Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Hydrology and Hydraulic Engineering Chair

Masters of Science in Hydraulic Engineering

Assessment of Impact of Turbidity on Reservoir Storage, A Case Study of Gilgel Gibe I Reservoir, Southwest, Ethiopia

By: Aduna Bekele Birmachu

A Thesis Submitted to the School of Graduate Studies of Jimma University, Jimma Institute of Technology in Partialfulfilllment of the Requierment for the Degree of Masters of Science in Hydraulic Engineering.

March, 2021

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Main Advisor: Mr. Tolera Abdissa (Assistant Professor)

Co-Advisor: Mr. Nasir Gebi (M.Sc.)

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Jimma, Ethiopia

DECLARATION

Hereby, I declare that, this thesis entitled as **"Assessment of Impact of Turbidity on Reservoir Storage of Gilgel Gibe I Reservoir"** is my original work and has not been presented for a degree in Jimma and any other university. All sources of material used for this thesis have been duly acknowledged.

Submitted by Aduna Bekele

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Signature Date

This thesis has been submitted for examination with our approval as university supervisors.

Approved by:

Main- advisor: Mr. Tolera Abdissa (Ass.Prof.)

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Signature Date

Co-advisor: Mr. Nasir Gebi (M.Sc.)

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Signature Date

ABSTRACT

Turbidity is one of the responsible factor for changing the quantity of water stored in reservoir by increasing surface water temperature and evaporation. Therefore, determination of the impact of turbidity on water stored behind the dam is crucial to understand several environmental phenomena and social issues. This study was centered on, assessing the impact of turbidity on reservoir storage of Gilgel Gibe I reservoir. The samples(data) were taken from the reservoir near to rainfall event ceased by stratifying the reservoir water randomly during different time, based on turbidity variation along the longitudinal axis of reservoir. To attain the goal of this study, both in laboratory and on field experiments were performed. To determine the relationship that turbidity has with surface water temperature and downward vertical alteration of water temperature along with turbidity variation, ten pools were burrowed and they were covered with white transparent plastic to preclude turbid water infiltration and entrance of soil water into the pools. Two Class A pans were used to determine surface water evaporation and storage change was evaluated from volume of water evaporated from Gilgel gibe I reservoir obtained at full supply level of the reservoir. Water temperature in pools and evaporation from pans were measured at a different time interval of a day and during different days of a month respectively. Water temperature data were recorded for 15 days at different time of interval and average value were taken to analysis the data. To determine surface water evaporation,40days of data were taken within 24hours interval and average value were exploited to analysis it. Data were analyzed using SPSS version20 software and MS excel 2016 spreadsheet to determine correlation and regression analysis respectively. Therefore, the study concluded that: turbidity had direct strong positive relation with water temperature at 9:00 and 13:00 observation hours and strong negative relation at 17:00 observation hours. The spearman`s rank correlation coefficient(r) value at 9:00 and 13:00 was +1 and at 17:00 was -1. The tests statistic values (F, R^2 and p) which obtained by simple linear regression and ANONA were given as: F (1, 8) = 126.730, 28.989 and 219.301, 0.965, 0.784 and 0.941 and P <.001, P=.001and P <.001 respectively for the three observation hours sequentially (9:00,13:00 and 17:00), water temperature decrease vertically from the top to the bottom layer of the pools which revealed by box and whisker plot, in which there is greater extinction of sunlight in most turbid than least turbid pool with the difference in water temperature of 9.78°C and 1.53°C for both water samples and F (2, 27) = 39.587 and p <.001 obtained by univariate general linear model, turbidity had direct strong positive relation with reservoir water evaporation with spearman`s rank correlation coefficient(r) value of +1. The test statistics attained from simple linear regression and ANOVA were given as: F (1, 8) =14443999.960, p<.001 and R^2 = 1 and turbidity has an impact on the water stored in a reservoir by engendering storage change. The difference in volume of the water evaporated from a reservoir for most turbid (226NTU) and least turbid (43.7NTU) water was, 65.812 cubic meters. The value of coefficient of determination was (R^2) = 1, which obtained from simple linear regression. All tests were statistically significant. The results revealed that, if reservoir water turbidity increase, it immensely affects the quantity of the water stored in the reservoir by causing significant loss of the water as water vapor.

Keywords*: Experiment, Gilgel Gibe I Reservoir, SPSS Software, Turbidity, Water Temperature*

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ACRONYMS

A.M.S.L	Above Mean Sea Level
ANOVA	Analysis of variance
DEM	Digital Elevation Model
DS	Dissolved Substance
EGoDWT	Experimental Guidelines on Determination of Water Turbidity
EPA	Enviromental Protection Agency
FAO	Food and Agricultural Organization
GGI	Geneva Group International
GIS	Geographic Information System
IS	Indian Standard
ISI	Indian Standard Institute
GGHPEIAR	Gilgel gibe Hydropower Enviromental Impact Assessment Report
LULC	Landuse Landcover
LULCC	Landuse Landcover Changes
NTU	Nephelometric Turbidity Unit
SAS	Statistical Analysis System
SPC	Suspended Particles Concentration
SPSS	Statistical Package for Social Sciences
SS	Sample Size
SSP	Suspended Solid Particles
UNIDO	United Nation Industrial Development Organization

1. INTRODUCTION

1.1 Background

Turbidity is the cloudiness of water engendered by large numbers of suspended individual particle (Gelda *et al.*, 2013). It is a major problem encountering the global environment, because the world has been facing an adverse global climate change which results the baring of land surface and soil erosion. This change has great influences on water bodies, highly the reservoirs which have been constructed with high cost and immensely required for socio-economic development of the countries. Turbidity has a strong positive relation with suspended sediment concentration and strong negative relation with the transparency of water (Modini, 2010).

The activity of LULCC for the expansion and intensification of farmland and construction of infrastructures heighten the alteration of: air temperature, net solar radiation, precipitation, surface runoff and alleviate soil erosion (Dibaba *et al.*,2016). This activity and events affects the clarity of surface water bodies (Gnanadesikan and Anderson, 2009). Reservoir turbidity can be reduced by managing and controlling an activity and events that initiate it (Szatten *et al*., 2018).

Turbidity causes the rise of water temperature due to the absorption and scattering of net solar radiation striking the surface of the water by suspended particles. Turbidmeter is an easy to handle and most popular device for suspended sediments measurement(Metzger *et al.*, 2018). Turbid water temperature can be reduced by lessening the concentration of suspended particles and removing plankton that drive the rise of turbidity. Both turbidity and water temperature diminish along the longitudinal axis of the reservoir near the surface of the water (Prestigiacomo *et al.*, 2008).

According to Laanaya *et al*.(2017), there are three long-familiar water temperature modelling. They are; Statistical, Deterministic and Stochastic models. All these models have their own limitations and need data to analysis water temperature for the different water body. For this research, parametric and non-parametric statistical type model was adopted, depending on the availability of the data required for analysis and their requirements.

Evaporation from artificial lakes and reservoirs is more than that of the natural water surface flow because of an increase in surface area of the body of water (Kohli and Frenken, 2015). Depending on the location, evaporative losses from a reservoir can be exceeding the consumptive water usage(Wurbs and Ayala, 2014). The physical drivers of reservoir evaporation are predominately governed by a magnitude of vapor pressure gradient between water surface and the overlying air. This gradient is governed by the surface temperature of the water, absolute humidity in the atmosphere and the amount of turbulent mixing of the air (Friedrich *et al.*, 2018). Reducing reservoir evaporation offers a potential option for water conservation at source through the concept of smart location and geoengineering. Therefore, estimation of the volume of water evaporated from a reservoir is immensely required to attain the planned goal of a dam(Coelho *et al.*, 2018)

According to Wolka (2012), many of Ethiopian reservoirs such as, Koka, Angereb, Legadadi and Gilgel Gibe I which have been established for hydroelectric power, urban water supply and irrigation accumulate alarmingly higher levels of sediment than expected. Due to this high rate of sedimentation, Gilgel Gibe I dam`s volume will be reduced by half within 12years and would be completely filled by sediment within 24 years, with an expected surveillance period of 70years, unless timely remedial measures are taken. Since, the relation between sedimentation and turbidity is positive, Gilgel Gibe I reservoir have been affected by turbidity. The accumulation of suspended particles in reservoir step-up its turbidity (Wolka, 2012). It causes the rise in water temperature as well as evaporation that results the falling of the quantity of water stored in the reservoir (Prestigiacomo *et al.*, 2008). Hence, the primary objective of this study was to assess the impact of turbidity on Gilgel Gibe I reservoir.

1.2 Statement of the problem

Ethiopia is one of the countries on the path of development and farming is an anchor for economic development of it. Mostly, deforestation is an activity which has been executed for expansion and intensification of agricultural area. This activity: increases soil erosion, affect the hydrological process and enhance river sedimentation (Dibaba *et al*.,2016).

Soil eroded from the catchment area of the water body causes water turbidity and this turbidity alleviates light rays to be scattered and absorbed instead of transmitted in a straight line through water (Paaijmans *et al*., 2008). It is induced by the existence of suspended particles and its pattern varies spatially and temporally in a reservoir (Gelda *et al.*, 2013). The intensity of suspended particles is eminent during the rainy season in water bodies. Density and the size of suspended particles lessen near the surface of the water along the longitudinal axis of the reservoir, due to an increase in the accumulation of suspended particles on the bed of reservoir (Szatten *et al*., 2018). Turbidity alters water temperature, as the suspended particles in the water column absorb and scatter sunlight and hence, ascertain the extinction of net solar radiation striking the surface of the water and there is spatial variation of surface water temperature (Paaijmans *et al*., 2008). Thus, as we move from upstream water courses to dam site, the near surface water temperature decreases, due to the fall of turbidity current in a reservoir along this axis (Gelda *et al.*, 2013). The raise of surface water temperature causes the increment of the number of moving water molecules that break from the water surface and escape into the air as water vapor(Benzaghta and Mohamad, 2009). Most of the time, the number of water molecules that removed from water body is larger than the number that re-enters the water surface from the air and become entrapped in the liquid (Brutsaert, 1982) and it causes falling of the quantity of water stored in the reservoir (Prestigiacomo *et al.*, 2008).

The catchment area of Gilgel Gibe I reservoir has been under the serious problem of soil erosion and a rapid loss of storage volume, due to excessive soil erosion and subsequent sedimentation in a dam reservoir. Deforestation, land degradation and farming activity facilitates soil erosion from catchment area of the reservoir. The eroded soil increase the concentration of suspended particle in the reservoir(Tesfaye and Tibebe, 2018) and it is the main drivers of water turbidity that affect the water stored in the reservoir by increasing near surface water temperature and surface water evaporation (Paaijmans *et al*., 2008).

1.3 Objectives

1.3.1 General objective

The general objective of this study is to assess the impact of turbidity on reservoir storage of Gilgel Gibe I reservoir through experiments.

1.3.2 Specific objectives

The specific objectives of the study were outlined as follows: -

1.To determine the relationship between turbidity and surface water temperature.

2.To investigate downward vertical alteration of water temperature along with turbidity variation.

3.To determine the relationship between turbidity and surface water evaporation.

4.To evaluate effects of turbidity on reservoir storage of Gilgel gibe I.

1.4 Research questions

1) What is the relationship between turbidity and surface water temperature?

2) Is water temperature alters vertically downward along with turbidity variation?

3) What is the relationship between turbidity and surface water evaporation?

4) What is the effects of turbidity on reservoir storage of Gilgel gibe I reservoir?

1.5 Significance of the study

Since the research centered on assessing the impact of turbidity on reservoir storage of Gilgel gibe I reservoir, it is expected to increase the knowledge and up to date information on the impact of turbidity on reservoir storage of Gilgel gibe I reservoir. It will also serve as a working document to policy makers, power planner and power supplier. The study moreover serves as baseline data for any further investigation, as a useful material for academic purposes and as an added literature to the existing knowledge.

1.6 Scope of the study

The scope of the research is limited in space and time. The research was conducted to assess the impact of turbidity on reservoir storage of Gilgel gibe I reservoir.

2. LITERATURE REVIEW

2.1 Water turbidity

Water is natural resource which is fundamental for all living things. It is the basic need for human being welfare and other ecosystems(Kale, 2016), but it has been affected by many factors such as: water turbidity, water temperature(Gelda *et al.*, 2013), algae and other organic matters(Ma *et al.*, 2015). Water turbidity is an expression of the optical properties of the water sample that alleviates light rays to be scattered and absorbed rather than transmitted in straight line through the sample. It shows the cloudiness of water which is induced by the existence of suspended particles (Gelda *et al.*, 2013), and turbidity diminish the transparency of a water (Ziegler, 2002). Turbidity is qualitative characteristics which is imparted by a solid particles obstructing the transmittance of light rays through the sample and it often indicates the presence of dispersed and suspended solid. It can be expressed by nephelometric turbidity units (NTU).

Depending on the method used, the turbidity units as NTU can be defined as the intensity of the light at a specified wavelength scattered or attenuated by suspended particles or absorbed at a method-specified angle, usually 90 degrees from the path of the incident light compared to a synthetic chemically prepared standard (Ziegler, 2002). Since water turbidity is a factor that affect water quality, the determination of its impact is mandatory (Paaijmans *et al*., 2008).

2.1.1 Causes of water turbidity

There are a number of substances that cause the turbidity of the water. These are:- suspended and dissolved particles originating from; reservoir catchment area, reservoir banks and bed, tannic acids often associated with peat and bog areas, Phosphorus, organic matter from sewage discharges, urban storm water runoff (Quality, 2008) and algae(Alaska, 2015).

2.1.1.1 Runoff water from erosion susceptible catchment area

A significant density of turbid flow follows high rainfall events in many lakes and reservoirs. An eminent turbidity occurs when a lot of water is running through the system as surface runoff after a rainfall event enters in the reservoir. Low turbidity can be due to slow moving or stagnant water that allows suspended particles to settle out of the water column (Jansen and Teuling, 2019).

2.1.1.2 Storm water runoff from urban area

Storm runoff events in the flood season affect the water quality of reservoirs and increase risks to the water supply for; power generation, irrigation and drinking. The phenomenon of turbid current intrusion results in water turbidity and anoxic conditions reappears after storm runoff ensuing in the deterioration of water quality. Problems of high outflow turbidity and sediment deposition in reservoirs often accompany storm runoff. High inflow volumes carrying a large amount of solids and organic matter increased the oxygen consumption rate and anoxic conditions reappeared after the storm runoff ended and accelerated the release of pollutants. The water quality problem aroused by rainstorms has become severe in the source reservoir which not only brings risk to the water plants but also seriously affects the city's water supply safety (Ma *et al.*, 2015).

2.1.1.3 Entrance of organic matter from sewage discharge

The input of easily degraded organic matter can lead to an increase in the oxygen consumption rate in the water and enhance the release of pollutants from the sediment. When turbidity of the reservoir rises due to the entrance of organic matter into it, the amount of dissolved oxygen decreases (Ma *et al.*, 2015).

2.1.1.4 Phosphorus and tannic acid

Suspended solids are important carriers of pollutants such as phosphorus which typically originate from small areas of a catchment. In the landscape, runoff and soil erosion from fertilized agricultural areas and lawns, erosion from riverbanks, riverbeds and sewage effluent are the major sources of phosphorus(Melcher, 2019). The relationship between phosphorus and turbidity is linear in the reservoir when the catchment area is used for agricultural production (Villa *et al*., 2019). When dissolved oxygen concentration is low in the water (anoxic), sediments release phosphate into the water column and this chemical causes excessive growths of algae that results reservoir turbidity(Melcher, 2019).

2.1.2 Impact of water turbidity

Impact of turbidity encompasses; alteration of surface water temperature and enhance surface water evaporation (Paaijmans *et al*. 2008), make water appear murky, causes the incident light to be scattered, partial blockage of incident light, changes water quality, diminish recreational values and aesthetics of water, reduce light penetration depth and affect life of fishes(Alaska, 2015).

a) Alters water temperature and increase surface water evaporation

Turbidity alters water temperature as the suspended particles in the water column absorb and scatter sunlight and decrease in the transparency of a water sample owing to the presence of suspended (Paaijmans *et al.*, 2008). This substances campaigns incident light to be scattered, reflected, and attenuated rather than transmitted in straight lines through the water bodies. An eminent intensity of the scattered, reflected or attenuated light, the greater the value of turbidity(Ziegler, 2002). Turbidity heightens the surface water temperature and evaporation from surface water body (Ali *et al.*, 2016).

b) Changes in water quality

As stated by Kerr (1995), suspended sediments can alter taste, odor, temperature and abrasiveness of water, reduce levels of dissolved oxygen particularly in deeper, decrease the pH of water and decrease water clarity. High turbidity can significantly reduce the aesthetic quality of lakes, streams and reservoirs (Ali *et al.*, 2016). It can step-up the cost of water treatment for drinking and food processing (Quality, 2008)**.**

c) Reduce light penetration depth

Raise in water turbidity associated with suspended solids attenuates the penetration depth of sunlight (Kerr, 1995) and due to the alteration of the concentration of suspended particles; there is fluctuation of light penetration depth. The relationship between turbidity and light attenuation could be expressed as:

$$I(z) = I_o * e^{-KTZ} \quad (2.1)$$

Where, I(z) is the light at distance z below the reference surface(depth), I_o is a light at the reference surface, z is distance from a reference surface to target point and K_T is a light penetration coefficient (Brown, 1984).

d) Affect life of the fishes

An eminence of suspended particle concentration in reservoir harms the life of fishes. These suspended particles reduce feeding rates, impair homing, cause degradation of habitat, increase coughing rate, alleviate physiological stress and histological changes and step-down their growth rates. If the suspended particles contain an organic matter and phosphorous, the generated toxic matter induce the death of the fishes. By causing the death of the fishes, it affects the economic development of the country (Kerr, 1995).

2.1.3 Temporal and spatial variation of water turbidity

Turbid density current of a reservoir varies seasonally in which; the concentration of suspended particles substantially increases during runoff events. The density of suspended particles is high during the rainy season in related with landuse landcover and activity performed on the upstream catchment area of the reservoir. Along the longitudinal axis of the reservoir, concentration of this suspended particles near the surface of the water decrease which causes the spatial variation of turbidity(Prestigiacomo *et al.*, 2008). Intensity and size of suspended particles decrease near the surface of the water along the longitudinal axis of the reservoir. Thus, as the distance far from upstream stretch of the reservoir to dam is increasing, the turbidity of water lessens due to sedimentation process(Gelda *et al.*, 2013). Turbidity of Gilgel gibe I reservoir varies spatiotemporally in which reservoir turbidity is high far from the dam outlet to the longest upstream edge and during the rainy season than the dry season respectively(Woldeab *et al.*, 2018).

2.1.4 Relationship between reservoir turbidity and sedimentation

Sediment transport into water sources and bodies results in the reduction of water quantity and quality, which results an increasing costs of water purification whilst reducing the available water for various other uses(Tundu, 2018). All reservoirs formed by dam on natural rivers are subject to some degree of sedimentation which is continuously supplied by rainfall, runoff, snowmelt and river channel erosion. More than quarter of the river runoff on a global scale is stopped by an artificial reservoirs(Tessler *et al.*, 2017). The creation of an artificial reservoir results a change in the runoff of water from the catchment area and contribute to changing the natural hydrological regime of the river not only through the reservoir itself, but also through human water management discharge regulations.

Many Ethiopian reservoirs such as; Koka, Angereb, Legadadi and Gilgel Gibe I that have been established for hydroelectric power, urban water supply and irrigation accumulate an alarmingly higher level of sediment than expected, owing to a severe soil erosion effect from catchment area of the reservoir. Due to this high rate of sedimentation, Gilgel Gibe I dam`s volume will be reduced by half within 12years and would be completely filled with sediment within 24 years unless timely remedial measures are taken, but the expected surveillance period of the dam is 70years. Soil particles eroded from catchment area affects reservoir as a suspended particle(turbidity) and sediment and turbidity has direct association with sediment. Since parts of the catchment area of Gilgel gibe I reservoir has been used for agricultural activity that amplifies the entrance of suspended and sediment particles in the reservoir, its turbidity and sediments accumulated on the bed of the reservoir is eminent. Since, the relation between sediment and turbidity is positive, Gilgel Gibe I reservoir also affected by turbidity (Wolka, 2012).

2.1.5 Relationship between reservoir turbidity and water temperature

As stated by Paaijmans *et al.* (2008), the suspended particles in the water column absorb and scatter sunlight and hence, determines the extinction of solar radiation which causes the rise of near surface water temperature. When turbidity of reservoir decrease, the surface water temperature of it also fall, due to the deep penetration of solar radiation (Ali *et al.*, 2016).

2.1.6 Relationship between reservoir turbidity and evaporation

Since the relationship between turbidity and water temperature is direct (Paaijmans *et al*., 2008), it depict that, the relationship between reservoir turbidity and evaporation is also proportional, because of the kinetic energy of warm water is higher than that of cool water which results substantial emission of water as water vapor (Ali *et al.*, 2016).

2.1.7 Methods used to measure water turbidity

a) Turbidimetry

Turbidimetry is a method used to measure reservoir turbidity in which the intensity of light transmitted through a medium (sample) is determined by ignoring the measuring of the scattered intensity of the light. The absorbed intensity of the light is calculated by deducting transmitted light intensity from released intensity of the light to the sample (Jenkins, 1982).

b) Nephelometry

Nephelometry is a method used to measure reservoir turbidity in which the degree of light scattered is evaluated. Measurement of turbidity by using nephelometry depend on a comparison of intensity of the light scattered by a sample under defined conditions with the intensity of the light scattered by a standard reference suspension under the same conditions. The absorbed intensity of the light is calculated by deducting scattered light intensity from released intensity of the light to the sample. The operation principle of nephelometry is that, the intensity of the light scattered by the suspended matter is proportional to its concentration. Since the amount of scattered light is far greater than the transmitted light in a turbid suspension, nephelometry offers higher sensitivity than turbidimetry (Jenkins, 1982).

2.1.8 Significance of water turbidity measurement

The knowledge of turbidity provides as: to understand the penetrating characteristics of the light striking the surface of natural water bodies, to empower us with the knowledge of its relation with water temperature and evaporation, to experience us with the factors that cause water turbidity, to know turbidity impacts on water stored in reservoir and aquatic ecosystem, it help as to know the mitigation measure to be performed to reduce water turbidity (Prestigiacomo *et al.*, 2008).

2.1.9 Reduction mechanism of water turbidity

Water turbidity can be reduced by managing and controlling an activity and events that cause it such as, proper management of the entrance of waste of construction material and appropriate implementation of agricultural practice(Szatten *et al*., 2018). The provisions of vegetative buffers are meant to intercept overland soil runoff before it enters a water body and also stabilize stream banks and shorelines to prevent erosion (Kerr, 1995). Silt barriers or curtains are used to control the entrance of suspended particles in reservoir and they are gaining more popularity as they are relatively inexpensive, durable and easily placed. Mostly, flexible curtain is applicable during construction execution near reservoir(Vermeyen, 2000).

2.2 Water temperature

As stated by Ali *et al.* (2016), the accurate prediction of water temperature in fresh water aquatic ecosystems such as reservoirs, ponds and lakes has gained renewed interest recently, because of anthropogenic global climate change. Water temperature increment in streams and rivers due to global climate change, logging of riparian forests, urbanization and discharges from heated influents has been studied extensively, however little attentions has been devoted for a fresh water aquatic ecosystems water temperature. It is mainly controlled by climatic parameters such as air temperature, solar radiation, humidity, wind speed and cloud cover and human activities like, deforestation and thermal pollution. Water temperature in fresh water aquatic ecosystem substantially influences surface water evaporation, hydroperiod and other processes. The rise in water temperature cause the increment of evaporation from surface water bodies and decrease hydroperiod(Prestigiacomo *et al.*, 2008). As aforementioned by Savannah(2019), a rapid increase in surface water temperature amplifies algal blooms and methane emission. Water temperature of Gilgel gibe I reservoir during the wet and rainy season lies between 22.2-22.87C^0 and 22.49-25C^0 respectively (Woldeab *et al*., 2018).

2.2.1 Water temperature modelling

Water temperature modelling is mandatory, because it is fundamental physical factor controlling water quality and quantity. There are three models used to model surface water temperature. These are; stochastic, deterministic and statistical model(Kerr, 1995).

a) Stochastic models

Stochastic model is a type of water temperature model, that decompose time series into a seasonal and a residual component, so as to produce daily forecasts of water temperature(Kerr, 1995). For a shorter time scales, mostly less than a week stochastic models are preferable than the other due to autocorrelation of water temperature(Benyahya *et al.*, 2008).

b) Deterministic models

Deterministic models are water temperature models that based on the mathematical representation of the physical processes of heat exchange between the water bodies and its natural environment(Kerr, 1995). It simulates the spatial and temporal variations of river water temperature based on energy balances of heat fluxes and mass balances of flow fluxes in a water body(Zhu *et al.,* 2017). Its development based on heat budget calculations along with some degree of hydrological or hydrodynamic modelling and it can provide accurate estimates of water temperature. The main limitation of this model is the acquiring the necessary data required for water temperature modelling(Kerr, 1995). These deterministic models need a great number of input variables, such as river geometry, hydrological and meteorological conditions and thus are often times impractical and time consuming due to their complexity(Zhu *et al*., 2017).

c) Statistical models

Statistical model is a type of water temperature model which is conventionally used. The main advantage of the statistical models over the other models is their relative simplicity and minimal data requirement, fewer parameters requirement, often need a shorter period of development and reduce costs of data and operation. However, they require long series of observations and direct sources of heat flow do not taken into account(Kerr, 1995).

2.3 Evaporation

As stated by Benzaghta and Mohamad(2009), evaporation refers to water losses from the surface of a water body to the atmosphere. It is the second largest component of the global hydrological cycle next to precipitation. It occurs when the number of moving molecules that break from the water surface and escape into the air as vapor is larger than the number that re-enters the water surface from the air and become entrapped in the liquid(Jansen and Teuling, 2019). Evaporation from reservoir is more than that of the natural water surface flow because of an increase in surface area of the body of water (Kohli and Frenken, 2015). A sizable quantity of water is lost every year by evaporation from storage reservoirs and evaporation of water from large water bodies influences the hydrological cycle.

Among the hydrological cycle, evaporation is perhaps the most difficult to estimate, due to complex interactions among the components of land-plant-atmosphere system(Singh and Xu, 1997). Reducing reservoir evaporation offers a potential option for water conservation at source through the concept of smart location and geoengineering (Friedrich *et al.*, 2018). Depending on the location, evaporative losses from a reservoir can be exceeding the consumptive water usage (Wurbs and Ayala, 2014). The estimation of the volume of water evaporated from a reservoir is immensely required to achieve the planned goal of a dam(Coelho *et al.*, 2018).

2.3.1 Effect of evaporation on reservoir storage

Evaporation causes; the depletion of reservoir storage due to loss of quantity of water from it (Husayn, 2015), reduce operational efficiency of the reservoir(Assouline *et al*., 2011) and affect the economic growth of country by reducing its productivity (Martínez-Granados *et al.*, 2011).

2.3.2 Factors affecting reservoir evaporation

Evaporation from a reservoir increases with the rise of: wind speed, air and water temperature, exposed surface area, solar radiation and with the fall of humidity and cloud cover. The physical drivers of reservoir evaporation are largely governed by a magnitude of vapor pressure gradient between water surface and the overlying air. This gradient is governed by the surface temperature of the water, absolute humidity in the atmosphere and the amount of turbulent mixing of air (Lenters, 2005).

2.3.2.1 Reservoir surface area

Evaporation is a surface phenomenon, and quantity of water lost through evaporation from water stored, which depends directly on the extent of its surface area exposed to the atmosphere. If the surface area of the reservoir increase, the area of the water which is exposed to the atmosphere is increase, that heighten the amount of the water escaped from the reservoir(Commission *et al.*, 2006).

2.3.2.2 Wind speed

Wind speed has direct relation with reservoir evaporation that affect it largely, since it removes a humid air above the surface of the water and replace the surface with dry air. The greater a movement of air above the water, greater is the loss of water vapor, because, wind energy carries water vapor from one place to other place. A reduction in wind speed has a substantial influence on the decreasing reservoir evaporation (Yan *et al.*, 2019).

2.3.2.3 Air and water temperature

The temperature of water and the air, at and above the surface of the water respectively affect the rate of reservoir evaporation. The rate of emission of molecules from liquid water is a function of temperature of the water and the air at and above the surface of the water. The raise water temperature causes the movement of water molecules that result the easily removal of the quantity of the water as water vapor. The higher the temperature, greater is the rate of evaporation and eminently affect the quantity of the water stored in the reservoir behind a dam(Commission *et al.*, 2006).

2.3.2.4 Solar radiation

Solar radiation at the surface of terrestrial and aquatic ecosystems is the primary and key energy for many physical, chemical and biological processes. Ethiopia is a high incident solar radiation country due to its location in the tropical zone and receives high solar radiation with an average potential of 5.26 kWh per square meter per day (Nage, 2018). It is a factor immensely affects reservoir evaporation by increasing the molecular movement of the water stored in the reservoir. A reduction of solar radiation that results from increasing both cloud cover and aerosol concentration decrease the scrapping of water as water vapor from reservoir(Yan *et al.*, 2019).

2.3.2.5 Relative humidity

Due to its intimate relation to other factors affecting evaporation, it is difficult to assess the effect of humidity separately. With high relative humidity, there is more chance that vapor molecules escaping from the water surface will collide with an air molecule and rebound into the liquid. Hence, evaporation is likely to decrease with increasing relative humidity, and its deficit depicts significant influence on the increasing reservoir evaporation (Sinha *et al.*, 2006). As ascertained by Yan *et al.*(2019), an increase in humidity of surrounding environment of reservoir decreases its surface water evaporation.

2.3.2.6 Vapour pressure difference

The rate at which water molecules leave the surface of the water depends on the vapor pressure of the liquid and the rate at which molecules enter the water depends on the vapor pressure of the air. The rate of evaporation therefore depends on the difference between saturation vapor pressure at the water temperature and at the dew point of the air that show higher the difference, more the evaporation. Among the climatic factors; solar radiation, diurnal temperature and wind speed has substantial influences on reservoir evaporation (Yan *et al.*, 2019).

2.3.3 Methods used to estimate reservoir evaporation

As stated by Jansen and Teuling (2019), there are a number of methods used to estimate evaporation from surface water bodies. These methods are; pan method, mass balance method, energy budget approach, mass balance and energy budget method, mass transfer model and empirical formula.

2.3.3.1 Pan evaporation method

A Pan is an instrument used to measures surface water evaporation in which evaporation is estimated in depth for a given day. There are a number of pans used to measure surface water evaporation such as; US class A pan, GGI-3000 and $20m^2$ evaporation tank of Russian federation(Yu, 2017). Owing to its availability US class A pan is most widely used type of pan which is mounted on an open wood frame to allow air circulation round and under the pan. Some pans contain thermometer and three-cup anemometer to measures water temperature and wind speed respectively(Kohli and Frenken, 2015).

2.3.3.2 Mass balance method

As stated by Kohli and Frenken(2015), evaporation is calculated as a change in volume of water stored and the difference between inflow and outflow. The feasibility of determining evaporation by this method primarily depends on hydrological and physiographical relative magnitude and setting. Therefore, it is unsuited for large flows water body (Finch and Calver, 2008).

2.3.3.3 Energy budget approach

Evaporation is estimated as the energy required to close the energy budget, when all the remaining components of the budget of the water body is known and evaporation is taken as a residual component of the energy budget. According to this method, energy related to evaporation is categorized as heat required to convert liquid water into water vapor and the energy of a water vapor molecule carried from a water body. The main disadvantages of this method are: it requires a large number of measurements, frequent measurements are needed, the difficulties inherent in making some elements of it and the expensiveness of making the measurement (Finch and Calver, 2008).

2.3.3.4 Mass transfer model

As provided by Finch and Calver(2008), a simple derivation of mass transfer equation used to estimate surface water evaporation is given as below.

$$E = C * u \ (e_s^* - e) \tag{2.2}$$

Where, E is surface water evaporation, C is mass transfer coefficient, u is wind speed, e_s^* is saturated vapor pressure of air at surface water temperature and e is vapor pressure of air at reference height.

2.3.3.5 Mass balance and energy budget method

Mass balance and energy budget method is a method invented by penman (1948) to estimate surface water evaporation from shallow water body and it is not intended for use to estimate evaporation from deep-water body. It is based on the two fundamental factors that determine evaporation, namely: available energy and atmospheric demand. For this research due to an intuitive appeal of apparent, its simplicity and data availability, pan evaporation method was used (Keijman, 1967).

2.3.4 Reservoir evaporation reduction methods

As stated by Waheeb Youssef and Khodzinskaya (2019), there are three methods used to reduce reservoir evaporation, namely physical, biological and chemical methods.

2.3.4.1 Physical method

It is a reservoir evaporation reduction method which contains, floating covers and injection of air bubbles into water. This floating covers act as an impermeable barrier against evaporation (Benzaghta and Mohamad, 2009). It is a most effective method among the three methods used to reduce surface water evaporation by a large percentage which lies between 70 and 95%. Floating continuous covers make an impermeable barrier but modular floating covers are individual units that can float freely and do not completely cover the water surface. Hence, evaporation reduction efficiency of modular floating covers is less than that of the floating continuous cover (Waheeb and Khodzinskaya, 2019).

2.3.4.2 Biological method

Biological covers such as; aquatic plants, windbreakers and palm fronds can reduce significantly the volume of evaporation from water reservoir. Palm fronds which are massive agricultural waste that reduce reservoir evaporation by reducing wind action over the water surface and traps humid air under the cover(Alam and AlShaikh, 2013).

2.3.4.3 Chemical method

When monolayer's chemicals are applied to water they form an invisible film that can be used to cover a reservoir and block evaporation by forming physical barrier to water molecules escaping the surface and a possible shield from air movements interacting with water surface molecules. Polar charged hydrophobic and hydrophilic molecular ends reduce reservoir evaporation by lowering the surface tension of water(Alam and AlShaikh, 2013).

2.4 Statistical data analyzing tools and methods

2.4.1 Software packages used to analysis statistical data

As stated by Acock (2005), there are three fundamental software packages used to analysis statistical data. These are: statistical analysis system (SAS), statistics and data (Stata) and statistical package for social sciences (SPSS).

2.4.1.1 Statistical analysis system (SAS)

Statistical analysis system(SAS) is a software package used to manage and analysis statistical data. But its major strength is data management rather than data analysis. It is strong in analysis of variance. However, it does not used for all statistical or graphical tasks(Acock, 2005).

2.4.1.2 Statistical package for social sciences (SPSS)

Statistical package for social sciences (SPSS) is a software package used occasionally for analysis of statistical data. It is fairly strong on analysis of variance than statistical analysis system. The merit of SPSS over SAS is that, SPSS predominately abandoned its mainframe version and revised its syntax to be consistent with a single user which allows considerable simplification(Acock, 2005). It is one of the most popular of the many statistical packages currently available for statistical analysis, because it allows for a great deal of flexibility in the data format, it provides the user with a comprehensive set of procedures for data transformation and file manipulation and it offers the researcher a large number of statistical analyses processes(Robert, 2006).

2.4.1.3 Statistics and data (Stata)

Statistics and data (Stata) is a software package which is preferred for statistical sophistication than data management than SAS and SPSS. It is the weakest method for statistical analysis of variance (ANOVA) and its consistency is impressive(Acock, 2005).

2.5 Hypothesis testing

Several problems in engineering require that, we decide whether to accept or reject a statement about some parameter. The statement is called a hypothesis and the decision making procedure about the hypothesis is called hypothesis testing. This is one of the most useful aspects of statistical inference, since many types of decision-making problems, tests or experiments in the engineering world can be formulated as hypothesis-testing problems(Robert, 2006). The decision of the statement depends on p-value.

P-value: P-values provide a sense of the strength of the evidence against the null hypothesis. The lower the p-value, the stronger the evidence is. P-value is simply the ratio of the model mean square error to the mean square. The confidence level for the statistical analysis is 95% which indicate that the p-value of the analyzed data should be less than 0.05(Robert, 2006).

2.6 Normality test

An assessment of the normality of data is a prerequisite for many statistical tests because, normal data is an underlying assumption in parametric testing. There are two main methods of assessing normality. Namely; graphs and numeric. There are formal ways to perform normality tests such as Shapiro-Wilk and Kolmogorov-Smirnov. The Shapiro-Wilk Test is more appropriate for small sample sizes (< 50 samples), but can also handle sample sizes as large as 2000. For this reason, Shapiro-Wilk test was used as our numerical means of assessing normality. If the significance value of the Shapiro-Wilk Test is greater than 0.05, we can reject the alternative hypothesis and conclude that the data comes from a normal distribution or the data is normal. If it is below 0.05, the data significantly deviate from a normal distribution. The skewness and kurtosis also used to test normality of the data. The working principle is that, the z- values for both skewness and kurtosis should lies between -1.96 and +1.96 to concluded a data is said to be approximately normally distributed. In order to determine normality graphically, we can use the output of a normal Q-Q Plot. If the data are normally distributed, the data points should close to the diagonal line. If the data points stray from the line in an obvious non-linear fashion, the data are not normally distributed (Park, 2008).

2.7 Statistical tests

A statistical test provides a mechanism for making a qualitative decision about a process or processes. The intent is to determine whether there is enough evidence to reject a null hypothesis or hypothesis about the process. There are two methods used to test statistical data. These are parametric and non-parametric test (Robert, 2006).

2.7.1 Criteria for test selection

There are two main concepts chiefly for the choice of considered an appropriate statistical test. These are: the nature of the hypothesis and the levels of measurement of the variables to be tested. After hypothesis nature is determined in which the hypothesis be either test of difference or test of relationships and the levels of measurement of the variables to be included in the analysis that constitute; nominal, ordinal, interval or ratio, the next step is to choose an appropriate statistical test for analyzing the data. Testing for differences, focus in determining whether differences in mean scores between groups are due to chance factors or to real differences between the groups as a result of the study's experimental activity. Testing of relationships among two or more variables involves asking the question, are variations in variable X associated with variations in variable Y? It also depend on the purpose of the statistical analysis, the number of sets of scores to be included in the analysis and whether the sets of scores are related or independent(Robert, 2006). The level of measurement of the data exploited for this study was ordinal and interval or ratio level.

Table 2. 1:Summary of the selection criteria of statistical tests for statistical data analysis.

Level of measurement	Relationship	Differences			
		One set of scores	Related two Sets	Independent two sets	More than two Sets
Nominal	Biserial and others	Single variable Chi-square test	McNemar significance of change $\chi 2$	Chi-square test of association	Chi-square goodness of fit
Ordinal	Spearman's rho	Kolmogorov Smirnov test for ranked data	Wilcoxon matched pairs signed ranks test	Mann-Whitney U test	Kruskal-Wallis test
Interval/ Ratio	Pearson's & Spearman's correlations Regression	One-sample t-test	Related samples t-test	Independent samples t-test	One-way or Factorial/ Multivariate ANOVA

Source: (Robert, 2006).

2.7.2 Parametric tests

Parametric tests are stronger and for the most part require less data to make a stronger conclusion than nonparametric tests. It makes assumption about population parameters and distribution from which sample taken. However, to use a parametric test, the data must be fulfilled normality test and also the data need to be continuous and interval or ratio level of measurement. If the data do not meet the criteria for parametric test, non-parametric tests are applicable (Garcia *et al.* ,2009). Parametric test contains: one-sample t-test, one sample z-test, one-way and two-way ANOVA and Pearson`s product-moment correlation coefficient(Management and Naukowe, 2011).

2.7.2.1 T-test

The Student t-test is probably the most widely used parametric tests. A single sample t-test is used to determine whether the mean of a sample is different from a known average. A pair-sample t-test is used to establish whether a difference occurs between the means of two similar data sets. Independent sample t-test is a statistical test that determines whether there is a statistically significant difference between the means in two independent variables (Graybill and Iyer, 1962). The t-test uses the mean, standard deviation and number of samples to calculate the test statistic. In a data set with a large number of samples, the critical value for the t-test is 1.96 for an alpha of 0.05 obtained from a t-test table.

2.7.2.2 The Z-test

Within z-test, the variance of the standard population rather than the standard deviation of the study groups is used to obtain the z-test statistic. Using the z-chart, like the t-table, we see what percentage of the standard population is outside the mean of the sample population. If, like the t-test greater than 95% of the standard population is on one side of the mean, the p-value is less than 0.05 and statistical significance is achieved. As some assumption of sample size exists in the calculation of the z-test, it should not be used if sample size is less than 30. If both the ‘n’ and the standard deviation of both groups are known, a pair sample t-test is best (Graybill and Iyer, 1962).

2.7.2.3 ANOVA test

Analysis of variance (ANOVA) is a test used to determine if one or more of the means of several groups are different from others. It incorporates means and variances to determine the test statistic and checks the impact of one or more factor/s by comparing the means of different samples. The test statistic is then used to determine whether groups of data are the same or different. There are three basic assumptions used in ANOVA test. These are: the populations from which the samples were taken are normally distributed, homogeneity of variance and random sampling. The test statistic for ANOVA is called the *F*-ratio (Elliott and Woodward, 2007).

2.7.2.4 Pearson’s correlation coefficient

Pearson’s correlation coefficient or simply correlation coefficient measures the strength of linear association between two measured variables. An important assumption in contribution is the normality of the variables analyzed, which could be true only for quantitative variables. It is calculated as:

$$R = \frac{cov(x, y)}{sd(x) * sd(y)} \tag{3.2}$$

Where: the value of ‘r’ ranges from -1 to +1. A value of the correlation coefficient closes to +1 indicates a strong positive linear relationship. A value close to -1 indicates a strong negative linear relationship. A value close to 0 indicates no linear relationship; however, there could be a nonlinear relationship between the variables (Draper and Smith, 1998).

The following key points show assumptions used for conducting Pearson correlation. These are: the two variables should be measured at the interval or ratio level, there needs to be a linear relationship between the two variables, there should be no significant outliers and the variables should be approximately normally distributed (Graybill and Iyer, 1962).

2.7.2.5 Regression analysis

As stated by Park(2008), there are many methods that we can use to check the validity of the relationships between two or more variables. Among them, in this study the two common methods are used. These are: scatter plot and linear regression analysis. The variables are separated into independent and dependent variables. The variables used to predict other variables are called independent (predictor) and the predicted variables are called dependent or outcome.

There are two basic terms fundamentally considered in regression analysis. These are: Standard error, which is an average error of each measurement sample point on the line of best fit. Out of all the curves the best-fit curve through smaller standard error and it is important because, it is used to calculate other measures, such as confidence intervals and margin of error. The second term is correlation coefficient; it is the act of the linear correlation between two variable x and y, and lies between +1 and -1 for sale inclusive. R = 1 indicates a perfect linear correlation and linear regression perfect, R = 0 is no correlation and R = -1 total negative correlation.

a) Scatter plot

In developing correlations, the first step is creating a scatter plot of the data to visually assess the strength and the form of some type of relationship. This plot depicts: if the points are very close to each other a fairly good amount of correlation can be expected between the two variables. On the other hand, if they are widely scattered a poor correlation can be expected between them. If the points are scattered and they reveal no upward or downward trend, then we say the variables are uncorrelated. If there is an upward trend rising from the lower left hand corner and going upward to the upper right hand corner, the correlation obtained from the graph is said to be positive. Also, if there is a downward trend from the upper left hand corner the correlation obtained is said to be negative(Park, 2008).

b) Linear regression model

Linear regression is a statistical analysis model for calculating the value of a dependent variable from an independent variable. It measures the association between two variables. It is a modeling technique, where a dependent variable is predicted based on one or more independent variable/s. Linear regression analysis is the most widely used of all statistical techniques.

Linear regression has a form:

$$Y = bx + a \tag{3.3}$$

Where, y represents response variable, x represents predictor variable, a, and b are coefficient letters, a, stands for the y-intercept and b, stands for the slope. Linear regression is significance hence, it helps in analyzing the strength of the association between the response and predictor variables and it adjusts for the effect of covariates or the confounders(Kumari and Yadav, 2018).

c) Generalized linear model

Generalized linear model is the extension of linear regression model which is used to analysis non- normally distributed data. It operated that, non-normal responses are transformed to a new quantity that behaves more like a normal random variable. This approach allows for regression modelling when responses are distributed as one of the members of exponential family. It is applicable when a non- normal errors and homogeneous variance comfortably assumed(Myers *et al.*, 2018).

d) Multiple regression models

Multiple regressions are an extension of simple linear regression. It is used when we want to predict the value of a variable based on the value of two or more other variables. A number of techniques can be used to indicate the adequacy of a multiple regression model; some of these are standard error and the coefficient of regression (R^2) values. The standard error of a statistic gives some idea about the precision of an estimate or predictor variable (Park, 2008).

2.7.3 Transformation of data

Data transformation can correct deviation from normality and uneven variance. If the data is not normally distributed, parametric test is not allowed to use in testing the differences between means of variable. To use the parametric test, we need first of all to normalize the data by using the transformation function recommended in statistics. The logarithm, square root and the reciprocal transformation are commonly used methods. After transforming the data, histogram, Q-Q plots and Box plot are plotted to verify if the transformed data are approximately normally distributed. If the transformed data is not fulfilling assumption of normally distribution we use nonparametric test (Elliott and Woodward, 2007).

2.7.4 Non-parametric statistical tests

Non-parametric also called distribution free test is a statistical procedure whereby the data does not match a normal distribution. All tests involving the ranking of data are non-parametric and also no statement about the distribution of data is made(Girish, 2019). Non-parametric tests make no assumptions about the distribution of the data. Nonparametric techniques are usually based on ranks and are usually less powerful than parametric tests. Nonparametric test constitutes: sample sign test, one-sample Wilcoxon test, Friedman test, Kruskal-Wallis test, Mann-Whitney test, Chi-square test, Spearman`s rank correlation test and Kendall`s tau test. Nonparametric tests are more preferable than parametric tests owing to non-requirement of assumption about normality of data and exploited for all types of data (Berkman and Reise, 2016).

2.7.4.1 Mann-Whitney U test

Mann-Whitney U test is a type of nonparametric test which is used to compare the difference between two independent groups (Graybill and Iyer, 1962). There are four assumptions to be fulfilled to perform Mann-Whitney U test. These are: level of measurement of dependent variables should be ordinal or continuous, independent variables should be measured in two independent groups (non-related), independence of observation should be encountered and the two variables should be non-normally distributed(Nachar, 2008). It is used to test the null hypothesis that two samples have the same median or alternatively, whether observations in one sample tend to be larger than observations in the other(Ali and Bhaskar, 2016). The samples values from both sets of data are ranked together. Once the two test statistics are calculated (test statistic for both samples), the smaller one is used to determine significance. Unlike other tests, the null hypothesis is rejected if the test statistic is less than the critical value (0.05). The U-value is widely available for this test (Graybill and Iyer, 1962).

2.7.4.2 Kruskal-Wallis test

The Kruskal-Wallis test uses ranks of ordinal data to perform an analysis of variance to determine whether multiple groups are similar to each other. This test ranks all data from the groups into one rank order and individually sums the different ranks of the individual groups. These values are then placed into a larger formula that computes an H-value for the test statistic.

The degrees of freedom used to find the critical value is the number of groups minus one (Graybill and Iyer, 1962).

2.7.4.3 Chi square test

The research hypothesis states that, the two variables are dependent or related. This is true if the observed counts for the categories of the variables in the sample are different from the expected counts. The null hypothesis is that the two variables are independent. This is true if the observed counts in the sample are similar to the expected counts (Park, 2008). If the probability of the test statistic is less than or equal to the probability of the alpha error rate **(**0.05), we reject the null hypothesis and conclude that our data supports the research hypothesis and we conclude that there is a relationship between the variables. If the probability of the test statistic is greater than the probability of the alpha error rate, we fail to reject the null hypothesis. We conclude that there is no relationship between the variables (Park, 2008).

2.7.4.4 Spearman's correlation coefficient

Spearman's rank correlation is nonparametric measure of the strength and direction of association that exists between two variables measured on at least an ordinal scale. It is used for when the assumption necessary for conducting the Pearson's correlation is failed. Spearman's rank correlation coefficient treating data in a somewhat 'qualitative' way for real data sets(Management and Naukowe, 2011). For this study Spearman's rank correlation was used to analysis the relationship that turbidity has with surface water temperature and evaporation.

2.7.4.5 Kendall's tau correlation coefficient.

Kendall's tau which was invented by Kendall (1938) is a correlation coefficient that can be used as an alternative to Spearman's rho for data in the form of ranks. It is a simple function of the minimum number of neighbor swaps needed to produce one ordering from another. It is advantageous than the other, infact that its distribution has slightly better statistical properties and that there is a direct interpretation of this statistics in terms of probabilities of observing concordant and discordant pairs. Kendall's tau is not applicable by many researchers due to its difficulty to compute. It is equivalent to Spearman's rho in terms of the underlying assumptions but they are not identical in magnitude, since their underlying logic and computational formulae are quite different. Kendall's tau represents a probability which is the difference between the probability that the observed data are in the same order versus the probability that the observed data are not in the same order (Management and Naukowe, 2011).

3. MATERIALS AND METHODS

3.1 Description of study area

3. 1.1 Location

Gilgel Gibe I reservoir is located in the southwestern part of Ethiopia, in Jimma zone of Oromia regional state in Omo -Gibe river basin with the total catchment area of $4218Km^2$ at the dam site or outlet and 260 km by road southwest of Addis Ababa and about 70km northwest of Jimma town (7°50′N and 37°20′E). The longitude and latitude of the catchment area are 36˚31'42.60"to 37˚25'16.05"E and 7˚19'07.15"to 8˚12'09.49"N (Assessment and Report, 1997). It is one of the five major reservoirs in Ethiopia in which its chief purpose is generation of hydroelectric power (Woldeab *et al.*, 2018). A dam of limited height is sufficient to obtain a reservoir with the required storage capacity. The scheme consists of: a rock fill dam with asphalt concrete facing, power tunnel along the left bank of the river, terminal surge shaft, an underground penstock and powerhouse equipped with three power units (Assessment and Report, 1997).

Table 3. 1:Summary of Gilgel gibe I reservoir characteristics

Description	Characteristic
Maximum normal water level	1677m a.m.s.l.
Average water level	1665m a.m.s.l.
Minimum normal water level	1651m a.m.s.l.
Total storage volume in million m^3	839
Live storage volume in million m^3	657
Dead storage volume in millionm^3	182
95% water level	1656m a.m.s.l.
Maximum dam height	40m
Crest dam length	1,600m
Crest dam elevation	1675m a.m.s.l.
Watershed area(Km^2)	4218
Full supply reservoir surface area(Km^2)	54
Dam type	Rockfill with bituminous upstream face

Sources: (Assessment and Report, 1997 and Woldeab *et al.*, 2018)

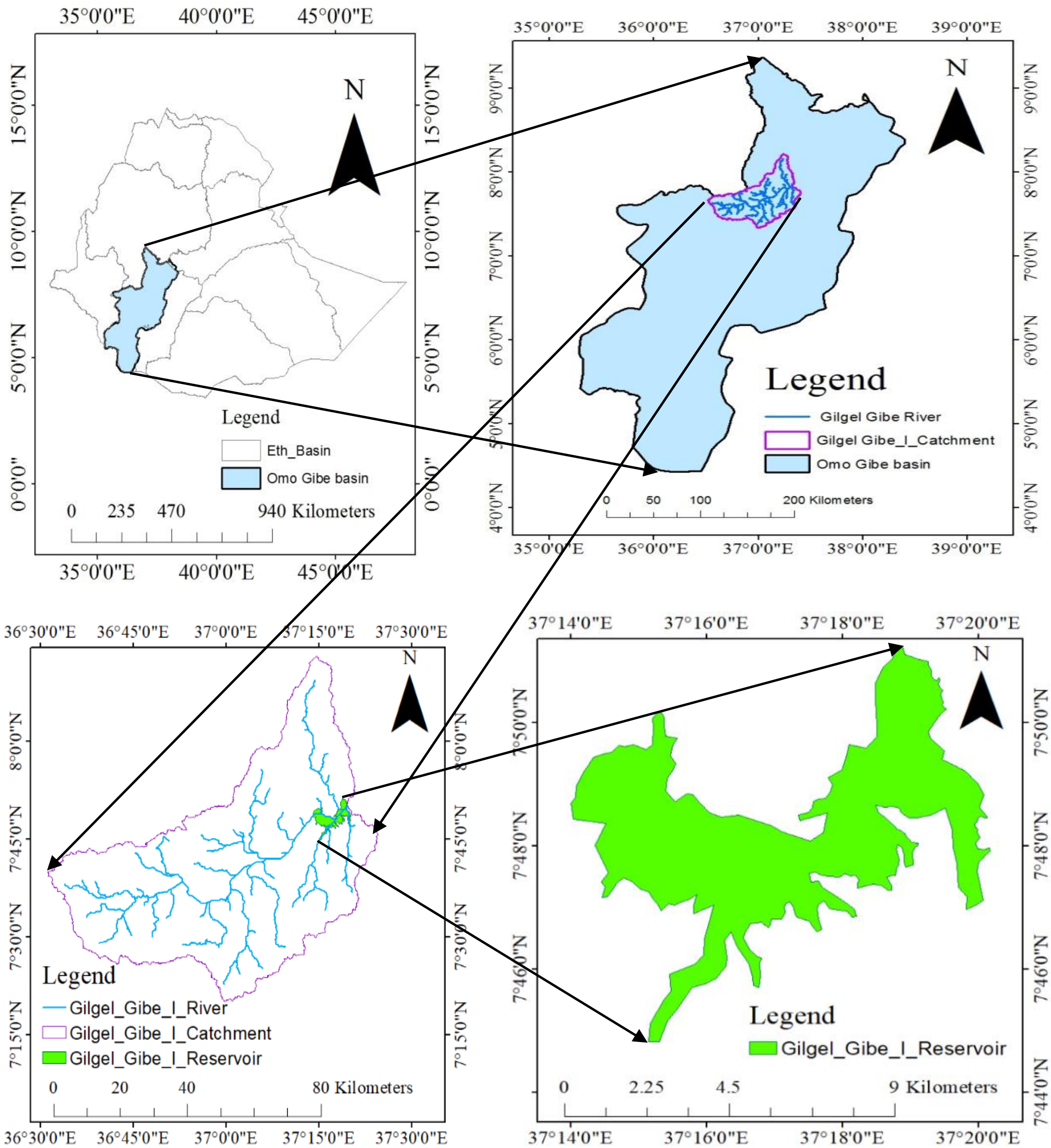

Figure 3. 1: Map of study area

3.1.2 Topography

The topography of the catchment area is heterogeneous with upper plateaus about 1650 m a.m.s.l., that are cut by deep V-shape valleys in the flanks and flat terraces around the Gilgel Gibe river in the center of the catchment (Dibaba *et al*., 2016) and it consists of a series of gentle sloping low hills and broad plains surrounded by hills or mountains(Assessment and Report, 1997). The right bank is more or less flat with some small hills while the left bank is steeper. The terrain is suitable for the construction of a reservoir with a capacity sufficient to regulate most of the river flows and ensuring that unusable spills are kept to a minimum. The riverbanks near the Deneba waterfalls become steeper and this section of the valley is suitable for the construction of water retaining structures (Assessment and Report, 1997).

3.1.3 Soil and Geology

Soil is an important parameter that determines the geological formation of an area. The major soil types in the catchment area were; Nitisols, Fluvisols, Acrisols and Vertisols with the Nitisol domination(Tesfaye and Tibebe, 2018). Soils at the project site are black in the valley bottom, grey brown in the hilly strip and red at higher levels and elevations(Assessment and Report, 1997).

The geology of the catchment area is related to the uplifting of the East African rift valley in the Upper Eocene (Tesfaye and Tibebe, 2018). It is characterized by a series of basic and subsilicic effusive volcanic rocks often inter-layered with reddish paleosols of Tertiary age. The volcanic layers of the project area generally dip a few degrees in a southwesterly direction and are crossed by minor north-east to south-west and northwest to southeast fractures and faults(Assessment and Report, 1997).

3.1.4 Hydrology

Hydrological data of Deneba hydrometric and Asendabo meteorological stations were used for the design of power plant. The mean annual discharge for the period between 1967 and 1992 is 50.4m^3/s for Deneba and 36.8 for Asendabo respectively. For the estimation of flood for a study area regional approach to the analysis was used based on the concept of hydrological homogeneity of different sites in a particular geographical area. This concept assumes that, the probability distribution of hydrological events in a hydrologically homogeneous area is the same, in spite of the scaling factor. In which the design assumed that, the Deneba and Asendabo sites are similar, since both are situated along the main course of the Gilgel Gibe river(Assessment and Report, 1997).

3.1.5 Landuse landcover

The dominant landuse of the reservoir catchment area is agriculture and grazing land in which a mixed farming system is common. Mostly in the upper part of the catchment area, coffee based forest was common(Tesfaye and Tibebe, 2018). It is also characterized by evergreen mountain thickets. Along the Gilgel Gibe River, the small amount of remaining riverine forest provides some habitat for wildlife and provides a source of fuelwood, fire wood, building materials and used for meeting a variety of domestic requirements. It has experienced landuse landcover changes from 1987 to 2010, due deforestation activity for the expansion and intensification of farm land required as a result of rapid population growth (Dibaba *et al*., 2016).

3.1.6 Climate

The climate of the study area is classified as; tropical humid, high-altitude and cool tropic area (Woldeab *et al*., 2018). The seasonal rainfall distribution takes a uni-modal pattern and it is maximum during the summer and minimum during the winter season. An average annual rainfall of the catchment area is about 1347mm. The maximum and minimum mean monthly rainfall is about 287 mm and 43 mm occurred during June and December respectively and its minimum, an average and maximum temperature are 11. 58C°, 19.2C° and 24. 78C° respectively (Tesfaye and Tibebe, 2018). The perceived humidity level in study area as measured by the percentage of time in which the humidity comfort level is muggy, oppressive or miserable and does not vary significantly over the course of the year (Assessment and Report, 1997).

3.2 Study design

For this study, applied, descriptive and quantitative approach research was adopted. An experimental study was used during the study period and the data were analyzed and interpreted using both descriptive and analytical methods of approach. Since, data were collected from reservoir to analyze turbidity impacts on Gilgel gibe I reservoir storage, the study was named as a quantitative approach.

3.3 Data collection

3.3.1 Primary data

Samples were collected from a reservoir using stratified and judgment sampling technique by considering turbidity variation along the longitudinal axis of a reservoir. These samples were collected using boats and cans and stored in plastic tanks. The collected turbid water from the reservoir after different rainfall events were used both for laboratory and field tests. Laboratory tests were conducted to determine water samples turbidity and the results were recorded and taken as primary data to perform field tests. Field tests were executed to determine: surface water temperature, downward vertical alteration of water temperature along with turbidity variation and to estimate evaporation for the determination of relationship between turbidity and reservoir water evaporation and to determine the effect of turbidity on reservoir storage of Gilgel gibe I reservoir.

3.3.2 Secondary data

The major sources of secondary data were; Jimma meteorological station, governmental and non-governmental publications, annual and inventory reports, previous studies and books.

3.4 Sample size

Quantity of the materials(samples) required were determined by laboratory tests conducted and the model that was used to analyze data. Many samples were taken from the reservoir at different rainfall event and turbidity of each sample was determined. Among the samples measured, ten turbid water samples with different level of suspended particles concentration were exploited for the execution of field experiment. The selection criterion was variation of suspended particles concentration in water samples.

3.5 Sampling procedures and samples preservation

Turbid water samples were collected from a reservoir after different rainfall events. Boats were used to collect the samples in the cans from different points along the longitudinal axis of the reservoir course. Samples which were collected from a reservoir in plastic cans and stored in a plastic tanks were transported to laboratory with a good care. Sample cell used to take a sample into turbidmeter was cleaned thoroughly and rinsed with turbidity free or distilled water to preclude light attenuation outside of a sample cell (appendix C, fig.1,2 and 3). The measured turbid water samples were taken to Jimma meteorological station by plastic tanks. All tanks held samples or turbid water volume which was collected from reservoir were sufficient to ensure a representative sample to allow for a replicate test, if it is required, and minimizing waste disposal was applied. Chemical preservation was not implemented for turbid water stored in the plastic tanks which were required for field experiment.

3.6 Laboratory test

3.6.1 Water turbidity

Laboratory experiment was executed in Jimma university, environmental health science and engineering department laboratory room to determine turbidity of water samples taken from Gilgel gibe I reservoir. It was measured using Indian Standard method IS 3025, which was reaffirmed 2002 and explicated in nephelometric turbidity unit (Alvarez *et al.*, 2014). Turbidmeter(instrument) was used to measure turbidity of water samples and an instrument was calibrated before each result watched to an agreed upon standard. Intensity of the light scattered was determined and turbidity of water samples were recorded and used for field test as an input data. Measured turbid water was taken to the field (Jimma meteorological station) for the execution of field experiments.

3.6.1.1 Calibration of turbidmeter

Turbidmeter was calibrated using reference standard solution (formazin polymer) and the two knobs on the turbidmeter. Among the three knobs of an instrument, the one knob on the bottom was used to set the instrument zero. After the standard solution and distilled water was prepared, turbid free distilled water was added to sample cell up to the horizontal mark and cell was wiped gently with a soft tissue to remove moist from outer part of the cell. After it was cleaned, sample cell with turbid water was placed into turbidmeter and pushed down until the vertical marks of the cell coincide with a mark in turbidmeter. A sample cell was covered and reading was adjusted to zero using set zero knob. After the instrument was set to zero, the standard solution prepared according to our need was added to the sample cell upto the horizontal mark and inserted into turbidmeter. The instrument displayed the turbidity values of the standard solution. The procedure was repeated twice for accuracy purpose.

3.6.1.2 Nephelometry method used to measure reservoir water turbidity

Nephelometry method was used to measure reservoir turbidity, in which the degree of light scattered is evaluated. Measurement of water turbidity by using nephelometry depend on comparison of intensity of the light scattered by sample under defined conditions with intensity of the light scattered by a standard reference suspension under the same conditions. The absorbed intensity of the light is calculated by deducting scattered light intensity from released intensity of the light to the sample. The operation principle of nephelometry is that, intensity of the light scattered by suspended matter is proportional to its concentration. Since, the amount of scattered light is far greater than the transmitted light in a turbid suspension, nephelometry offers higher sensitivity than turbidimetry (Jenkins, 1982). This method was used to measure reservoir water turbidity taken from Gilgel gibe I reservoir. Due to, intensity of the light scattered during the measurement of reservoir water turbidity greater than intensity of the light transmitted, this method was preferred than turbidimetry.

3.6.1.3 Laboratory principle performed during measurement of reservoir turbidity

Turbidity measurement was performed as a comparison of the intensity of the light scattered by samples under defined conditions with the intensity of the light scattered by standard reference solution under the same conditions. The more eminent intensity of the light scattered, the higher the turbidity. Primary standard reference suspension exploited was, formazin polymer (Alvarez *et al*., 2014).

3.6.1.4 Laboratory procedure followed during measurement of reservoir turbidity

a) Preparation of reagent

One (1) gram hydrazine sulphate powder was weighted accurately and dissolved in turbidity free distilled water of 100milliliter. Standard flask filled with dissolved solution of hydrazine sulphate using funnel to prevent solution wastage. The solution was placed properly with a good care in laboratory room (Alvarez *et al*., 2014).

Ten (10) gram Hexamethylenetetramine powder weighted accurately and dissolved in turbidity free distilled water of 100milliliter. Standard flask filled with dissolved solution using the funnel to preclude solution wastage and the solution was held with great care in laboratory room.

b) Preparation of 400 NTU standard solution

Five milliliter hydrazine sulphate solution mixed with five milliliter of hexamethylenetetramine solution dissolved before in standard flask and mixture was kept until 24hours. Hundred (100) milliliter turbidity free distilled water was added to the solution and it was used as a reference standard solution to measure samples water turbidity. Using the above prepared reference solution, turbidity of all turbid water samples was measured and these measured samples were taken to the field to perform field test (appendix C, fig. 4).

3. 7 Field test

Field test was conducted to determine the relationship that turbidity has with surface water temperature and evaporation, and to determine the downward vertical alteration of water temperature. The evaluation of the relationship that turbidity has with surface water temperature and downward vertical alteration of water temperature was measured by preparing reservoir models after burrowing the pools or test holes and thermometer(instrument) was used to measure this temperature. The determination of the impact of turbidity on the reservoir storage was performed using pan evaporation method. By taking the most turbid and least turbid samples, the field test was executed to determine the impact of turbidity variation on reservoir storage of Gilgel gibe I, using pan evaporation. All these tests were executed in Jimma meteorological station.

3. 7.1 Water temperature

3.7.1.1 Reservoir models preparation

Selection of an area for the execution of field tests depend on: proximity of a reservoir area and meteorological station in the catchment area of the reservoir, availability of an instrument exploited for field test and accessibility of area for models preparation. Among all meteorological stations in catchment area of Gilgel gibe I reservoir, Jimma meteorological station was selected, since it fulfills the above requirements. The experimental area consists of black cotton soil and was covered with grass which was kept short. Before the pools were burrowed, the area was cleaned to prevent the reflection of incoming solar radiation before reaching the required area.

The pools were distributed over the experimental area and created by digging holes of 0.45m diameter, 0.2m depth and 3m apart from each other's. The holes were lined with white transparent plastic, which was pressed tightly against the soil to maximize plastic–soil contact and kept in place by a small metal ring. This plastic transparent used to precludes the infiltration of turbid water into the ground from pools and entrance of ground water from the adjacent soil into pools (appendix C, fig.5 and 6).

3.7.1.2 Water temperature measurement

To attain the objectives related to this activity, all pits were filled with turbid water with different level of concentration of suspended particles up to 10 mm under the rim of the pools. The surface water temperature and vertical variation of water temperature of each pool turbid water was measured with handheld digital thermometer according to ASTM D6176-97(2015). Data were recorded for fifteen (15) days of a month at different time of a day (appendix C, fig.7). Quantity of the water lost owing to evaporation was replaced with in 24hours interval early to the recording of data to keep the level of the water at the same level and to reduce impacts of water level drops on pools water temperature. The results were obtained by dividing water temperature collected during the observation time of period by an experimental period for all observation time of days for all pools turbid water. The observation hours selected were; 9:00, 11:00, 13:00,15:00 and 17:00hours of a day to determine the relationship between turbidity and surface water temperature, and 9:00, 13:00 and 17:00 hours of a day to determine downward vertical alteration of water temperature. To determine the relationship between turbidity and surface water temperature, among the collected data, data recorded at 9:00, 13:00 and 17:00 was used and to depict downward vertical alteration of water temperature, data recorded at 13:00 hours was exploited. The recorded results were analyzed using SPSS version 20 software and MS excel 2016 spread sheet.

3.7.2 Pan evaporation

Surface water evaporation for water samples taken from reservoir were determined using an instrument called class A evaporation pan by converting pan evaporation to surface water evaporation using 0.75 pan coefficient value. The applicable dimensions of US Class A pans are: 1.207m in diameter and 0.254m depth. It was located on wooden platform about 0.15m above the ground(Kohli and Frenken, 2015). Pans were set properly to make level of water added to it at the same level. This experiment was done in Jimma meteorological station using two pans for most and least turbid water samples, and for the other samples, interpolation was used to determine the values of pan evaporation for a given values of water turbidity obtained in laboratory test (appendix C, fig.8 upto 11).

Pan evaporation data for two pans were collected for 40 days with in 24hours interval in depth (mm) by using a vertical rod in stilling well near the center of pan. Water lost owing to evaporation was replenished when level of the water reached 30mm below the full level of a pan, since it should not have to dropped more than 50mm below the full supply level of pan (Althoff *et al*., 2019). To obtain intensity of pan evaporation, data recorded during study period was averaged by dividing the sum of collected data by observation days. Surface water evaporation was determined using pan evaporation and pan coefficient by multiplying pan evaporation for each pan by pan coefficient (0.75) value.

3.7.3 Reservoir storage change

Determination of the effect of turbidity on reservoir storage was performed using volume of water evaporated for different turbid water samples. By taking the most turbid and least turbid samples, field test was executed to determine the effect of turbidity variation on reservoir storage using pan evaporation installed in Jimma meteorological station. Volume of water evaporated from the reservoir was obtained using the depth of water evaporated from reservoir and surface area of Gilgel gibe I reservoir at full supply level ($54Km^2$). Storage changes due to variation of reservoir turbidity was estimated by using volume of water evaporated from reservoir for most and least turbid water samples.

3.8 Tool and methods used to analysis statistical data recorded

SPSS is a software package (tool) used occasionally for the analysis of statistical data. It is fairly strong on analysis of variance. The merit of SPSS over other is that, it largely abandoned its mainframe version and revised its syntax to be consistent with a single user which allows considerable simplification. This tool constitutes number of methods used to analysis the statistical data recorded during experiment to test the hypothesis(Acock, 2005).

3.8.1 Hypothesis testing

Several problems in engineering require that, we decide whether to accept or reject a statement about some parameter. The statement is called hypothesis, and the decision making procedure about hypothesis is called hypothesis testing. This is one of the most useful aspects of statistical inference, since many types of decision-making problems tests or experiments in engineering world can be formulated as hypothesis-testing problems. This test evaluates two mutually exclusive statements about a population to determine which statement is best supported by the sample data. The two statements are null and alternative hypothesis written together and should be tested to arrive at conclusion about the population based on samples. The hypothesis was tested using statistics obtained from different tests. The intent is to determine whether there is enough evidence to reject a null hypothesis. Different statistics were used to get confidentiality on accepting and rejecting of null hypothesis, which constitutes: calculated probability(p), fixed ratio(F), correlation coefficient(r) value and coefficient of determination (R^2)(Robert, 2006). To attain the specific objectives of this study, hypothesis testing procedure was performed to determine the effect of independent variable(turbidity) on dependent variable (water temperature and surface water evaporation).

a) Deciding significance level of effect using p-value

The *p* value (calculated probability) is the probability of the event occurring by chance if the null hypothesis is true. The *p* value is a numerical value which lies between 0 and 1 and is interpreted by researchers in deciding whether to reject or retain the null hypothesis. It provides a sense of the strength of evidence against the null hypothesis. The working principle is that; the lower the *p* value, the stronger the evidence is and vice versa. It is simply the ratio of the model mean square error to the mean square. The confidence level for the statistical analysis is 95% which indicate that, the *p*-value of the analyzed data should be less than 0.05. A null hypothesis is accepted if the *p* value reported is greater than its allowed maximum value and rejected when the value is less than or equal to the permitted value(Robert, 2006). The value of *P* can be reported with equal sign and numerical value obtained, if the *p* resulted from statistical test is greater than or equal to .001, and if it is less than .001 it is reported as *p* less than .001(American psychological Association, 2009).

3.8.1.1 Normality test

An assessment of the normality of data is a prerequisite for many statistical tests, because, normal data is an underlying assumption in parametric testing. There are two main methods used in an assessing normality of a data. They are: graphical and numerical methods.

There are formal ways to perform normality tests such as; Shapiro-Wilk and Kolmogorov-Smirnov. The Shapiro-Wilk Test is more appropriate for small sample sizes (< 50 samples), but can also handle sample sizes as large as 2000. For this reason, Shapiro-Wilk test was exploited as our numerical means of assessing normality. The result concludes that, if the significance value of the Shapiro-Wilk test is greater than 0.05, alternative hypothesis is rejected and reported as, the data comes from a normal distribution. But, if it is below 0.05, the data significantly deviate from a normal distribution and alternative hypothesis is accepted. The skewness and kurtosis also used to test normality of the data. The working principle is that, the z- values for both skewness and kurtosis should lies between -1.96 and +1.96 to conclude a data is approximately normally distributed.

In order to determine normality graphically, the output of a normal Q-Q plot was used. It depicted that, if the data are normally distributed, the data points should close to the diagonal line and if the data points stray from the line the data are not normally distributed (Park, 2008). If the above results confirmed the normality, parametric statistical test can be used. For this study to use univariate general linear model, data were transformed using double square root transformation method to convert non-normal data to normal.

3.8.1.2 Linear regression

Linear regression is a statistical analysis model for calculating the value of a dependent variable from an independent variable. It measures the association between two variables (predictor and response variable). It is a modeling technique, where dependent variable is predicted based on one or more independent variables. Linear regression analysis is the most widely used of all statistical techniques (Kumari and Yadav, 2018). Linear regression has a form:

$$Y = bx + a \tag{3.2}$$

Where y is a response variable, x is a predictor variable/s a and b are coefficient letters, a stands for the y-intercept and b stands for the slope. Linear regression is significant, because it helps in analyzing the strength of association between the response and predictor variables and it adjusts for the effect of covariates or the confounders(Kumari and Yadav, 2018). Both correlation coefficient and coefficient of determination could be reported by linear regression. The term correlation coefficient shows the linear correlation between two variables (independent and dependent variable). This correlation coefficient lies between plus and minus one. It depicts that, R = +1 indicates a perfect linear correlation and linear regression perfect, R = 0 is no correlation and R = -1 total negative correlation. Coefficient of determination indicates the percentage of the variance in the dependent variable that the independent variables explain. It measures the strength of the relationship between model and dependent variable and evaluates the scatter of the data points around the fitted regression line. Its value ranges from 0 – 100percent or from 0-1. The high value of coefficient of determination revealed that, changes in the predictors were related to changes in the response variable and a model explained a lot of the response variability. A low value of coefficient of determination indicates that, independent variable is not explaining much in the variation of dependent variable(Park,2008).

For this study, linear regression was used to test statistical significance of the relation that turbidity had with surface water temperature and evaporation. To test this significance, turbidity was taken as an independent variable and surface water temperature and evaporation were exploited as dependent variables. The test statistics obtained were compared with the allowable statistic to generalize about the relation. The result and interpretation of the test was displayed in chapter four.

3.8.1.3 ANOVA

Analysis of variance (ANOVA) is a test used to determine whether one or more of the means of several groups are different from others or not. The purpose of ANOVA is to test the existence of any significant difference between the means of two or more groups. It incorporates means and variances to determine test statistic and checks the impact of one or more factors by comparing the means of different samples. The test statistic is then used to determine whether groups of data are the same or different. The test statistic for ANOVA is called the *F*-ratio. When hypothesis testing is being performed with ANOVA, the null hypothesis is stated as, all groups are the same or there is no variation of the mean of the samples. In ANOVA test, *F*-value is calculated and compared to the critical value in which the critical value is one (1) (Elliott and Woodward, 2007). There are two types of variances when we use ANOVA to test data. These are: between-group and within-group variance. The within-group variability (error variance) is the variation that cannot be accounted for in the study design. It is based on random differences present in our samples. However, the between-group or effect variance is the result of our test. These two estimates of variances are compared using the *F*-test. A simplified formula for the F statistic test was given as:

$$F = \frac{MS_b}{MS_w} \quad (3.1)$$

Where: MS_b is the mean square between the groups and $MS_w$is the mean squares within groups(Ali and Bhaskar, 2016).

For this research, ANOVA in linear regression was used to test statistical significance of the relation that turbidity has with surface water temperature and evaporation by taking turbidity as a predictor and water temperature and evaporation as the responses variables. The obtained value of *F* was compared with the critical value and the relation was confirmed if it is greater than the critical value and rejected of it is less than one. The result was displayed and interpreted in next chapter of results and discussion.

3.8.1.4 Univariate general linear model

Univariate general linear model is a model used to analysis normally distributed and continuous dependent variables for categorical independent variables(Graham, 2008). It used to analysis a Univariate statistical data to depict a single variable distribution in a unit sample(Canova *et al.*, 2017). Univariate general linear model assumes that, both factors categorical (predictors) and covariates (scale predictors) have a linear relationship to the response variable. For this study covariate variable did not considered. It tests homoscedasticity or homogeneity of variances to reject or accept null hypothesis (Horton, 1978).

For this study, Univariate general linear model was used to test statistical significance of data in the analysis of, downward vertical alteration of water temperature along with turbidity variation. To determine the downward vertical alteration of water temperature between a groups, the level of pool water was taken as a categorical independent variable and water temperature at 13:00 observation hours for all data samples was taken as dependent variable. Both box and whisker plot and the graph of linear regression were used to generalize the downward vertical alteration of water temperature. Pools water level and water temperature for most and least turbid pools water were exploited as categorical independent variable and dependent variable respectively to plot simple linear regression graph. The data were transformed by using double square root transformation method, before the use of univariate general linear model to test the statistical significance of data, used to analysis downward vertical alteration of water temperature in different turbid water. The statistical significance of variation was tested using F and p values resulted from Univariate general linear model. Both test statistics attained were compared with their critical values to test the statistical significance of alteration of water temperature along with turbidity variation. The critical value used for F was one and for p 0.05. The result was interpreted and discussed in chapter four.

3.8.1.5 Spearman's rank correlation coefficient

Spearman's rank correlation coefficient was introduced by Charles (1904) to determine the monotonic relationships between variables. It is a nonparametric measure of the strength and direction of association that exists between two sets of variables measured on at least an ordinal scale. It does not require the assumption that, the relationship between sets of variables is linear and used when the assumption necessary for conducting the Pearson's correlation coefficient was failed.

Spearman's rank correlation coefficient assesses the existence of how monotonic association between two variables without making any assumptions about the normality distribution of the samples drawn from population. To perform this test, both independent and dependent sets of variables were arranged in descending order and their ranks are assigned for all variables. Then after, the Spearman`s rank correlation coefficient, generally denoted by $\rho$ is computed. The spearman`s rank correlation coefficient lies between plus and minus one inclusively. Positive correlation coefficient depicts that, there was a direct positive relationship between variables. Negative correlation coefficient shows, the existence of negative relationship between the variables and a zero correlation coefficient is an implication of non-relationship between the variables (Management and Naukowe, 2011). For this study, to depict the correlation that turbidity has with surface water temperature and reservoir evaporation, spearman`s rank correlation coefficient was used. Spearman ranked correlation coefficient was used by taking water turbidity as an independent variables and surface water temperature as dependent variables to study the relationship between turbidity and surface water temperature. To determine the relationship between turbidity and surface water evaporation, turbidity was taken as predictor variable and evaporation as the response variable and the results were analyzed and discussed in results and discussions chapter.

3.10 Conceptual/Theoretical Framework

Turbidity is a complex and dynamic concept, which is affected by many factors and influences water characteristics and its quantity. The conceptual framework of the research is given as below.

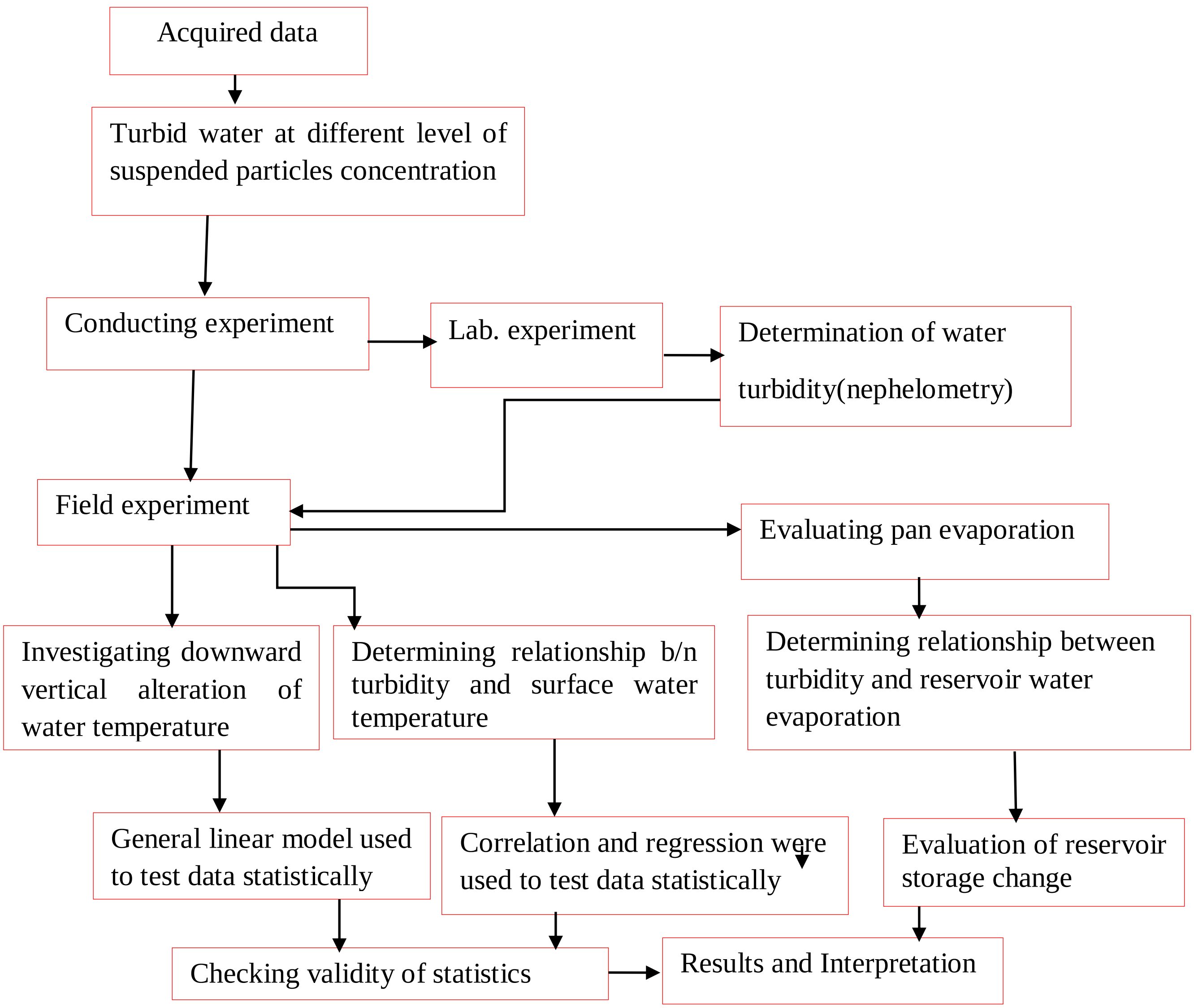

Figure 3. 2: Conceptual framework of the research

4. RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the result of both laboratory and field tests to assess the impact of turbidity on reservoir storage of Gilgel Gibe I reservoir. The testing program includes: measurement of reservoir water turbidity, determination of relationship that turbidity has with surface water temperature and surface water evaporation, evaluation of downward vertical alteration of turbid water temperature and determination of effect of turbidity variation on reservoir storage of Gilgel gibe I reservoir, using 10 samples.

4.2 Laboratory test result

4.2.1 Water turbidity

An experiment was executed in Jimma University, department of environmental health science and engineering laboratory room, using an instrument called turbidmeter with some chemicals. Water turbidity laboratory test results for typical reservoir water samples are shown in table 4.1 below.

Table 4. 1: Reservoir water turbidity recorded

Laboratory test results of reservoir water turbidity	
Sample number	Reservoir water turbidity(NTU)
1	226
2	203
3	194
4	166
5	115
6	89.3
7	74.72
8	68.2
9	50.3
10	43.7

Table 4.1 above depicted that, reservoir water turbidity varied significantly during the rainy season. Quantities of suspended particles entering the reservoir depend on intensity of the rainfall and an anthropogenic action executed in catchment area of the reservoir and in reservoir body. When intensity of the rainfall heightens, amount of suspended particles entered into the reservoir was amplified, due to an increment of soil erosion from catchment area of the reservoir and eddies raised from bed of the reservoir. Concentration of total suspended solid(TSS) in Gilgel Gibe I reservoir was much higher than maximum value of the guideline ambient environment standards for Ethiopia reservoir, which is 50 mg/L(EPA and UNIDO, 2003), due to the existence of improper integrated catchment management and an anthropogenic action. Maximum amount of total suspended solid in Gilgel gibe I reservoir obtained during study period was 75.33mg/L which was obtained from (226/3), that assured the above result reported. Hence, suspended particles were the main causes of reservoir water turbidity in Gilgel gibe I reservoir, which was imparted by soil erosion.

There was the spatial variation of reservoir water turbidity vertically and horizontally along the longitudinal axis of the reservoir, owing to the settlement of suspended particle on bed of the reservoir and horizontal movement of particles along the stretch of the reservoir course. This variation of water turbidity with rainfall events was illustrated in previous study done by Paaijmans *et al*. (2008) and Chapman (1996) for small natural puddles and natural river respectively which revealed that, turbidity of surface water body step-up along with rainfall events.

In this study, measured reservoir water turbidity values in Gilgel Gibe I reservoir were ranging from 43.7 to 226 NTU, which were also proximate to 40–155 NTU measured by Ambelu *et al*. (2013) and 47.07 to 95.3 NTU, which were measured by Woldeab *et al*. (2018) for the same reservoir at different period. It is within the range of stated normal values reported by Chapman (1996), that ranges from 1 to 1000 NTU for reservoir water turbidity. Since, samples were taken near to the rainfall events ceased, and due to the existence of landuse landcover change on catchment, obtained turbidity values in this study were greater than the values reported by Ambelu *et al*. (2013) and Woldeab *et al*. (2018) done on the same reservoir.

4.3 Field test results

4.3.1 Relationship between turbidity and surface water temperature

Surface temperature of water samples taken from Gilgel gibe I reservoir was determined in the field using an instrument called thermometer according to ASTM D6176-97(2015). Detail of average surface water temperature for ten different samples pools turbid water are shown in table 4.2 below. Results were obtained by dividing water temperature recorded during observation time of period by an experimental period for all observation time of days for all pools turbid water. Summary of surface water temperature observation for different pools turbid water at different time of observation has been presented on appendix A.

The relationship between turbidity and surface water temperature was analyzed using spearman ranked correlation coefficient for all data collected at 9:00, 13:00 and 17:00 observation hours. Result of spearman ranked correlation coefficient is tabulated below. Statistical significance of relationship was tested using simple linear regression and ANOVA.

Table 4.2: Average surface water temperature recorded

Observation hrs.	Average surface water temperature recorded for different pools turbid water (°C)									
	1 (226)	2 (203)	3 (194)	4 (166)	5 (115)	6 (89.3)	7 (74.72)	8 (68.2)	9 (50.3)	10 (43.7)
9:00hrs	23.52	22.92	22.65	22.33	21.95	21.75	21.53	21.37	21.06	20.87
11:00hrs	27.48	26.84	26.60	26.21	25.82	25.51	25.28	25.15	24.85	24.70
13:00hrs	33.29	30.69	30.31	29.79	29.23	29.02	28.84	28.72	28.52	28.45
15:00hrs	29.34	28.44	28.21	27.69	27.01	26.76	26.54	26.41	26.11	25.96
17:00hrs	22.19	22.85	23.15	23.43	23.73	23.94	24.21	24.53	24.91	25.10

Table 4. 2: Correlation coefficients and significance values.

Correlations

			Water turbidity(NTU)	Turbid water surface temperature(°C)	Remarks
Spearman's rho	Water turbidity	Correlation Coefficient	1.000	1.000**	
		Sig. (2-tailed)	0.000	0.000	9:00hrs
		N	10	10	
	Turbid water surface temperature	Correlation Coefficient	1.000**	1.000	
		Sig. (2-tailed)	0.000	0.000	
		N	10	10	
Spearman's rho	Water turbidity	Correlation Coefficient	1.000	1.000**	13:00hrs
		Sig. (2-tailed)	0.000	0.000	
		N	10	10	
	Turbid water surface temperature	Correlation Coefficient	1.000**	1.000	
		Sig. (2-tailed)	0.000	0.000	
		N	10	10	

			Turbid water surface temperature(°C)	Water turbidity(NTU)	Remarks
Spearman's rho	Turbid water surface temperature	Correlation Coefficient	1.000	-1.000**	
		Sig. (2-tailed)	0.000	0.000	
		N	10	10	17:00hrs
	Water turbidity	Correlation Coefficient	-1.000**	1.000	
		Sig. (2-tailed)	0.000	0.000	
		N	10	10	

Table 4. 3: Model summaries of data.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Remark
1	0.982[a]	0.965	0.960	0.169511	9:00hrs
1	0.885[a]	0.784	0.757	0.727646	13:00hrs
1	-0.970[a]	0.941	0.933	0.239086	17:00hrs

a. Predictors: (Constant), Water turbidity

b. Dependent Variable: Turbid water surface temperature at 9:00,13:00 and 17:00 observation hrs.

Table 4. 4: ANOVA results of data.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.	Remarks
1	Regression	6.301	1	6.301	219.301	0.000[b]	9:00hrs
	Residual	0.230	8	0.029			
	Total	6.531	9				
1	Regression	15.349	1	15.349	28.989	0.001[b]	13:00hrs
	Residual	4.236	8	0.529			
	Total	19.585	9				
1	Regression	7.244	1	7.244	126.730	0.000[b]	17:00hrs
	Residual	0.457	8	0.057			
	Total	7.701	9				

Table 4. 5: Coefficients summary of data.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Remarks
1	(Constant)	20.488	0.115		178.153	0.000	
	Water turbidity	0.012	0.001	0.982	14.809	0.000	9:00hrs
1	(Constant)	27.334	0.494	0.885	55.370	0.000	13:00hrs
	Water turbidity	0.019	0.004		5.384	0.001	
1	(Constant)	25.420	0.162	-0.970	156.711	0.000	17:00hrs
	Water turbidity	-0.013	0.001		-11.257	0.000	

Table 4.2 above shows that, all recorded data points of average daily surface water temperature of pools water during study period of 15 days. All data were collected at, 9:00hrs, 11:00hrs, 13:00hrs, 15:00hrs and 17:00hrs of a day. As illustrated in table 4.2 above, average surface temperature of the water alters in relation with the variation of water turbidity and net incoming solar radiation. It revealed that, average surface water temperature increased when turbidity of reservoir water raised depending on incoming net solar radiation striking the surface of water for all observation hours except 17:00hrs. But, at 17:00 observation hours of a day, water turbidity and surface water temperature were inversely proportional to each other, due to less penetration of sunlight in most turbid water, and it cooled within a short period of time than the least turbid water through which light rays could penetrate in deep and it cooled slowly. The difference between average daily surface water temperature of the most and least turbid pools water were given as, 2.65°C, 4.84°C and -2.91°C at 9:00, 13:00 and 17:00 observation hours respectively. During midday, surface water temperature raised conspicuously with increasing water turbidity due to greater intensity of incoming net solar radiation.

After carefully observing the results of spearman ranked correlation and other different models, this analysis discovered that, there is perfect positive relationship between water turbidity and surface water temperature of pools water at both observation hours by achieving spearman ranked correlation coefficients values of +1 and *P* values of <.001. But, at 17:00 observation hours, there is perfect negative relationship between turbidity and surface water temperature with spearman ranked correlation coefficient value of -1 and *P* value of <.001.

From simple linear regression and ANOVA tests results, the relationship between turbidity and surface water temperature is statistically significant with fixed ratio values of F (1, 8) = 126.730, 28.989 and 219.301 at 9:00, 13:00 and 17:00 observation hours respectively and *P* values of, *P*<.001, *P*=.001 and *P*<.001 for the three observation hours sequentially. The values of R squared for the three observation data at these observation hours (9:00, 13:00 and 17:00) were reported as 0.965, 0.784 and 0.941 respectively. These statistics indicated that, the significant variation of surface water temperature occurred along with water turbidity variation. Equation of the lines for given the observation data were listed below.

$$T_1 = 0.012Tu + 20.488 \tag{4.1}$$

$$T_2 = 0.019Tu + 27.334 \tag{4.2}$$

$$T_3 = -0.013Tu + 25.42 \tag{4.3}$$

Where, $T_1, T_2 \ and \ T_3$ represent surface water temperature at 9:00, 13:00 and 17:00 observation hours respectively and Tu denote water turbidity. All above equations indicate that, an amount by which surface water temperature raised or failed rely on the strength of net incoming solar radiation for values of water turbidity.

The relationship between turbidity and surface water temperature also presented by Paaijmans *et al.* (2008) which stated that, as turbidity of water increased, the surface water temperature also raised except during the late afternoon(17:00hrs). An increment of suspended soil particles in water caused the raise of surface water temperature and furthermore change the temperature dynamics of small water collections during daytime. As stated by Paaijmans *et al*. (2008), the surface water temperature of pools water has raised to or exceeds 42°C when turbidity of the water increased, in which the result of this study was proximate to this value with 33.29°C for the most turbid pool water at 13:00 observation hours.

4.3.2 Downward vertical alteration of water temperature along with turbidity variation

Alteration of water temperature vertically downward was tested between groups at the same and different level of pools water and within a group at different level of pool water. Detail of average turbid water temperature at different level of pools water for ten samples were shown in table 4.7 below. To analysis this variation, average of the data collected at 13:00 observation hour was used, owing to the existence of positive significant variation of water temperature within a group and between the groups at this observation hour.

Table 4. 6: Average turbid water temperature at different level of the pools

Water turbidity (NTU)	Average turbid water temperature(°C)								
	9:00hrs			13:00hrs			17:00hrs		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
226	23.52	18.70	16.69	33.29	26.85	23.51	22.19	21.91	20.88
203	22.92	18.97	17.23	30.69	27.35	24.07	22.85	22.39	21.78
194	22.65	19.15	17.48	30.31	27.49	24.37	23.15	22.87	22.10
166	22.33	19.39	18.11	29.79	27.61	24.71	23.43	23.09	22.43
115	21.95	19.64	18.37	29.23	27.92	25.20	23.73	23.43	22.87
89.3	21.75	19.76	18.50	29.02	28.05	25.54	23.94	23.73	23.20
74.72	21.53	19.87	18.69	28.84	28.17	25.83	24.21	23.91	23.35
68.2	21.37	20.02	18.78	28.72	28.28	26.07	24.53	24.19	23.55
50.3	21.06	20.26	19.11	28.62	28.39	26.43	24.91	24.52	24.14
43.7	20.87	20.44	19.48	28.55	28.48	27.09	25.10	24.69	24.35

4.3.2.1 Box and Whisker plot and Best-fit curve

In analysis procedures, the value of average turbid water temperature was considered as the dependent variable and water pool level as an independent variable. Box and whisker plot to show the downward vertical alteration of water temperature along with turbidity variation for a water samples taken from Gilgel Gibe I reservoir was displayed below. Variability of turbid water temperature for two samples (most and least turbid water) was illustrated using the line graph plotted below.

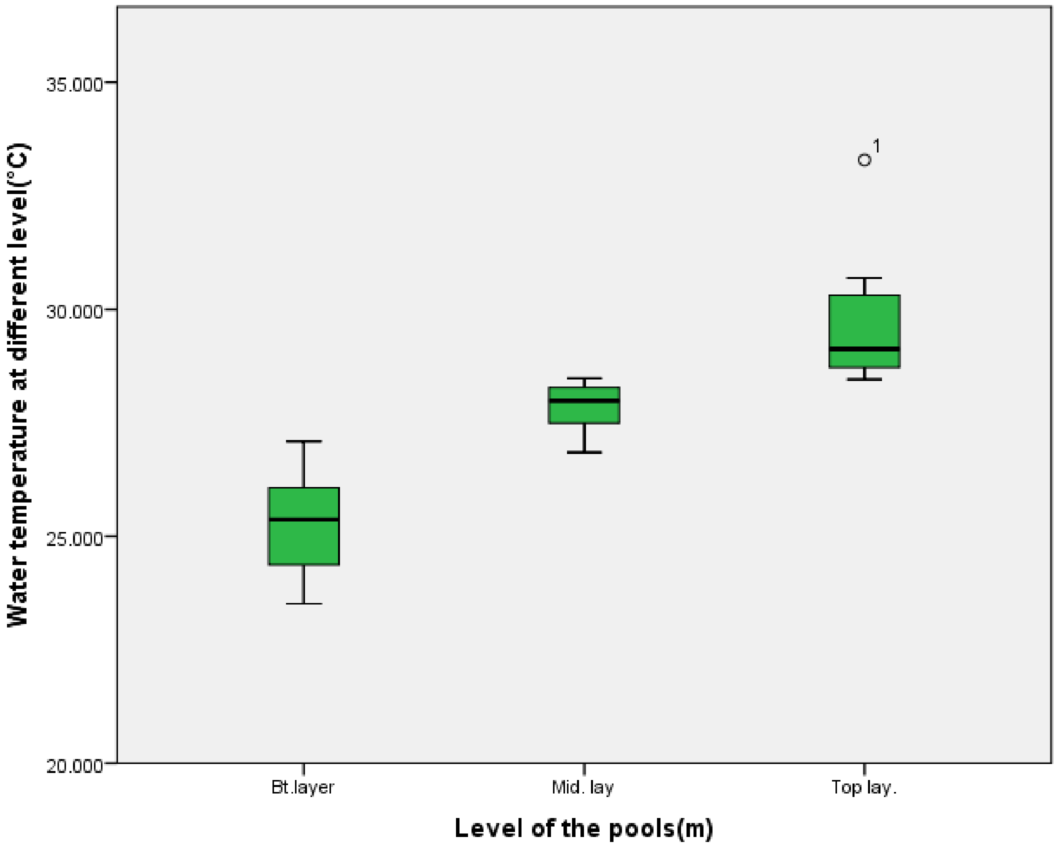

Figure 4. 1: Box and Whisker plot of turbid water temperature at 13:00 observation hrs.

4.3.2.2 Normality tests

Table 4. 7: Normality tests using statistics

Tests of normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk			Skewness		Kurtosis	
	Statistic	df	Sig.	Statistic	df	Sig.	Statistic	Std. Error	Statistic	Std. Error
D.sqrt	0.102	10	0.200*	0.974	10	0.641	-0.003	0.356	0.427	0.833

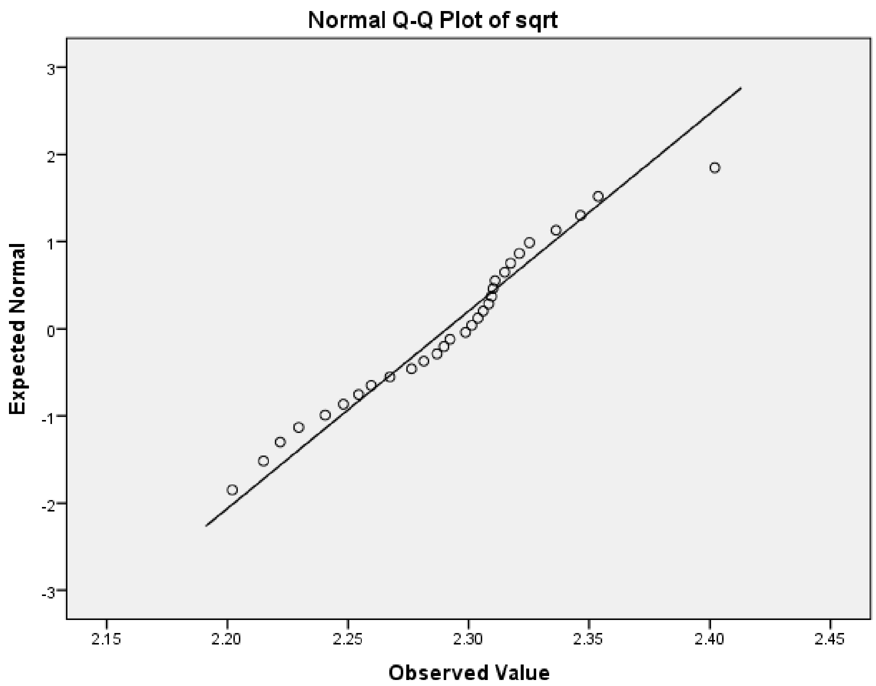

Figure 4. 2: Normal Q-Q plot of double transformed water temperature(°C) data

Table 4. 8: Tests of between-subjects effects for statistical significance test

Tests of Between-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	22867.706	1	22867.706	467.100	0.002
	Error	97.914	2	48.957[a]		
Pool level	Hypothesis	97.914	2	48.957	39.587	0.000
	Error	33.391	27	1.237[b]		

Table 4. 9: Parameter Estimates for statistical test

Parameter	B	Std. Error	T	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	29.686	0.352	84.415	0.000	28.964	30.408
Bottom layer	-4.404	0.497	-8.855	0.000	-5.424	-3.384
Middle layer	-1.827	0.497	-3.674	0.001	-2.847	-0.807
Top layer	0					

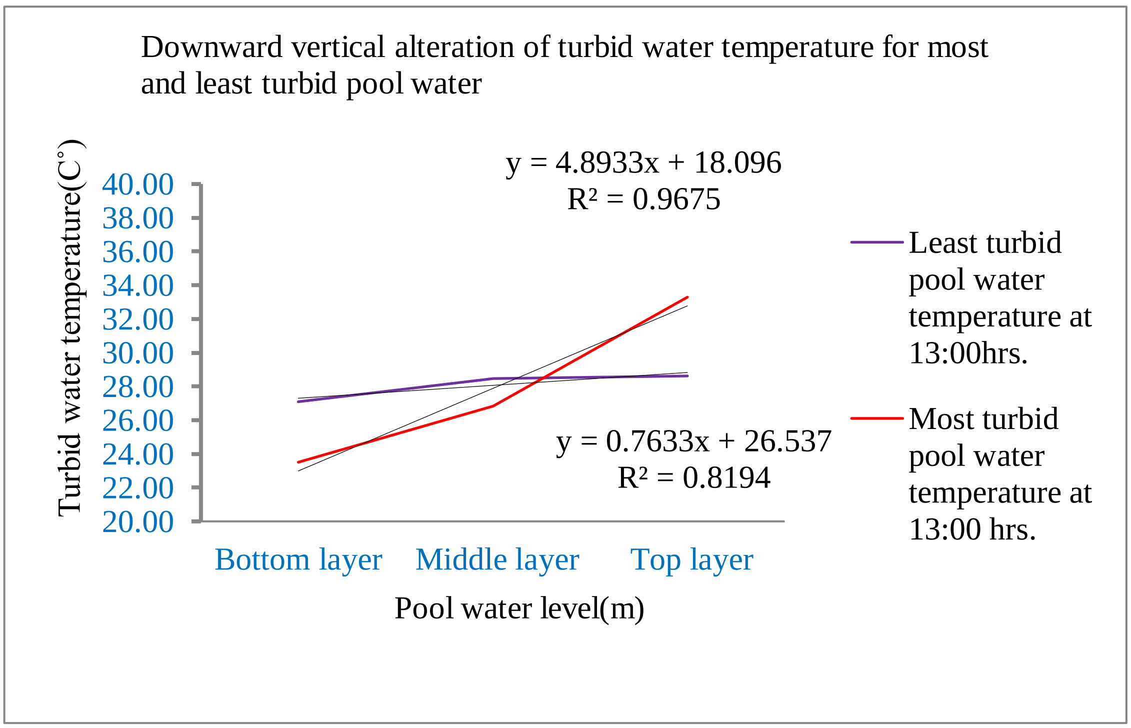

Figure 4. 3: Downward vertical alteration of turbid water temperature at 13:00 observation hours for most and least turbid pools water.

As depicted in table 4.7 above, there is stratification of water temperature within a group at different level and variation of water temperature between the groups of turbid pool water, due to absorption and scattering of net solar radiation by suspended particles. Suspended particles in water diminished penetration depth of this net solar radiation. The recorded data shown in table 4.7 revealed that, at the same level of different pools water, measured value of water temperature is different, due to the variation of water turbidity. An alteration of water turbidity stimulates the variation of water temperature in which, in most turbid pool water, there is less penetration of net solar radiation that caused water temperature to be high at the surface.

Downward vertical alteration of water temperature occurred between pools water and within a pool water. For all water samples and at all observation hours of a day, water temperature at the top layer (1cm from water surface) is greater than water temperature at the middle (9.5cm from surface water level) and bottom layer (1cm from bed of the pool). This study only measured water temperature at three time points during daytime to show downward vertical alteration of water temperature, but only one time points was selected (13:00) to analysis the variation of water temperature. Table 4.7 above illustrates, there is significant variation of water temperature at the midday (13:00hrs) than at 9:00 and 17:00hrs within a pool water and between pools water. For most turbid pool water, the difference in water temperature between top and bottom layer is 9.78°C and 1.53°C for least turbid at midday (13:00). This variation of difference in water temperature indicates that, extinction of net incoming solar radiation striking the surface of water is significant in most turbid water than least turbid water.

From box and whisker plot, black line in the box indicate the median, the box represents the interquartile range (25%-75%), range bars show, the minimum and maximum values and small circle represents an outlier. Box and whisker plot revealed that, there is prominent downward vertical alteration of water temperature along with turbidity variation. Due to the existence of absorption and scattering of net incoming solar radiation, water temperature decreased vertically from top surface of the water to the bottom. The box and whisker plot depicted that, at the top and bottom of the pool water, there is great variability of water temperature with the alteration of water turbidity and at the middle of pool water, water temperature variability was less relative to the bottom and top of pool water.

To test normality of double transformed data, both, statistics attained from shapiro-Wilk `s and visual inspection of Q-Q plot were used. According to shapiro-wilk`s, to test a normality of data, p value should be greater than 0.05. The statistics called z-values attained from skewness and kurtosis also used to test normality of data and it should lie between -1.96 and +1.96, to say a given data is approximately normally distributed. From visual inspection of Q-Q plot to test normality of data, the dots should be distributed near to the line. A shapiro –willk`s *p* test of value 0.641 and visual inspection of Q-Q plot indicated that, the double square root transformed water temperature data were approximately normally distributed with skewness and kurtosis values of -0.003(SE=0.356) and 0.427(SE=0.833) respectively. The z-values obtained were -0.0084 and 0.513 which confirmed that, data is approximately normally distributed. Since, data confirmed normality test, univariate general linear model was used to test statistical significance of water temperature variation.

Statistical significance of the result was determined by using *F* and *P* value resulted from Univariate general linear model obtained after transforming the data using double square root transformation. From table 4.9 above, F (2, 27) =39.587 and P value of <.001, which shows that, there is significant downward vertical alteration of water temperature along with turbidity variation. From figure 4.3 above, downward vertical alteration of water temperature along with turbidity variation was eminent for most turbid water than least turbid water, due to absorption and scattering of net solar radiation by suspended particles in the water. For most turbid water, water temperature decreased highly and for least turbid water, it decreased smoothly from top to the bottom vertically, with R squared values of 0.9675 and 0.8194 respectively.

As reported by Paaijmans *et al.* (2008), there is stratification of water temperature in most turbid water than least turbid water. This study ascertained that, the alteration of this water temperature is prominently high during midday, which also illustrated by Paaijmans *et al.* (2008). Hence, sunlight penetrate turbid water column only to certain depth, which devolved on water turbidity and strength of incoming sunlight.

4.3.3 Relationship between turbidity and surface water evaporation

Average intensity of surface water evaporation recorded for ten different turbid pans water is shown in table 4.11 below. Summary of pan evaporation data collected for two pans during 40 days of study period has been presented on appendix B.

4.3.3.1 Relationship between turbidity and pan evaporation

Determination of pan evaporation is crucial to evaluate surface water evaporation, when pan method is used to determine surface water evaporation. Due to variation of climate condition among days, it is impossible to fix pan evaporation from a single day data recorded. Hence, 40 days of data recorded were exploited to fix average daily pan evaporation for this study.

Table 4. 10: Average intensity of pan evaporation

Sample number	Reservoir water turbidity (NTU)	Pan evaporation(mm/day)
1	226	4.722
2	203	4.517
3	194	4.437
4	166	4.187
5	115	3.733
6	89.3	3.503
7	74.72	3.374
8	68.2	3.315
9	50.3	3.156
10	43.7	3.097

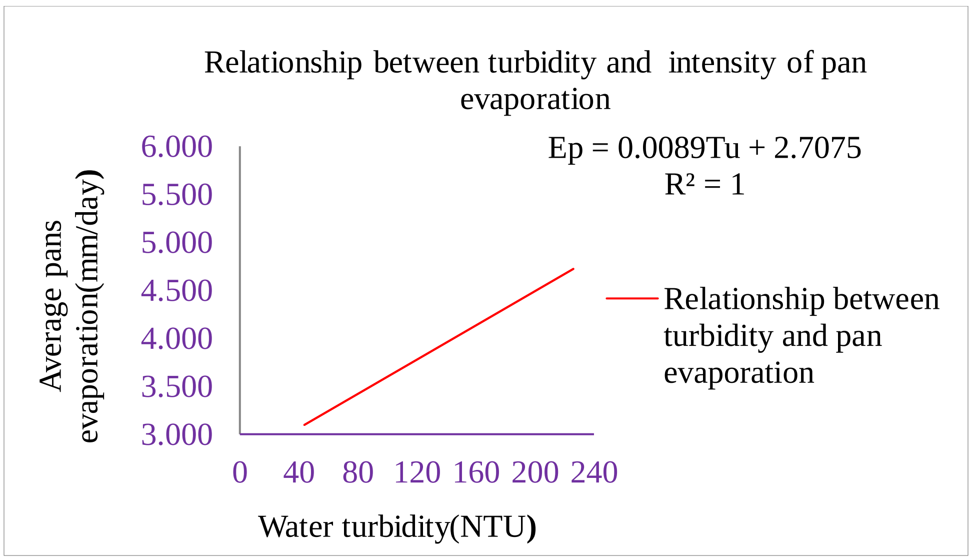

Figure 4. 4: Relationship between turbidity and intensity of pan evaporation

Table 4.11 above depicted that, intensity of surface evaporation of pans water varied with an alteration of water turbidity. Field test which was executed for 40 days in Jimma meteorological station reflected that, when turbidity of the water raised, pan water evaporation also increased. It observed that, if water turbidity raised from 43.7 to 226 NTU, pan evaporation increased from 3.097 to 4.722mm/day with an uncertainty value of ±0.1mm (WMO, 2010) at 95% confidence level. The difference in intensity of pan evaporation for the most and least turbid pan water is 1.625mm/day. The above results indicated that, the existence of an eminent suspended particles concentration caused the rise of pan water evaporation in relation with net solar radiation striking water surface.

As illustrated on figure 4.4 above, there is strong direct relationship between turbidity and pan water evaporation, which reflected that, as water turbidity increased pan water evaporation also amplified. To show strength of this relation, R squared value was used which displayed as 1, and it indicates, variation in water turbidity engendered the alteration of pan water evaporation. An equation of a line for data is given as:

$$E_p = 0.0089Tu + 2.7075 \qquad 4.4$$

Where, Tu represent water turbidity and Ep represents pan evaporation.

Table 4. 11: Average reservoir water evaporation

Sample number	Reservoir water turbidity (NTU)	Reservoir water evaporation(mm/day)
1	226	3.542
2	203	3.388
3	194	3.328
4	166	3.140
5	115	2.799
6	89.3	2.628
7	74.72	2.530
8	68.2	2.487
9	50.3	2.367
10	43.7	2.323

Table 4. 12: Correlations between turbidity and reservoir water evaporation

Correlations

			Water turbidity(NTU)	Reservoir water evaporation(mm/day)
Spearman's rho	Water turbidity	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	10	10
	Reservoir water evaporation in mm unit depth	Correlation Coefficient	1.000	1.000
		Sig. (2-tailed)	0.000	0.000
		N	10	10

Table 4. 13: Model summary of the data

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000	1.000	1.000	0.000361

Table 4. 14: ANOVA result of data

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.878	1	1.878	14443999.960	0.000
	Residual	0.000	8	0.000		
	Total	1.878	9			

Table 4. 15: Coefficients for data of turbidity and surface water evaporation

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	Constant	2.031	0.000		8301.085	0.000
	Water turbidity	0.007	0.000	1.000	3800.526	0.000

From table 4.12 above, there is perfect positive relationship between water turbidity and surface water evaporation, in which surface water evaporation was obtained from pan water evaporation and class A pan coefficient value (0.75). It reflected that, surface water evaporation is less than pan evaporation, owing to an additional energy supplied by pan, that alleviates pan water evaporation. Variation of reservoir water turbidity caused the alteration of reservoir water evaporation, which shows, when water turbidity increased, reservoir water evaporation also raised, due to the existence of suspended particles in reservoir water. These suspended particles increased surface water evaporation, owing to their absorption and scattering ability of net incoming solar radiation and they released additional energy to water body that increased the movement of water particles, and as a result surface water evaporation. The average daily reservoir water evaporation recorded were 3.542mm/day and 2.323mm/day for most turbid and least turbid reservoir water respectively. The measurement was executed with in 24hours interval for 40 days at 8:30hours of a day in Jimma meteorological station from September 10-Octember 20, 2020.

As ascertained by Paaijmans *et al.* (2008), turbidity increased surface water temperature which results an increment of an amount of water particles escaping as water vapor from water surface. It observed that, higher water temperature result in significant loss of water quantity, due to evaporation. Hence, an increment in water turbidity caused the raise in surface water evaporation in which this study confirmed this statement.

By carefully observing the results on spearman ranked correlation coefficient and other different models, this analysis discovered that, there is perfect positive relationship between turbidity and intensity of average surface water evaporation, by achieving spearman ranked correlation coefficient(r) value of +1 and P values of <.001. From simple linear regression and ANOVA test results, the relationship between turbidity and average surface water evaporation is statistically significant, with coefficient of determination (R squared) values of 1, fixed ratio value of F (1, 8) =14443999.960 and P value of <. 001. It concluded that, the raise in water turbidity amplified surface water evaporation.

The equation of the line for the given observation data is given as:

$$E_r = 0.007Tu + 2.031 \qquad (4.5)$$

Where, Tu represent water turbidity and E_r represent average reservoir water evaporation.

4.3.4 Evaluation of effect of turbidity on reservoir storage of Gilgel Gibe I reservoir.

Table 4. 16: Relationship between turbidity and Volume of water evaporated from reservoir

Sample number	Reservoir water turbidity (NTU)	Volume of water evaporated in cubic meter
1	226	191.241
2	203	182.938
3	194	179.689
4	166	169.580
5	115	151.169
6	89.3	141.891
7	74.72	136.627
8	68.2	134.273
9	50.3	127.811
10	43.7	125.429

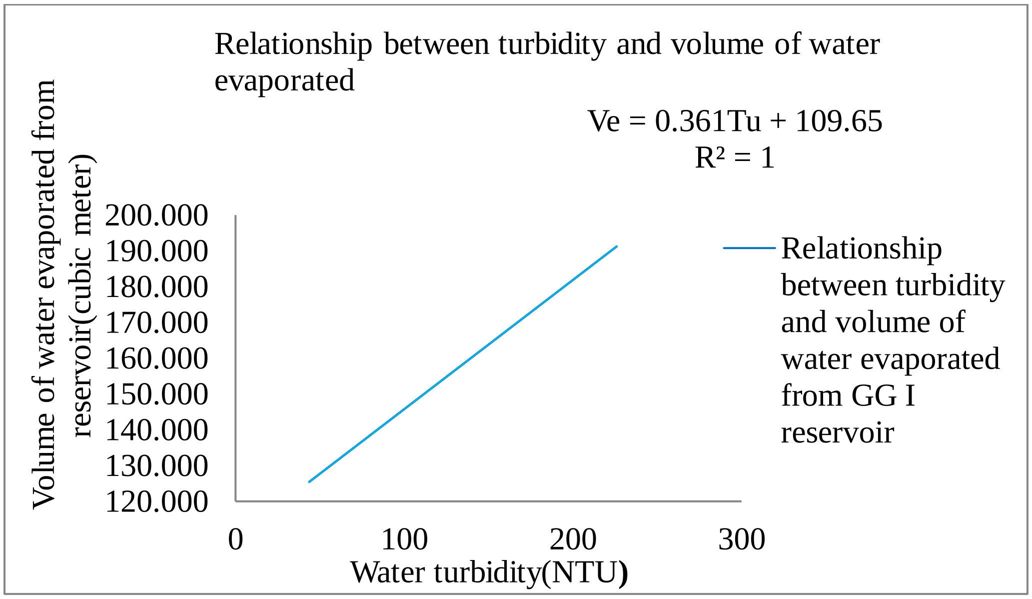

Figure 4. 5: Relationship between turbidity and volume of water evaporated from Gilgel gibe I reservoir at full supply level.

As observed in table 4.17 above, if turbidity of reservoir water increases, volume of the water evaporated from it also amplified, due to an eminent increment of surface water temperature that causes escaping of water molecules from reservoir. This table illustrated that, when water turbidity raised from 43.7 to 226 NTU, volume of water evaporated from the reservoir increased from 125.429 to 191.241 cubic meters. A change in volume of water is reported as 65.812 cubic meters which caused an eminent storage change, due to the raised water turbidity that results the raise of surface water evaporation and then caused falling of reservoir storage.

Paaijmans *et al*. (2008) reported that, rises in water turbidity results, an increment of surface water evaporation, that decreases longevity of water in the puddles. This study depicted that, if water turbidity increased in the reservoir, it caused storage change of this reservoir by decreasing quantity of water stored in the reservoir. Figure 4.5 above shows that, there is strong positive direct relationship between turbidity and volume of the water evaporated from reservoir with coefficient of determination value of 1.

An equation of the line is given as:

$$V_e = 0.361Tu + 109.65 \quad (4.5)$$

Where, Tu and V_e represent water turbidity and volume of water evaporated from Gilgel gibe I reservoir respectively.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Basically, all objectives of the study were successfully achieved. From the study, it was found that, there exist relationships between turbidity and surface water temperature, downward vertical alteration of water temperature occurred, there exist relationship between turbidity and surface water evaporation and variation of reservoir water turbidity caused the storage change of reservoir, due to the raised surface in surface water evaporation.

The study showed that, there was a strong positive correlation between turbidity and surface water temperature at 9:00, 13:00 with spearman ranked correlation coefficient(r) value of +1 and strong negative correlation at 17:00 with spearman ranked correlation coefficient(r) value of-1. It revealed that, when reservoir water turbidity increased, surface water temperature also raised. Downward vertical alteration of water temperature occurred within a group and between the groups, owing to the absorption and scattering of net incoming solar radiation that diminished penetration depth of this net solar radiation.

As depicted in this study, there was a strong positive relationship between reservoir water turbidity and surface water evaporation with spearman ranked correlation coefficient(r) value of +1. This is due to, an increment of surface water temperature along with the rise of reservoir water turbidity. Since, the raises of surface water temperature increased the motion of reservoir water particle, it caused prominently the rise reservoir water evaporation. Because, surface water evaporation caused removal of water particles as water vapor, it affected quantity of water stored in reservoir. The volume change that occurred due to the alteration of reservoir water turbidity is 65.812 cubic meters. Therefore, as reservoir water turbidity increased, surface water temperature and evaporation raised, which results the falling of reservoir storage.

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5.2 Recommendation

The significant change in reservoir storage of Gilgel gibe I occurred, as this study revealed. Hence, based on the result of the study, the following major recommendations were suggested:

- There should be proper land management practices that encourages afforestation, thereby, precipitation during the rainy season could be infiltrated into the ground and reduce the soil erosion from catchment area of the reservoir.
- Communities who are using the resources of the area should get awareness of turbidity impact on reservoir storage.
- There should be strong encouragement and support of appropriate techniques in water and soil conservation practice in the community level, so that, silting-up of reservoir and entrance of suspended particles in the reservoir due to increased runoff could be reduced.
- It is recommended to collect more data in order to get better understanding of the impact of turbidity on reservoir storage.
- It is important to identify covariate variables that are required to determine the impact of turbidity on reservoir water.

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APPENDICES

Appendix A

Table 1: Surface water temperature recorded at different hours for different turbid water

	Turbidity	226	203	194	166	115	89.3	74.7	68.2	503	43.7
Days	Hours	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
	9:00hrs	26	24.8	24	23.6	23	22.5	22	21.8	21.3	21.2
	11:00hrs	30.4	29.5	29.2	28.8	28.1	27.9	27.7	27.6	27	26.6
1	13:00hrs.	36.8	32.6	31.4	30.8	29	29.2	29	29	28.8	28.8
	15:00hrs	32	30	29.8	29.6	29.1	28.8	28.7	28.5	27.8	27.6
	17:00hrs	24	24.6	25	25.4	26	25.8	26.2	26.6	26.8	27
	9:00hrs	25	23.8	23.6	23.2	23	22.4	22.4	22.2	21.8	21.6
2	11:00hrs	30.4	29.4	29.2	28.8	28.5	28.3	28.1	27.8	27.4	27.2
	13:00hrs.	36.2	31.4	31	30.2	29	29	28.8	28.8	28.6	28.6
	15:00hrs	32	31.2	31	30.3	29	28.8	28.6	28.1	27.8	27.5
	17:00hrs	23.4	23.6	23.8	24	24	24.4	24.8	25	25.2	25.4
	9:00hrs	23.8	23.4	23.2	23	23	22.8	22.6	22.4	22.2	22.2
	11:00hrs	27.8	26.4	26.1	25.7	27.4	26.3	26.1	25.9	25.6	25.5
3	13:00hrs.	36.2	33	32.2	30	29	29	28.9	28.7	28.5	28.4
	15:00hrs	29	27.8	27.5	26.1	25.3	25	24.8	24.9	24.6	24.57
	17:00hrs	20	20.8	21	21.6	22	22.4	22.8	23	24.2	24.5
	9:00hrs	22.8	22	21.8	21.4	21	20.2	20.1	20.1	19.7	19.6
	11:00hrs	30.2	29.6	29.2	28.4	27.5	27.2	27	26.8	26.4	26.2
4	13:00hrs.	30	29.2	28.8	28.2	28	27.5	27.4	27.4	27.3	27.3
	15:00hrs	30.6	29	29.7	28.6	27.2	27	26.5	26.3	25.8	25.5
	17:00hrs	21.4	22.8	23.1	23.4	24	23.8	24.1	24.2	24.6	24.8
	9:00hrs	24	23.2	22.8	22.4	22	22	21.9	21.9	22	22
	11:00hrs	27	26.4	26.2	25.7	25	24.6	24.2	24	23.6	23.5
5	13:00hrs.	30.8	28.4	28.2	27.9	28	27.6	27.6	27.5	27.58	27.5
	15:00hrs	29	28.2	28	27.6	27	26.7	26.3	26.1	25.8	25.6
	17:00hrs	19	20.1	20.4	20.6	21	21.6	21.8	23.2	23.5	23.8
	9:00hrs	24.4	24.1	24	23.9	24	23.6	23.3	23.3	22.9	22.8
	11:00hrs	28	27.6	27.4	27.1	26.5	26.3	26.1	26	25.7	25.6
6	13:00hrs.	34	30.4	30.3	30	29	29.1	29	28.9	28.8	28.7
	15:00hrs	27.9	27.4	27.1	26.6	26	25.8	25.5	25.4	25.1	24.9
	17:00hrs	24.6	25	25.4	25.6	26	26.2	26.4	26.8	27	27.4
	9:00hrs	22	21.6	21.4	21.1	21	20.6	20.5	20.5	20.3	20.2
	11:00hrs	23.2	23	22.9	22.75	22.4	22.2	22	21.9	21.75	21.6
7	13:00hrs.	26	25.4	25.5	25.3	25	24.6	24.4	24.3	24.1	24
	15:00hrs	24	23.75	23.6	23.42	23	22.8	22.72	22.7	22.5	22.54

	17:00hrs	20.4	20.8	21.2	21	21	21.1	21.3	21.4	22	22
	9:00hrs	21.4	21	20.8	20.5	20	20	19.7	19.8	19.6	19.5
	11:00hrs	24.2	23.7	23.5	23.2	23	22.5	22.34	22.3	22.16	22.08
8	13:00hrs.	36.5	31.8	31.4	31.1	31	30.6	30.5	30.5	30.46	30.45
	15:00hrs	31.4	30.6	30	29.6	29	28.76	28.6	28.5	28.2	28
	17:00hrs	25.2	25.8	26.2	26.4	27	26.7	27.1	27.4	27.5	27.6
	9:00hrs	23	22.7	22.6	22.4	22	22	21.8	21.5	21.4	21.2
	11:00hrs	26.7	26.4	26.2	25.9	25.5	25.3	25.18	25.1	24.8	24.7
9	13:00hrs.	33.9	32	31.5	31.2	31	30.7	30.5	30.5	30.4	30.48
	15:00hrs	30.6	30	29.8	29.5	29	28.7	28.56	28.5	28.3	28.22
	17:00hrs	24	24.6	25	25.4	26	25.8	26.2	26.6	26.8	27
	9:00hrs	24.2	23.9	23.8	23.6	23	23	22.7	22.5	22.1	21.8
	11:00hrs	30.2	29.6	29.3	28.8	28.1	27.8	27.54	27.5	27.2	27.14
10	13:00hrs.	33.8	32.4	32	31.7	31	31	30.6	30.4	30	29.8
	15:00hrs	32	31.5	31	30.6	30	29.82	29.7	29.6	29.3	29.16
	17:00hrs	25.6	25.8	26	26.4	27	26.8	26.8	27	27.3	27.3
	9:00hrs	25	24.6	24.3	23.8	24	23.4	23.1	22.8	22.4	22
	11:00hrs	27	26.4	26.14	25.8	25.2	24.8	24.5	24.3	24	23.9
11	13:00hrs.	31.8	31	30.8	30.5	30	29.5	29.2	29	28.6	28.5
	15:00hrs	28.2	27.6	27.32	27	26.5	26.24	26	25.8	25.4	25.26
	17:00hrs	21	21.4	21.6	22	23	23	23.2	23.6	24.2	24.4
	9:00hrs	22.6	21.8	21.4	21.1	21	20.6	20.3	20	19.6	19.4
	11:00hrs	28	27.3	27	26.6	25.9	25.64	25.4	25.3	25.12	24.8
12	13:00hrs.	32	30.2	30	29.5	29	29	28.7	28.5	28.1	28
	15:00hrs	30.6	30	29.6	29	28.6	28.4	28.1	27.9	27.64	27.5
	17:00hrs	25	25.8	26.2	26.6	27	27.2	27.4	27.8	28	28.2
	9:00hrs	23.6	23.1	22.8	22.6	22	22.1	21.8	21.6	21.3	20.8
	11:00hrs	29.6	28.8	28.6	28.1	27.7	27.4	27.1	27	26.72	26.68
13	13:00hrs.	36.8	31.5	31.1	30.6	30	29.9	29.7	29.5	29.1	29
	15:00hrs	26.6	25	24.7	24.2	23.4	23.14	23	22.9	22.68	22.6
	17:00hrs	19	19.3	19.4	19.6	20	20	20.2	20.4	20.8	21
	9:00hrs	22.6	21.8	21.4	20.9	21	20.3	20.1	19.8	19.5	19.3
	11:00hrs	27	26.3	26	25.6	25	24.76	24.5	24.4	24.18	24.12
14	13:00hrs.	33.8	31.4	31.2	30.8	30	30	29.8	29.6	29.2	29
	15:00hrs	29	28.5	28.2	27.8	27.1	26.8	26.54	26.5	26.3	26.18
	17:00hrs	21.4	22.8	23.1	23.4	24	23.8	24.1	24.2	24.6	24.8
	9:00hrs	22.4	22	21.8	21.5	21	20.8	20.6	20.3	19.8	19.5
	11:00hrs	26	25.44	25.2	24.86	24.4	24.1	23.82	23.7	23.46	23.34
15	13:00hrs.	30.8	29.6	29.3	29	29	28.6	28.5	28.3	28.2	28.2
	15:00hrs	27.2	26	25.8	25.4	25	24.7	24.5	24.6	24.4	24.32
	17:00hrs	18.8	19.6	19.8	20	20	20.5	20.7	20.8	21.1	21.3

Appendix B

Table 2: Daily pans water evaporation recorded for most and least turbid water samples

Observation days	Evaporation from least turbid evaporation pan	Evaporation from most turbid evaporation pan
1	2.4	3.93
2	4.7	6.92
3	4	5.2
4	4.08	5.42
5	4.63	5.86
6	3.43	4.28
7	3.8	4.97
8	0.4	0.86
9	3.1	4.58
10	2.16	3.08
11	2.46	3.28
12	1.8	3.1
13	4.34	5.63
14	2.14	3.4
15	3.32	4.97
16	2.14	3.24
17	2.36	3.74
18	3.57	4.68
19	2.88	3.84
20	3.2	5.38
21	2.84	3.88
22	4.44	5.76
23	4.56	5.92
24	2.58	4.26
25	3.8	5.7
26	4.08	5.95
27	2.4	4.34
28	2.1	3.58
29	2.2	3.94
30	2.14	3.72
31	3.20	5.64
32	2.98	5.42
33	3.4	6.13
34	2.76	3.74
35	3	5.52
36	4.1	6.58

37	3.12	5.58
38	3.4	6.26
39	2.54	4.62
40	3.34	5.98

Appendix C

Photo taken during experiments execution

Figure 1. Sample taking from Gilgel gibe I reservoir using boat and plastic cans

Figure 2. Stored water samples in plastic tanks

Figure 3. Cell and rinsing a cell

Figure 4. Reading and recorded water turbidity

Figure 5   Burrowed pool

Figure 6. covering pool by plastic

Figure 7. Measuring water temperature at surface, middle and top of pool water

Figure 8. Setting class, A pan in the field (Jimma meteorological station)

Figure 9. Pouring water to a pan

Figure 10. Searching level of the water

Figure 11. Reading and recording depth of the water evaporated