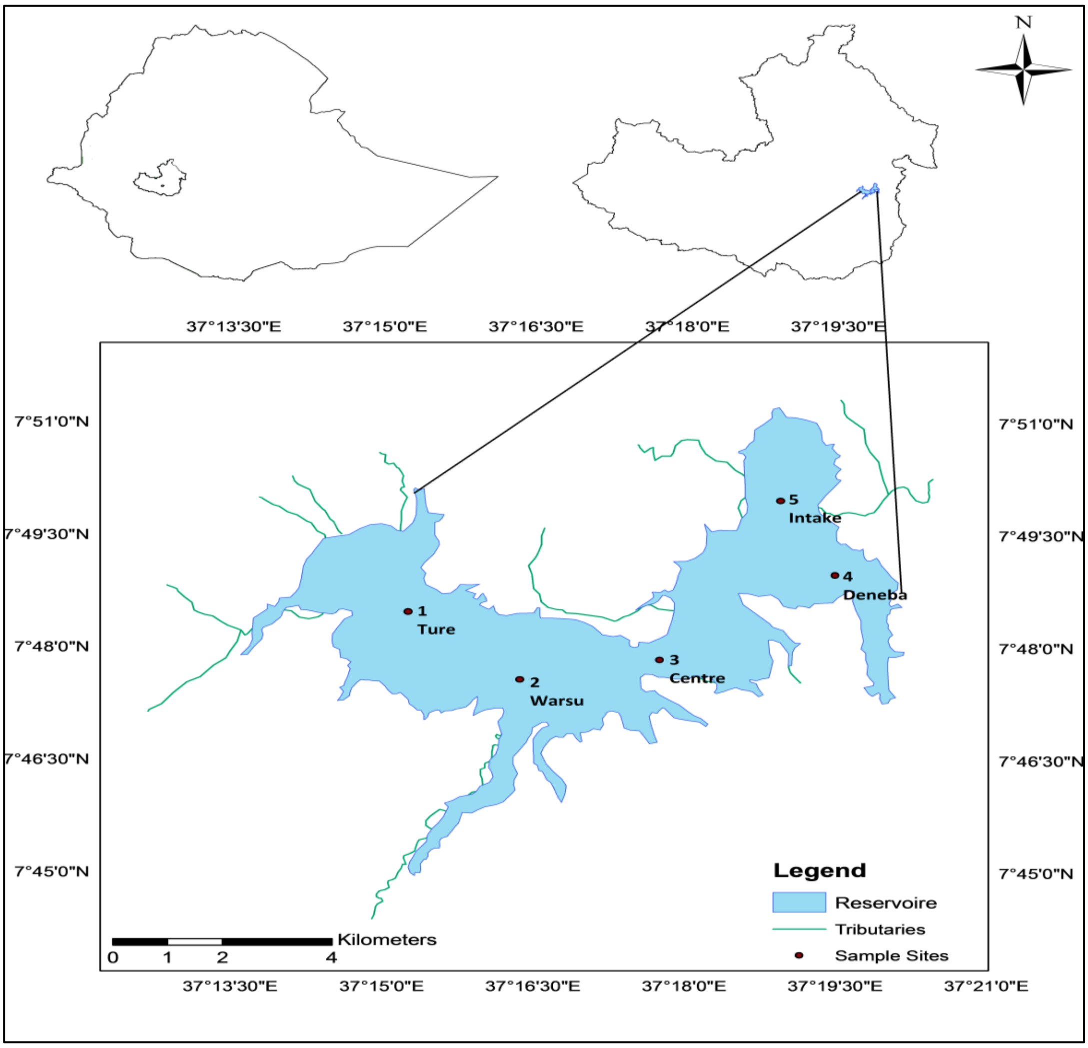

Fig. 2.1 Location of spatial sampling stations in the Gilgel Gibe I Reservoir

2.2.1.1 Hydrological condition

Climate change undeniably have clear effect on ecosystems, biodiversity and human systems throughout the world (Kotir 2011) and expected to affect rains, increase the frequency of droughts, and raise average temperatures, threatening the availability of fresh water (Alcadi et al. 2009). The temporal variations and changes of natural factors such as meteorological and hydrological conditions, which are usually beyond human control, also induce variations and changes in water quality (Rostami and Hassan 2018).

Temperature and precipitation are among factors that contribute to the variability of aquatic ecosystems by affecting the water quality parameters, increases nutrient load and impaired the life of aquatic biota. Their variability is the very important side influencing on climate variability and extremes (Fahad et al., 2015) and examination on air temperature and precipitation behavior is vital for short-term planning and the prediction of future climate conditions (Bhuyan et al., 2018).

Meteorological data on air temperature, rainfall and reservoir water level of the study area were collected from Sokoru Meteorological station. Temperature and precipitation data for the study area were analysed from 2000 – 2014 and the water level data of the reservoir was analysed from 2004/5 to 2016/17.

2.2.1.2 Temperature (Minimum and Maximum)

The monthly mean temperatures ranged from a minimum of 12.3 ^{O}C during December to a maximum of 29.2^{O}C in February which was the peak monthly temperature and the higher temperature occurred between January and April (Table 2.1). The minimum yearly mean air temperature was 12.61 ^{O}C in 2000 and the maximum was 27.27 ^{O}C during the period of 2012 (Table 2.2) with difference of 14.66 ^{O}C. Pairwise multiple comparisons (Tukey test) procedure using One Way Analysis of Variance for minimum temperature values showed that there was a statistically significant difference ($P < 0.05$).

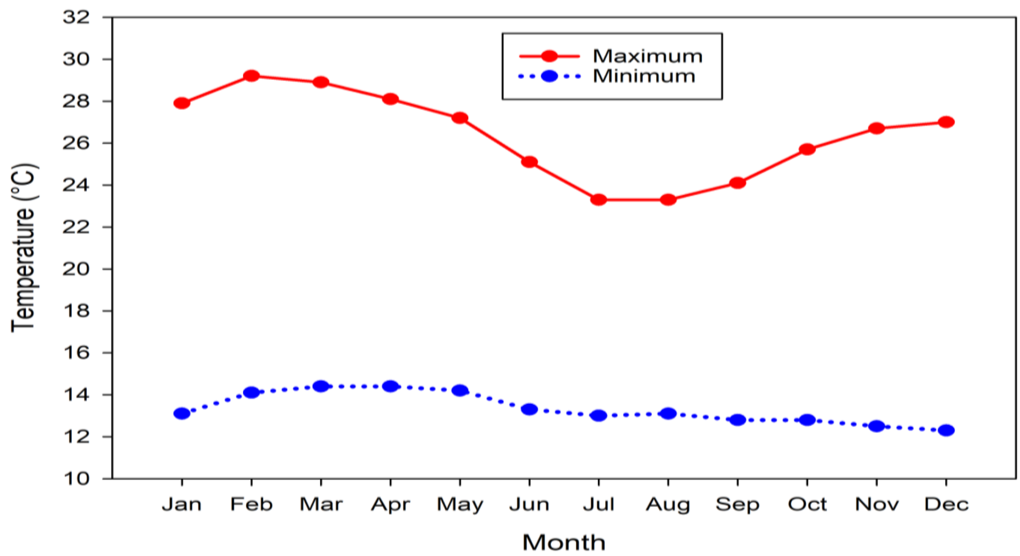

Fig. 2.2 mean of minimum and maximum monthly temperature during 2000 – 2014 (Sokoru Meteorological station)

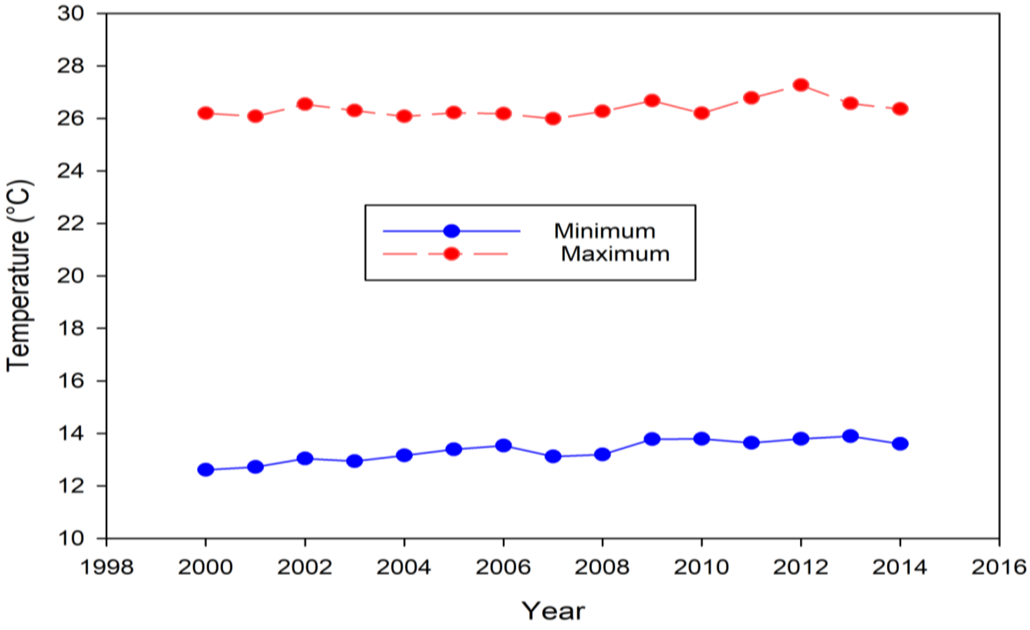

Figure 2.2 Mean of minimum and maximum annual air temperature variations in the Gilgel Gibe watershed (2000-2014) (Sokoru Meteorological station)

The graph for the air temperature (Fig. 2.2) scenario for both minimum and maximum temperature are likely to be inconsistent from the year 2000 – 2014, but there was an increment when we observe the data for most of the year.

2.2.1.3 Reservoir water level

The yearly distribution of the water level of the reservoir is also described in (Fig. 2.3) fluctuating throughout the year. The reservoir had lowest water level during 2008/9. Except the years documented high water level (2006/7, 2011/12 and 2016/17), most of the rest lowest water level swing between 1661.85 and 1665.001 m.a.s.l.

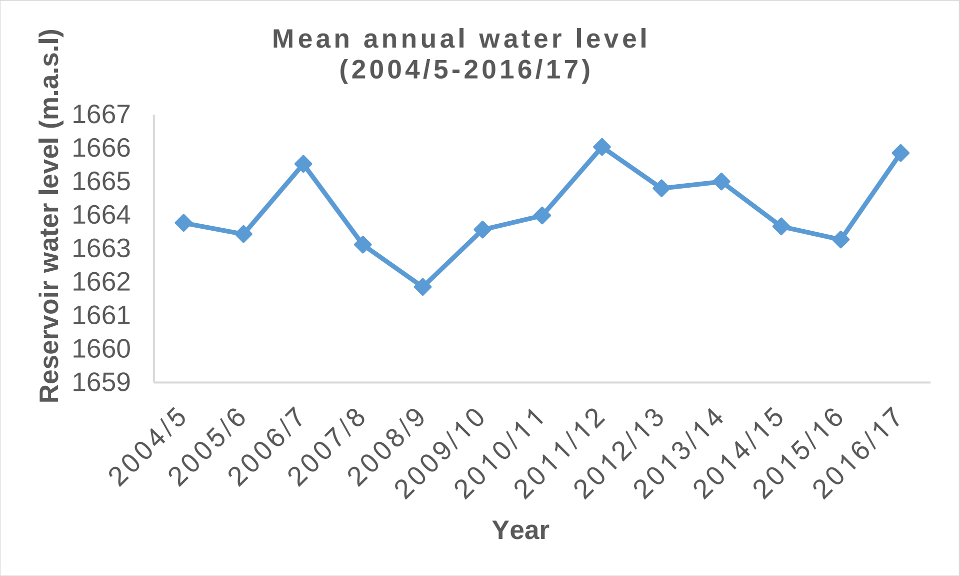

Figure 2.3 Mean annual water level measurement of Gilgel Gibe I Reservoir from year 2004/5 to 2016/17 (Sokoru Meteorological station)

2.2.1.4 Precipitation

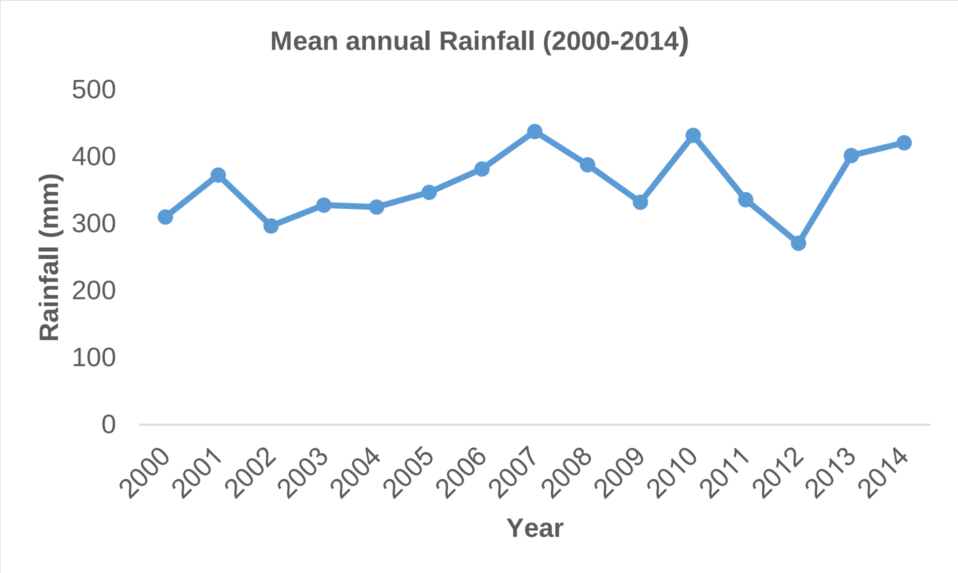

Figure 2.4 Mean annual rainfall in the Gilgel Gibe catchment from year 2000 to 2014 (Sokoru Meteorological station)

Fig.2.4 showed the fluctuation of the value of annual rainfall showed variability throughout the year. Relatively a very low rainfall value was observed in 2012, increased during 2007, 2010, 2013 and 2014.

2.2.2 Sample collection

Five sampling sites (stations) were identified (Ture (St. 1), Warsu (St. 2), Centre (St. 3), Deneba (St. 4) and Intake (St. 5). Sample site determination was made on the relative proximity of the pelagic zone towards the tributaries; hence St. 1, St. 2, St.4 and St.5 sites were comparatively near to Gibe, Nadaguda, Yedi and Nedhi river inflows while the sampling site St.3 was chosen as an approximately central point. Samples were taken from 11/18/14 to 11/26/14 and from 03/21/15 to 03/28/15 representing wet season and dry seasons.

During each season fifteen water samples for laboratory analysis (three from each location) were taken from different sampling sites of the reservoir using a Van Dorn Sampler, and collected in clean 250 ml polyethylene bottles after pre-rinsing with sample water. All samples were collected in cold boxes and transported to the laboratory. For analysis of Nitrate, total suspended solids (TSS) and total dissolved solids (TDS) samples were filtered by What-man filter paper with a pore size of 0.45 microns using the standard method (APHA 1999).

2.2.3 Water quality analyses

Twelve physicochemical water quality parameters were analyzed on-site and in the laboratory. Onsite measurement of Temperature, pH, Conductivity, and dissolved oxygen was done using a HACH, HQ40d portable multi-meter, and Turbidity was measured using Wag tech turbidity meter with a model number of wag-WT 3020. Other physicochemical parameters including five-day biochemical oxygen demand (BOD_5), TSS, total nitrogen (TN), TDS, only nitrate (NO_3^-), total phosphorus (TP), and soluble reactive phosphorus (SRP) were investigated in the laboratory of Environmental health science and technology at Jimma University after the samples have been refrigerated at 4°C for 24 hours. The average values of water quality parameters were calculated for analysis in this study (Gu et al., 2016).

BOD_5 was the difference between the concentration of dissolved oxygen (DO) in water sample taken instantaneously and concentration of DO from water sample that has been incubated for 5 days at 20OC in the dark. TSS and TDS were determined using the gravimetric method (APHA 1999). For TSS water samples are filtered through a pre-weighed glass fiber filter paper (whatman 0.45µm pore size), and are placed into a 105°C drying oven to remove any remaining water, then removed from the oven and placed in a desiccator to cool to room temperature and the difference in weight is calculated as TSS. For TDS the filtrate was evaporated to dryness in a pre-weighed dish and dried to a constant weight at 180 °C. The increase in the weight of the dish after drying represents the total dissolved solids.

TP was analyzed by the Ascorbic acid method with direct reading on a spectrophotometer following persulfate oxidation (APHA 1999). In this method water sample undergo a digestion process to convert combined phosphate in to orthophosphate which then reacts with ammonium molybdate and potassium antimonyl tartrate in an acid medium to form a heteropoly acid - phosphomolybdic acid this reaction can be reduced by ascorbic acid to form highly coloured molybdenum blue (APHA 1999). Nitrate was analysed using a kit LCK 138 that covers a concentration range of 1-16 mg/ L. Inorganically and organically bounded nitrogen compounds were oxidized to nitrate by processing with peroxo disulphate, and finally determined by reading on a spectrophotometer.

2.2.4 Statistical methods

Concentration differences for each water quality variable between the wet and dry season were examined using the Mann - Whitney U test, and differences among sites were examined using one-way ANOVA, both at a significance level of $p< 0.05$. Spearman rank-order correlations (Spearman R coefficient) were used to study the correlation structure between variables as datasets had a non-normal distribution of water quality parameters. The boxplot analysis was used to assess temporal variability in water quality parameters concentrations based on the median, minimum, maximum, and 25th and 75th percentile values (Dou et al. 2016). The reservoir water quality variables were also subjected to multivariate statistical techniques using Principal components analysis (PCA), which is one of the most commonly used multivariate statistical techniques (Quinn and Keough 2002). Data analyses were performed with PAST, Statistica 8 software and SPSS version 20.

2.3 RESULTS

2.3.1 Spatial and seasonal water quality variation

The physicochemical parameters under study are given in Table 2.3 (wet season) and Table 2.4 (dry season). The concentrations of EC, pH, BOD_5, TP, TN, NO_3^-, TDS and TSS were significantly different among seasons (Mann-Whitney U test, $p < 0.01$), while other parameters remained the same during the dry and wet season.

Spatial descriptive statistics result of the analyzed parameters showed significant changes among sampling sites indicating spatial variability of chemical composition in wet season (Table 2.3) and dry season (Table 2.4).

2.3.2 Water temperature

Water temperature varied from 22.2°C to 22.87°C in the wet season and 22.49°C to 25°C in the dry season (Table 2.3 and 2.4) with higher temperatures in the dry season (Fig. 2.2). Spatially, the concentration was highest at St. two sampling site for both wet and dry seasons (Tables 2.3 and 2.4). The temperature during the study period was within the range of 20 ^{0}C – 30 ^{0}C (Table 2.3and 2.4), which is suitable to sustain warm-water aquatic life.

Table 2.3 The median values of water quality parameters among five sites at Gilgel Gibe I Reservoir during the Wet Season (11/18/14 to 11/26/14)

	St. 1		St. 2		St. 3		St. 4		St. 5	
WQ parameters	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
DO	5.28[a]	4.8-5.7	3.94[a]	1.9-4.9	3.85[a]	2.1-6.2	4.38[a]	2.9-5.6	4.58[a]	2.2-7.3
EC	80.27[a]	79.8-80.9	87.1[b]	83.7-91	83.2[ab]	81.5-85.6	80.27[a]	79.8-80.9	81[a]	79.5-82.6
WT	22.8[a]	22-24	22.87[a]	21.9-24	22.8[a]	22-24	22.8[a]	22-24	22.2[a]	21.6-23
pH	6.46[a]	6.3-6.6	6.72[a]	6.5-6.9	6.8[a]	6.5-7.3	6.46[a]	6.3-6.6	7.05[a]	6.5-7.8
BOD_5	17[a]	16-18	21.79[a]	19.3-25	21.8[a]	18.6-25	15.78[a]	1.5-23	24.75[a]	21.7-30.6
TP	0.17[a]	0.16-0.18	0.11[a]	0.1-0.13	0.24[a]	0.14-0.34	0.17[a]	0.16-0.18	0.23[a]	0.15-0.32
SRP	0.01[a]	0.01-0.01	0.04[bc]	0.03-0.06	0.05[bc]	0.03-0.06	0.01[a]	0.01-0.01	0.01[a]	0.01-0.01
TN	1.19[a]	0.5-2	1.52[a]	1.3-1.6	2.2[a]	2.2-2.3	1.19[a]	0.5-2	1.93[a]	1.4-2.8
NO_3^-	0.69[a]	0.4-0.9	0.66[a]	0.4-0.9	0.62[a]	0.6-0.8	0.69[a]	0.4-0.9	0.64[a]	0.6-0.8
TDS	64.7[a]	64-65	68.67[b]	67-71	66.3[a]	65-68	64.67[a]	64-65	65[a]	64-66
TSS	30[a]	10-50	120[b]	60-160	51.8[a]	20-80	30[ac]	10-50	86.67[a]	70-100
TURB	53.57[a]	42.7-67.5	47.07[a]	41-56.5	95.3[a]	37-117	53.57[a]	42.7-67.5	77.7[a]	41-148

Except for EC (µS/cm), WT (°C), pH and TURB (NTU) the rest are in mg/L. The different superscript letters indicate statistical difference among sites at $p<0.05$

WQ =water quality, St. = station, WT= Water temperature, DO=Dissolved oxygen, EC=electrical conductivity, pH, BOD=Biological oxygen demand, TP= Total Phosphate, SRP=soluble reactive phosphorus, TN= Total Nitrogen, NO_3^- = Nitrate, TDS=Total dissolved, TSS = total suspended solids, TURB= Turbidity

Table 2.4 The median values of water quality parameters among five sites at Gilgel Gibe I Reservoir during the dry Season (03/21/15 to 03/28/15)

WQ parameters	St. 1		St. 2		St. 3		St. 4		St. 5	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
DO	4.58[a]	3.2-5.9	3.06[a]	2.1-4.4	6.38[a]	5.5-7.2	3.52[a]	1.9-6.4	3.86[a]	2.1-6.3
EC	111.8[a]	107.9-117	106.5[ac]	106-107	103.5[bc]	100-106	97.4[b]	95.5-98.6	98[b]	97-100
WT	23.87[a]	23-24.5	25[a]	23.7-26.5	22.8[a]	22-24	23.7[a]	22-25	22.49[a]	21.6-23
pH	7.55[a]	7.4-7.7	7.14[a]	6.8-7.5	7.54[a]	7.2-7.8	8.09[a]	7.8-8.4	7.4[a]	6.6-8
BOD_5	1.63[a]	0.8-2.8	4.04[a]	3.9-4.2	1.05[a]	0.24-2.6	2.14[a]	0.6-4.8	1.45[a]	0.8-2.5
TP	0.49[a]	0.3-0.7	0.32[a]	0.3-0.34	0.28[a]	0.2-0.3	0.32[a]	0.2-04	0.27[a]	0.2-0.3
SRP	0.01[a]	0.01-0.01	0.04[a]	0.01-0.06	0.04[a]	0.02-0.07	0.06[a]	0.02-0.11	0.07[a]	0.03-0.12
TN	10.6[a]	9.8-12	4.3[a]	1.5-7.1	8.58[a]	2-12	11.63[a]	9.8-13	11.26[a]	10.9-11.7
NO_3^-	1.68[a]	1.2-2.3	1.18[a]	0.9-1.4	1.14[a]	0.6-1.9	1.45[a]	1.3-1.7	1.06[a]	1.1-1.1
TDS	84.7[a]	82-88	81[ac]	81-81	79.5[bc]	77-81	75.7[b]	74-77	76[bc]	75-77
TSS	450[a]	135-845	330[a]	170-490	485[a]	115-1030	372[a]	165-555	383[a]	120-630
TURB	77.6[a]	56-107	48.57[a]	44.7-54	6.38[b]	120-142	49[a]	44.9-9.6	50.06[a]	47.6-53

Except for EC (µS/cm), WT (°C), pH and TURB (NTU) the rest are in mg/L. The different superscript letters indicate statistical difference among sites at $p<0.05$

WQ =water quality, St. = station, WT= Water temperature, DO=Dissolved oxygen, EC=electrical conductivity, pH, BOD=Biological oxygen demand, TP= Total Phosphate, SRP=soluble reactive phosphorus, TN= Total Nitrogen, NO_3^- = Nitrate, TDS=Total dissolved, TSS = total suspended solids, TURB= Turbidity

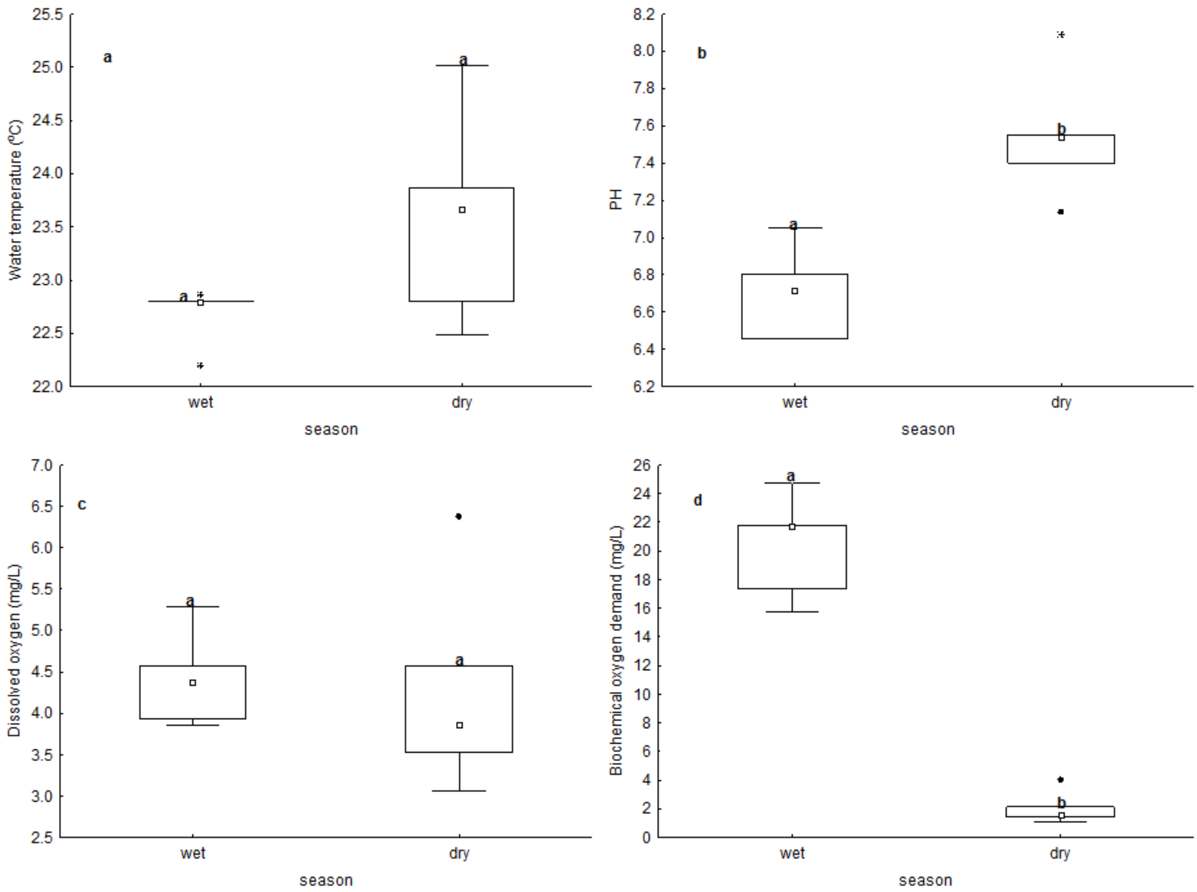

Fig. 2.5 Box and whisker plot of seasonal variation of water quality parameters. In the figure the letters a, b, c, & d represent Water temperature, pH, DO and BOD_5 respectively. Moreover, small white squares represent median values, boxes represent the interquartile range, plus signs represent extremes, small black dots represent outliers and range bars show maximum and minimum values. Different letters (a and b) over boxplots indicate a significance difference (Mann-Whitney U test $p < 0.05$).

2.3.3 pH

Overall the pH values ranged from 6.5 to 8.1 (Fig. 2.5b). Spatially, the highest concentration value of pH recorded at St. five (7.05) and St. 4 (8.09) during the wet and dry seasons, respectively (Table 2.3 and 2. 4).

2.3.4 Dissolved oxygen

The concentration of DO varied from 3.85 mg/L to 5.28 mg/L during the wet season and 3.06 mg/L to 6.38 mg/L in dry season (Table 2.3 and 2.4). There was no significant difference between the seasons in median DO (Mann-Whitney U test, $P > 0.05$) (Fig 2.5c). However, seasonal PCA analysis revealed that the DO is among the variables that characterizes PC2 (Fig. 2.8).

2.3.5 Biochemical oxygen demand

BOD_5 value ranges from 15.78 mg/L to 24.75 mg/L in the wet season and from 1.05 mg/L to 4.04 mg/L in the dry season (Table 2.3 and 2.4). The wet season values exceed the guideline ambient environment standards for Ethiopia (≤ 5mg/L). The BOD_5 gives an estimate of the amount of biochemically degradable organic matter present in a sample. BOD_5 varied seasonally ($P < 0.05$). During the wet season, BOD_5 was positively correlated with pH ($r = 0.98$, P, < 0.01) and the highest BOD_5 median value (24.8 mg/L) was recorded at St. five in wet season (Table 2.3) and at St. two in the dry season 4.04mg/L was recorded (Table 2.4). The seasonal PCA (Fig. 2.6) has showed that BOD_5 is among the variables that explained 61.54 % of variability and associate negatively in PC 1.

The PCA including all data extracted two significant PCs with Eigenvalues > 1, and explained 78 % of the total variance of the seasons. The first PC separated dry season samples from wet season samples and was positively associated with EC, pH, TP, TN, NO_3^-, TDS and TSS while negatively with BOD_5 (Table 2.5). Variation in Turbidity, SRP, Temperature and DO were important in interpreting PC 2 (Fig. 2.6).

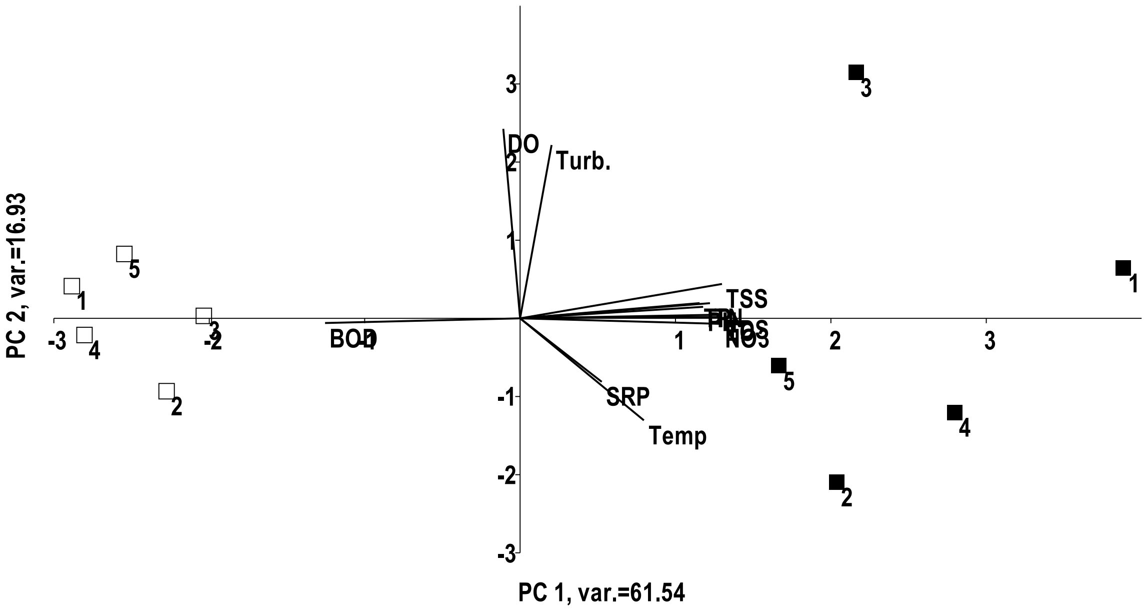

Fig. 2.6 PCA seasonal analysis of water quality parameters for Gilgel Gibe I Reservoir, numbers 1-5 signify sampling sites. wet and dry seasons are represented by square and dark square respectively

Table 2. 5 The factor loadings values and explained variance of water quality. Positive and negative strong correlations are marked bold.

Parameters	PC 1 61.54%	PC 2 16.93%
DO	-0.0799	**0.9423**
Temp	0.59	-0.5064
EC	**0.9577**	0.00142
pH	**0.8724**	0.0577
BOD_5	**-0.9294**	-0.0234
Turb	0.1496	**0.8613**
TSS	**0.9617**	0.1705
TDS	**0.9615**	0.0184
NO^-_3	**0.9556**	-0.0268
TN	**0.9051**	0.0759
TP	**0.8557**	0.0758
SRP	0.3885	-0.3163

2.3.6 Electrical conductivity and TDS

Conductivity ranged from 80.27– 87.1µS/cm in the wet season and 97.4 µS/cm – 111.8 µS/cm in the dry season. The EC mean values were observed to be statistically highest in wet season for sampling site two (87.1 µS/cm) and sampling site three (83.2µS/cm) while in dry season highest values were recorded at site one (111.8µS/cm) (Table 2.3) and site two (106.5µS/cm) (Table 2.4). Seasonally, conductivity varied significantly ($P<0.01$). The first quartile of EC in the dry season is higher than the 4th quartile of the wet season (Fig. 2.7a). The highest concentration values results were recorded in St. two (91µS/cm) during the wet season (Table 2.3) and in St. one (117µS/cm) in dry season (Table 2.4). Seasonally, EC is the variable most strongly associated with PC 1 (Fig. 2.6). EC and TDS were common for both wet and dry season to vary statistically in sampling sites (Table 2.3 and 2.4). There was a highly significant positive correlation of TDS with EC both in the wet season ($r = 0.976$ at $P < 0 .01$) and in the dry season ($r =0.972$ at $P < 0.01$). TDS was also among the variables seasonally explained PC 1 (Fig. 2.6).

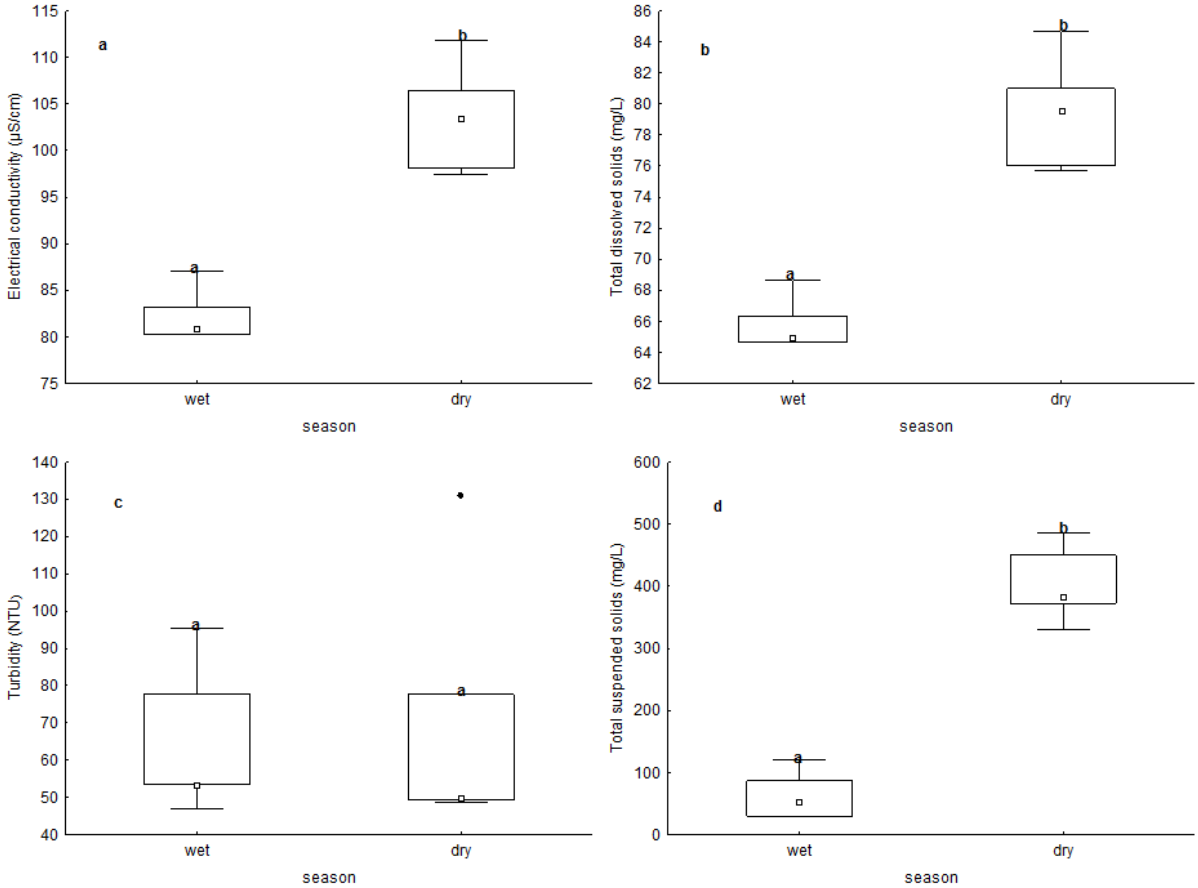

Fig. 2.7 Box and whisker plot of seasonal variation of water quality parameters. EC (a), TDS (b), Turbidity (c) and TSS (d). Small white squares represent median value, box represents interquartile range (25-75 percentages), small black dot in fig. 2.7c represents outliers and range bar shows maximum and minimum values. Statistically significant differences (Mann-Whitney U test $p < 0.05$) are represented by a and b.

2.3.7 Turbidity and TSS

The value of turbidity ranged from 47.07 NTU – 95.3NTU during the wet season and 48.57 NTU -77.6 NTU during the dry season (Table 2.3 and 2.4), with no significant difference between seasons (Fig. 2.7c). The highest mean concentration values of turbidity were observed at Site three (95.3mg/L) during the wet season and 77.6mg/L at site one in dry season (Table 2.3 and 2.4). Turbidity is one of the variables associated with PC 1 (Fig. 2.6).

TSS values obtained at sampling sites in wet season vary between 30mg/L-120mg/L and in dry season it varies 330mg/L-450mg/L (Table 2.3 and 2.4). The dry season had a significantly higher TSS concentration value than the wet season (Mann-Whitney U test) (Fig. 2.7d). Elevated values (120 mg/L) of TSS recorded at St. two sampling site during the wet season

(Table 2.3), while all sites had high TSS during the dry season comparing the wet season. TSS is also characterizes the PC 1 of seasonal variability (Fig. 2.6).

2.3.8 Nutrients

The dry season inter-quartile ranges of TN, and NO_3^- found to be high, indicating a higher variability in their concentration as compared to the wet season (Fig.2.8c and 2.8d). The seasonal Mann-Whitney U test for the concentration of total phosphorus, total nitrogen, and nitrate showed a significant difference at $p < 0.01$ and these nutrients have higher concentration during the dry season (Fig.2.8a, c and d). The mean concentrations of available forms of nutrients, namely NO_3^- (1.68 mg/L) and SRP (0.07 mg/L) were higher during dry than wet seasons (Table 2.4).

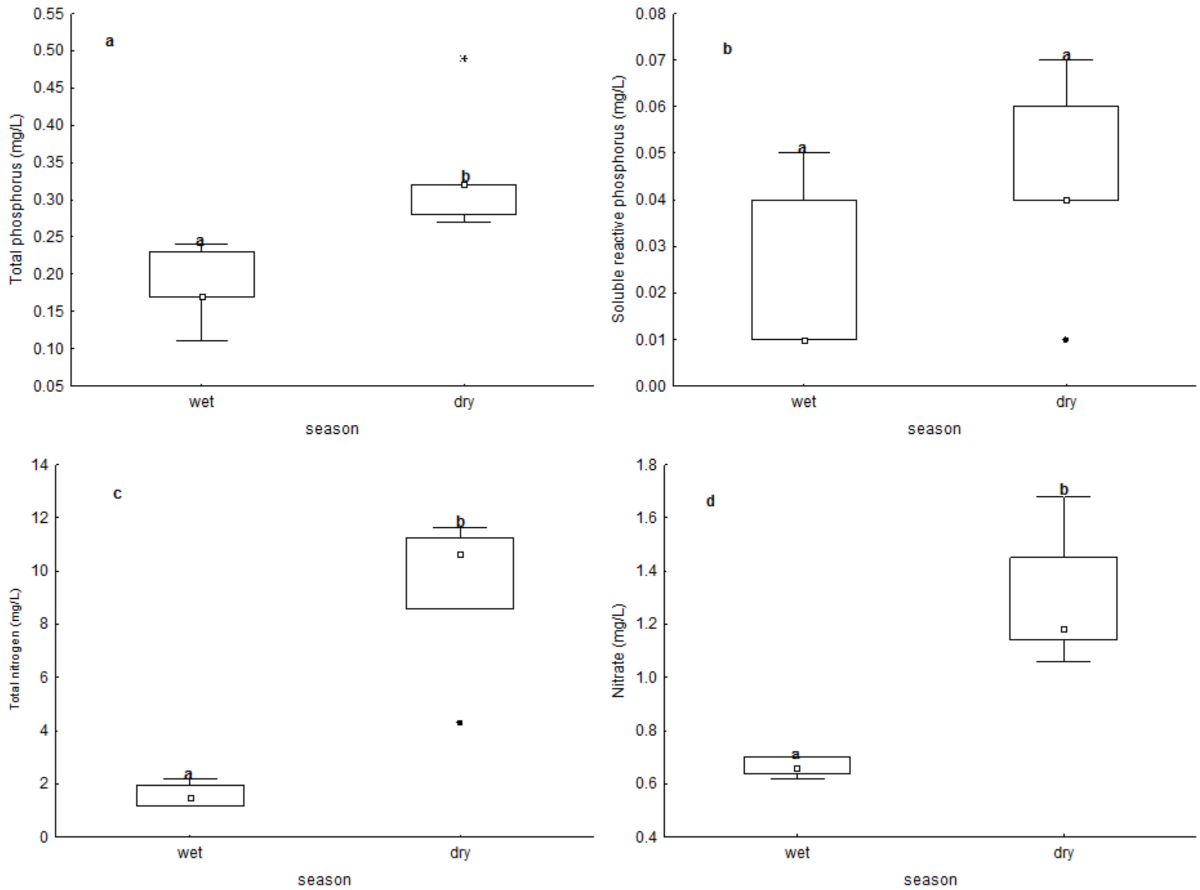

Fig. 2.8 Box and whisker plot of seasonal variation of water quality parameters. TP (a), SRP (b), TN (c) and Nitrate (d). Small black squares represent median value, box represents interquartile range (25-75 percentages), plus sign represent extremes, small black dot represents outliers and range bar shows maximum and minimum values.

Statistically significant differences (Mann-Whitney U test $p < 0.05$) are indicated by a and b.
Nitrate is one of the characteristic variable of PC 1 (Fig. 2.6). The highest concentration of NO_3^- (1.68 mg/L) recorded at St.one sampling site and for SRP (0.07mg/L) was at St.five sampling site during the dry season (Table 2.4). In the wet season, highest value for SRP (0.04mg/L) was observed at St.two and (0.05mg/L) at St. three sampling site (Table 2.3). The median value of total nitrogen varied from 1.19 mg/L to 2.2 mg/L during the wet season (Table 2.3) and 4.3 mg/L to 11.6 mg/L in dry season (Table 2.4). Total nitrogen is among the nutrient variables that associate with PC 1 (Fig. 2.6). High TN median value (2.2 mg/L) observed at St. three sites during the wet season (Table 2.3) and (11.6 mg/L) at St.four sampling site during the dry season (Table 2.4). The concentration of total phosphorus was higher in the dry season, ranging from 0.27 mg/L to 0.49 mg/L (Table 2.4).
The highest concentration of TP (0.24 mg/L) was recorded during the wet season at St. three sampling site and 0.49 mg/L at St. one sampling site in the dry season (Table 2.4). Seasonally, nutrients were associated positively with PC 1, explaining a total of 61.54 % (Fig. 2.6).

2.4 DISCUSSION

The study found that there was a distinct seasonal pattern in water quality of the Gilgel Gibe I Reservoir, with most parameters higher during the dry season (EC, pH, TP, TN, $NO3^-$, TDS and TSS) in contrast to BOD_5, which was higher during the wet season. The observed maximum dry season temperature is most likely associated with increased temperature of surface water because of higher air temperature.The high pH value during the dry season could be due to low water level causing a concentration of base cations, or an excess of primary productivity over respiration during that season, consuming CO_2 and reducing H^+. The decreased pH value in wet season may be due to the effect of lower pH in rain and runoff water from the tributaries. Similar results for seasonal variability in pH were reported in lakes in Nigeria (Araoye 2009, Irenosen et al. 2013), and in the Pahuj Reservoir of Central India (Khan and Parveen 2012). The pH range of the study was within the range of acceptable water quality (6.5 to 8.5), which is typical of most major drainage basins of the world (Carr and Neary 2008). It is also within the range of the guideline for ambient environment standards of Ethiopia (6 - 9 mg/L) (EPA and UNIDO 2003).

DO values of the Gilgel Gibe I Reservoir range from 3.06 – 6.38 mg/L, where the higher end (6.38 mg/L) is within the range of other reservoirs in the region, and relative to earlier measurements in Gilgel Gibe I Reservoir. For instance, the Geray reservoir in the northern highlands of Ethiopia had DO values ranging from 3.9 mg/L – 10.4 mg/L (Goshu 2007), and summary statistics of water quality parameters for Gilgel Gibe I Reservoir from 2006 to 2008 revealed DO ranging from 5 mg/L to 8.2 mg/L (Ambelu et al. 2013).

This reduction in the current study of the concentration of DO may be associated with turnover or the release of anoxic bottom water from the deep reservoir (DWAF 1996) or the decomposition of organic materials input through runoff (Makhlough 2008). In terms of potential biological effects, about half of our measurements were below the recommended minimum threshold of 5.0 mg/L DO for functioning and survival of biological communities, though no sites averaged DO below 2 mg/L where death of most fish may occur (Chapman 1996). In this study, DO and Temperature had a positive relationship, where a similar pattern with a positive relationship between dissolved oxygen and temperature was seen in North Central Nigeria (Meme et al. 2014).

The BOD_5 at Gilgel Gibe I Reservoir ranged from 1.05 mg/L to 24.75 mg/L, and was very high during the wet season. This seasonal pattern was consistent with the work of Irenosen et al. (2012) in Nigeria. Higher BOD_5 values indicate high consumption of oxygen, presumably resulting from the oxidation of a high organic pollution load. This might be a result of organic load through runoff from the surrounding land use in the study area, as suggested by Saxena and Saksena (2012). BOD_5 values of 2 mg/L or less imply healthy waters while BOD_5 values of 10 mg/L or more are typical of water bodies receiving wastewaters (Chapman 1996). In terms of impact on ecosystem services, a BOD_5 range of 0 - 4 mg/L is recommended for sensitive species such as salmonid fish, and for other beneficial uses (EPA and UNIDO 2003). In Gilgel Gibe I Reservoir, the mean BOD_5 for all sites falls within the desired range during the dry season, but greatly exceeds the 4 mg/L threshold during the wet season, indicating that organic pollution and resulting oxygen consumption is a major concern during that season (Saxena and Saksena 2012).

The studied EC values (80.27 – 111.8 µS/cm) were similar to the work of Ambelu et al. (2013), which was 70-110 µS/cm; and lower than the conductivity values of Bira dam (394 -402 µS/cm), Tekeze dam (260 - 300 µS/cm) and Tendaho reservoir (569 µS/cm) (Tessema 2014). This difference may be due to the different geological characteristics of these watersheds. The observed values at Gilgel Gibe I Reservoir are also in the low range of conductivity of most natural freshwaters values proposed by Chapman (1996) which ranges from 10 µS/cm to 1,000 µS/cm. This range of EC is not of particular environmental or ecological concern.

Changes in the precipitation pattern may lead to droughts, floods, soil erosion, and loss of biodiversity and agricultural productivity (Liang et al. 2018). The linkage between water quality and precipitation is more prominent in heavy rainfalls. Precipitation, which produces surface runoff undoubtedly affects water quantity and consequently water quality indirectly (Rostami and Hassan 2018). Data of 2000-2014 from Sokoru metrological station showed that annually rainfall resulted in a significant difference ($p < 0.05$) and, statistically there was a significant difference between maximum temperature and rainfall annually.

The sources of material in TDS and EC can come from nature (geological condition) and human activities (Marandi et al.,2013; Rusydi et al.,2015). Electrical conductivity is also considered to be a rapid and good measure of dissolved solids that reflects the pollution status as well as tropic level of the aquatic body (Ranjeeta et al 2011; Heydari et al. 2013). Total dissolved solids denote various kinds of organic substances and in higher concentration reduce its palatability (Sarda and Sadgir 2015).

The human activities in the watershed coupled with unpredictable variability in temperature and annual rainfall will also eventually cause to vary and reduce reservoir water level. This will negatively affect the domestic water users, livestock; the aquatic ecosystems even reduce electricity production of the hydroelectric plant. The values of the EC obtained in this study is not of particular environmental or ecological concern to be discussed here. However, the higher EC and TDS, during the dry season than the wet season is consistent with the findings of Zinabu (2002). This may be associated with evaporation and the absence of a dilution effect, while the lower values during the wet season are assumed to be due to dilution from the direct rain and the large volume of water from the tributaries.

Turbidity and TSS are the most visible indicators of water quality and refer to particles present in the water column (Folorunso 2018). Increased surface runoff contributes to turbidity, which is often associated with total suspended solids (Packman et al., 1999). TSS is the main responsible factor for turbidity and turbidity is indicative of TSS concentration (Hannouche et al., 2011). TSS increases the turbidity of a waterbody, which decreases light penetration, which in turn impairs photosynthetic activities of aquatic plants, potentially leading to oxygen depletion (Bilotta and Brazier 2008).

The measured turbidity values in Gilgel Gibe I Reservoir (ranging from 47.07 NTU – 95.3 NTU) were also proximate to 40-155 NTU measured by Ambelu et al. (2013) of the same reservoir, and it is within the range of the stated normal values by Chapman (1996) which ranges from 1 to 1,000 NTU. The range of turbidity and EC during the dry season were similar to those found in the Upper Lake of Bhopal of India (Parashar et al. 2006) and the Bibi Lake in India (Umerfaruq and Solanki 2015). The concentration of TSS in Gilgel Gibe I Reservoir is much higher than the maximum value of the guideline ambient environment standards for Ethiopia (50 mg/L) (EPA and UNIDO 2003). During storm event and extensive rainfall, there is increase in concentrations and/or loadings of various pollutants including total suspended solids (TSS), nutrients, and microorganisms (Göransson and Bendz 2013).

Total nutrient concentrations were higher in the dry season than the wet season, and both TN and TP were high enough to suggest eutrophication. Similar seasonal patterns in nutrient concentration were observed by Zinabu (2002) from Lake Chamo in the rift-valley lakes of

Ethiopia and Garg et al. (2010) in Ramsagar reservoir of India. A high dry season mean value of TP was also reported by Ibrahim et al. (2009), which could be due to the increased concentration effect of reduced water volume. The concentration of available forms nitrate and soluble reactive phosphorus in Gilgel Gibe I Reservoir were also highest during the dry season, though the seasonal difference in SRP was not significant. Similar seasonal variation has been observed for nitrate and orthophosphate in a river in Bangladesh (Alam et al. 2012).

However, according to Chapman (1996), concentrations in excess of 0.2 mg/L of nitrate will be liable to stimulate algal growth and indicate possible eutrophic conditions. The values of total nitrogen were in the range of eutrophic conditions.

Eutrophication is often connected with low species diversity, high productivity, harmful growth of aquatic plants, and blooms of cyanobacteria that can be toxic to humans and other animals, including livestock and wildlife (DWAF 1996). A concentration of SRP above about 0.025 mg/L is typically taken as an indication of eutrophic conditions (DWAF 1996), and based on the Redfield (1963) ration N: P value was also greater than 20 which indicate P limitation. So Gilgel Gibe I Reservoir also exceeds that threshold. Shen (2002) stated that the number of algae increased when total phosphorus in the water was 0.1 mg/ L to 0.75 mg/L, encompassing the range that this study found in Gilgel Gibe I Reservoir. Based on these observations, the concentration of TN and TP of the water in the Gilgel Gibe I Reservoir is high enough to support growth of cyanobacteria, and blooms of cyanobacteria have indeed been observed during the study period.

Spatially, there was significant variation at $p < 0.05$ among the five sampling sites. Forexample, EC and SRP showed variation in site two and three than the rest. TDS showed variation in site two and TSS showed variation in site two and four during the wet season (Table 2.3). In dry season, EC was different in site two and three. TDS was varied in all sites except site one and turbidity was varied in site three (Table 2.4), which may be caused by pollution sources and/or climatic factors (Palma et al. 2014).

2.5 CONCLUSIONS AND RECOMMENDATION

In this study, we assessed the spatial and seasonal variability of the physicochemical properties of the water in Gilgel Gibe I Reservoir. The measured parameters showed a seasonal fluctuation, with predominantly higher concentrations during the dry season than the wet season. Parameters like pH, EC, and nitrate had values within the range of the standards for

water quality, and below the level at which they are harmful. Whereas others like DO and BOD_5, were fluctuating beyond the allowable level, suggesting a problem with low oxygen levels at times; for instance, BOD_5 was particularly high during the wet season. The values of TN and TP in the Gilgel Gibe I Reservoir suggest a eutrophic condition, and this is of major concern. High concentrations of nutrients, and variation among reservoir sampling sites, may reflect the effect of anthropogenic activity in the watershed and tributary system. We tried to explore simple and inexpensive water quality monitoring as in the developing nations where resource is limited with a short duration of sampling, and found major water quality changes.
Further detailed studies which include other seasonal or monthly water physicochemical trend analysis and land use changes in the watershed to relate it with tributary water quality in order to characterize reservoir water quality change is needed. This will help to identify which tributary is primarily responsible for eutrophication and resulting impairment, and will ultimately allow for corrective action to be taken (e.g., Carpenter et al. 1998).

3

3. TROPHIC STATE AND DEPTH PROFILE OF PHYSICOCHEMICAL WATER QUALITY PARAMETERS AT GILGEL GIBE I RESERVOIR

Trophic state and depth profile of physicochemical water quality parameters at gilgel gibe I reservoir

3.1 INTRODUCTION

Reservoirs suffer from heavy sedimentation rates and supply of organic nutrients and minerals due to enhanced erosion from their catchments (El-Radaideh 2016). The difference in water retention time from the tributaries greatly influenced the reservoir ecosystem (Pinto-Coelho et al. 2006). This in relation to seasonal change alters the different compartments of reservoir water bodies in a complex dynamic way (Pagioro and Thomaz 2002) finally impaired the physicochemical and biological characteristics of reservoir water (Gikas, 2009).

The variations of water quantity and water quality depend on types of aquatic ecosystems and natural factors such as climate, topography and catchment geology (Zakeyuddin et al.2016). Water quality deterioration is also a common problem in reservoirs like Gilgel Gibe I Reservoir surrounded by anthropogenic activities, which is cascading to it making susceptible to water quality degradation. Because of anthropogenic activities, the aquatic system is facing serious problem of eutrophication and deterioration of water quality (Panwar & Malik 2014). Eutrophication of lakes and reservoirs is a major water quality problem that poses significant environmental, economic and social threats around the world (Wagner and Erickson 2017).

Agriculture is commonly pointed out as the major contributor to surface water eutrophication, with inefficient practices resulting in high nutrient surpluses transferred to water bodies through runoff and leaching (Ramos et al. 2018). During the wet season, concentrations of most water quality parameters were greatest in incoming water from agricultural land hence pollution and eutrophication risk is closely associated with drainage from agricultural land (Woldeab et al. 2018).

The trophic state determines the condition (oligotrophy, mesotrophy, eutrophy and hypereutrophy) of an aquatic ecosystem. Trophic State Index (TSI) assist in decisions about risks of algal blooms as well as the control of eutrophication which has become a global concern to decision makers regarding the management of water resources (Cunha et al. 2013).

The trophic state condition of a reservoir has to be assessed to provide information on the trophic status of the reservoir because eutrophication can lead to damage of human health, the environment, society, and the economy. Therefore, determining the trophic condition of a water body is an important step in the scientific assessment of each aquatic system (Wetzel 2001).

Temperature, pH, DO, EC and alkalinity also regulate various water quality parameters in the aquatic ecosystem (Radhika et al., 2004; Camacho et al., 2015), among these, DO considered to be the most important parameter because it determines the health of the ecosystems (Yang et al. 2013). The concentration of DO is controlled by respiration, photosynthesis and atmospheric air (Holtgrieve et al. 2010). Therefore, to recognize and protect the ecology of natural aquatic system analysis of the vertical profile of this and other physicochemical parameters is very essential (Patil et al., 2012). Vertical variability in the water column is also a natural occurrence and influenced by temperature gradients and light attenuation in the water column. These in turn influence biological activities and water chemistry (Anderson 2002) therefore describing vertical profiles of water columns at different depths of water is imperative to understanding the biochemical cycles and nutrient dynamics of an aquatic ecosystem (Reimer et al. 2008).

Due to the conservational concerns from existing anthropogenic activities and the potential future developmentsf Gilgel Gibe I Reservoir, we found that the assessment of vertical water quality is crucial to ensure the health of reservoir in suppling suitable environment for the aquatic community. Different studies have been carried out but vertical variation and distribution of physicochemical parameters of reservoir water column has not been well documented and also there is a lack of crucial information on the trophic status and water quality of the reservoir.

The objective of this study was to assess variability of the water quality parameters at different depth in the Gilgel Gibe I Reservoir and determine its Trophic Status.

3.2 MATERIALS AND METHOD

3.2.1 Study area

The Gilgel Gibe I Reservoir is situated in the Gibe - Omo River Basin in Oromiya regional state of Jimma zone, 260 km southwest of Addis Ababa (Fig.3.1). The climate of the study area is classified as tropical humid and belongs to the high altitude cool tropic area of the country. There is unimodal pattern of seasonal rainfall distribution where up to 60% of the rainfall falling during the rainy season (Demissie et al. 2013). According to the Ethiopian National Meteorological Agency, from the year 1968 - 2015 the average annual rainfall in Jimma stations was 243mm and minimum (43mm) recorded in August and and December, respectively.

The reservoir was built on the Gilgel Gibe river in 1998, with a primary purpose of hydroelectric power production. The reservoir is characterized by a large 40m high dam, with a storage capacity of 839 Mm^3 covering more than 54 km^2 of land. At its full supply level and with a conveyance system of tunnels and an underground powerhouse consisting of three 61.3 MW generating units (EEPCO 2011).

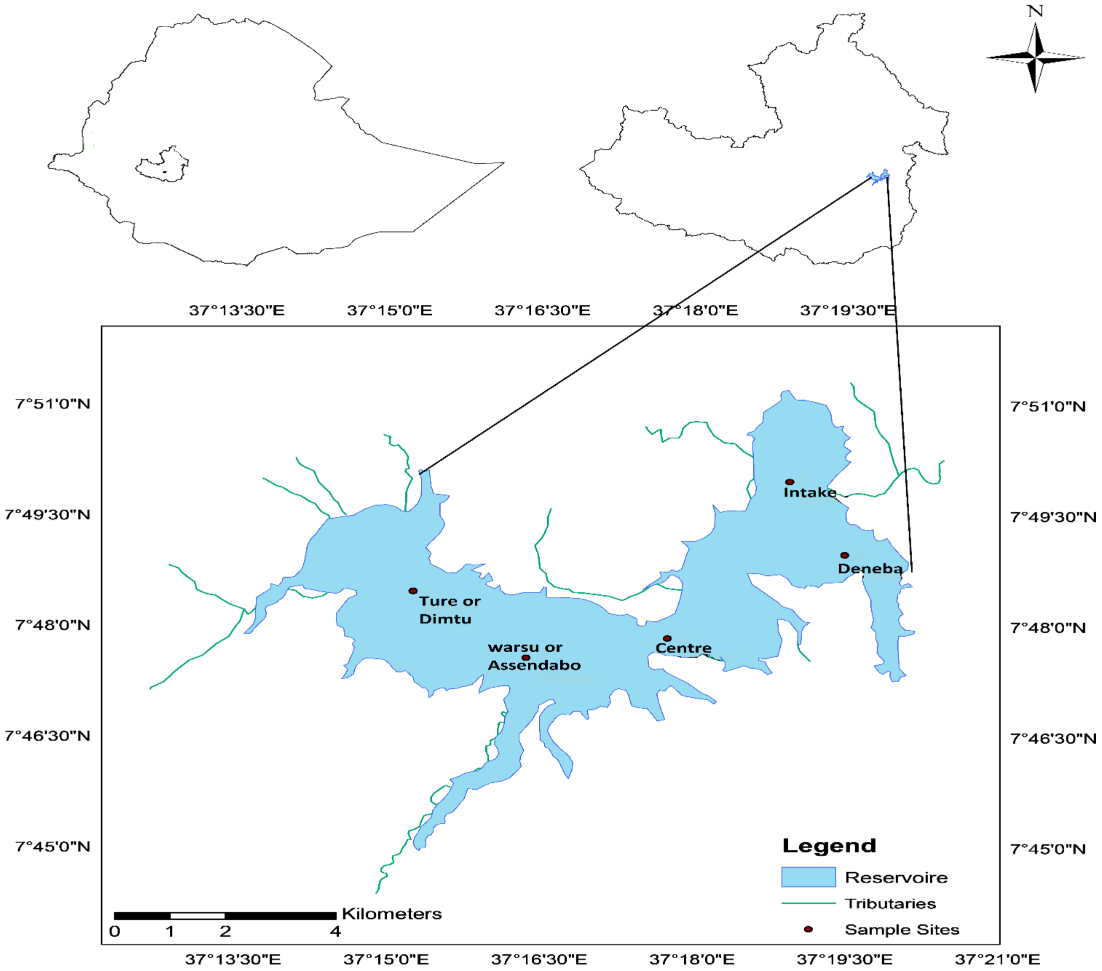

Fig.3.1 Location of depth sampling sites at Gilgel Gibe I Reservoir

The site began operation in 2004 and is currently generating 184MW at its full capacity, with annual average flow of 50.4 m^3/s, reservoir active storage of 657 million m^3, and reservoir dead storage of 182 million m^3. Based on Ethiopian National Meteorological Agency, from the year 2005/6 – 2014/15 the minimum reservoir water level was 1654 m.a.s.l and the maximum was 1671.2 m.a.s.l., with maximum and minimum depths of 35m and 2m, respectively, and an average depth of 20m. The reservoir receives water from the surrounding tributaries, namely the Nadaguda, Nedi, Yedi and Gilgel Gibe rivers. The total catchment area is 4,225 km^2, and the watershed is highly agricultural, serving as an important food source for the region (Wakjira et al. 2016).

Table 3.1 Geographic coordinates and elevations of the sampling sites along the reservoir

Sampling site	coordinates		Altitude
Ture or Dimtu	N 07^0 42.712	E 037^0 13.377	1671
Warsu or Assendabo	N 07^0 46.445	E 037^0 16.130	1671
Centre	N 07^0 47.847	E 037^0 17.251	1669
Nedhi	N 07^0 50.941	E 037^0 18.755	1671
Yedi	N 07^0 48.849	E 037^0 19.408	1670

3.2.2. Sample collection

Five sampling sites (stations) were identified spatially in the pelagic zone of the reservoir. These were Assendabo or Warsu site, Dimtu or Ture site, Centre, Intake and Deneba site. The sampling was carried out during the wet season of October 2018. Water samples for laboratory analysis were taken from different sampling sites at different depths of the reservoir using a Van Dorn Sampler, and collected in clean 250-mL polyethylene bottles after pre-rinsing with sample water. Water depth was determined using a calibrated string by measuring tape weighted at one end. All samples were put in cold boxes and transported to the laboratory. For analysis of nitrate, total suspended solid (TSS) and total dissolved solid (TDS) samples were sifted by Whatman filter paper with a pore size of 0.45 μm using the standard method (APHA 1999). Data for the determination of the trophic state index (TSI) were mean values of TP and Chl.a collected spatially at the surface water.

3.2.3 Water quality analyses

Water quality parameters were analyzed on-site and in the laboratory. Onsite measurement of temperature, pH, conductivity, and dissolved oxygen were done using a HACH, HQ40d portable multi-meter, and turbidity was measured using Wag tech turbidity meter model number of wag-WT 3020. Chl.a was measured onsite using portable fluorometer. Secchi depth was used to measure the water transparency. Other physicochemical parameters including 5-day biochemical oxygen demand (BOD5), TSS, total nitrogen (TN), TDS, nitrate ($NO3-$), total phosphorus (TP), and soluble reactive phosphorus (SRP) were investigated in the laboratory of Environmental Health Science and Technology at Jimma University.

BOD_5 was measured after incubation of DO for 5 days at 20 °C in the dark. TSS and TDS were determined using the gravimetric method (APHA 1999). For TSS, water samples were filtered through a pre-weighed glass fiber filter paper, and were placed into a 105 °C drying oven to remove any remaining water, then removed from the oven, and placed in a desiccator to cool to room temperature, and the difference in weight was calculated as TSS. For TDS, the filtrate was evaporated to dryness in a pre-weighed dish and dried to a constant weight at 180 °C.

The increase in the weight of the dish after drying represents the total dissolved solids. TP was analyzed by the ascorbic acid method with direct reading on a spectrophotometer following persulfate oxidation. In this method, water sample undergo a digestion process to convert combined phosphate in to orthophosphate which then reacts with ammonium molybdate and potassium antimonyl tartrate in an acid medium to form a heteroply acid—phosphomolybdic acid; this reaction can be reduced by ascorbic acid to form highly colored molybdenum blue (APHA 1999). Comparison of water quality parameters among depths in the reservoir were conducted using one-way ANOVA and Tukey’s pairwise comparisons with 5% significance level. The probable contributing source of the investigated physicochemical water quality parameters at different depth was identified using Principal components analysis.

To determine the trophic status of the reservoir we used a trophic state index developed by Cunha et al. (2013) for tropical/subtropical reservoirs (TSItsr) that categorize the trophic status in to six trophic levels based on TP and Chl a. concentrations, using the following formula: -

$$TSI_{tsr} = \frac{TSI(TP)_{tsr} + TSI(Chla)_{tsr}}{2}$$

Where -

$$TSI(TP)_{tsr} = 10\left[6 - \left(\frac{-0.27637 \ln TP + 1.329766}{\ln 2}\right)\right].$$

and

$$TSI(Chla)_{tsr} = 10\left[6 - \left(\frac{-0.2512 \ln Chla + 0.842257}{\ln 2}\right)\right]$$

TP is total phosphorus (µg/L)

Chl a is chlorophyll a (µg/L)

TSItsr is trophic state index for tropical/subtropical reservoirs.

We analysed data on total phosphorus (TP) and chlorophyll a (Chl.a) monitored at different sites within the reservoir.

3.2.4 Statistical methods

Data analyses were performed with PAST for PC analysis and Statistica 8 software for descriptive and correlation analysis

3.3 RESULTS

During the study time the overall reservoir sampling depth ranged from 1m to 15m. Table 3.2 showed distribution of median values for observed reservoir water physicochemical parameters at various depth of the water column and Table 3.3 presents their correlations. During vertical analysis, depths of the studied reservoir were compared with the physicochemical parameters of water, except for TSS, TDS, TP and SRP the rest showed statistically significant difference at $p < 0.05$ level.

Negative correlations were found between depth and DO, water temperature and pH (r= -0.78), (r= -0.61) and (r= -0.72) at $p < 0.05$ level respectively,while positive correlations were found between EC, BOD_5, turbidity and nitrate (r= 0.78), (r= 0.55), (r= 0.819) and (r= 0.674) respectively at $p < 0.05$ level (Table 3.3).

Table 3.2 Descriptive statistics of water quality parameters at different depth of the Reservoir

Para meters	surface		5m		10m		15m	
	Median	Range	Median	Range	Median	Range	Median	Range
DO	7.93	7.21 - 8.7	6.8	6.6 - 7.4	5.6	5 - 6.1	4.38	3.5 - 4.9
Temp	26	24.9 -28.7	23.9	23.4 - 24.9	23.3	22.8 - 24.7	22.37	21.9 - 22.9
EC	77.7	77 - 78	78.5	78.3 - 78.9	80.6	79.4 - 82	86.4	82.3 - 94.8
PH	8.05	7.86 - 8.3	7.8	7.75 - 7.8	7.4	7.27 - 7.5	7.23	7.1 - 7.3
BOD_5	3.62	0.76 - 4.9	4.14	1.69 - 5.3	4.9	2.59 - 5.9	6.14	5.4 - 6.9
Turb	46.3	43 - 50	49.8	43.6 - 55.7	59.6	50.8 - 70.2	72.9	64 - 78.8
TSS	124.9	116 - 130	141.6	130 - 164	165	156.8 - 181.6	214	146 - 443.6
TDS	319.8	230 - 381	365.5	341 - 381	381.6	321 - 423	387.2	320 - 422
NO_3^-	4	1.8 - 6.4	2.3	0.5 - 3.8	1.1	0.24 - 2.4	0.26	0.03 - 0.4
TP	0.39	0.06 - 0.8	0.46	0.07 - 0.8	0.56	0.08 - 0.9	0.72	0.39 - 1.24
SRP	0.24	0.02 - 0.6	0.31	0.04 - 0.7	0.37	0.05 - 0.7	0.3	0.18 - 0.9
Chl a	13.1	12.5 - 13.7	9.2	8.4 - 10.5	4.9	3.14 - 6.8	1.4	1.14 - 2.2

3.3.1 Temperature

The temperature of surface waters column was ranged from (24.9 – 28.7°C) which was the highest temperature. The difference between the surface and bottom temperature was in the average of 1.7°C. The descriptive statistics showed a reduction in temperature from surface with a median 26^0c, 23.9^0c at 5m, 23.3 at 10m depth and 22.4^0c at depth of 15m (Table 3.2). The value below surface seems stable (Fig. 3.2). Vertically it was positive correlated with pH, nitrate and Chl. a (r=0.85), (r= 0.74) and (r= 0.83) respectively at $p < 0.05$ level, while negatively correlated with EC, turbidity and TDS (r= -0.58), (r= -0.59) and (r= -0.72) respectively at $p < 0.05$ level (Table 3.3). Kruskal-Wallis test showed that there was a statistically significant difference between surface and 15m depth at ($P < 0.05$).

3.3.2 Dissolved oxygen

Vertical variation of the median dissolved oxygen concentration is presented in Table 3.2. It was relatively consistent in the surface water of the Reservoir. The surface layer was characterized by well oxygenated (7.21mgL – 8.66mg/L) water column, the concentration ranged from 7.21mg/L(at surface) to 7.39 mg/L (at 5m). It decreases to the concentration of (4.96 mg/L – 3.51 mg/L) at the depth of 15m (Table 3.2 & Fig. 3. 2), with recorded range value of 8.66mg/L -3.51mg/L from surface to bottom.

Vertically there was a significant positive correlation of Dissolved oxygen with temperature, pH, NO_3^{-}, and Chl.a (r=0.82), (r=0.97), (r=0.81) and (r=0.93) respectively at $p < 0.05$ level, while negatively correlated with EC, BOD_5, turbidity, TDS and TP (r = - 0.72), (r= -0.65), (r= -0.86), (r = - 0.56, and (r= -0.45) respectively at $p < 0.05$ level (Table 3). The Kruskal-Wallis test showed a statistically significant difference ($P < 0.05$) among all depth.

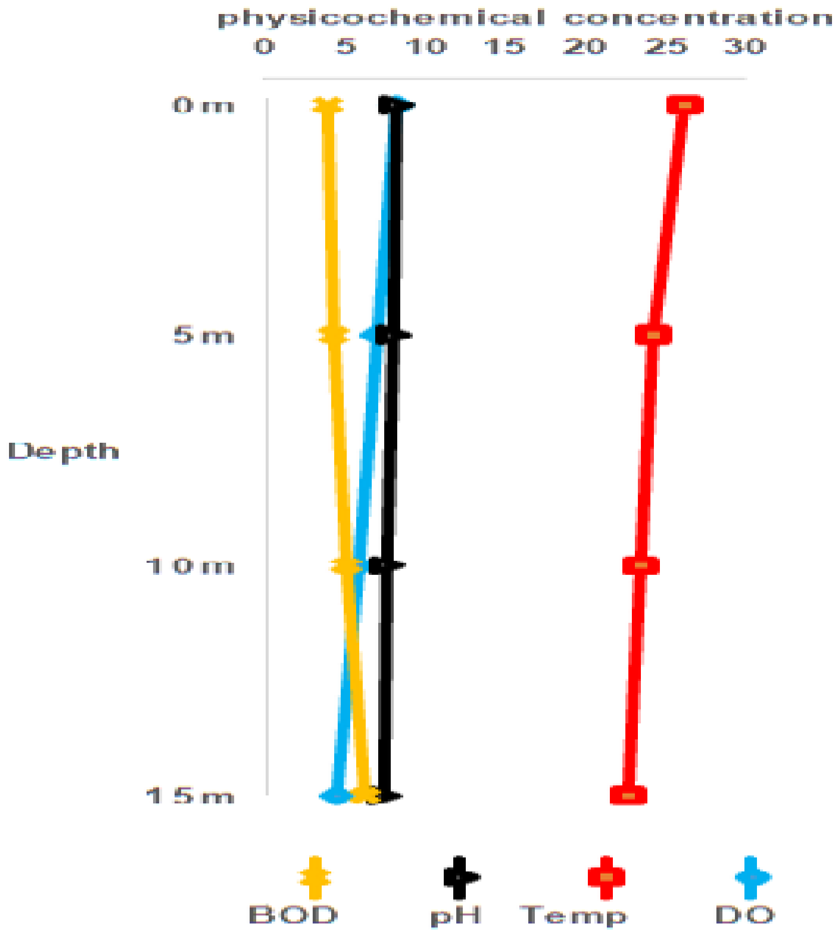

Figure 3.2 Depth variation of water quality parameters based on median concentration (DO mg/L, Temperature ^{O}C, pH and BOD_5 mg/L) at Gilgel Gibe I Reservoir

3.3.4 pH

The median vertical pH values ranges from 8.1 (surface water column) to 7.2 (bottom). The pH distribution of the surface waters ranges from 7.86 - 8.29 (Table 3.2) showed that it was alkaline and its concentration seems consistent or even (Fig 3.2). Comparing to the surface column the pH values at deep water column are low and ranged from 7.07-7.34. The Kruskal-Wallis test showed a statistically significant difference ($P < 0.05$) among the depth of surface versus 15m, surface Vs 10m and 5m versus 15m.

Vertically there was a significant positive correlation of pH with NO_3^- and Chl.a (r=0.81), (r=0.92) at $p < 0.05$ level, while negatively correlated with BOD_5, turbidity and TDS (r = -0.51), (r= -0.83) and (r= -0.56) respectively at $p < 0.05$ level (Table 3.3).

3.3.5 BOD5

Surface BOD_5 concentration (0.76mg/L - 4.9mg/L) was lower than the BOD_5 concentration 15m depth (5.4mg/L-6.9 mg/L) with the median value of 3.6 – 6.14 respectively (Table 3.2). The concentration of BOD_5 at the depth of 10m and above increases while DO decreases (Table 3.2 & Fig 3.2). There is a statistically significant difference between 1m depth and 15m depth of BOD_5 concentrations at $P < 0.05$. It was negatively correlated with Chl. a (r= -0.65) at $p<0.05$ and positively correlated with turbidity (r=0.74) at $p < 0.05$ level (Table 3.3).

Table 3.3 Depth correlation among water quality parameters in Gilgel Gibe I Reservoir $p < 0.05$ level

	Depth	**DO**	**Temp**	**EC**	**pH**	**BOD**	**Turb**	**TSS**	**TDS**	**$N0^{-}_{3}$**	**TP**	**SRP**	**Chl. a**
Depth	1												
DO	**-0.94**	1											
Temp	**-0.78**	**0.82**	1										
EC	**0.82**	**-0.72**	**-0.58**	1									
pH	**-0.91**	**0.97**	**0.85**	**-0.66**	1								
BOD	**0.61**	**-0.65**	-0.35	**0.59**	**-0.51**	1							
Turb	**0.87**	**-0.86**	**-0.59**	**0.71**	**-0.83**	**0.74**	1						
TSS	0.49	-0.48	**-0.37**	**0.78**	-0.40	0.38	**0.31**	1					
TDS	0.48	**-0.56**	**-0.72**	**0.51**	**-0.56**	0.32	0.46	0.39	1				
No^{-}_{3}	**-0.72**	**0.81**	**0.74**	**-0.57**	**0.81**	-0.48	**-0.62**	-0.37	**-0.50**	1			
TP	0.45	-0.45	-0.33	0.11	-0.48	0.25	**0.59**	-0.05	0.36	-0.16	1		
SRP	0.09	-0.13	0.01	0.15	-0.11	0.47	0.42	0.06	0.37	0.013	**0.58**	1	
Chl. a	**-0.96**	**0.93**	**0.83**	**-0.79**	**0.92**	**-0.65**	**-0.84**	-0.49	**-0.55**	**0.75**	-0.33	-0.12	1

3.3.6 Electrical conductivity

The values of EC increases with depth (Fig. 3.3). The median depth conductivity values ranges from 77.7µS/cm (surface) to 86.4µS/cm (15m), the value was highest at the bottom (15m depth). There was statistical significant difference ($P < 0.05$) between surface versus 15m, surface Vs 10m and 5m versus 15m. Depth wise it has a positive correlation with BOD_5, turbidity, TSS and TDS ($r= 0.59$), ($r= 0.71$) ($r= 0.78$) and ($r= 0.51$) at $p < 0.05$ while negatively correlated with pH, NO_3^- and chl.a ($r= -0.66$), ($r= -0.57$) and ($r= -0.79$) respectively at $p < 0.05$ level (Table 3.3).

3.3.7 Total dissolved Solids

Vertical concentration of TDS ranges from 230mg/L (at the surface) to 422mg/L (15m) with the median value of 319.8mg/L (surface), 365.5mg/L (at 5m), 381.6mg/L (at 10m) and 387.2mg/L (15m). It has a negative correlation with NO_3^- and chl.a ($r= - 0.50$) and ($r= - 0.55$) at $p < 0.05$ (Table 3). Though the concentration value increases with depth (Fig.3.3), no significant differences were detected in TDS among the monitored depths.

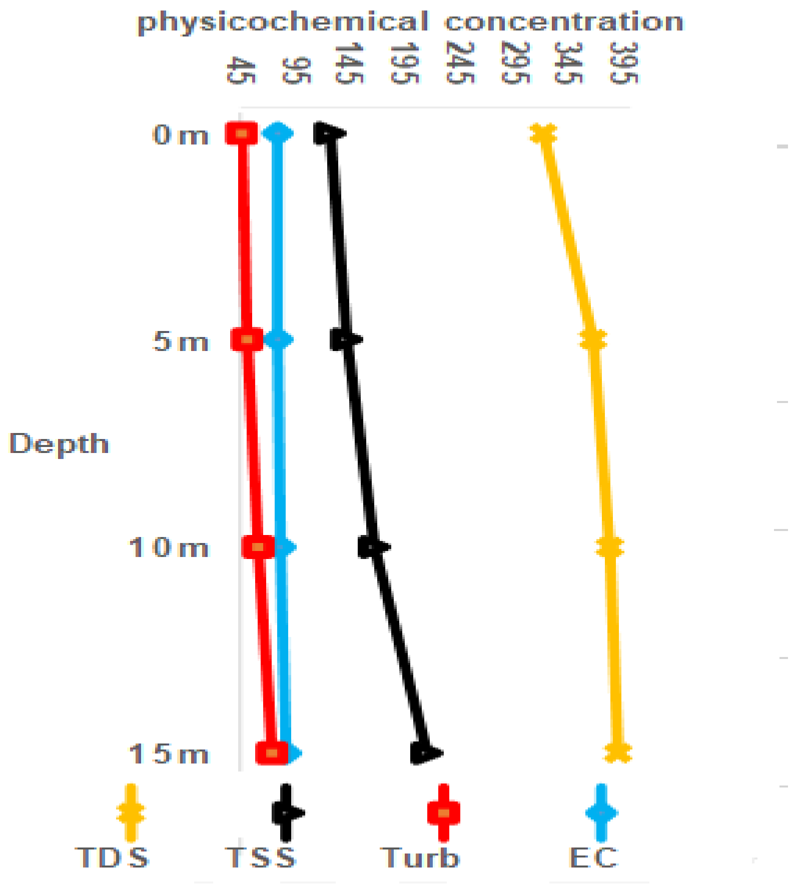

Figure 3.3 Depth variation of water quality parameters based on median value (EC µS/cm, TDS mg/L, Turbidity NTU, and TSS mg/L) at Gilgel Gibe I Reservoir

3.3.8 Turbidity

The median vertical turbidity values ranges from 46.3 (surface water column) to 72.9 (bottom). Its concentration increases with depth. Comparing to the values of surface column with the bottom, its' concentration was highest at the bottom and ranged from 64 – 78.8 NTU. The Kruskal-Wallis test showed a statistically significant difference ($P < 0.05$) among surface versus the depth of 10m and 15m, 5m versus 15m.

It was positively correlated with TP (r= 0.59) while negatively correlated with $NO3^-$ and Chl. a. (r= 0.62) and (r= -0.84) at p<0.05 level (Table 3.3).

3.3.9 Total suspended solids

There was an increase in the median values of TSS with depth, 124.9mg/L, 141.6mg/L, 165mg/L and 214mg/L for surface, 5m, 10m and 15m respectively (Table 3.2) it showed slight increment with depth (Fig. 3.3) and the concentration 15m was significantly differ from the rest depth. It has no correlation with any of water quality parameters. The Kruskal-Wallis test showed a statistically significant difference (P < 0.05) among surface vs 15m and surface vs. 10m.

3.3.10 Nutrients

Nutrient concentrations in the water are important ecologically, as phytoplankton may bloom if sufficient nutrients are present. In the Gilgel Gibe I Reservoir, nitrate is far more plentiful than soluble reactive phosphorus (Fig 3.4). It ranges from 6.4 mg/L (surface) – 0.03 mg/L (bottom) while SRP ranges from 0.02 mg/L to 0.88mg/L (Table 3.2). TP and SRP showed very low concentration with almost uniform distribution throughout the water column (Fig. 3.4). There were low median values of TP and SRP (0.39mg/L and 0.24mg/L) than nitrate at the surface water column. TP has positive correlation with SRP (r= 0.58) at p < 0.05 level.

The Kruskal-Wallis test showed a statistically significant difference (P < 0.05) between surface vs 15m depth. Nevertheless, no significant differences were detected for TP and SRP among the observed depths.

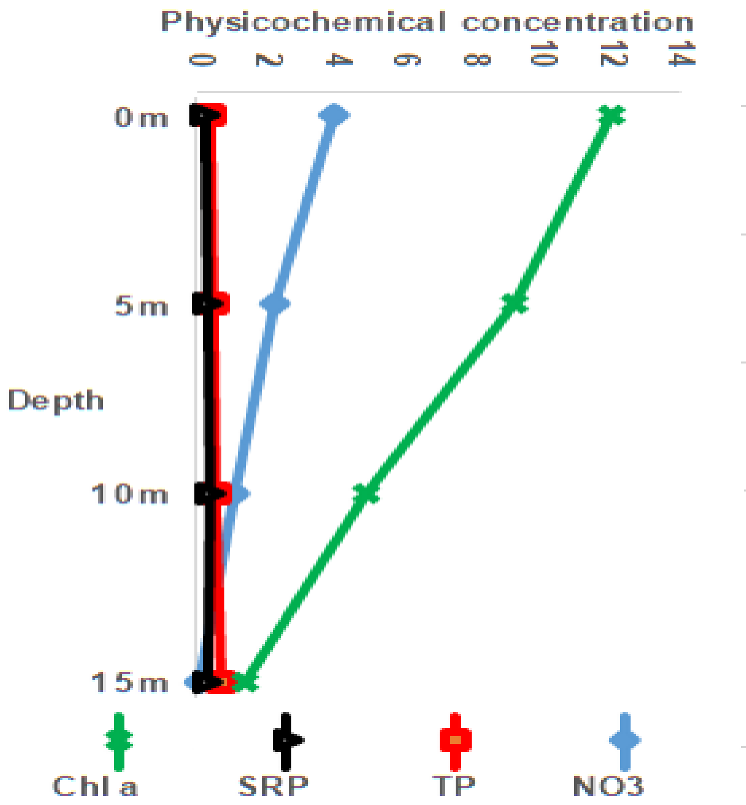

Figure 3.4 Depth variation of water quality parameters based on median concentration (NO_3^- mg/L, Chl.a mg/L, TP mg/L, and SRP mg/L) at Gilgel Gibe I Reservoir

Highest concentrations of TP and SRP were observed at the depth of 15m (Table 3.2). There is a statistically significant difference between surface and 15m depth for nitrate concentrations at $P < 0.05$.

3.3.11 Trophic state index (TSI)

Based on the formula and mean values of TP and Chl.a (Table 3.4) Gilgel Gibe I Reservoir has a TSItsr value of 56.33 that categorized the reservoir as **Eutrophic** condition (Table 3.5).

Table 3.4 Mean values of surface water concentration of TP and Chl.a at five sites within Gilgel Gibe I Reservoir

Water quality parameters	Mean (SD)	Min	Max
TP	39.72 (0.28)	0.056	0.814
Chl.a	13.09 (0.43)	12.5	13.7

Table 3.5 Trophic state categories including the respective means for chlorophyll a and total phosphorus, the associated TSItsr (trophic state index for tropical/subtropical reservoirs)

Trophic state category	TSItsr
Ultra-oligotrophic	≤51.1
Oligotrophic	51.2–53.1
Mesotrophic	53.2–55.7
Eutrophic	55.8–58.1
Super- eutrophic	58.2–59.0
Hypereutrophic	≥59.1

Source Cunha et al. (2013)

3.3.12 Chlorophyll a and Secchi depth

Surface Chl. a concentration ranges from (13.69 mg/L – 12.53 mg/L) with the median values of 13. Chl.a was among the variables that explain 58.7% of PC 1 (Fig. 3. 6), with the loading value of 0.948 (Table 3.6). We found dense masses of blue green algae in the pelagic zone and along the shoreline swept by the winds (plate 3.1a & b) and this occurrence of blue green algae in the studied Gilgel Gibe I Reservoir suggests the presence of ample nutrients for its blooming. Chlorophyll-a is an indirect measure of the amount of algal biomass in the water column. It is one of the primary trophic state indicator used to evaluate the overall health of the aquatic systems (ERD 2013). Algal bloom also provides sufficient information in water quality and water degradation in reservoir (Swaminathan, 2003). Algal bloom or Chlorophyll-a are important in biomonitoring of aquatic environment because these reflect the condition of physicochemical parameters in the water ecosystem (Zbikowski et al., 2007).

Water transparency in the reservoir as measured by Secchi disc had an overall median of 0.26cm with a minimum value of 0.24cm and a maximum of 0.29cm (Table 3.2).

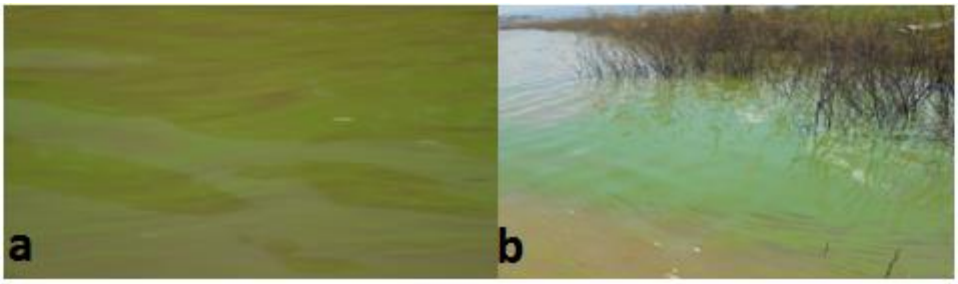

Plate 3.1 Dense masses of Chl.a at Gilgel Gibe Reservoir I

3.3.13 Principal components analysis

Principal component analysis was used to find out the probable depth characteristic for the investigated water physicochemical parameters. Eigenvector categorized the twelve water physicochemical parameters in to two groups or components. The PCA analysis extracted two PCs with eigenvalue >1, and explained 73% of the total variance in the data set.

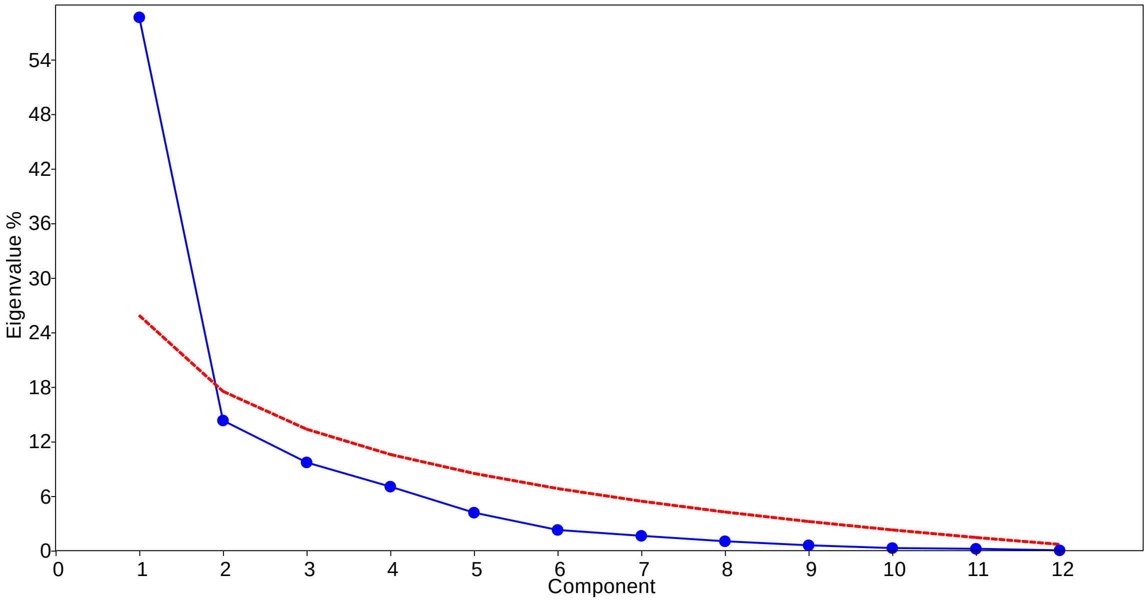

Figure 3.5 Screen plot showing the components to be considered

The screen plot reveals the eigenvalues arranged from large to small as a function of the principal component numbers. It helps to determine the number of important components. After the second component (Fig. 3.5) the other components cannot be considered, because the curve start tilt downward. The screen plot used to detect the number of PCs to be reserved in order to get the basic data structure (Palma et al., 2014).

Table 3.6 The factor loadings values and explained variance of water quality. Positive and negative strong correlations are marked bold.

Parameters	PC 1 58.7%	PC 2 14.3%
DO	**0.962**	0.070
Temp	**0.835**	0.202
EC	**-0.814**	-0.242
pH	**0.936**	0.063
BOD_5	**-0.697**	0.227
Turb	**-0.888**	0.273
TSS	**-0.552**	-0.385
TDS	**-0.665**	0.100
NO^-_3	**0.800**	0.269
TP	-0.461	**0.726**
SRP	-0.281	**0.843**
Chl.a	**0.948**	0.126

The first PC which explained 58.7% of the variance positively associated with DO, pH, temperature, chl.a and nitrate (Fig. 3. 6), accounts for high loadings at 1m and 5m depth, while negatively associated with turbidity, BOD_5 DO, TDS, EC and TSS (Table 3. 6) and are the characteristics of 10m and 15m depth (Fig. 3. 6). Likewise, PC 2 which explain 14.3% of the total variance, associated with positive loadings of SRP and TP, found to be the characteristics of 5m depth (Fig. 3. 6).

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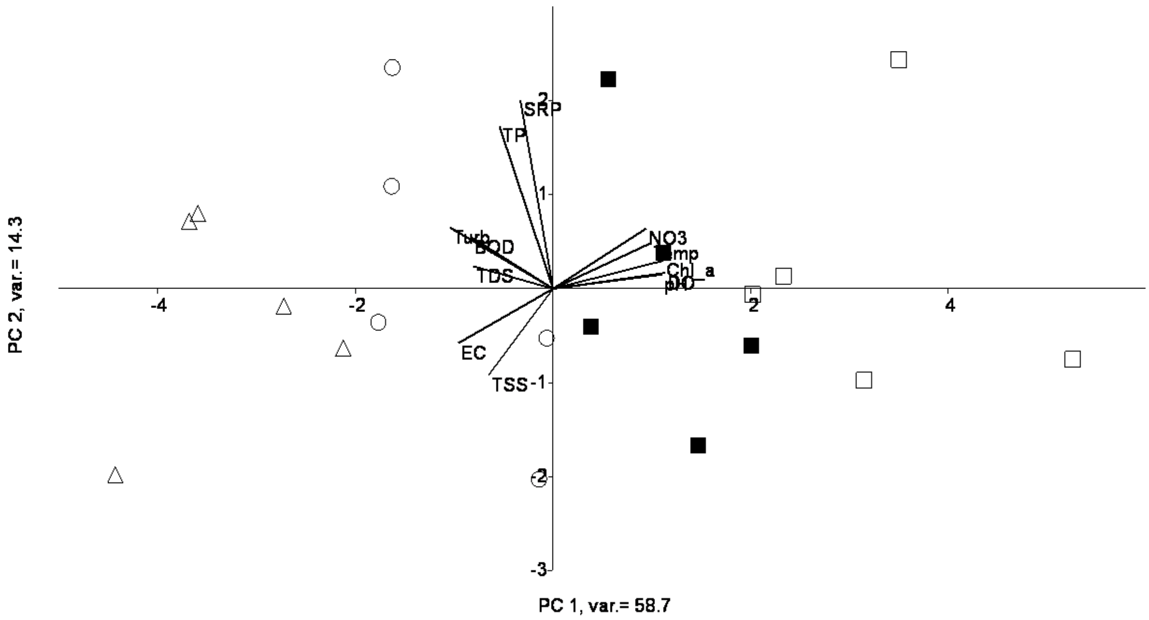

Figure 3.6 PCA depth analysis of water quality parameters for Gilgel Gibe I Reservoir (the different depths, 0m, 5m, 10m and 15m represented by square, dark square, circle, and triangle respectively)

3.4 DISCUSSION

This study showed significant depth variability in the distribution of water physicochemical parameters. Except TDS, TP and SRP the rest water quality parameters (DO, Temperature, pH, EC, BOD5, Turb, TSS, NO3, and chl.a) showed a statistically significant difference among different depth.

Temperature, pH and DO decreased as the depth increased. This decline of temperature, pH and DO as the depth increases is also similar with Zhou et al. (2013) and Panwar & Malik (2014) findings'. The concentration of DO never fell below 3 mg/L. However, reduced concentrations of dissolved oxygen, when combined with the presence of toxic substances may lead to stress responses in aquatic ecosystems because the toxicity of certain elements is increased by low concentrations of dissolved oxygen (ANWQMS 2000).

Trophic state and depth profile of physicochemical water quality parameters at Gilgel Gibe Reservoir I

Water temperature is one of the most important physical characteristics of aquatic ecosystems and affects a number of water quality parameters (Dirican 2015). Decreases in pH values and dissolved oxygen with increasing water depth are similar with the Environmental Research and Design report (2013), which was common due to increased production of CO_2 from sediment decomposition processes (ERD 2013).

The water temperature indirectly controls the rate of algal photosynthesis and aquatic respiration through enzymes, leading to changes in the carbon dioxide content due to metabolic activities. As algae quickly take up carbon dioxide, it supports carbonate ($HCO3^-$) decomposition and increase of the pH value. Reversely, the increase of carbon dioxide produced by aquatic respiration processes can inhibit the carbonate decomposition and causes subsequently the decrease of the pH value (Zang et al., 2011).

Aeration and aquatic plants may explain high surface water column oxygen concentration. Prokopin et al. (2010) suggests that aeration plays a key role in the distribution of oxygen at depths near the surface of water. Photosynthesis by aquatic plants during the daylight removes carbon dioxide (CO_2) from the medium which may attributed to the increased values of DO and decreases carbonic anhydride, thus increasing the pH value (Silva 2008; Panwar and Malik 2014) hence high value of pH is linked with high organic content and eutrophic condition (Kalff, 2002).

Measures of DO indicate whether there is a disturbance to these competing processes and defines the living conditions for aerobic (oxygen requiring) organisms (ANWQMS 2000). Most organisms require oxygen for their metabolic activities and the composition of aquatic communities in a lake is highly dependent on the oxygen conditions. Due to adaptations of aquatic life to the wide range of oxygen conditions, for some species the lack of oxygen in the deep water limits their vertical distribution, whereas for other species that can tolerate periods without oxygen (Lampert & Sommer 2007).

The wet season median pH of 6.46 - 7.05 reported previously by Woldeab et al., (2018) as compared to the present recorded surface values (7.86 - 8.29) revealed that the reservoir system was at neutral and alkaline state. The increase in pH level at surface water may be related with increase in temperature because warm waters develop increased pH levels due to conversion of CO_2 to organic carbon by photosynthesis (Araoye 2009), photosynthesis, respiration, and nitrogen assimilation also affect concentration of pH. For example, when nitrate (NO_3^-) is assimilated an equivalent number of hydrogen ions must be removed (Lampert & Sommer 2007) hence the lower values of pH in the bottom water column, are probably attributed to higher levels of organic matter (Al-Taani et al. 2018).

However, the pH range of the study was within the range of acceptable water quality (6.5 – 8.5) and also within the range of the guide line ambient environment standards for Ethiopia 6.5-9.0 for fish production (EPA 2001; EPA and UNIDO 2003).

At bottom depth the increased released of nutrient associated with increased concentration of BOD_5 and causes the low content of dissolved oxygen due to consumption of oxygen (Fig. 3. 2). This is in agreement with the work of (Zhou et al. 2013) suggesting that this increment was aggravated through the decomposition of organic matter, and by chemical reactions in bottom water column. Makhlough (2008) also stated that in tropical area, decomposition rate is high at the bottom as a result oxygen production (through photosynthesis) is less than oxygen consumption Decomposition of organic matters at the bottom of water provide inorganic nutrient (nitrogen and phosphors component) for algal growth in tropical reservoirs and lakes (Kalff 2002). The studied range of BOD_5 was 0.76 - 8.9 mg/L, this was above the maximum allowable value of European Union (3.0-6.0mg/L) (Chapman 1996). This has an implication on deterioration of Gilgel Gibe I reservoir water quality.

Turbidity which is a measure of suspended particles in the water column is contributed by both organic sources like algae and other organic matter as well as colloids and sediment materials (ANWQMS 2000; ERD 2013), Turbidity and total suspended solids increased corresponding with depth this is also in agreement with the work of Ling et al. (2016). Aris et al., (2014) proposed the cause as most likely due to the settling and re-suspension of inorganic solid particles. Because depth increment of BOD_5, turbidity and TSS was due to organic sources, possibly we can have inferred that Gilgel Gibe I Reservoir is with high productivity and the bottom oxygen level was low due to decomposition of organic matter. It is also true that in water bodies with low productivity, most of the organic matter has been decomposed before it reaches the bottom water and therefore does not use up the oxygen there (Lampert & Sommer 2007) in our study the concetration of dissolved oxygen decreased as the water depth increased.

The occurrence of Total solids in suspended particle and when it settled out, influence the aquatic ecosystems. In suspension, it to reduces light penetration and thus affect primary production while settling it devastate benthic organisms and their habitat. Adverse effects can also occur on fish due to mechanical and abrasive impairment of gills (ANWQMS 2000).

EC showed an increasing trend as the depth increased, the same observation was made by Ling et al., (2016) suggesting that the increment was due to the inorganic dissolved solids from the decaying submerged biomass and sediment. Kaul et al. (1980) stated that an increase in conductivity values indicates a tendency towards higher level of eutrophication, in addition Panwar and Malik (2014) facing the same situation argued that it is because of adsorption of dissolved salts in the surface of suspended particles which coming with water flood and discharged to bottom sediments.

In comparing water depth with water quality parameters, a positive correlation was observed in nitrate ion this was in agreement with work of Baatar et al. (2017). Except nitrate, vertical distribution of other nutrient (TP and SRP) was uniform and have positive correlation this is likely due to the release of SRP from the organically - bound phosphorus (Chapman, 1996). The available nutrient (nitrate) decrease with depth. High amounts of DO in the surface layers may cause ammonium to oxidize to nitrate (nitrification), and consequently the highest nitrate concentrations were found in the surface layers while in the hypolimnion, due to DO depletion, nitrification is likely to be hindered, and denitrification can proceed rapidly, which reduces nitrate levels (Noori et al., 2018).

Formation of available nutrients from organic matter and total nutrients occurs to a large degree near the bottom of the water body, probably caused by the regeneration of particulate matter sedimentation from the epilimnion (Baker and Richards, 2006) and causing significant reduction of water quality (Eutrophication), usually the result of nitrate and phosphate contamination (Panwar and Malik 2014). The less concentration of nutrient on the surface water column may be associated with phytoplankton consumption during photosynthesis (Silva 2008). Our study recorded surface water column nitrate concentration ranges 1.8 – 6.4mg/L hence concentrations of nitrate in excess of 0.2 mg/L tend to stimulate algal growth and indicate possible eutrophic conditions (chapman 1996), Schindler et al. (2008) also suggested that the appearance of dense or floating algal blooms can be signs that eutrophication may be taking place. The presence of Chl.a can be used as a non-specific indicator of the trophic status (level of pollution) of a water body (ANWQMS 2000). Water bodies with high nutrient contents (especially those classed as eutrophic) have high levels of chlorophyll (5-140 µg l-1) (chapman 1996), where the values of this study was in this range. An understanding of the Chl.a enables researchers to draw conclusions about a water bodys' health and ecological status. Chlorophyll a (Chl a) concentration is often used as a general indicator of plant biomass because all plants, algae and cyanobacteria contain about 1−2% (dry wt) chlorophyll a. Nutrients alone cannot indicate whether a water body actually has a nuisance plant problem, whereas increased chl.a in the water indicates that plants, algae or cyanobacteria are actually growing (ANWQMS 2000).

Water transparency is affected by a number of factors, like suspended particles (such as algae or inorganic particles). Good water column transparency has a range of 1m – 2m Secchi disk depth, but aquatic systems with a Secchi disk depth of less than 1m are considered to exhibit poor water column (ERA 2013). Correlation of chl.a was more linked with surface and 5m depth. This explains the occurrence of chl.a at the surface water column (Fig. 3.6). The low water transparency observed during the study period may be linked to chl.a (algae) and increased surface runoff accompanied by sediment load from tributaries. The distribution of algae above 5m may be due to vertical mixing that can keep algae below the euphotic zone for prolonged periods, resulting in very low populations of primary producers and associated zooplankton (Morris and Fan. 1998).

3.5 CONCLUSION

The result of this study revealed significant relations of physicochemical variables in water column of the reservoir and pollution loads were accumulated higher towards the bottom of reservoir water. The decrease of dissolved oxygen vertically and the increased concentration in EC, TSS, BOD_5, and nutrients values is associated with runoff, pollution load and decomposition of organic matter. Particularly the increased value of BOD_5 from surface to bottom (0.76Mg/L – 6.9 mg/L) corresponding to organic matter decomposition that consumes dissolved oxygen and high nutrient concentration showed the signs of organic pollution. Decrease in pH were associated with release of carbonic anhydride when dissolved oxygen was used. The reservoirs water was characterized by nearly alkaline at the surface and neutral at the bottom. The surface water temperature showed relatively higher values (30°C) with variations down the water column.

Generally, the impacts of one factor were dependent on other factors. For example, the nutrient loading effect on phytoplankton abundance in ecosystems is dependent on light availability and sedimentation (Richardson & Jorgensen 2013) Chlorophyll content is influenced by factors, such as nutrient, phosphorus, pH, water flow, water temperature and others (Johan et al., 2018) so this study has implication on reservoir water quality degradation. The TSItsr result has also showed that the reservoir is in eutrophic state. Eutrophication may cause structural changes to the reservoir water ecosystem such as increased production of algae and aquatic plants, depletion of fish species, general deterioration of water quality and other effects that reduce and stop the whole function/use.

4

4. EFFECT OF LANDUSE ON WATER QUALITY IN TRIBUTARIES OF THE GILGEL GIBE I RESERVOIR

This chapter is published in Environmental Monitoring and Assessment could be cited as:Woldeab, B., Ambelu, A., Mereta, S.T. and Beyene, A., 2019. Effect of watershed landuse on tributaries' water quality in the east African Highland. *Environmental monitoring and assessment*, *191*(1), p.36.

Effect of landuse on water quality in tributaries of the Gilgel Gibe I Reservoir

4.1. INTRODUCTION

For a long time, landuse was considered as a local environmental issue but has attained global importance in recent years (Kambwiri et al. 2014). Globally, during the past decade, expansion of agricultural activities and other changes in landuse have led to the decline of quality of natural waters (Hassan et al. 2015). The relationship between landuse and hydrology is now of interest worldwide (Calder 1998) as landuse changes at the local level have a combined effect that cannot be mitigated solely by local action. Landuse within watersheds can significantly impact the water quality and quantity of river water and all other freshwater sources (Huang et al. 2013, Bowden et al. 2015, Faiilagi 2015) because they disrupt their water balance and the partitioning of precipitation into evapotranspiration, runoff, and ground water flow (Foley et al. 2005).

The quality of water has recently become as important as its quantity because water quality directly affects human health, ecological health, use of water resources and accelerated water pollution (Zamani et al. 2012). Understanding the relationship between landuse and water quality facilitates efforts to identify primary threats to water quality (Ding et al. 2015). Landuse and land cover types can act as nutrient transformers or nutrient barriers by preventing their movement towards streams in the form of dissolved and suspended nutrients (Basnyat et al. 2000). All types of human landuse affect water (Verheul 2012). Changes in landuse and land cover interact with anthropogenic and natural drivers to affect the water quality of watersheds (Chu et al. 2013).

Landuse is among the main factors influenced negatively the aquatic ecosystem health (Ayivor and Gordon 2012; Kambwiri et al. 2014; Pullanikkatil et al. 2015; Du Plessis et al. 2015). Many of Africa's water resources are underutilized but pollution of both surface and ground water resources has been increasing in recent decades (Pullanikkatil et al. 2015).

As in many other developing countries, significant landuse changes have occurred in Ethiopia since the last century (Alemu 2015). These changes are associated with population increase, expansion of the agricultural sector and climate change (Getachew and Melesse 2013) and cause high risk of eutrophication and siltation on the reservoir (Woldeab et al. 2018).

Effect of landuse on water quality in tributaries of the Gilgel Gibe I Reservoir

Gilgel Gibe I Reservoir is vital for the local communities as protein source (fish), source of income, water for livestock and act as education and research area. The watershed approach is generally preferred to address non-point source pollution in which contaminant sources can be described and watershed outputs examined (Zhu et al. 2008). Devi et al. (2008) assessed the siltation and nutrient enrichment of Gilgel Gibe I Reservoir, Temene et al. (2013) evaluated the effectiveness of various management practices, Mertens (2014) studied landuse dynamics in the planosol soil belt, Abate & Lemenih (2014) quantified landuse/ land cover dynamics and Woldeab et al. (2018) assessed seasonal and spatial variation of reservoir water quality. Spatial analysis of recent landuse and land cover changes has been carried out in the catchment area of the Gilgel Gibe I Reservoir (Getahun 2015). However, the influence of changing catchment characteristics in relation to the limnological aspects of river water are not well recognized since the quality of water in an ecosystem is a reflection of its watershed (Kambwiri et al. 2014).

To address the issue of water quality in tributaries of Gilgel Gibe I Reservoir, limnological information in relation to landuse land cover change is needed because the availability of resources in healthy aquatic ecosystems depends on good water quality and, in turn, on physicochemical properties and biological diversity (Venkatesharaju et al. 2010). Due to the existence of different landuses and land covers in the sub-watersheds of the Gilgel Gibe watershed, assessment of the water quality of tributaries may identify the sub-watersheds that effect the water quality of Gilgel Gibe I Reservoir, which is a major source of water for the local populations and their livestock.

Therefore, the aim of this study is (1) to categorize the different landuses classes (2), to identify the spatial and temporal relationships between landuse and tributary water quality and (3) to estimate the influence of various landuse types and nutrient concentration on the water quality of tributaries in the watershed of Gilgel Gibe I Reservoir.

4.2. MATERIALS AND METHODS

4.2.1. The study area

The study area encompasses four water sources of Gilgel Gibe I Reservoir, namely the Gibe, Nadaguda, Yedi and Nedi rivers with their sub-watersheds**.** Gilgel Gibe catchment is located in southwest Ethiopia, about 260 km from Addis Ababa. It covers an area of 4,225 km^2 at altitudes between 1,096 and 3,259 m above sea level and consists of four sub-watersheds: Gibe, Nedi, Nadaguda and Yedi. The catchment is located between 7° 22' 72'' and 7° 34' 84'' latitude N and between 37° 21' 05'' and 37° 28' 80" longitude E (Fig. 4.1). The average annual rainfall in this humid highland area is about 1,550 mm and the average temperature is 19^{o}C (Tamene et al. 2013).

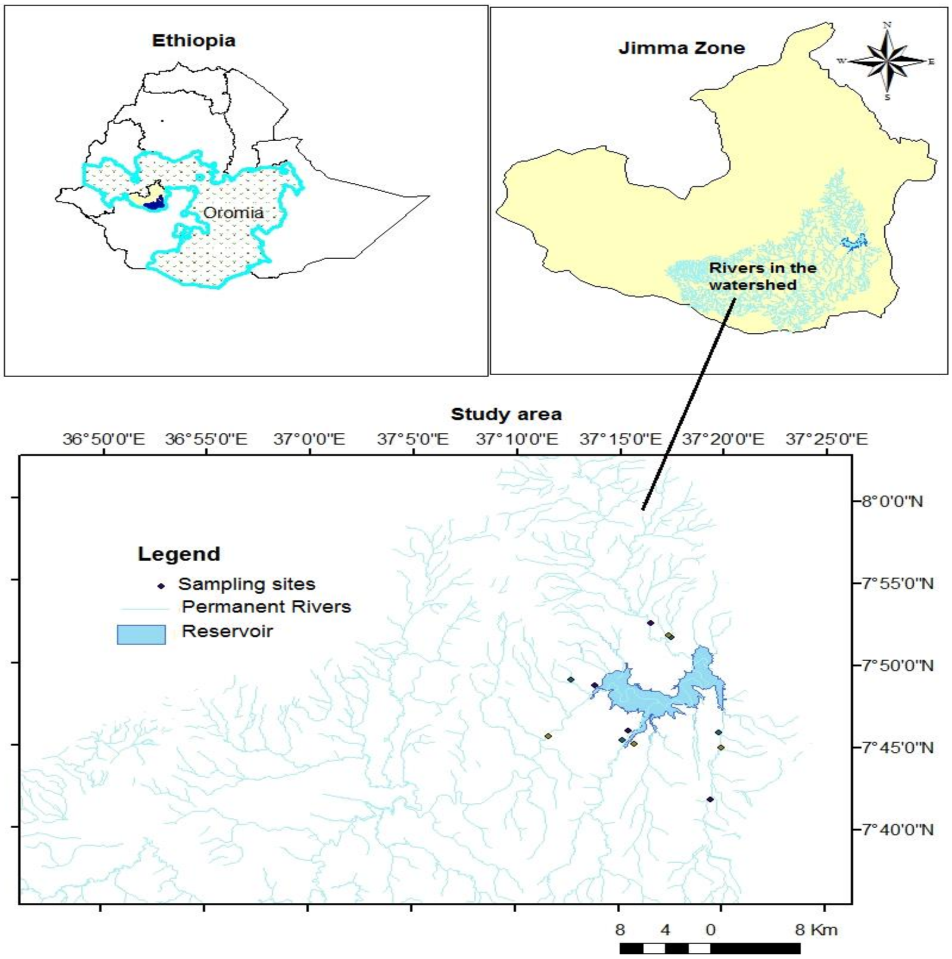

Fig. 4.1 Sampling sites on major tributaries of Gilgel Gibe I Reservoir

4.2.3 Data sources

4.2.3.1 Satellite data

Data were collected from remote sensing sources (Landsat 8 Operational Land Imager (OLI) imagery), digital elevation model (DEM) and field measurement (ground truth). Eight Landsat aerial photos, with a spatial resolution of 30m, were acquired in 2015 during both dry season (February) and wet season (July) from the USGS-Glovis website and used to map the land cover in the study area.

4.2.3.2 Water sample collection

Field sample collection was carried out for two seasons (wet and dry season) from October, 2014 to March, 2015 under stable flow conditions. Three sites along the main stem of each tributary of the Gilgel Gibe I Reservoir were identified and totally 12 sites were sampled (Fig. 4.1). Selection of sampling sites along the main stem was based on landuse type near the tributaries. Water samples were collected 0.5 m below the water surface and in the middle of the rivers' width. Water samples were collected with clean 250 ml polyethylene bottles being rinsed with sample water before samples were collected. All samples from the four tributaries were transported in cold boxes to Jimma University Environmental Health Science and Technology Laboratory for analysis.

4.2.3.3 Determination of landuse types

ERDAS IMAGINE 2014 and ArcGIS 10.4 were used to create landuse land cover maps based on images acquired on February 5, 2015. Image correction was made with geospatial tools (geometric and radiometric). The DEM, with 30-m spatial resolution, was used to delineate the catchment boundaries of the study area. Supervised and unsupervised classifications were implemented and the landuse categories of each tributary sub-watershed were identified from the aerial photos and mapped.

The information classes identified from the aerial photos used in the study were natural vegetation (forest, bush and shrub), farmland (cultivated, fallow and grazing land), settlements and bare land, and water bodies. GPS readings were obtained to check the accuracy of the classified land cover information for each landuse and land cover type in each of the four studied sub-watersheds.

4.2.3.4 Water sample analysis

Twelve physicochemical water quality parameters were selected for analysis and analysed on-site and in the laboratory. On-site measurement of temperature, pH, conductivity, dissolved oxygen were done using HACH, HQ40d portable multi meter and turbidity was measured using Wagtech Turbidity Meter, Model Wag-WT 3020. Other physicochemical parameters, including BOD_5, TSS, TN, TDS, nitrate (NO_3^-), TP, and SRP were analysed in the laboratory.

BOD_5 is the difference between the concentration of DO in water sample taken instantaneously and concentration of DO that has been incubated for 5 days at 20^{O}C in the dark. TSS and TDS were determined using the gravimetric method (APHA 1999)**;** TSS water samples were filtered through a pre-weighed glass fiber filter paper, and placed into a 105° C drying oven for 12 hours to remove any remaining water, then removed from the oven and placed into a desiccator to cool at room temperature; the difference in weight was calculated as TSS and for TDS the filtrate of water sample was evaporated to dryness in a pre-weighed dish and dried to a constant weight at 180 °C. The increase in the weight of the dish after drying represents the total dissolved solids.

Nitrate was analysed using the LCK 138 laton – HACH (UK) kit that digests a sample volume 1-16 mg/L. Inorganically and organically bounded nitrogen is oxidized to nitrate by digestion with peroxodisulphate finally determined by a spectrophotometer and TP was analysed using standard methods (APHA 1999).

4.2.3.5 Statistical analysis.

Descriptive statistics (median, range and standard deviation) of the wet and dry season's water quality data obtained from the three landuses categories were used to examine the relationship between landuse and the water quality of tributaries. The water quality data obtained for the different landuse areas in the four sub-watersheds were compared to estimate their impact on water quality during the wet and dry seasons using nonparametric tests. Differences among groups were identified using the Kruskal-Wallis test. Correlations were examined using Spearman's rank correlation procedure. Data analyses were performed with SPSS software Version 20.

4.3 RESULTS

4.3.1 Landuse categories of the study area

Eight landuse classes were identified and consolidated into four classes (Fig. 4.2) and show their characteristics in tabular form to calculate areas and percentages of each landuse for easier visualization of how each landuse is distributed as a percentage of the total study area (Table 4.1).

Table 4.1 Areas of the landuse classes in the four sub-watersheds of the Gilgel Gibe I Reservoir watershed

Landuse classes in the main watershed			Landuse classes in the sub-watershed							
			Gibe		Yedi		Nadaguda		Nedi	
Landuse	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Natural vegetation	155,673.3	36.85	116,034.2	38	4,781.82	22.4	13,829.34	34.6	21,075.87	37.7
Farms	191,349.5	45.3	137,262.2	44.9	11,280.64	52.9	18,650.56	46.6	24,194.02	43.3
Settlements	69,851	16.54	49,988.8	16.4	4,558.42	21.4	5,366.34	13.4	9,885.43	17.7
Water	5,527	1.31	1,772.16	0.58	724.46	3.4	2,171.13	5.4	807.27	1.4
Total	422,400.8		305,057.4	72.2	21,345.34	5.05	40,017.37	9.47	55,962.59	13.3

4.3.2 Description of landuse/land cover (LULCC) classes in Gilgel Gibe watershed

Natural Vegetation: This category includes forestland (secondary forest, especially eucalyptus vegetation**,** natural forest patches on steep slopes and riparian vegetation) bush and shrub land widely distributed.

Farmland: Cultivated and fallow land and pastures; this category is widely distributed; also sporadic herbaceous plant communities separated by bare space.

Settlements and bare land: Farmsteads and land with sparse or no above ground vegetation like eroded surfaces, silt deposits and rocky areas. Because it was difficult to distinguish between bare land and settlements, these two categories were consolidated as one.

Water bodies: Rivers and wetlands

Gibe sub-watershed is the largest sub-watershed of the Gilgel Gibe catchment, accounting for 72.2% of the study area. Farmland is the dominant land use type. Nedi watershed is the second largest sub-watershed (13.2%). Agriculture is the main land use type in Nedi, Nadaguda and Yedi sub-watersheds, accounting for 43.3%, 46.6% and 52.9% of their areas, respectively.

The mapped study area covers 422,400.8 km^2 and is dominated by farmland (cultivated, fallowed land and pastures), which covers 191,349.5ha (Table 4.1). As a result of population growth and movements, farmers are expanding agricultural land and grazing land into forests and brush land (Ambelu 2009).

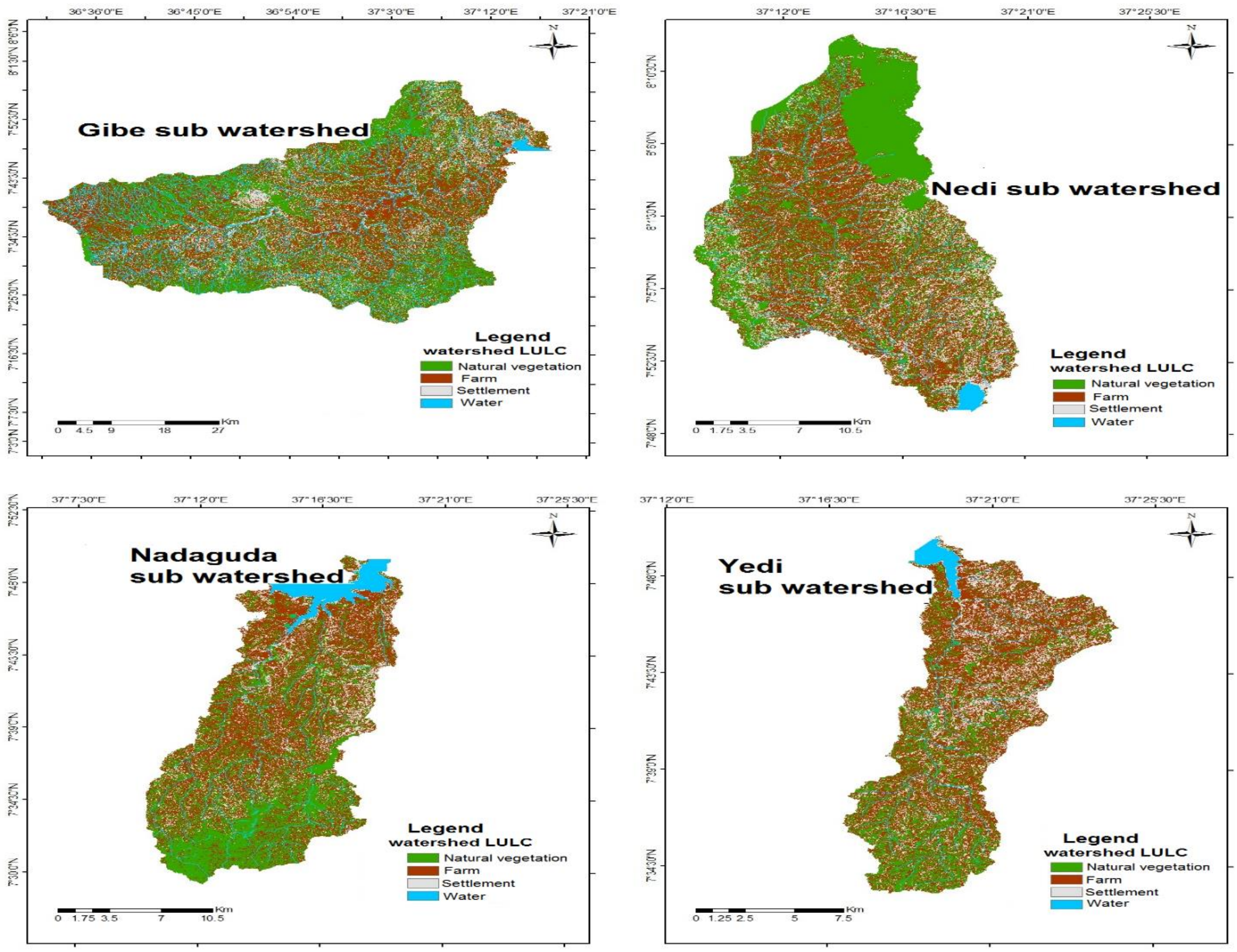

Fig.4.2 Landuse composition of the four sub-watersheds in Gilgel Gibe watershed.

Fig. 4.2 shows the four sub- watersheds in the study area. GIS analysis classified the landuse in the study watershed into four landuse classes. These are farmland (45.3%), naturally vegetated land (36.9 %), settlement and bare land (16.5%) and water (1.3%).

4.3.3 Water quality

The descriptive statistics of physicochemical parameters under study during the wet season (Table 4. 2) and dry season (Table 4. 3) provide a summary of the median and value ranges of the 12 measured parameters during the wet and dry seasons. Kruskal-Wallis statistical test ($p < 0.05$) showed significant differences in the distributions of DO, temperature, BOD_5, TP, SRP, TN, TDS, TSS, and turbidity across the three landuse categories during the wet season (Table 4.2**).** During the dry season, all water quality parameters except DO, temperature and BOD_5 had similar distributions across the three landuse types**.** All variables except DO, EC, TP, and SRP showed significant seasonal differences in the Mann-Whitney U test ($p < 0.05$).

Table 4.2 Descriptive statistics of wet season tributary water quality in the four sub-watersheds of Gilgel Gibe. Except for EC (µS/cm), WT (^oC), pH and TURB (NTU) the rest are in mg/L

WQ Parameters	Gibe		Yedi		Nadaguda		Nedi	
	Median	Range	Median	Range	Median	Range	Median	Range
DO	5	4-6	4.9	4.6-5.2	4.8	4.5-5.4	4.8	4.25-5.8
EC	119	97-135	110.7	100-122	111	101-122	113	100-128
WT	23.8	23-24	24.1	24-24.3	23.9	23.6-24	24	23-25
PH	7.27	6-8	6.4	6-6.8	6.9	6.8-7	7	6.5-7.4
BOD5	6.4	5-7	6.3	6-6.8	6.5	5.8-7	6.5	5.7-7
TP	0.24	0.08-0.4	0.22	0.12-0.4	0.17	0.15-0.2	0.2	0.12-0.3
SRP	0.12	0.08-0.19	0.12	0.07-0.18	0.11	0.08-0.2	0.1	0.06-0.2
TN	13.5	6-20	12.51	9.5-16	11.7	9-14	12	6-16
NO3-	1.2	0.75-1.6	1.12	1-1.3	1.27	1.05-1.5	1.28	1-1.5
TDS	92	79-102	90	86-98	88	81-97	87	80-93
TSS	536.7	120-1020	280.7	135-463	270	130-475	367	120-512
TURB	57.9	42-82	57.2	45.6-79	57	46-79	56.7	44-79

WQ =water quality, WT= water temperature, TURB= turbidity

Table 4.3 Descriptive statistics of dry season tributary water quality in the sub-watersheds of Gilgel Gibe I Reservoir.

WQ Para meters	Gibe		Yedi		Nadaguda		Nedi	
	Median	Range	Median	Range	Median	Range	Median	Range
DO	5	4.8-5.6	4.8	4.7-5	5	4.9-5.3	4.9	4.7-5
EC	129	107-145	120.7	110-132	121	111-132	123	110-138
WT	24.9	24.9-25	25.5	24.9-26	24.8	24.5-25	24.9	24-25.7
PH	7.3	7-7.9	7.4	6.9-8	7.29	6.9-7.8	7.81	7.54-8
BOD_5	4.9	4.6-5.4	5.23	4.9-5.8	5	4.6-5.5	5	4.3-5.5
TP	0.21	0.17-0.3	0.18	17-0.2	0.19	0.14-0.23	0.15	0.1-0.2
SRP	0.07	0.05-0.1	0.08	0.05-0.1	0.1	0.06-0.14	0.05	0.04-0.06
TN	9.12	7.6-10.3	11.18	9.9-12.6	7.9	6.9-9	6.4	6.05-7
NO_3^-	0.69	0.6-0.8	0.76	0.56-0.9	0.7	0.5-0.9	0.8	0.73-0.9
TDS	104	92-111	103	99-110	98	90-106	107	101-115
TSS	117.5	102.4-130	115.7	108-125	113.9	100.6-125	122.7	118-130
TURB	41.7	40-43	44.7	41-49	43.7	40-50	45	42-51

Except for EC (µS/cm), WT (^oC), pH and TURB (NTU) all variables are in mg/L WQ =water quality, WT= water temperature, TURB= turbidity

4.3.4. Dissolved oxygen

DO concentrations ranged from form 4mg/L to 6mg/L and 4.7mg/L to 5.6mg/L during the wet season and dry season, respectively. The highest median DO value (5.6 mg/L) and the lowest value (4.4 mg/L) were recorded at naturally vegetated and farmland sites, respectively, in the wet season (Fig.4.3). In wet and dry season, among land use types (natural vegetated areas, agricultural areas and settlement) statistical significant differences were observed.

The values for pH (r = -0.674), EC (r = -0.709), BOD_5 (r = -0.830), TN (r = -0.870), TDS (r = -0.691), TSS (r = -0.882), turbidity (r = -0.702), TP (r = -0.716), and NO_3^- (r = -0.525) were negatively correlated with DO at $p < 0.05$. The inter-quartile range (IQR), which is the difference between the 75th and 25th percentiles, was very high for naturally vegetated landuse type in both wet and dry season, indicating high variability. During the wet season, in multiple comparisons using Kruskal-Wallis statistical analysis, DO was significantly different at $p< 0.05$ between the naturally vegetated and agricultural landuse types.

4.3.5 Temperature

Water temperatures obtained during the sampling period for the dry season differed significantly at 95% confidence level among sites. Generally, water temperature among tributaries varied between 23^0C -25^0C and 24^0C-26^0C in the wet and dry seasons, respectively (Tables 4. 2 and 4.3). These values are within the range of 20^0C – 30^0C, and likely suitable for aquatic organisms.

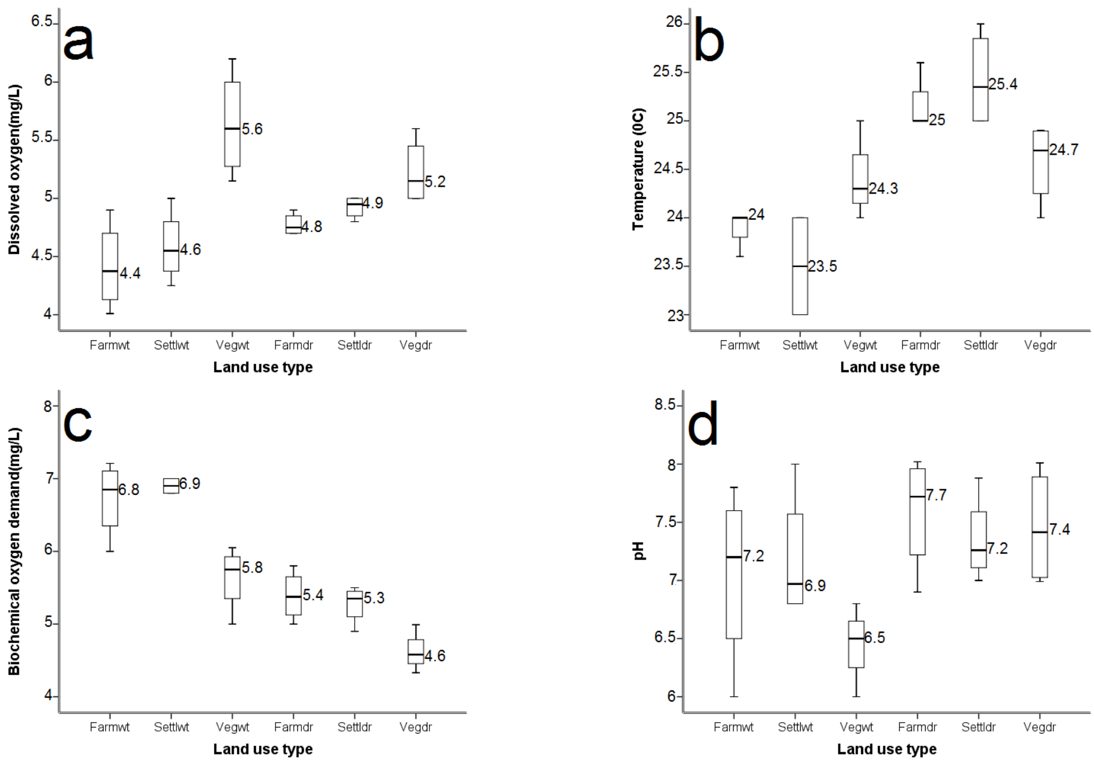

Fig. 4.3 Box plot describing DO (a), temperature (b), BOD_5 (c) and pH (d) concentration at sites in the three landuse types

4.3.6 BOD_5

BOD_5 concentrations ranged from form 5mg/L to 7mg/L and 4.3mg/L to 5.8mg/L during the wet season and dry season, respectively. The highest median BOD_5value (6.9mg/L) was recorded for settlement landuse in the wet season and the lowest (4.6 mg/L) value for naturally vegetated landuse type in the dry season (Fig. 4. 3c). BOD_5 values for naturally vegetated landuse were significantly lower than those for all other landuse types in the wet season. BOD_5 concentration and other water quality parameters measured during the wet season were significantly correlated with TP (r = 0.650), TDS (r = 0.610), and turbidity (r = 0.601) at $p < 0.05$, TN and TSS (r = 0.742), (r = 0.795) at the $p < 0.01$ level. In the dry season, nitrate was significantly correlated (r = 0.576) at $p < 0.05$ level. Values of BOD_5 were also significantly higher during the wet season. at $p < 0.05$ level.

The inter-quartile range (IQR), which is the difference between the 75^{th} and 25^{th} percentiles, was high (Fig. 4.3) for agricultural land use type in both wet and dry seasons, indicating a high variability in biochemical oxygen demand levels in the agricultural areas.

The inter-quartile range (IQR), which is the difference between the 75^{th} and 25^{th} percentiles, was high (Fig. 4.3) for agricultural landuse type in both wet and dry seasons, indicating a high variability in biochemical oxygen demand levels in the agricultural areas.

4.3.7 pH

The results over the sampling period showed that median values of pH (6 - 8) in the tributaries were slightly basic. During the wet season, maximum pH values were found in the settlement landuse type (Fig. 4.3d); pH showed also a significant positive relationship with BOD_5 (r = 0.824), TN (r = 0.621), TSS (r = 0.777) at p< 0.01 and with TP, TDS and turbidity at p<0.05. There was no significant difference in pH among the three landuse types during both seasons.

4.3.8 Electrical conductivity

During the wet season, EC values ranged from 97µS/cm -135µS/cm, with the highest median value of 113µ/cm (Table 4. 2) and during the dry season, the values ranged from 107µS/cm-145µS/cm, with the highest median value of 129µS/cm (Table 3). Fig. (4.4a) shows high loadings of EC associated with agricultural landuse during the wet and dry season. EC was positively correlated with pH (r = 0.851), BOD_5 (r = 0.832), TSS (r = 0.824,), and turbidity (r = 0.732) at p<0.01. TP, TN, and TDS showed (r = 0.639), (r = 0.686) and (r = 0.669) at p< 0.05 in wet season, while in dry season, EC was negatively correlated with turbidity (r = -0.710) at p< 0.01 but positively with TP (r = 0.653) at p< 0.05**.**

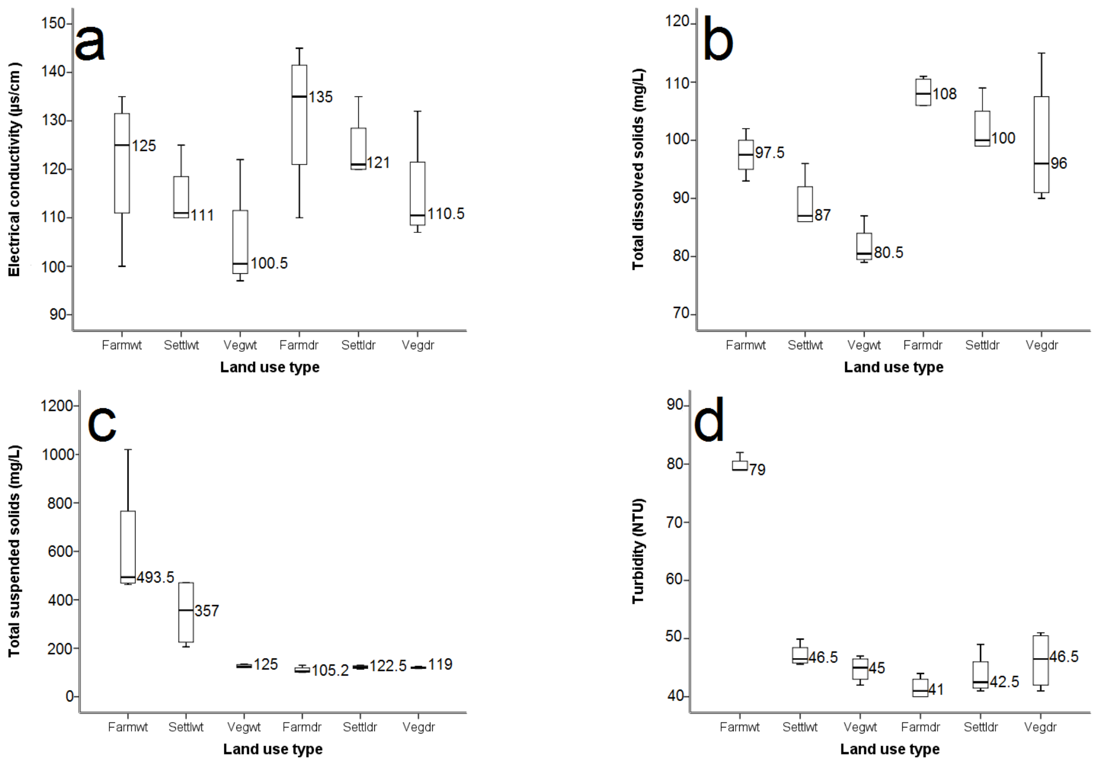

Fig. 4.4 Box plot describing EC (a), TDS (b), TSS (c) and turbidity (d) concentrations in different landuse types in Gilgel Gibe watershed

4.3.9 Total dissolved solids

TDS values ranged from 79mg/L-102mg/L in the wet season and 90mg/L-115mg/L in the dry season. During the wet season, they were significantly associated with TP (r = 0.931,) SRP (r = 0.788) and TN (r = 0.900) at p <0.01. EC (r = 0.6691), BOD_5 (r = 0.610), and NO3- (r = 0.653), all at the p < 0.05 level. In multiple comparisons using the Kruskal-Wallis test, TDS values were significantly different at p <0.05 between naturally vegetated and agricultural landuse types during the wet season. The highest median value (108mg/L) was observed for agricultural landuse type in the dry season, and the highest median value for this landuse was 97.5mg/L in the wet season (Fig. 4.4b).

4.3.10 Total Suspended Solids

Total Suspended Solid (TSS) content of water depends on the amount of suspended particles, which is directly related to turbidity of water. In this study, the concentration of TSS varied from 120mg/L-1,020mg/L during the wet season and 100.6mg/L-130mg/L during the dry season, which were significantly ($p<0.05$) different using the Mann-Whitney U test. During the wet season, agricultural landuse showed significant difference than in the naturally vegetated and settlement landuse categories (Fig. 4.4c). Wet season TSS values were also significantly correlated with EC ($r = 0.824$), TP ($r = 0.853$), TN ($r = 0.938$), TDS ($r = 0.879$), BOD_5 ($r = 0.795$), SRP ($r = 0.828$), pH ($r = 0.777$) at $p <0.01$ and NO_3^- ($r = 0.673$) at $p< 0.05$

4.3.11 Turbidity

Turbidity values ranged from 42 - 82 NTU during the wet season and from 40 - 51 NTU during the dry season. During the wet season, multiple comparisons using the Kruskal-Wallis test to compare turbidity for the three landuse categories showed a significant difference at $p <0.05$ between naturally vegetated and agricultural landuse. Turbidity in the wet season was significantly correlated with EC ($r = 0. 732$), TP ($r = 0.957$), TN ($r = 0.895$), NO_3^- ($r = 0.758$), TDS ($r = 0.961$), TSS ($r = 0.885$), SRP ($r = 0.770$), all at the $p<0.01$ level, and with BOD_5 ($r = 0.601$) at $p<0.05$. There were no significant differences in turbidity values between the seasons.

4.3.12 Nutrients

Seasonal analysis of total phosphorous, soluble reactive phosphorus, total nitrogen and nitrate distribution among the three landuse types using the Mann-Whitney U test and spatial analysis using Kruskal-Wallis test showed significant differences at the $p< 0.05$ level. During the wet season, all high nutrient values were associated with agricultural landuse (Fig. 4.5). TN and nitrate concentrations were higher than the other two nutrients, with median value ranging from 11.7mg/L – 13.5 mg/L and 1.12 mg/L – 1.28 mg/L, respectively (Table 4. 2).

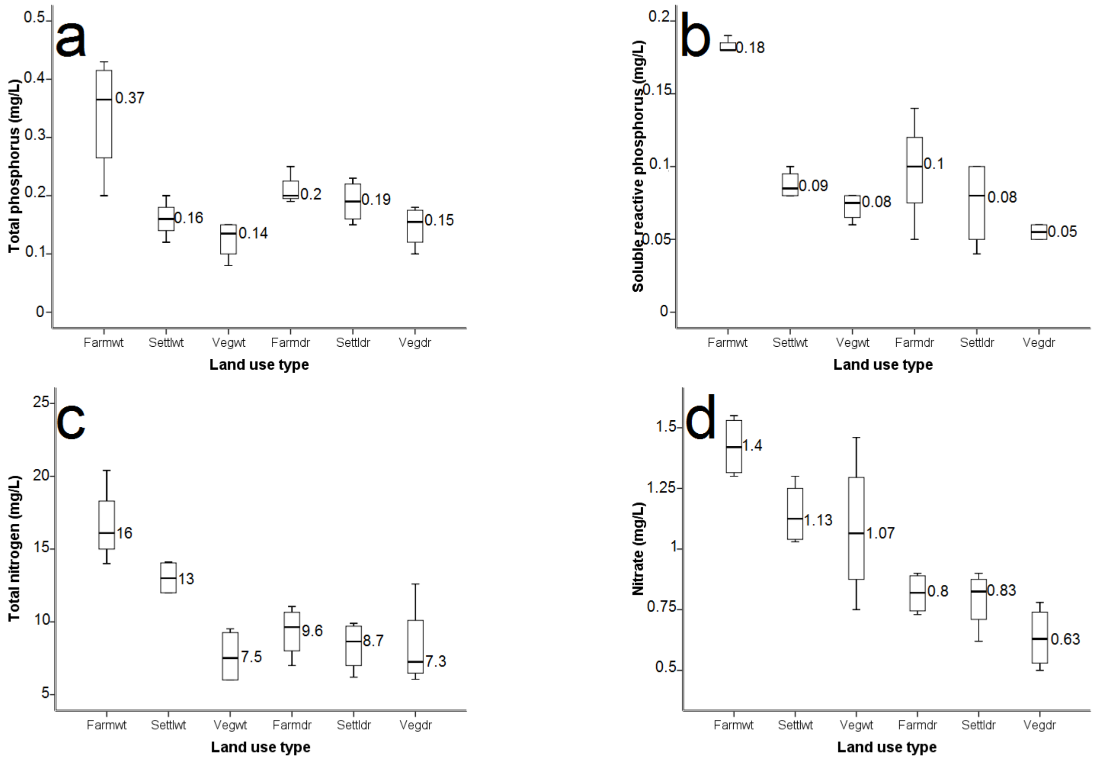

Fig. 4.5 Box plot describing TP (a), SRP (b), TN (c) and NO_3^- (d) concentration in different landuse types in the Gilgel Gibe watershed during the wet season

Total phosphorus (TP) strongly correlated with SRP, TN, NO_3^-, TDS, TSS, and turbidity (r = 0.767, 0.919, 0.801, 0.931, 0.853, and 0.957, respectively), at $p < 0.01$. Using the Kruskal-Wallis test, TP, SRP and TN showed significant difference at $p < 0.05$ between naturally vegetated and agricultural landuses in the wet season.

4.4 Distribution and variation of nutrients among tributaries

This result was based on wet season data collection of TSS, turbidity and nutrient (Table 4.4) (October 2018) from four tributaries of the four sub watersheds as to support and give priority for the conservation and management of subwatershed.

Table 4.4 Median and range of TSS, Turbidity, TP, SRP and Nitrate among the four major tributaries in wet season

Tributary name	TSS (mg/L)		Turbidity (NTU)		TP (mg/L)		SRP (mg/L)		NO^{-}_3 (mg/L)	
	Median	range	Median	range	Median	range	Median	range	Median	range
Gibe river	116.95	112.4- 121.6	34.12	23.9 - 47	0.49	0.196-0.63	0.09	0.03-0.18	2.8	1.7-4.5
Nadaguda river	117.7	101.2- 125.2	24.8	18.9 - 27	0.56	0.19-0.94	0.21	0.03-0.87	1.7	0.23-3.54
Nedhi river	122.37	119.4 - 126	45.43	42.8 - 48	0.6	0.48-0.68	0.3	0.06-0.72	3.2	1.5-4.6
Yedi river	137	113.6 – 150	45.52	40.7 - 49	0.6	0.45-0.72	0.09	0.05-0.18	2.8	0.48-3.8

Principal component analysis techniques are useful tools for identification of important water quality parameters and possible factors/sources that influence the aquatic systems. PCA of water quality parameters for the major rivers in the study area showed differences in nutrient concentration during the study period. Correlation of principal components and original variables is given by loadings (Ndungu et al. 2015). For the first component DO, TDS and TP recorded high positive loadings of 0.8624, 0.7374, and 0.4479 respectively negative loadings were observed for temperature (-0.8784) and electrical conductivity (-0.8432). In the second component high positive loadings of 0.7451, 0.681, 0.5351, 0.5224 and 0.4836 were detected for TSS, turbidity, SRP, nitrate and BOD_5 respectively but pH accounted -0.5265. The high loadings represent a relatively a high correlation among them.

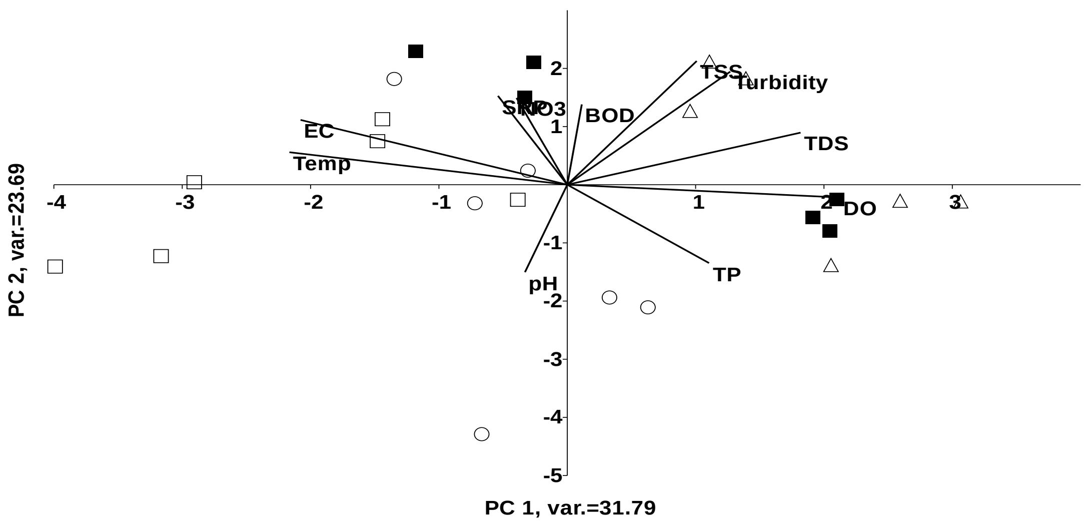

Fig.**4.6** PCA analysis of water quality parameters for major tributaries in the Gilgel Gibe catchment (sampling sites for major tributaries Gibe, Nadaguda, Nedhi and Yedi represented by square, circle, dark square and triangle respectively)

The PCA analysis extracted two PCs with eigenvalue >1, and explained 55.48% of the total variance. The first PC which explained 31.79% of the variance positively associated with DO, TDS, and TP while negatively associated with EC and temperature. These parameters were also linked with Nedhi and Yedi tributary system (Fig. 4.6) than other tributaries. The second

PC that explained 23.69% of the variance positively associated with TSS, turbidity, SRP, nitrate, and BOD_5 while negatively linked with pH.

The bi-plot of the first and second principal components showed that water quality parameters (TDS, TP, DO, turbidity, TSS, SRP and nitrate) allied with Nedhi and Yedi tributary system hence these are the parameters influencing these two sites. The available forms of nutrients (nitrate and SRP) were considered as the most important factor of PC 2, and total phosphorus for PC 1. We also observed agricultural activities to the very near edge of the two tributary systems in these tributaries (Plate 4.1).

Plate 4. 1 Cultivation near the tributaries in the study area (Gilgel Gibe watershed)

Kruskal-Wallis test for tributaries' nutrient has showed that there was a statistically significant difference ($P < 0.05$) between Nitrate Vs SRP and Nitrate Vs TP in all tributary system which is indication of change in nutrient during this study.

The results of PCA in this study revealed that nutrients which are associated with TSS and turbidity were more specifically distributed in Nedhi and Yedi rivers. This clearly indicates that they are major contributor of nutrients to the reservoir system hence conservation priority should be given to the watershed of these rivers.

4.3. DISCUSSION

This study, based on field observations and empirical measurements, found water quality to be strongly associated with landuse in the Gilgel Gibe watershed. EC and TDS were lower in the naturally vegetated area than in the agricultural and settlement areas in the wet season. This agrees with the work of Githaiga et al. (2003), Ngoye and Machiwa (2004) and Kambwiri et al. (2014). EC of water was a good indicator of the amount of ionisable substances like phosphates, nitrates and nitrites, also noted by Tafangenyasha and Dzinomwa (2005). TDS concentration was strongly correlated to conductivity. During wet and dry seasons the highest levels of EC and TDS in both agricultural and settlement landuse types indicateing release of dissolved ions from agricultural and settlement areas.

Tafangenyasha and Dzinomwa (2005) also stated that increases in water conductivity levels indicate that the amount of ionisable substances like nutrients are washed into and dissolved by the water system. Increases in EC and TDS during the dry season may be attributed to decreases in water level due to reduced surface runoff and increased evapotranspiration.

Anthropogenic activities are major causes of excess nutrient loads in surface waters (Hamaidi 2013). In our study, we demonstrated that among the four studied tributaries of the Gilgel Gibe I Reservoir, Gibe sub-watershed has the largest agricultural land area and carried the largest nutrient load, corroborating the study by Hassan et al. (2015). Nutrient concentrations were higher in both agricultural and settlement areas than on naturally vegetated land during the rainy and dry season. SRP was significantly higher in the agricultural area during the wet season (Fig. 4. 5b).

Seasonally higher loads of inorganic materials and nutrients were recorded during the rainy season than during the dry season when surface and river runoff were lower. This is in agreement with the work of Ngoye & Machiwa (2004), Takeda et al. (2009), Kebede et al. (2014) and Bonansea et al. (2016) and may suggest anthropogenic sources of nutrients such as agricultural fertilizer and animal wastes that leach into the aquatic system. Yalemsew et al. (2015) found that 95% of the annual nitrate load was transported from the Gilgel Gibe watershed during the wet season.

Agricultural landuse is the major landuse category in the main watershed and is highly concentrated in the Gibe sub-watershed, comprising 13, 7262.2ha of its land area (Table 4. 1). The highest median values of pH in the dry season (7.7) and in wet season (7.2) were associated with agricultural landuse (Fig. 4. 3d). All recorded pH values were within pH range (6-9) suitable for fish health and growth (EPA and UNIDO 2003).

Gibe watershed also maintained a higher mean values for almost all water quality parameters during the wet season (Table 4. 2**).** This will have indication for the sources of variability and identify relationships between tributary water quality and agricultural landuse. In Gilgel Gibe I Reservoir, there was a strong association between the values of most of the water quality variables and agricultural land. This may lead to eutrophication and ecological disturbances (Ribeiro et al. 2014).

Though this study (2014/15) found high concentrations of TSS and high levels of turbidity in all four tributaries, during 2018 (Table 4.4) water quality assessment measurement of Turbidity and suspended sediment values were higher at Yedi river and then Nedhi river hence most of the sediment loading happens from these rivers. Total suspended solids (TSS) constitute the main vector of contaminants during wet weather periods (Ashley et al., 2005), including nutrients present in water bodies come from runoff and erosion (Hasan et al. 2012). This may reflect a negative influence on tributary system by agricultural discharges (Ndungu et al. 2015).This is in agreement with Kebede et al. (2014). Soil distribution in the catchment is closely associated with its geology. The landscape in the catchment is characterized by deep weathering rock profiles (Regassa et al. 2014), variation in soil type, topography, and land cover sensitive to erosion (Lencha and Moges 2015). Soils in the Gilgel Gibe catchment are associated with planosols and vertisols, which are highly susceptible to erosion (Mertens, 2014). Increased surface runoff contributes to turbidity and its positive relationship with total suspended solid concentration facilitates the estimation of total suspended solids (Daphne et al. 2011) and is the effective indicator of TSS (Huey and Meyer 2010). Turbidity may be caused by soil erosion, excess of nutrients and various wastes and pollutants disposed into water bodies (Gandaseca et al. 2014; Pullanikkatil et al. 2015). Higher concentrations of total nitrogen, higher electrical conductivity and turbidity during the wet season in the agricultural areas are consistent with Ribeiro et al. (2014).

Non-Point Source for pollutants include different land use classes like, agriculture, construction sites and urban runoff. TSS and turbidity also increased significantly under agricultural landuse during the wet season (Fig.4. 4c and 4. 4d). Highest concentrations of TSS and turbidity from these sites occur during high flow event (surface runoff) and cause impairment of water bodies. During the wet season, tributaries had high (1020 mg/L) TSS values (Table 4. 2) due to heavy runoff, which has been reported by other studies (Ling et al. 2014). The lowest TSS concentration (100.6mg/L) was recorded during the dry season (Table 4. 3).

4.6 CONCLUSIONS AND RECOMMEDATIONS

Overall, this research was conducted to reveal the impact of watershed landuse on the water quality of rivers in a watershed characterized by different types of landuse. Results of the study could be used to better understand the fluctuation of water quality parameters under landuse changes in different seasons. Long-term landuse changes and unsustainable agricultural activities have deteriorated the quality of the tributary water system. Among four landuse categories of the Gilge Gibe catchment, agricultural landuse was found to have the highest pollution loads and thus the greatest effect on water quality, followed by settlement landuse. The high pollution loads may cause further declines in water quality and cause eutrophication. This situation requires proper landuse management and conservation to alleviate the problem. It is also essential to maintain a riparian buffer zone along all river and stream channels in the Gilgel Gibe catchment to mitigate the impacts of the land-based anthropogenic activities. In order to further reduce the surface inflow of pollutants into Gilgel Gibe I Reservoir, we recommend that farmers also maintain a buffer zone around the reservoir. These preventive measures may be achieved through proper motivation of farmers and provision of incentives and guidance by local elders enforcing traditional conservation laws.

5

GENERAL DISCUSSION, CONCLUSION AND FUTURE PROSPECTS

5.1 GENERAL DISCUSSION

An agroecosystem dominates landscapes in many areas of the world, particularly in highland regions. Agroecosystems are complex environmental systems involving interactions of many species, processes of natural ecosystems and activities associated with agricultural production. Historic productivity gains in agriculture have sometimes been associated with practices that rely heavily on external inputs of energy and chemicals. The intensity to which the environment has been modified to increase productive capacity has resulted in the land degradation, soil erosion and reduction in both water quality and quantity. Water quality has attracted considerable attention globally due to impact on human and animal health, aquatic life, recreation, industry, and agriculture. Accelerated increase in global population has laid sever impacts on water quality through point and non-point source, and increased water use.

In the tropics, the sedimentation of reservoirs may be one of the most economically crippling in the near future because land use changes near and within watershed catchments. Water managers are increasingly facing challenge of building public or stakeholder support for resource management strategies (Stave, 2003). The problem is becoming more critical in Ethiopia than elsewhere (Desta, 2005). Wolancho (2012) argued that Ethiopia was heavily affected by watershed management problems due to poor cultivation practices, deforestation and overgrazing, loss of soil fertility, rapid degradation of natural systems, sediment depositions in the lakes and reservoirs and sedimentation of irrigation infrastructures. Dechasa (2010) also indicated as erosion destruct the environment in Ethiopian highlands. Thus, understanding reservoir influencing factors that can lead to impairments in the socio-economic and political well-being of Ethiopia require raising of stakeholder awareness of resources.

Central to this effort, the variability and concentration of suspended sediment needs special attention in terms of tributary and reservoir water quality. Increased concentration change depends on seasonal variability especially in response to extreme and intense rainfall events and anthropogenic activities in the watershed. Dissolved particulate matters commonly reach rivers through runoff; they transferred in to the reservoir and substantially affect the water quality in various ways. The presence of organic and inorganic compounds that either suspended or dissolved in water are important to determine the water quality (Perera et al. 2014). In developing countries, water quality deteroration is commonly as a result of weak management practices and illegal waste disposal (Li et al. 2015; Ling et al. 2017; Zinabu et.al, 2019), and effects as a result of land use changes in the watershed. Measuring seasonality and many other variables that can act synergeticly or antagonisticaly is vital in understanding their effect and interaction in the environment. The change of water quality parameters may not be the same in different localities even within a country. Among reasons seasonal changes may not be the same due to its linkage with complex natural process and human activities in a particular catchment. Gilgel Gibe I reservoir is dependent on complex functions of physiographic characteristics of its catchment. These functions have potential effect on water quality. Low DO and high BOD_5 documented in our study indicated organic pollution load from the watershed. This could be mainly resulted from intensive biological processes (photosynthesis) due to algal growth caused by nutrient, respiration and decomposition of organic matter (Rajwa-Kuligiewicz et al. 2015). The value of TN and TP also suggested eutrophication likely to taking place in the Gilgel Gibe I reservoir. The reservoir depth analysis of water quality has also shown variability in vertical distribution of physicochemical parameters. This implies, different depth allows the existence of various physicochemical concentration that may be related to various interacting factors at different water column.

Intensification of human socio-economic activities **(**livelihood strategies) and major land use changes influence watershed systems. These factors have strong consequences for surface water quality, especially in developing countries (Chen and Lu 2014; Khan et al. 2017). Farmers in Ethiopia are highly striving to be out of poverity, hoping to achieve their basic needs in lifetime from the environment in which they live. In this attempt, sustainable resource usage has been limited, leading to increased run-off and soil erosion that bring sediment accumulation on reservoirs. In particular, Gilgel Gibe I watershed where farming is the major economic activity in the area becomes vulnerable for watershed degradation. Local communities in the watershed are an integral part of the system, thus perceptions of resource utilization have to be understood in the context of impacts on the environment. Watershed management as a measure of development implies that the resources within a defined watershed should be utilized for the benefit of the local population and in harmony with the environment (Förch1and Schütt 2004). There are areas in Ethiopia such as in Oromia, Amhara, and Tigray regions where an integrated watershed management approach were reported as effective in improving agricultural productivity, groundwater and surface water recharge. However, to create awareness concerning the implementation of integrated watershed management in the study areas among different stakeholders, workshops were organized for participants from different sectors. They reached on consensus to establish national taskforce that would work in integrated watershed management on basins. Yet, during this study, instead of conservation and management practices, aggravated resource depletion was observed. Most of the local people in Gilgel Gibe I watershed are farmers and don't have any other means to generate additional income. Lack of livelihood diversification worsens watershed degradation due to absence of demarcation of buffer zones and being not familiar to obey land use management policies. Inadequate management of watershed together with a lack of soil and water conservation practices could favour degradation of ecosystems (Medeiros et al. 2010). It is known that watershed provides essential goods and services to local communities.In this thesis, knowledge, attitude and conservation practice of the local communities were assessed to determine their participation in watershed conservation. In line with this, Heyd and Neef (2004) suggested "local people participation is a crucial prerequisite for the conservation and sustainable use of water resources". The implications of afromentioned causes could be land use changes in the watershed via farmers that can further influence ecological and social services (Rong et al.2009).

Local land use changes are fundamental agents of climate change at all scale and are significant forces that impact biodiversity and water. At local and regional scale, land cover change can have profound impacts on aquatic systems due to new land use practices that adversely affect water quality and sedimentation (Rong et al. 2009). Gilgel Gibe I reservoir water quality strongly associated with land use changes and has the highest pollution load (Woldeab et al. 2019). Agricultural activities such as cultivation of marginal land, increased use of fertilizers, and deforestation increasing the risk of eutrophication and loss of biodiversity (Bhateria and Jain 2016). Thus, the observed sediment accumulation in the reservoir has implication for loss of storage capacity that affects macroinvertebrates and fish species. Thus, fish species have decreased radically (causing food insecurity), incure loss of habitat and biodiversity. Sediment accumulation in the reservoir would result low production of hydroelectricity (power fluctuation), and failing to meet the country's demand for power. Therefore, land use and land cover change becomes a problem that needs to be solved urgently. Off-farm activities and ecological conservation practice to support watershed management mainly in developing countries are far from the existing (Panda and Behera 2003). Improving the present poor practices of farmers in watershed conservation and restoration initiatives is mandatory.

Ethiopia has a history of watershed management initiatives dating back to the 1970s. The basic approach has recently shifted from top-down (community-based approaches) in the early 2000s (Gebrehaweria et al. 2016). The involvement of local people with their traditional knowledge, in combination with modern techniques is the main characteristics of integrated watershed management (Heathcote 2009). This approach requires managing human activities and natural resources on a watershed basis taking into consideration the connected interests and needs of the environment, economy and society. In the studied catchment, efforts to promote community participation and involvement have been minimal. Consequently, most of the interventions carried out have not been successful (PHE 2011).

The findings also indicated that socio-economic factors, knowledge and practice had significant impact on watershed conservation, causing Gilgele Gibe I watershed degradation. Conservation measures with proper follow-up techniques have important implications for improved watershed resource in sustainabable ways (Belayneh et al. 2019). Repeated run off and land slide occurred in the area as a result of improper follow-up and maintenance in Gilgel Gibe I catchment. Agidew and Singh (2018) stated that such uncertainty is manifested by a farmers' reluctance to participate in the watershed management. Assefa (2018) in his study also supported that farmers were not motivated because of the destruction of previously developed micro-watersheds due to frequent run off and human and animal disturbances. In our study, there was also variation in involvement of local people in conservation activities. Significant variability of community practices have been noticed in the study area. Poor public participation is among watershed problems to be solved on a sustainable basis by watershed management (Erdogan 2013). Participation was at individual level and contexts. Lack of such systematic cooperation can hamper effective resource management and environmental planning as noted in literature (Kim et al. 2015). It has been observed that farmers used their own conservation measures as much as possible, however, soil and water conservation structures are inconsistently distributed throughout damaged areas. Watershed management and conservation is effective in improving agricultural productivity, especially conservation measuresare held during critical times of the year by selecting appropriate strategies (Morgan 2009; Kato et al., 2011; Adimassu et al., 2014; Melaku et al. 2018). Mati (2006) also explained as the design of conservation structures should consider severity and extent of erosion damage or risks as well as the suitability of land to the identified intervention.

The hydroelectric dam is one of the technology that provides access to modern energy. Dam is also one of the potential water control to provide non-energy services like flood control and irrigation. It has also a strategy to attain sustainable growth. The intention in developing hydroelectric plant was based on a) social and economic benefit (provide constant supply of water and satisfy the electric power energy need to improve the social status). Locally, it can provide agricultural-based economy, and nationally can reduce foreign currency for fossil fuel consumption, and b) environmental benefit (reduce the use of biomass as a source of energy). Nevertheless, in the rural areas, electricity can be transmitted to thousands of kilometres away from the generating plant while the local dwellers are devoid of this access. Poor households are forced to use fuel-wood to meet their energy needs. This has implication on unequitable resource usage, and hence difficult to mobilized community based resource management. This problem will generate burden on limited vegetation/forest resources in the watershed.

Furthermore, the current perception of the community is also linked with insufficient compensation payment that could result in livelihood crises and social as well as economic problems. Less access to land and water is among many problems prominent as impact of displacement. In the study area, if the condition of resource management to reduce degradation is not improved, sustainability of the environment is extraordinary. Though protecting the Gilgele Gibe I dam from siltation and other possible problems (including landslide) is a priority to stakeholders, due to natural environmental phenomena and persistent anthropogenic actions around the dam the reservoir may disappear without achieving its expected reservoir life span, initially supposed to serve for 50-70 years.

Watershed management problems are usually quite diverse as a result of involving a wide range of biological, geological, chemical, and physical processes. It involve complex human, social, and economic contexts. More complexity is also added because watershed management commonly involves land and water integration across spatial and temporal scales. Research findings indicated that increased global change pressures which include inter alia, and climate change have increased concerns over the supply of adequate quality freshwater (IPCC, 2007; Smeti et al., 2009). Effectively addressing these wide-range of factors often require the application of integrated and participatory watershed management.

5.2 STRENGTHS AND LIMITATIONS OF THE STUDY

This study had both strengths and limitations. One of the strength is addressed the issue of spatial and temporal variation of water quality parameters with in the reservoir and tributary water quality in relation to the land use system. This is vital to give impression about what is in reality as to minimize the problem related with pollution and water quality degradation. It also tries to evaluate the trophic state of the reservoir suggesting the reservoir was eutrified. The study also reported the sub watershed with intensified agricultural activity as to give priority by stakeholders in the area and decision makers to manage and make decision for conservation action of the watershed.

The study had also some limitation. Sampling size and seasonal conditions are the main limitation of this study. Seasonal water samples (two wet seasons and one dry season) were collected to represent the water quality for the reservoir and tributaries. These may not allow the trend to generalize yearly variations of the water quality parameters. As in the case of developing nations, where resource is limited major water quality changes were explored in a short duration of sampling based on simple (in terms of automatic sampling equipment) and inexpensive water quality monitoring methods. Thus, due to lack of resources (logistic materials support) the study could not be protracted beyond these above mentioned limitations.

5.3 CONCLUSION

Reservoirs, beside hydroelectric generation, provide water for domestic uses, recreation, irrigation, fishing etc. However, seasonal change and anthropogenic activities have led significant changes in their water quality and function as well. Land use pattern, poor farming system overgrazing, deforestation and overall Poor watershed management practices cause accumulation of excess sediment, which is the most important challenges and aggravated impairment of reservoir water quality. This may affect the aquatic ecosystem service, reduction in aquatic biodiversity and reduce the reservoir storage capacity consequently failed in the intended function of the reservoir such as. electricity, fishing, water supply and etc.

Despite its limitations, this study recognize suspended solids may impair the reservoir (sediment loads), nutrient and contaminant transport, observe blue green algae reveals that it is eutrified and the high N: P ratio and TSI classification provide justification that the reservoir is considered as eutrophic system. Therefore, all these facts have sounded the alarm regarding the future of reservoir water resource to be conserved and used sustainably for future generation.

5.4 FUTURE PERSPECTIVE

Our results demonstrated that the reservoir water quality was degraded from spatio-temporal assessment result due to natural and anthropogenic activities going on in the watershed releasing sediment load and pollutants by tributaries through runoff. The status of reservoir water was eutrified, in terms of nutrient parameters method (Redfield ratio) and the trophic state index of Carlson (1977). The results are undeniable. A comprehensive index that provide a global vision on overall water quality (Xu 2005) will be suggested for detailed understanding of the watershed and reservoir ecosystems and further research with a multidisciplinary team performing intensive continuous monitoring of the reservoir with its catchment in space and time should be conducted.

Management recommendations

- Give priority (identify susceptible areas') for implementation of conservation structures
- Discuss the constraints of poor watershed conservation practices and strengthen the capacity of farmers' participation
- Watershed condition should be evaluated frequently to provide and support protection programme
- Maintaine buffer zone through incentives for farmers who performed well.
- Establish non-agricultural activities (like handicrafts, sewing etc.) that act as an alternative to farming activities and minimize the burden on exploitation of natural resource.

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Publications

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2. Megersa, M., Beyene, A., Ambelu, A. and **Woldeab, B.,** 2014. The use of indigenous plant species for drinking water treatment in developing countries: a review. *Journal of biodiversity and environmental sciences*, *5*(3), pp.269-281
3. Woldeab, B., Beyene, A., Ambelu, A., Buffam, I. and Mereta, S.T., 2018. Seasonal and spatial variation of reservoir water quality in the southwest of Ethiopia. *Environmental monitoring and assessment*, *190*(3), p.163.https://doi.org/10.1007/s10661-018-6527-4
4. Woldeab, B., Reta Regassa, Tibebu Alemu, and Moa Megersa, 2018. Medicinal Plants Used for Treatment of Diarrhoeal Related Diseases in Ethiopia. Hindawi. *Journal of Evidence-Based Complementary and Alternative Medicine.* Volume 2018, Article ID 4630371Evidence-Based
5. Woldeab, B., Ambelu, A., Mereta, S.T. and Beyene, A., 2019. Effect of watershed land use on tributaries' water quality in the east African Highland. *Environmental monitoring and assessment*, *191*(1), p.36.https://doi.org/10.1007/s10661-018-7176-3

Major Activities and responsibilities

- Faculty Team leader of Teaching learning enhancement
- Department head
- Delivering courses like Biodiversity, Ethno biology, Wetland management for Ecotourism and Biodiversity conservation BSc. students
- Advising BSc. Thesis

Certificate and other skills

- Basic training certificate on FRG (Farmers Research Groups)
- Computer Skill: (Very good in MS word, MS, excel Internet and Power Point)

Reviewed journals

- International Journal of Environmental science and Technology