# ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

## SCHOOL OF HUMANITIES AND LAW

### DEPARTMENT OF GEOGRAPHYANDENVIROMENTAL MANAGEMENT

**GIS-BASED ANALYSIS OF CAUSES, EXTENT AND CONSEQUENCES OF DEPLETION OFLAKE ABIJATA, CENTRAL RIFT VALLEY OF ETHIOPIA**

**BY: ABDI IBRAHIM**

**August, 2016**

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**BY**

**ABDI IBRAHIM**

**ADVISOR: TESFAYE GENEMO (PhD)**

**A Thesis submitted to The Department of Geography and Environmental management**

**In partial Fulfilment of the Requirements for the Degree of Master of Arts in Geography and Environmental Management, Specialization in Land and Water Resource Management**

**August, 2016**

**ADAMA, ETHIOPIA**

# D E C L A R A T I O N

I hereby declare that the thesis entitled "GIS-Based Analysis of Causes, Extent and Consequences of Depletion of Lake Abijata" has been carried out by me under the supervision of Dr. Tesfaye Genemo, Department of Geography and Environmental Management, Adama Science and Technology University, Adama during the year 2016 as a part of Master of Art's. I further declare that this work has not been submitted to any other University or Institution for the award of any degree or diploma. Any material and information in a study other than my own are dully acknowledged.

Name____________________________________________

Signature__________________________________________

Date of Submission: August 2016

Adama Science and Technology University

Department of Geography and Environmental Management,

## Certification

As thesis advisor, I hereby certify that I have read and evaluated this thesis prepared by Abdi Ibrahim under my guidance entitled “GIS-Based Analysis of Causes, Extent and Consequences of Depletion of Lake Abijata, Central Rift Valley of Ethiopia” I recommended that it be submitted as fulfilling the MA thesis requirement.

| Advisor | Signature | Date |
|---|---|---|
| TesfayeGenemo(PhD) | ______________________ | _________________ |

As members f the Board Examiners of the thesis Open Defense Examination we certify that we have read, and evaluated the MA thesis prepared by Abdi Ibrahim, and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirement for the MA degree.

| Chair Person | Signature | Date |
|---|---|---|
| _______________________ | ______________________ | ____________________ |
| Internal Examiner | Signature | Date |
| _______________________ | ______________________ | ____________________ |
| External Examiner | Signature | Date |
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**_Abstract_**

*Lake Abijata suffers from water level fluctuation due to several natural and anthropogenic factors. As it located at terminal position (no surface water outflow), it highly affected by the fluctuation. This fluctuation is disturbing the stability of the lake ecosystem and imposing very serious impacts on the lives of plants, fish and many birds in and around the lake. Hence, studying of the cause, extent and consequences of shrinking of the lake was found to be very important. The main purpose of this study is to identify the factors that contribute to the water level fluctuation, to quantify the extent of fluctuation and impacts of shrinking of the lake on its ecosystem, eco-tourism and fishing activities. The research methodology includes computing of annual water abstraction, annual rainfall, annual maximum temperature and multi-satellite image analysis. The result of the study revealed that the shrinking of the Lake Abijata water level is caused by natural factors such as increasing in temperature and decreasing of rainfall in the area and human activities ( over use of water for irrigation and production of soda ash). Lake Abijata is dramatically reduced in size (about 43.13% of its area between 1985 and 2015) due to both natural factors and human activities (the most dominant one). Due to decreasing of Lake Abijata water level and increasing of alkalinity of lake water, natural ecosystem of the lake is highly affected. This also totally changed the socio-economic setup of the area. Since Lake Abijata is seriously, affected, special attention is needed to conserve the water in the lake by controlling the excessive use of water and save the lives lake ecosystem including fauna and flora.*

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**ABRIVIATIONS**

APA: American Psychological Association

ARDO: Agricultural and Rural Development Office

ATJKW: AdamiTulluJidoKombolcha*Woreda*

CRVE: Central Rift Valley of Ethiopia

CSA: Central Statistical Agency

DA: Development Agent

ENSA: Ethiopia National Security Agency

FGD: Focus Group Discussion

GIS: Geographic Information System

INSA: Information Network Security Agency

KII: Key Informant Interview

LEPO: Land and Environmental Protection Office

MoWR: Ministry of Water Resource

NGO: Non-Governmental Organization

NMA: National Meteorological Agency

RS: Remote Sensing

UTM: Universal Transverse Mercator

OWRB: Oromia Water Resource Burea

# CHAPTER ONE: INTRODUCTION

## 1.1Background of the study

A Lake is a standing water body that occupies a depression in the land surface. Lake and lake shores are attractive places to live and recreate. Clean, sparking water abundant wild life; beautiful scenery, aquatic recreation and fresh breezes all come to our mind when we think of going to the lake. Despite their great value, lakes are fragile and ephemeral (Thompson, 2005).

Water level in great lakes of the world continued to fall with drought condition and leave many concern about the water supply for the communities, crops, ecosystems and shipping industries. The great lakes hold 20% of the world`s fresh water reserves (Jessica, 2013). The cause of shrinkage has been attributed to drought and lower level of rainfall suspected to be caused by global warming, contributed with an increased demand for water by growing population. Further, farming and overgrazing of the soil has led to desertification, where crescent shaped sand dunes shift across the dry lake bed (Hidden, 2012).

The Ethiopian Rift Valley has highly variable elevation, width and tectonic setting. Very interesting feature of the northern and central sectors are the existence of open and closed lakes situated within the large depression. We find the major lakes in the central main Ethiopian Rift with relativity high elevations as compared to the *Afar* and *Chew Bahir* Rift bordering Kenya (Kassaye, 2010).The main Ethiopian Rift Valley lakes suffer from water level fluctuation due to several natural and anthropogenic factors. Lakes located at terminal position (no surface water outflow) are highly affected by the fluctuations. These fluctuations are disturbing the stability of ecosystems, putting very serious impact on the lives of many animals and plants around them. The depletion of vegetation cover not only increases sedimentation in lakes but also decrease canopy and interruption losses, each in turn increase the run off coefficient. Increasing population and expansion of irrigation projects are putting pressure on the vegetation of the rift valley basin (Kassaye, 2010).

In general the level of Lake Abiyata fluctuates according to the precipitation trends in the highlands. However, the recent drastic decline in its level and the increase in salinity coincide with the time of large-scale water abstraction. The current and future uncontrolled water abstraction will have obvious environmental repercussions, which are thought to bring grave consequences to the lacustrine environment in the foreseeable future. The protection of the environment requires integrated water management at a basin wide scale. Changes in Lake Abiyata should be perceived jointly with the abstraction of water for irrigation around Lake Ziway (Ayenew, 2002).

## 1.2 Statement of the Problem

Natural ecosystems are "open" systems in the sense that there is free transfer of energy and matter in and out of the system, keeping the system in a dynamic equilibrium. However, the human intervention on environment has induced a challenge on the ecological balance. These interventions are seriously affecting this balance. Change in lake level results from a shift in the regional water balance are among these imbalances; particularly in closed terminal lake responses are partly from climate changes but the system tends to maintain equilibrium between input and output ( Anna, 2006). And this is more relevant in the semi-arid African tropics, including Ethiopia, where there are large inter-annual climate changes and increasing population pressure making the region more sensitive to the fluctuations of water resources (Servat et.al., 1998).

According to Brook (2003), some of the Ethiopian lakes are shrinking and completely dried up due to several factors resulted from human activities and natural factors such as climate change, sedimentation, soil erosion, over use of water for different purposes: irrigation, over consumption and industrial factory purpose and lack of enforcement of management strategy framework. These problems have increasingly affected the Abijata lake. As noted by Tenalem (2003), Abijiata had showed insignificant water level fluctuation. However, during the past three decades it has started to show extreme water level fluctuation as explained by Dagnachew (*etal*., 2005). Accordingly, its depth was 13 meters in 1970-72. However, this figure has dropped to 7 meter in 1989.

This extreme level fluctuation is equivalent to water volume of 1, 405 and 541 million $m^3$ respectively. Considerable water volume decline of lake Abijiata was observed in 1985 and 1990, amounting to 425 million $m^3$ or 53 percent of its volume reduction in 2005 (ibid, 2005Cited in EWHS, 2010).

Different studies were conducted, on Lake Abijata by different researchers during the past few decades. Among these studies, K.Reaugh (2011) predicted that Abijata may dry up within 10years, due to increasing irrigation around Lake Ziway. Ayenew (2002) also clearly concluded that, the change in Lake Abijata is due to water abstraction for irrigation around Lake Ziway.This is because the main water source of Abijata lake is lake Zeway through Bulbula river followed by Horakalo river from Langano lake. But the purpose of this study will be to examine the spatial and temporal Abijata lake water fluctuation in the study area using Remote Sensing and Geographic Information System technologies.

However, since there is no enough study that consider the major natural and anthropogenic causes and its degree of effect on the lake water level fluctuation with its socio-economic, cultural and natural consequences, this study aims to fill this research gap. At least, this study will try to answer the proposed research questions.

## 1.3 Objectives of the Study

### 1.3.1 General Objective

The general objective of the study is to assess the cause, extent and consequences of shrinking of Lake Abijata, Adami Tullu Jido Kombolcha Woreda Central Rift Valley of Ethiopia.

### 1.3.2 Specific objectives

More specifically, this study is intended to:

- identify the major anthropogenic and natural causes for the shrinking of lake Abijata.
- assess to what extent lake Abijata has been shrunk temporally and spatially using GIS and Remote Sensing technologies.
- examine the effects of shrinking of the lake on socioeconomic, cultural and natural setting of the area.

## 1.4 Research Question

In order to attain the above stated objectives, the following basic research questions have been answered in the course of the study.

1. What are the major anthropogenic and natural causes for the shrinking of lakeAbijata?
2. To What extent Lake Abijata has been shrunk temporally and spatially?
3. What are the social, economic, cultural, and natural consequences of the shrinking of Lake Abijata?

## 1.5 Significance of the Study

The findings of this study may provide baseline knowledge about natural and anthropogenic causes, extent and consequences of shrinking of Lake Abijata. The output of this study could be essential for natural resources managers, policy makers, environmentalists and local community in order to have appropriate water resource utilization and protection mechanisms. Moreover, the findings of this research work may give insight for researchers and students interested in related research theme for further investigation of the area.

## 1.6 Scope and Limitation of the Study

The spatial scope of the study was limited to Adami Tulu Jido Kombolcha*Wereda* , specifically to Abijata Lake, with an interest of assessing the natural and anthropogenic causes, extent and natural, cultural and socioeconomic consequences of shrinking of Abijata Lake. And the temporal scope was also based on the long term meteorological data (rainfall and temperature) analysis obtained from National Meteorological Agency (NMA) branch of Adami Tulu Jido Kombolcha*Wereda*, and the amount of water utilized by soda ash factory. Four seasons Landsat images of Abijata Lake was obtained from Information Network Security Agency (INSA) substantiated by Google Earth, which is taken in last thirty years.

The major limitation the researcher faced in this study were unwillingness of companies to give data, lack of full meteorological data(pan evaporation, wind speed, humidity, long and short waves and Lake Abijata water level etc) to compute the water balance of the lake and lack of recent data on water level and bird population.

## 1.7 Organization of the Thesis

The thesis was organized into five main chapters. The first chapter is an introductory part that includes background, statement of the problems, objectives, research questions, significance, scope and limitations of the study. Chapter two reviews concepts related to causes and consequences of Lake water level fluctuation in central rift valley of Ethiopia and conceptual framework. Chapter three provides description of the study area and methodology used. Chapter four presents results and discussion and the chapter five gives conclusion and recommendations.

# CHAPTER TWO: REVIEW OF RELATED LITERATURE

## 2.1 Concepts of Lake Water Fluctuation

Lake and ponds occur in a wide range of depths, sizes, and permanence from deep lakes having permanent body of surface water to shallow ponds having water for only a few weeks each year. These factors also vary within each lake or pond, resulting in diverse communities of aquatic plant growing in various patterns. Certain types of plants require relatively high water level, while others cannot tolerate standing water. Therefore, the balance between inputs and outputs of water, which in turn controlled by the hydrological processes, controls changes in water level. Many hydrological processes are sensitive to changes in climate. For example, during prolonged drought, precipitation inputs generally decrease and evaporation outputs increase resulting in a drawdown of lake level or even a complete drying out. Climate also affects the lake water balance by changing the amount of stream flow and ground water flow into the lake, but the response of the hydrological processes to climate is complicated because of the complex interactions among climate, vegetation, soil and ground water, such interactions are also strongly affected by land-cover change caused by natural (eg. wild fire) or anthropogenic (eg. agriculture) processes (M. Hayashi, 2010).

### 2.1.1 Ethiopian Lakes and their Temporal Variation

Ethiopia has 11 fresh and 9 saline lakes, 4 crater lakes and over 12 major swamps or wetlands. Majority of the lakes are found in the Rift Valley Basin. The majority of Ethiopian lakes are rich in fish. Most of the lakes, except Ziway, Tana, Langano, Abbaya and Chamo, have no surface water outlets. Lakes Shala and Abijata have high concentrations of chemicals and Abijata is currently exploited for production of soda ash (MoWR, 2004 ; Seleshi et al ., 2007).

All the rest major Ethiopian lakes are confined to the Rift floor. Most of the lakes are fed by perennial rivers originated from the highlands (Ayenew, 2004) and therefore their levels fluctuate according to the rainfall trends in the flanking highlands (Street, 1979).

Seasonal lake level fluctuations may alone amount up to 1meter (Tesfaye, 1982), with the annual maximum in October or November (Mercier et al .2002). The effect of recent tectonic activity on the hydrological regimes of the lakes is not thoroughly investigated, but some changes in lake level may be attributed to the opening or reactivation of rift faults (Ayenew, 2004). For example, changes in the discharge of springs around lake Langano have been observed after recent seismic activity led to the formation of new faults (Ayenew, 1998).

The main purposes of large scale anthropogenic water - withdrawals from Ziway and Abijata lakes are for irrigation and soda production. Due to lack of records and controls the abstraction rates can only be estimated (Ayenew, 2004). The endorheic one (Abijata) of the rift lakes prove to be especially susceptible to level height alternations. According to the study made by Ayenew (2004) the terminal lakes showed the most drastic changes. From 1976 to 2000, the water level of lake Abijata dropped by 4.3 meter, the mean depth being only 8meter. He further proposed in his report that the sharp decrease in lake level can be attributed to upstream water abstraction for irrigation purposes and water withdrawal for soda ash production. On the contrary, lake Beseka and lake Hawassa have expanded since the beginnings of measurements in the 1970s . The non - endorheic lakes ( lake Langano) show little or no change for the same period of time (Ayenew, 2004).

According to Schütt et al . (2002), population pressure, deforestation and a change in cultivation have led to an increased sediment yield in the lake Abaya‘s tributaries, thus influencing basin bathymetry and volume. Moreover, neo-tectonics seem to have caused an uplift of the sill departing the basins of lake Abaya and lake Chamo, hence controlling lake Abaya‘s outflow (Schütt et al .,2002). Due to a combination of those two factors a water level increased roughly, 2meter has been observed since 1987. Lake Ziway is locally called ― Hara Danbal and it is one of the important lakes among the CRV of Ethiopia . Because, this Lake contains fresh water that originates from the two incoming rivers (Katar and Meki) and rainfall, it has been used for agriculture, domestic water supply and recreation. Moreover, soil adjacent to eastern lake shore near Chafe Jilla is full of minerals and it is used for livestock of the area and adjacent highland community.

Like other exorheic lake, lake Ziway is undergoing all processes, such as fluctuation of lake level and volume with respect to anthropologic activities and climatic change. According to Ayenew (2007), if all proposed land area is irrigated, annual water abstraction from the Lake and major Rivers will be about 150 - 180 $Mm^3$with 30 cm reduction in the level of lake Ziway which ultimately lead to a drastic decrease in the level of lake Abijata and drying up of the feeder Bulbula river.

Climatic change may also have significant influences on the level and area of lake Ziway. Increasing in temperature and other climatic parameters (sunshine duration, wind speed and relative humidity of the air) and decreasing in length of rainy season , result in decreasing of inflow of water to the lake. This can affect the lake level decline that might reach up to 62cm in the coming 90 years; consequently, the water surface area of the lake Ziway can also shrink to 25 km2( Lijalem, 2006).

## 2.1.2 Lake Level Fluctuations in the Main Ethiopian Rift Valley

Ethiopia is gifted with a variety of aquatic ecosystems, especially a number of lakes that are of great scientific interest and economic importance. The majority of the Ethiopian lakes are confined within the Rift Valley that extends from Kenya border in the south to the Afar Depression in the north. The principal determination of the lake`s position in the series is the open or closed nature of its individual drainage. At present in Ethiopia there are three major closed systems (the Awash River-Afar drainage, the northern rift lakes, the southern rift lakes), numerous crater lakes with seepage-in and out, and two cryptodepressions with marine inputs. Salinity is primarily determined by evaporative concentration, enhanced in lakes associated with past marine influence or recent volcanic activity by readily soluble materials in the catchment, and by some thermal-reflux pathways. However, anomalously dilute closed lakes exist, indicative of other processes of solute loss. Ethiopia contains some 7000$km^2$ of inland water whose scientific benefit is largely unexploited. With the exception Lake Tana, (which includes all the large lakes) are within closed drainage systems, although several are individually open systems.(Halcrow, 1989)

The Ethiopian Rift system extends from the Kenyan border up to the Red Sea and is divided into four sub-systems: Lake Rudolf, Chew Bahir, the Main Ethiopian Rift and Afar drainage. The MER contains three separate lake basins holding the Ziway, Langano, Abijata and Shalla lakes; Lake Awasa, and Lake Abaya-Chamo. The climate is semi-arid in the central part of the MER, semi-arid close to the Kenyan border and arid in the Afar region (Ayenew,2007). The annual rainfall within the limits of the rift varies from around 100 mm in much of the Afar up to around 900 mm close to lake Abaya. The elevation within the rift varies widely from close to 2000 m a.s.l at lakes Abaya and around 120 m below sea level in the Dalol Depression. Many of the lakes are located within a closed basin fed by perennial rivers. The major rivers in the region are Awash, Meki-katar, Dijo and Bilate feeding lakes Abhe, Ziway, Shalla and Abaya respectively. Lakes Ziway, Abijata and Langano are connected by small rivers of Bulbula and HoraKello (Ayenew, 2007).

The major input to the MER lakes comes from highland rainfall generating perennial and seasonal flows in the form of rivers and surface runoff. The amount and distribution of highland rainfall strongly controls the level and size of these lakes (Ayenew, 1998). Ground water recharged by direct rainfall is also vital to many lakes (Ayenew, 2002a, 2007). The lake level records show extreme fluctuation over half a century; the Ethiopian case is dramatic. Despite long-term pumping of Kenyan lakes for horticultural development, the reduction in the size is minimal. This signals that the lake level changes that took place in Ethiopia may dominantly be natural rather than anthropogenic, with the exception of lakes Abjata and Ziway.

## 2.2 Natural and man-induced Factors Affecting Lake Water Level

### 2.2.1 Natural Factors Affecting Lake Water Level

The water-level of a lake changes seasonally and fluctuates annually due to the difference of seasonal or yearly precipitation and evaporation. The stable condition of the lake-level is decided by a balance between inflow and outflow. In an arid zone, such stability of a closed lake is regulated by the change of evaporation surface, too. Apart from the various inflow and outflow components, the water balances of lakes are governed by climate, anthropogenic factors, volcano-tectonism, and sedimentation. The sensitivity of lake level changes to the balance between inflows and outflows is higher in closed lakes than in open lakes (Murimi, 1994, cited in Kasaye,2010).

The Ethiopian Rift Lakes are located in a hydrogeologically complex rift environment where many natural and anthropogenic factors played important role in changing the size and level of most of the lakes. The natural factors include the change in the average annual mount of precipitation and evaporation rates (climatic), volcano-tectonism and sedimentation (geological) and runoff amounts (hydrological) (Kassaye, 2010).

### 2.2.2 Human-induced Factors Affecting Lake Water Level

Humans drive degradation of lake water quality in several primary ways, among them deforestation, agriculture, and development. There are many processes which result from these drivers and serve to directly decrease water quality. These include soil erosion and siltation, overfishing, and chemical fertilizer, runoff, among others. As a result of lake degradation there are immediate impacts on human and natural health, as well as secondary or tertiary consequences as a result of decreased productivity and resource levels (Bitwas et al., 2004). Identifiable anthropogenic drivers are measured by direct processes that threaten lake water quality. The impacts of decreased water quality are complex, interrelated, and difficult to measure, but also (ideally) ameliorable through well designed policy interventions. The following anthropogenic drivers will be described here: urbanization, industry, agriculture, and deforestation. Population pressures and urbanization significantly affect cities near lakes and the lakes themselves: "Urbanization and human settlement in close proximity to the Ethiopian lakes are among the greatest potential causes of change in water quality and quantity" (Zinabu, 1998). Continuous increases in population harm soils, cause pollution and water scarcity, and in turn impair future development. Urban development and the construction of roads on steep slopes or across streams increase chances of landslides and the blocking of riparian corridors (Gregersen, 2007).

Although much of Ethiopia depends on agriculture and livestock production, water is still diverted from lakes for some industrial purpose. Agriculture, which typically takes the form of either crop farming or livestock herding, is widely recognized as having deteriorating impacts on the quality of nearby water. Many cases show that when agricultural production intensifies, farmers utilize more pollutants, which causes nutrient oversaturation, eutrophication, and red tides in river, lakes, and streams in the surrounding area (Tedesse, 2005, cited in Kassaye). Deforestation, which may occur due to need the for fuel wood, land for livestock production, or timber or non-timber forest products, is another common threat to water quality of lakes. With the loss of "protective vegetative cover," a landscape loses the qualities of its soil that keep it from eroding. Deforestation leads to increased sedimentation or the filling of water bodies with sediment from surrounding areas ( Gregersen, 2007).

Generally, the anthropogenic factors that bring about lake level fluctuation in the Ethiopian Rift are changes in land use, water abstraction for irrigation, and extraction of minerals (such as soda ash) and construction of dams for generation of hydroelectric power. The newly established floriculture and horticulture enterprises are also abstracting water from the Central Ethiopian Rift lakes (Huib and Herco, 2006, cited in Kassaye, 2010).

## 2.3 Effect of Water Use on the Water Balance

Total water use for irrigation in the CRV is approximately 162 Mm3/year. Total evaporation from the lakes are estimated at 2506 Mm3/year (Ayenew, 2004). This means that total water extraction for irrigation equals approximately 6,5%of annual evaporation. The size of Lake Abyatahasdecreased rapidly during the last years and has a volume of 800 Mm3(Legesse&Ayenew, 2006). Major human activities using water in the CRV are:

- Water use for irrigation
- Domestic water use by human population
- Water consumption by cattle population
- Water evaporation for soda-ash production

Major natural variation affecting water availability in the CRV:

- Variation in precipitation
- Variation in evapotranspiration

## 2.4 History of Remote Sensing

Remote sensing is broadly defined as the art and science of obtaining information about an object without being in direct physical contact with the object (Colwell 1983, Lillesand et al. 2004). Trying to detect objects from afar was probably one of the defense and protection strategies of our early ancestors. During the time when there were no reliable weapons to protect from aggressive animals, their early warning system was detecting danger from afar and preparing a quick escape. Histories of early wars between different kingdoms describe in one way or another importance of collecting information about the enemy from afar. This might not have involved anything more than selecting a strategic high point where observation with the naked eye revealed the desired information. This all indicates that remote sensing is as old as human history itself.

The modern usage of the term ‘Remote Sensing` has more to do with the technical ways of collecting airborne and space borne information. Earth observation from airborne platforms has a one hundred and fifty years old history although the majority of the innovation and development has taken place in the past thirty years. The first Earth observation using a balloon in the 1860s is regarded as an important benchmark in the history of remote sensing (Lillesand et al. 2004). Since then platforms have evolved to space stations, sensors have evolved from cameras to sophisticated scanning devices and the user base has grown from specialized cartographers to all rounded disciplines. It was the launch of the first civilian remote sensing satellite in the late July 1972 that paved the way for the modern remote sensing applications in many fields including natural resources management (Tucker et al. 1983, Csaplovics 1992, Campbell 1996, Lillesand et al. 2004).

The multispectral data provided by the on-board sensors led to an improved understanding of crops, forests, soils, urban growth, land degradation and many other earth features and processes. The Landsat images that were made available soon after its launch disclosed the shocking reality of Amazonian deforestation. The so-called ‘fish-bone’ pattern that was detected by remote sensors revealed the role of new roads in facilitating deforestation. All navigable waters in the Amazon that might have been used for illegal log transportation were also detected (Peres et al. 1995). Thisevent not only triggered the alarm of global deforestation but also opened the door for wide acceptance of remote sensing for natural resources conservation.

The 80's saw a sharp increase in the application of remote sensing for natural resources management (Tucker 1980, Guyot 1990). The increasing availability of powerful desktop computers and the advances in object oriented GIS have allowed many sectors to explore the use of remotely sensed products. Precision agriculture, health care, disaster early warning systems and a wide variety of other fields have quickly adapted the opportunity that remote sensing has brought about. Since the early 1990s, there has been a logarithmic increase in the use of remotely sensed information for land management, coastal ecology, biodiversity research, wildlife ecology, greenhouse effect monitoring and similar tasks. Applied geospatial researches that link the natural resource disciplines with the remote sensing field started to take off (e.g. Csaplovics 1992).

From 1980 to 1990 alone the use of remote sensing data for tropical deforestation monitoring grew almost seven fold (Rudel et al. 2000). The increase in these applications has also provided opportunities for feedback for the improvement of radiometric sensitivity, spatial, temporal and spectral resolutions. New generation of platforms and scanning systems like RADAR, LIDAR and SONAR systems are now emerging. While optical remote sensing provides digital images of the amount of electromagnetic energy reflected or emitted from the surface of Earth at various wavelengths, active remote sensing of long-wavelengths microwaves (RADAR), shortwave length laser light (LIDAR), or sound waves (SONAR) measures the amount of backscatter from electromagnetic energy emitted from the sensor itself (Bergen et al. 1999).

The contemporary trends, in addition to the applications mentioned earlier, are the 'real time' or 'near real time' data reception through remote sensing. Data or information captured onboard satellites is becoming increasingly available via the Internet in a real time or near real time fashion. Weather data from the European geostationary platform Meteostat or polar orbiting MODIS Aqua or satellite telemetry animal tracking data can now be directly received just few seconds or minutes after the event has happened. Today the application of remote sensing has transcended into tracking animals throughout their seasonal migration since 1992. The need for remote sensing in animal tracking has come up due to low rate of ring recovery (Meyburg etal. 2000). This telemetry information is providing the vital flyways that need criticalscrutiny and immediate interventions. The sensation created by the female stork 'Prinzessin'during her flight to and from Africa (van den Bossche 2002) and the subsequently raisedpublic awareness, spotted eagle and other raptors journey to and from Africa (Meyburg et al. 2000), water bird monitoring (Izhaki et al 2002) are few of the many examples. This application is, though, still concentrated in the hands of a few institutions rich in technological resource.

## 2.5 History of GIS

Although its antecedents go back hundreds of years in the fields of cartography and mapping, structured GIS as such started to emerge in the 1960s (Goodchild 1992). Portraying different layers of data on a series of base maps, and relating information geographically has been a practice long before computerized GIS. The technique of superimposing several cartographic maps on one another has been painstakingly used even during the mid 19th century (Foresman 1998).

The blending of computer technology and cartography in the 1960s paved the way for the possibility of using the technique of overlaying and superimposing maps in fields other than cartography. The powerful multiplication which results from the integration of climate, terrain, environmental, agronomic, economic, social and institutional management data, makes available for scientists and managers alike a new and powerful monitoring and modeling tool. However, these early GIS packages were often written for specific applications and required a level of computing power usually found in government or university settings (Foresman, 1998). In the 1970s, private vendors began offering off-the shelf GIS packages. Intergraph and Environmental Systems Research Institute (ESRI) emerged as the leading vendors of GIS software (Foresman 1998). As computing power increased and hardware prices plummeted in the 1980s, GIS became a viable technology for natural resources managers (Jensen 1996). As Allan (1990) noted the process of adopting GIS was however far from smooth. The Vector or Raster map politics along the professional line was the major hurdle. These two groups advocated mutually exclusive procedures that were problem for data integration in the 1970s and 1980s.

*"The traditional mapping community was certain that the vector system of spatial data management would solve all problems and those that it would not solve were not worth considering. This argument was particularly attractive to the vector group as their approach meant that they need make no change in scope of their mapping activities, since the vector approach was wholly compatible with their conventional system of coordinated geographic*

*control and presentation of detail. They were interested in linear and pointdata and not at all concerned with providing data on the spaces between lines*" (Allan 1990).

As far as natural resources managers or wildlife ecologists were concerned, vector maps would provide the boundaries of the conservation areas but no data on the structural and physical habitat within the boundary. The strong presence of remotely sensed data in raster format in the 80s forced these GIS developers and vendors to address this part of a market niche too. Specialized groups in raster GIS emerged as a result and the full-fledged competition between raster and vector GIS further pushed the development of GIS into an environment where both systems are supported and function in a way that complement each other.

The successful implementation of separate attribute table and location information in the early 80s as well as the successful integration of relational database management systems in small desktop computers to handle attribute tables has given GIS the momentum to reach all sectors of academic, research and development - that includes biodiversity studies, wildlife conservation, land resource management and so on.

The natural resource management and conservation community also played a great role in the development of GIS. Several custom-made products emerged using standard contemporary products. Most of the algorithms for such products function as extensions or plug-ins that have largely been developed within the conservation community. Today the web mapping and multi-user GIS systems are setting the trend of mapping and analysis in the developed world. Real time remote sensing and/or GIS animation is also becoming a common phenomenon (see Riede 2004 for examples of prototypes and details in animation of migratory species movement via web). The emergence and strong acceptance of Open Source products is also making GIS available to many end users. As satellite data are generally digital and consequently amenable to computer-based analysis for classifying land cover types, the advance in GIS and its growing availability for the general users is a promising trend for the application of low cost remote sensing in developing countries.

## 2.6 Role of Remote Sensing in Natural Resource Change Detection

Remote sensing refers to the technique of obtaining information about an object or feature through the analysis of data acquired by a device that is not in contact with the object or feature under investigation (Lillesand and Kiefer, 2000). For the past couple of decades the application of remote sensing (RS) not only revolutionized the way data has been collected but also significantly improved the quality and accessibility of important spatial information for natural resources management and conservation. The rapid acceptance of the use of remote sensing for conservation and nature protection coincides with the frequent reporting of wide spread modification of natural systems and destruction of wildlife habitats during the past three to four decades. Concerns about the increase in adverse environmental conditions prompted the remote sensing experts and users to quickly catch up with the evolving technology.

The parallel advance in the reliability of Geographic Information System (GIS) has allowed the processing of the large quantity of data generated through remote sensing (Lunetta et al. 1999) . It is now more or less up to the commitment and seriousness of the international and local natural resources and biodiversity management organizations to make sure their institutional systems are ready to fully seize this opportunity, in order to develop the required capability of natural resources mapping and periodical monitoring.

Undoubtedly the remote sensing and GIS technology has enabled ecologists and natural resources managers to acquire timely data and observe periodical changes. Although space borne and airborne generated data are becoming basic tools for the day-to-day activities of natural resources managers, ecologists, conservationists and others, its full potential and reliability are still unused in many of ecosystem conservation programmes. The trend and extent of wild animal species range and habitat within such ecosystems are even less known. Mapping ecosystems with all their habitats and associated components is hardly possible (Edwards et al 1996). Habitats or ecosystem are dynamic, interrelated and change through time either due to environmental factors (Lamb et al 2001) or anthropogenic pressures (Osborne et al. 2001). In the recent past, acquiring the necessary data to generate information for this purpose had been time consuming and expensive (Hepinstall et al 1997).

Consequently, our knowledge of internationally important ecosystems and habitats, which are situated in economically poor countries, is inadequate (Stattersfield 1998). Since the invention of satellite remote sensing techniques and the advent of affordable powerful computing devices, such areas are also getting the deserved international attention with detailed studies as well as mapping. This is a big step forward towards monitoring global biodiversity and towards supporting the efforts of national and regional natural ecosystems conservation. Planners and resource managers need a reliable mechanism to assess the consequence of the changes resulted by the stress imposed on natural resource by detecting, monitoring and analyzing land use changes quickly and efficiently. The conventional method of environmental data collection and analysis are not efficient in delivering the necessary information in a timely and cost effectively fashion. Hence viewing the Earth from space has become essential to comprehend the cumulative influence of human activities on its natural resource base. Remote sensing technology however can play a vital role in providing accurate and reliable information with cost effective and lesser time compared to other methods. Remote sensing provides a viable source of data from which updated land cover information can be extracted efficiently and cheaply in order to inventory and monitor these changes effectively. Thus change detection has become a major application of remotely sensed data because of repetitive coverage at short intervals and consistent image quality (Mas, 1999).

According to Lillesand et.al. (2005), remote sensing has helped in the development of various environmental management methodologies, providing the following advantages when compared to conventional ground based methods:

- Synoptic view: Remote sensing facilitates the study of various features of earth`s surface and the spatial relationship between features,
- Accessibility: Remote sensing makes it possible to gather information about areas that are not accessible for ground surveys, like mountainous areas or foreign lands, and
- Time: Since information about a large area can be gathered quickly, these techniques save time and effort.

# CHAPTER THREE: BRIEF DESCRIPTION OF THE STUDY AREA AND RESEARCH METHODS ANDMATERIALS

## 3.1Brief Description of the Study Area

### 3.1.1 Location

The study was on Abijata Lake located in Adami Tullu Jido Kombolcha *Woreda*, East Shoa zone of Oromia National Regional State. Geographically,Abijata lake is located between $38^0$31'40''E- $38^0$39'10''E latitude and $7^0$32'30''N- $7^0$39'10''N longitude (See figure3.1below). It is relatively located between two *weredas* (*Adami Tulu Jido Kombolcha* from East Shoa zone and *ArsiNegelleWereda* from Western Arsi zone). It is located at 168Km south of Addis Ababa. Lake Abijata is found in what is known as main rift valley of Ethiopia. Significant part of the main rift valley lakes of Ziway, Abijata, and Langano are also found in study area. The land lies between 1500 and 2300 m.a.s.l except the area around mount Aluto. The major source of water for the lake is Bulbula river which overflow of Lake Zeway and HoraKello river (LEPO, 2015).

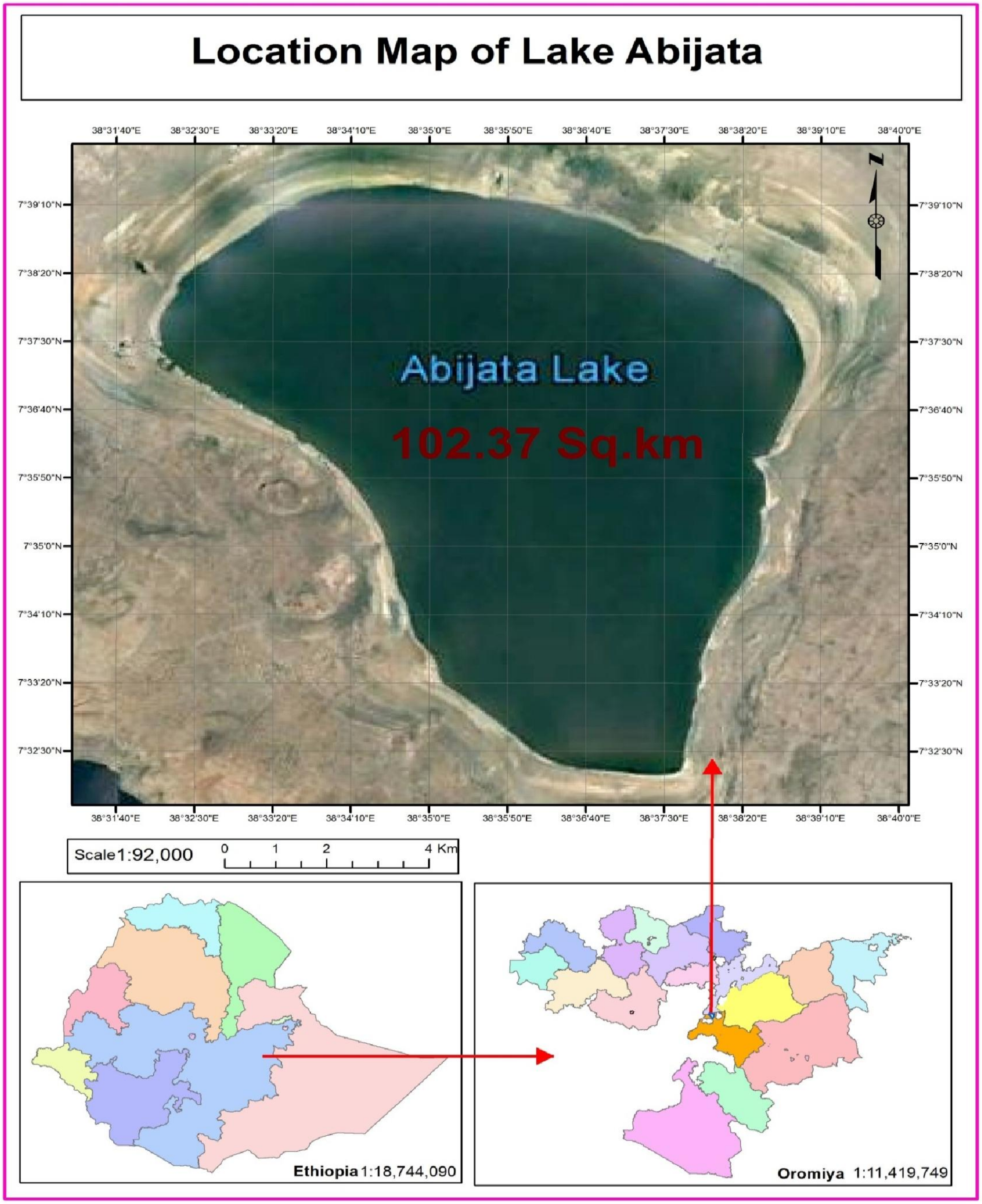


Figure 3.1: Location Map of Lake Abijata

Source: LandSat image (1985 1nd 1995) and Google Earth (2005 and 2015).

### 3.1.2 Topography and Climate

The altitude of the study area ranges between 1500 and 2300m above sea level. The relief of the area is characterized by plain and flat stretched land, with some small mountain, hills and gorges. The climate of the area is characterized by semi-arid climate with the average annual rainfall of 650-750 mm and $26^0$c average annual temperature. The main rainy season is between June and September and the dry season lasts from October to February. The soil type of the area is classed as Sandy clay (ARDO, 2015).

### 3.1.3 Demographic and Socioeconomic Characteristics

According to information obtained from Administration Office; the total population of AdamiTulluJidoKombolcha*Woreda* is 141,405, as projected from the 2007 Population and Housing census (CSA,2007). Out of the total population, 84.7% lives in rural areas while the remaining 15.3% lives in urban areas. In terms of sex distribution, 71,167 of the populations are male while 70,238 are female. The population is composed of mainly ArsiOromos and Islam is the dominant religion. There are also different ethnic communities living in the towns. These ethnic groups are living together with mutual understanding and tolerance.

The communities in 43 rural*kebele* administration units are settled farmers, engaged both in crop and livestock production. The major crops produced in the area are maize, sorghum, haricot beans and teff. Both modern and traditional irrigation is practiced in the *woreda* around Ziway Lake, Bulbula and Jido rivers.Farmers who practice irrigation farm activity mainly produce onion, tomato, greenbeans and cabbage for market consumption at large. Rearing livestock is the second mostimportant livelihood in the *Woreda* amongst the majority of the farmers, and hence there arenumerous livestock as a resource such as Cattle, Goat, Sheep, Horse, Donkey and Poultry (ARDO, 2015).

## 3.2 Research Methods and Materials

### 3.2.1 Research Design

This study was based on partially mixed sequential dominant status-quantitative design. This is because, as indicated in Powell *et al*., (2008), quantitative and qualitative phases occur one after the other, with the quantitative phase being given higher priority and mixing occurring at the data interpretation stage. These, as noted in Hesse-Biber (2010), are triangulation, complementarity and methodological synergy. Triangulation helps to examine a research problem by using more than one method. On the other hand, complementarity allows the researcher to gain a fuller understanding of the research problem and/or to adequately clarify a given research result. Lastly, a synergy of methods have applied, whereby, the results from one method help develop the other method.

### 3.2.2 Data types and Source

The purpose of this study is to assess the natural and anthropogenic causes, extent and socio-economic, cultural and natural consequences of Lake water level depletion. The most important data for this study were satellite image, topographic map; long term climate data (rainfall and temperature) and first hand socio-economic data. The study needs both qualitative and quantitative types of data.

The data were obtained from Primary and secondary sources. Secondary data were obtained from different governmental organizations such as AdamiTulluJidoKombolcha*woreda* Land and Environmental Protection office, Agricultural and rural development office, Water resource and Irrigation Authority, Abijata-Shalla Soda Ash Share Company, National Meteorological Agency (NMA), Information Network Security Agency (INSA)  and Google Earth and published and unpublished documents. The researcher also used other secondary data from related research material, journals, and documents from different organizations specifically for review of related literature.

### 3.2.3 Instruments of Data Collection

The necessary data for study was obtained through Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs). Landsat satellite images of 1985 TM, 1995 ETM, 2005 ETM+, 2015 ETM+ that include three bands (1,2 and 3) and with spatial resolution of 30m were acquired from Information Network Security Agency (INSA) and Google Earth. In addition, a topo map of 1:50,000 scale was acquired and used as reference for accuracy assessment. The climate data (rainfall and temperature) of thirty years were obtained from National Meteorological Agency, *Bulbula* station.

To obtain primary qualitative data related to the natural and anthropogenic cause of shrinking of the lake and the socioeconomic, cultural and natural consequences of lake water level depletion for the study, the researcher used FGD and KII. The first stage was purposive selection of three *kebeles (DastaAbijata. AdanshoBoranota and HurofaLolee)*, that bound Lake Abijatain the *woreda*, followed by the selection of elders who lived for a long time and have knowledge about the study area. The Group discussants of 7 people were purposively selected from AdamiTulluJiddoKombolcha*woreda*; Agricultural and Rural Development Office, Land and Environmental Protection Office, *Woreda* Administration Office, DAs, NGO, AbijataShalla National Park representatives and elders. One session of discussion was made with the above Focus Group Discussants for three hours at *DestaAbijataKebele*. Moreover Key Informants of 15 elders who lived in the area for long time and knowledgeable about the problem were selected from three*kebeles* of the *Woreda*.Suitable conditions were set for the discussants and key informants sothat they were able to describe the issues under investigation precisely in their own language,*Afan*Oromo.

### 3.2.4Methods of Data Processing and Analysis

Satellite imagery provides an excellent source of data for performing structural studies of a landscape (Sachs et al., 1998). Four series of dry-period satellite images (TM for 1985, ETM for 1995, ETM+ for 2005 and ETM+ 2015 images) were obtained from Information Network Security Agency (INSA) and Google Earth. Both geometric corrections were conducted.

Geometric correction transforming image pixel positions by correcting for the optical geometry and to compensate for distortions caused by the motion of the image platform and shape of the terrain. Image enhancement was used to increase the details of the images by assigning the image maximum and minimum brightness values to maximum and minimum display values. The TM, ETM and ETM+ images were geo-referenced usingArchGIS software. The Universal Transverse Mercator (UTM) geographic projection, and datum, zone 37 North, were used in geo-referencing the images.

The main purpose of the utilization of the three series images (TM 1985, ETM 1995, ETM+ 2005 & ETM+ 2015) is to investigate the rates and extent of change over 30 years of Lake Abijata water level. It gave a clear map of the level of fluctuation of lake water shore.

The data collected with the above instruments were analyzed by using different software's.The rainfall and temperature data over a period of time wasanalyzedusing Microsoft Excel spreadsheet to plot rainfall and temperature trends of the area for the last 30 years. In addition to this SPSS software was used to see the correlation of lake water level with rainfall and temperature. Data have presented in tables, graphs and supported by theoretical arguments.

By stacking the layers and then clipping the lake images with the corresponding shape file, the clipped image of lake was presented for better visualization (Appendix2, 3, 4 and 5). The area of the lake for each year was then obtained by calculating the area of the corresponding shape files using the ArcGIS10.3 The main purpose of the utilization of these series images is to investigate the rates and intensity of changes in lake water area over 30 years. It gave a clear picture of the rate and intensity of lake water depletion in terms of area. The results of FGDs and KIIs were also paraphrased and support by the theoretical argument.

## Analytical Framework

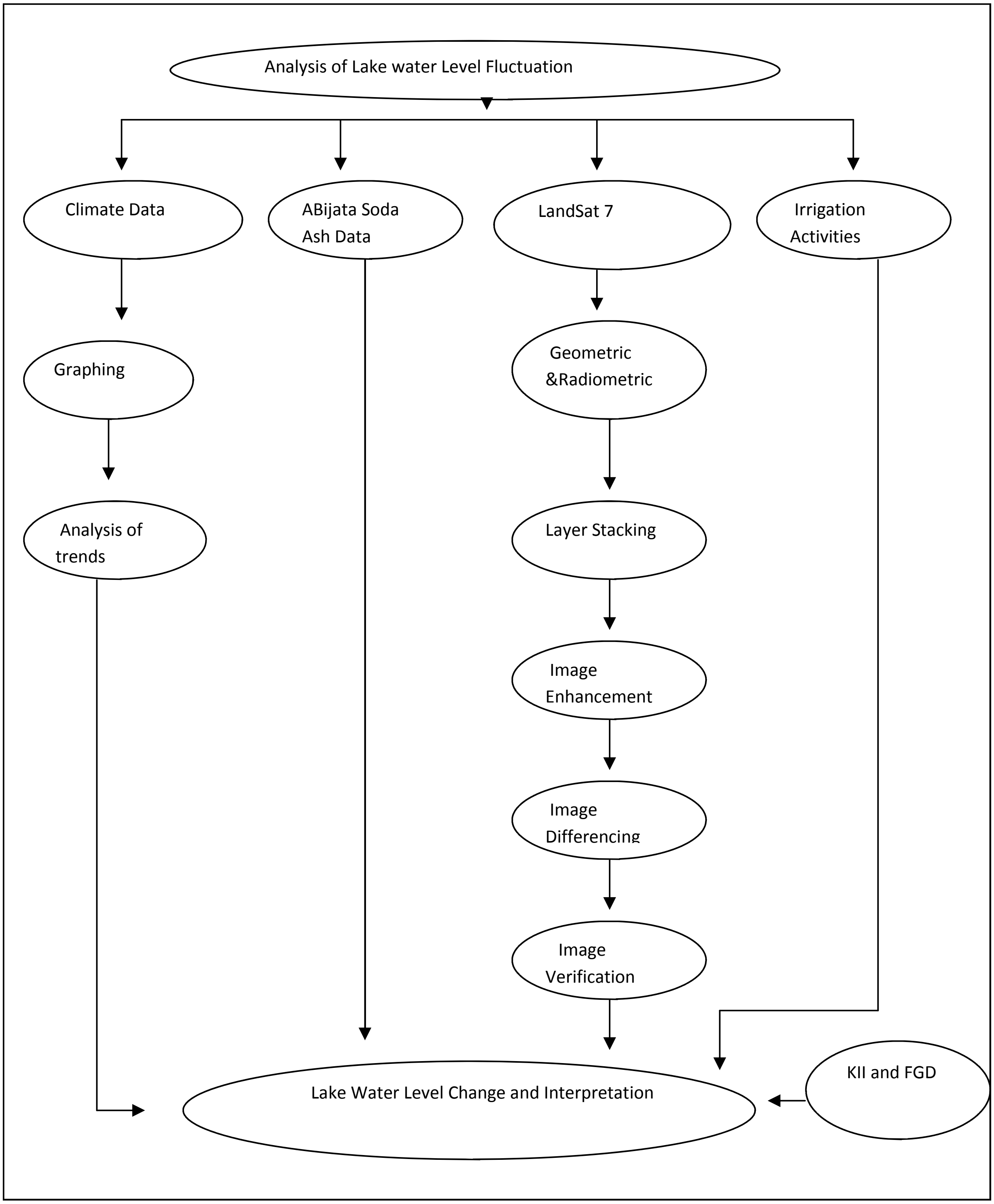


Figure3.2: Analytical Framework

## 3.3 Reliability and Validity Checks

As per the arguments of Golafshani (2003) validity and reliability in their continuum should be recognized in every scientific research, as they are ways to establish a truth in a multiple way. One of the defining conceptualization concerning validity and reliability given by American Psychological Association (APA, 1985:19) as it was noted in (Getachew, 2013) has stated validity and reliability as:

> ….reliability refers to the degree to which observed scores are free from errors of measurement that can be gauged by consistency of scores while validity refers to the appropriateness, meaningfulness and usefulness of the specific inferences made from a given measurements.

In other words, reliability is the extent to which our measuring instruments measure and yield a consistent output (Golafshani, 2003; Gomm, 2009). Moreover, as statements of Knapp and Mueller (2010), validity is the usefulness of research instruments in addressing research objectives and research questions. Therefore, as a principle, in order to assure the validity of the research, the researcher has been tried to review quite adequate conceptual and empirical literatures related to the problem under investigation. This enables the researcher incorporates major themes in data generating instruments so as to investigate the problem in all-embracing way. In the same way, the researcher has been consulted methodological aspects on past research outputs and scholarly articles undertaken in order to select accurate data generation tools and techniques. In case of reliability of the study, the researcher has been also avail himself in friendly and good interpersonal relation with research subjects to extract reliable data in case of qualitative data collection procedures such as FGDs and KIIs.

## 3.4Ethical Consideration

The researcher has been protected any personal information and photos of Key informant and Discussant not to pass to third party and not to publish without their consent. They were also been informed about the objectives and outcomes of the research quite adequately.

They were also been informed that their personal information will be kept confidentially that will never be publicized nor given to any third party without their full willingness in case the need arises from other party. In addition to the ethics on human subjects, research ethics was consider acknowledgement of data generated by others and appropriate citations of scholarly research outputs, books, journals, websites, and any other related documents in order to assure intellectual and scientific integrity of the research. By recognizing this, the researcher have tried to cite and acknowledge all the information taken from different scholarly literatures and data generated by other individuals or organizations.

# CHAPTER FOUR: DATA ANALYSIS AND PRESENTATION

## 4.1 Introduction

The study assessed the main factors for high water level change problem of Lake Abijata specially since 1985. Analysis have carried out based on data generated from meteorological stations, satellite image, focused group discussions, unstructured interviews and review of related literature. The discussions helped to understand the natural and human induced factors of Lake Abijata water level change.

## 4.2 Pattern of Rainfall and Temperature as Factors on the Lake Level

Landscape, hydrological setting and the climates determine the average lake water level. In semi-arid and arid climate, where evaporation exceeds precipitation on an annual basis, lake can be hydrologically closed with no outflow; evaporation then would be the dominant or only form of water output. Unlike water outflow by surface or groundwater, evaporation is directly controlled by water level, although total lake evaporation depends on the lake area that expands and shrinks depending on water level. Therefore, large, closed water bodies may have only weak feedback mechanisms to stabilize the water level if the lake area does not change appreciably with changes of water level. Such lakes can be subject to large sudden rise of water level as a result of high runoff, but the subsequent downward recession is slow, being limited by the difference between precipitation and evaporation (Todhunter and Rundquist, 2004 cited in Hayashi, 2007).

The annual and seasonal rainfall variability almost accounts 50 to 80% in Ethiopia (Tsidu and Bayable, 2011). According to NMA (2007) report the temperature in the country has been increasing by 0.37 $^{0}$C every ten years, and the maximum daily temperature has increased with 1.5$^{0}$C. Consequently, the droughts and floods are the most common existing natural hazards that have been caused huge loss of life and properties. The arid, semiarid anddry sub-humid regions in generally, and particularly CRV is the most affected by drought. According to Gizachew and Shimelis (2014) cited in Tadesse 2015),drought frequency ranging from 2 to 5 times in CRV within next 33 years. At the same time they predicted as rainfall and mean temperature changes significantly vary within the area.

### 4.2.1 Rainfall

Rainfall is the main source for the variability in the water balance over space and time , and change in rainfall has very important implication for hydrology and water resources. Hydrological variability over time in a watershed is influenced by variations in rainfall over daily, seasonal, annual and decade time scale. The annual precipitation, measured at several stations in the CRV, tends to be consistent over the period from 1966 till 1999 (Wako, 2004). From 1996 till 2005 however, annual precipitation tended to be decreasing with 10-15% (Hengsdijk, 2007). Such drops have occurred before and this decreasing precipitation trend is too short to call it a structural change in climate.

The level of lake Abijata fluctuates with the trend of rainfall in the watershed. Accordingly, in this study annual rainfall record (1985 - 2015) of Bulbula station was used to analyze the effect of rainfall on the trend of the fluctuation in the water level of lake Abijata. From the analysis, the distribution of rainfall in Ziway-Abijata watershed show decreasing pattern for the duration of analyzed period.

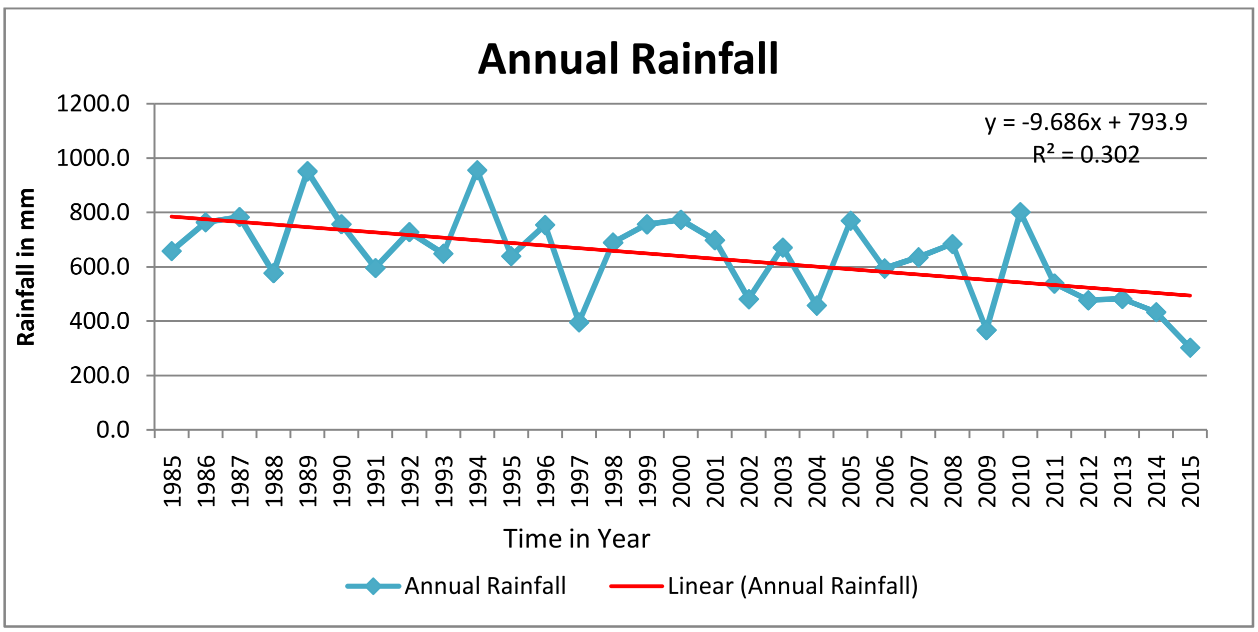


Figure 4.1: Mean Annual Rainfall of the Catchment

Source: National Meteorology Agency Bulbula Branch

From figure 4.1, time series rainfall of Bulbula station is negative trend which shows that rainfallwasapparently decreasing patterns especially in the last 30 years. The period of 30 years may be assumed as average time to draw decisive conclusion about long term trends of rainfall of the watershed and that gave a negative trend of rainfall over the years.

### 4.2.2 Temperature

Temperature is one of the main climatic factors that affect water budget of a place. It is the main components of evaporation and that takes place from water bodies and evapo-transpiration from living things. According to Kassaye (2010), the water level of Lake Abiyata is declining drastically due to large scale-water abstraction, decreased overflow from Ziway and increased evaporation. The significant association of the level of Lake Abiyata with evaporation seems to be realistic since the lake is closed topographically and is located at a terminal position in the CER. This increasing in temperature affects considerably evaporation from lake water surface and evapo-transpiration from watershed. Increasing in evaporation from water bodies and land surfaces resulted in declining of annual water budget of the lake. This phenomenon also affects the surface runoff in the watershed.

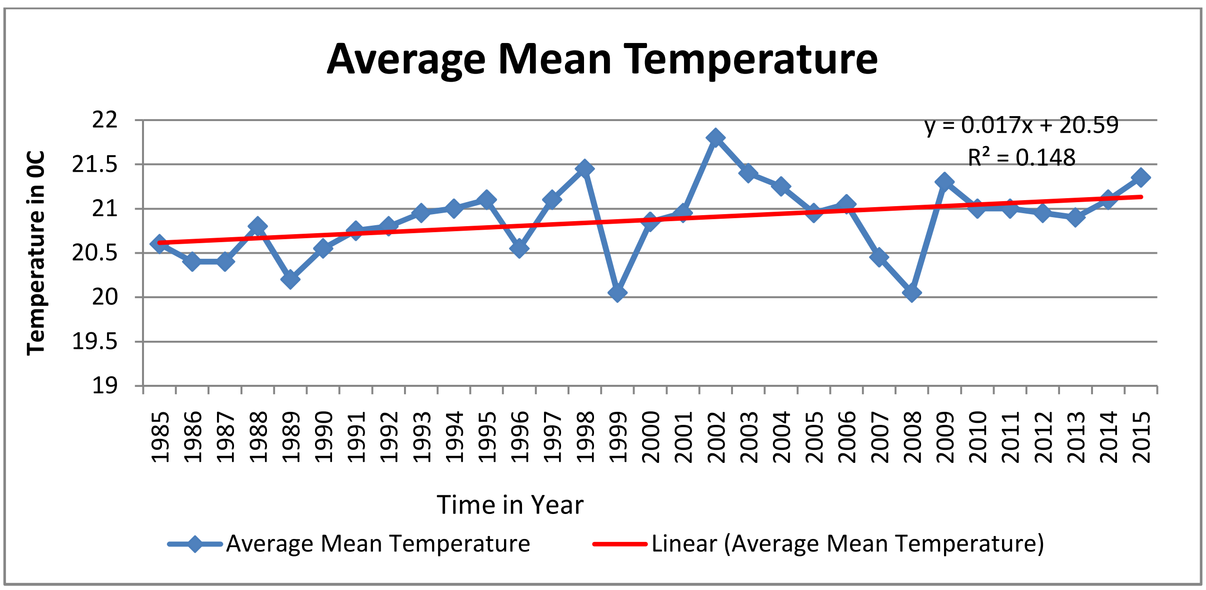


Figure 4.2: Average Mean Temperature in the Catchment

As indicated in Figure 4.2, the long-term annual values show a clear pattern of variation. The long term mean annual temperature at Zeway Meteorological Station is almost around 27.5$^0$C between 1985 and 2015. All the long-term mean maximum, minimum and average temperature values are comparatively increasing which is related to the generally accepted rising global temperature condition at the present time. This fact has also been confirmed by the FGD and KII participants for this study. One of the key informants, for instance, said '…now I am about 69 years old. I think that the temperature has been increased since my childhood in our area. The increasing temperature has brought impact on Lake Abijata and our economic activities.This increasing trend of temperature may increase the rate of evaporation from the lake and evapo-transpiration in the watershed and therefore, negatively affects water budget of the lake . As temperature increases the rate of evaporation increases and consequently lake level decreases. This increasing of evaporation and evapo-transpiration is one of the probable causes of the lake water fluctuation.

## 4.3 Correlation Coefficients and their Interpretations

There are always time lags between precipitation events and lake level fluctuations. Moreover, most of the rainfall stations are located on the Graben Shoulder of the Highlands, only few stations are situated in the Rift valley (Stefan et al., 2004) . Ayenew, (2004) also investigated the relationship between lake levels and rainfall in the Zeway-Awassa basin from 1970s to mid 90s and found that terminal lakes like Abijjata had started showing less correlation to rainfall after the mid 80s due to water abstraction and change in land use and hence the rainfall and temperature records can be less realistic. For this reason, poor correlation coefficients between lake level with rainfall and temperature have been observed in the area. There is an insignificant correlation between Lake water level and rainfall as well as temperature for Lake Abijata. For the Current study, correlation of lake level with rainfall and temperature is summarized in Table4.1.

Table4.1: Correlation analysis for lake level with Rainfall and Temperature

| | | Annual Rainfall in mm | Annual Temperature(0C) |
|---|---|---|---|
| Lake water level | Pearson Correlation | 0.065 | 0.103 |
| | Sig. (2-tailed) | 0.767 | 0.641 |

**. Correlation is significant at the 0.01 level (2-tailed).

## 4.4 Abstraction of Water for Irrigation

The total irrigation potential of Ethiopia is estimated to be 3.6 million hectares of which only 5.5 percent has been developed up to now (MOWR, 2002; 2007). The Rift Valley Lakes basin has a total water resource potential, of 5 billion cubic meters. However, less than 1 percent of its estimated amount was being developed to irrigation farms. Most of the irrigation farms in this basin are found around Lake Zeway and its spills out river Bulbula due to their suitability for irrigation practice in comparison with those highly mineralized lakes like Langano, Abijata, and Shalla (MOWR, 2007).

Major irrigation activities with three phase of irrigation development project were proposed covering a total area of 5500 hectares and were introduced around Lake Zeway and its catchments in early 1980s (Dagnachew etal., 2005). As noted by Tenalem (1998) and Makin etal., 1976; cited in Dagnachew etal., 2005), the annual removal of water for irrigation from Lake Zeway in 1998 was estimated at about 28 million $m^3$. Hence if the proposed irrigated area (i.e. 5500 hectares) is developed fully, the estimated annual water requirement will be 150 million $m^3$. This would result in 3 meters reduction in the level of Lake Zeway and ultimately drastic reduction in level of Lake Abijiata and its major tributary Bulbula River. (Dagnachew et al. 2004) also reported that a state farm established in the early 1980s south of Lake Ziway pumps water from the Bulbula river for irrigating 1004 ha of vegetable crops (data 2001). The same authors estimated that associated irrigation water extraction corresponds with about 24 million $m^3$ per year. Recently, the extraction of water from Lake Zeway and Bulbula River has increased owing to the expansion of irrigation activity in the area (OWRB, 2004). In addition to large scale irrigation, there are large numbers of small scale irrigation around lakeZeway and Bulbula river. The direct impact of human interference in the hydrological system of Lake Abijata, i.e. Lake Abyata and Bulbula River, cannot be neglected. Lake Abyata is fed by precipitation and inflow from Bulbula and Horakelo rivers. Some major irrigated production systems, like, Ziway State Farm, two private farms and some smallholderplots, are located along Bulbula river. In total approximately 25 Mm3/year is extracted from Bulbula River, equal to 10 to 15% of the annual discharge (OWRB, 2007).

Flower plantations are now the national focus to earn foreign currency. They are booming around Lake Zeway and Bulbula River. They are thought to create job opportunity for locals.

However, the water abstraction from the lake and river, almost no opportunity for local people and exposing the ecosystems to uncontrolled chemical usage poses an unknown danger (see figure 4.3d).

Figure 4.3a: Bulbula river at the upstream

Figure 4.3b: Bulbula river at downstream

Figure 4.3c:Some Water pump motors around Bulbula River

Figure 4.3d: SherEthiopias water pump motors on Lake Zeway

It could be observed from Figure 4.3b and 4.3c, Bulbula usually gets dry downstream before the main dry season. Drying of Bulbula river has significant effects on downstream community and lake Abijata water level. As noted by production Manager of Abijata-Shalla Soda Ash Share Company, the company has witnessed that there are hundreds of motor pumps standing and ready to irrigate thousands of hectares of land around Bulbula river and that there is no control of water being removed by different stakeholders. List of some of the major irrigation fields in Adami Tulu JidoKombolcha*woreda* is shown in the table to follow (Table4.1).

Table 4.2:Irrigation farms abstracting water from Zewaylake and Bulbula river

| | Name of irrigation farm | Water source for the farm | Number of pumps/ valves | Discharging capacity of each pump/ liter/ second | Irrigated farm in hectare | Duration of active operation | Annual Water Abstraction in m3 |
|---|---|---|---|---|---|---|---|
| 1 | Maremiabetoch fruit and vegetable farm | Zeway | 2 | 1= 46lt/sec<br>1=225lt/sec<br>Total=271lt/sec<br>-7804800lt/dy | 79 | 8hrs/day | 2,848,752 |
| 2 | Sher Ethiopia flower Farm | Zeway | 14 | 58lt/sec<br>Total=812lt/sec<br>-14616000lt/dy | 500 | 5hrs/day | 5,334,840 |
| 3 | Batu domestic water supply | Zeway | 3,of which one is stand by | 20lt/sec<br>Total=40lt/sec<br>-1728000lt/dy | - | 12hrs/day | 630,720 |
| 4 | Castel Winery farm | Bulbula | 3 | 116lt/se<br>Total=348lt/sec<br>12528000lt/dy | 450 | 10hrs/day | 4,572,720 |
| 5 | ETCO Aneno farm | Bulbula | 1 | 77.3lt/sec<br>Total=77.3lt/sec<br>2782800lt/dy | 93 | 10 hrs/day | 1,015,722 |
| 6 | Segal Private farm | Bulbula | 3 | 58lt/sec<br>Total=174lt/sec<br>6264000lt/dy | 90hec | 10hrs/day | 2,286,360 |
| 7 | Sher Ethiopia A/Tullu Flower farm | Bulbula | 10 | 58lt/sec<br>Total=580lt/sec<br>10440000lt/dt | 200 of 700hec | 5hrs/day | 3,810,600 |
| 8 | Small scale farms | Bulbula | 191 | Total=estimated 3241lt/sec<br>116676000lt/dy | 2909hec | 10-12hr/day | 31,502,520 |

Source: A/T/J/KombolchaWoreda Irrigation Authority (2015)

Generally, according to information obtained from A/T/J/Kombolcha Woreda Irrigation Office , there are 226 water pumping motors in Adami Tulu JidoKombolcha Woreda around Lake Zeway and Bulbula River excluding small scale irrigators around the lake. These pumping motors are actively engaged in pumping for about 8-10 hrs/day. Moreover, these 226 motor pumps have the capacity to take 5543.3liters/second which is equivalent to 52,002,234m$^3$/year. From this 43,187,922m$^3$of water is abstracted from Bulbula rive in

*Bochessa, Dodicha, Gerbi widena, Halaku Gulenta Boke, Golba Aluto and Anano Shisho kebeles*. This exceeds the amount of water abstracted from Bulbula river that estimated by Dagnachew in 2005 (as 28Mm$^{3}$). All interviewees from *Dasta Abijata, Hurufa Lole, Adansho Boranota and Arba Kebeles*are depending on Bulbula River for their cattle, and themselves for drinking and swimming at downstream. However in the recent years the river is flowing only during the rainy season and it dries up for months in the year. For instance, the river was dried last year starting from October, 2015, due to the expansion of irrigation in the upstream. The respondents also admitted that, last year due to drying of Bulbula River, they face shortage of water for their livestock. As a result, they went to A/T/J/Kombolcha *Woreda* Administrative Office (found in Zeway) and ask them to release the water which is trapped for irrigation. The *woreda* administrative also responded to their question and force the farmers of upstream to released the water. However, they release the water only for two weeks.

The current status of water balance of Lake Abjata is supported by FGD discussions. All participants assured that drought and rainfall variability, and expansion of irrigation on Zeway lake and Bulbula river were experienced in the previous decades; as the result, Lake Zeway and Bulbula River are being intensively used by the population living around the main feeding river. This activity of the population largely influenced the amount of inflow of the lake. In addition, a great deal of water pumped from the lake for production of Soda Ash by Abijata-Shalla Soda Ash Company and these adversely affected the lake level and its ecology. Therefore, drought, rainfall variability, as well as over pumping of the lake water contributed for the water level depletion of Lake Abijata.

## 4.5Abstraction of Water for Production of Soda Ash

The Abijiata Soda Ash plant is a factory which was established in 1984/85 near Lake Abijiata on the northern shore. It is the only soda ash producing factory in Ethiopia (viability project, 2004). This project was established on the initiation of a German based company under the auspices of the Ministry of Mines and Energy to provide a raw material to the Caustic Soda factory at Zeway and in later stage to export high grade soda ash (Woinshet, 1989).The company started large production of Soda ash in 1985. For soda ash production, the factory totally depends on salty water (brine) abstracted from Lake Abijiata through pumping and evaporation system.

Figure 4.4: Partial View of Abijata-Shalla Soda Ash Plant

Abijiata Soda Ash Plant was established without conducting in depth and sounding feasibility study. Indeed, the cost that may be incurred on the area as a result of ecological disturbance by Soda Ash Factory in general and ultimate loss of the whole water, spectacular bird population and the fish etc. were not well articulated (Mohammed 1993).

The observable effect of soda ash started to be clearly seen in the years 1985, 1989, 1990 and 1998 when the lake started to show dramatic depth level, surface area and volume reduction (Dagnachew, etal, 2005). In 1998, when the company approximately pumped 13 million $m^3$of brine water from the lake, it had showed a depth reduction equivalent to 0.7m based on the average lake area of 180 $km^2$(Ayenew, 2003). Moreover as data presented in table4.3, below Show starting from 1988 up to 2015 Abijata-Shalla Soda Ash Share Company has consumed about 27,357,320.90$m^3$ of water to produce soda ash. As data obtained from

Abijata-Shalla Soda Ash Share Company, they produce 5500tones of soda ash per year and to produce 1tone of soda ash they abstract 73m$^3$of brine. But the company's plan is to produce 200,000 tones of soda ash per yearin the near future which is equivalent to14,600,000m$^3$ of brine water per year which is more than 50% of the total water abstracted to soda ash that produced between 1988-2015. Moreover, they have the plan to pump brine water from Lake Shalla since Lake Abijata is on the way to dry. This would result the worst environmental and economic tragedy in the area.

Table4. 3: Amount of water pumped from the lake by Abijata-Shalla Soda Ash Share Company

| Production year | Amount of water in m$^3$ | Production year | Amount of water in m$^3$ | Production year | Amount of water in m$^3$ |
|---|---|---|---|---|---|
| 1988 | 2,094,756.51 | 1998 | 1,282,709.78 | 2008 | 402,741.66 |
| 1989 | 1,121,351.08 | 1999 | 1,242,187.06 | 2009 | 396,390.67 |
| 1990 | 1,430,242.00 | 2000 | 1,125,365.56 | 2010 | 388,728.07 |
| 1991 | 1,814,447.70 | 2001 | 1,297,594.19 | 2011 | 405,150.46 |
| 1992 | 1,525,880.75 | 2002 | 1,551,829.55 | 2012 | 397,485.55 |
| 1993 | 1,424,717.75 | 2003 | 1,131,905.05 | 2013 | 365,132.50 |
| 1994 | 1,170,576.00 | 2004 | 575,442.07 | 2014 | 383,323.09 |
| 1995 | 1,685,661.80 | 2005 | 248,196.30 | 2015 | 401,500.73 |
| 1996 | 1,256,102.01 | 2006 | 333,908.00 | | |
| 1997 | 1,525,299.27 | 2007 | 380,695.75 | | |
| Total | | | | 27,357,320.90 | |

Source: Abijata-Shalla Soda Ash Share Company (2015)

Abstraction of brine water from Lake Abijiata by Soda Ash Factory not only caused dramatic depth, surface area and volume reduction of the lake but it also leads the lake to have high concentration of solutes which in turn increase the alkalinity of the lake. Higher alkalinity in turn causes reduction of population of various species and ultimately leads to the death of fish eating birds (Dagnachew et.al, 2005). In this specific study, some informants have replied that the establishment of Abijata-Shalla Soda Ash Share Company is the reason why Lake Abijiata has been shrunk. According to one elder (63years old) from Desta Abijata *Kebele* since the establishment of the factory, the company is pumping water from the lake continuously without considering the inflow of Bulbula River which is the main feeding river. The amount of water inflow through Horakelo and Gogessa are imminent to change the water level of the lake.

## 4.6 Analysis of Multi-temporal Satellite Images of Lake Abijata

In this study an attempt has been made to show the extent of depletion of Abijata lake by using different parameters. For this purpose satellite images were used to analyze water resource depletion of the lake since 1985. The analysis of the Landsat images (with acquisition years: 1985, 1995, 2005 and 2015) indicated that Lake Abiyata is declining. Regarding the depletion of lake size (area), shrinking in size has been observed during these three decades. Accordingly, as observed from change result of the satellite images 1985 and 2015, the lakes surface area which was 180km$^2$(1985) was reduced to 177.13 km$^2$ , 112.89km$^2$ and 102.89km$^2$ in the years 1995, 2005 and 2015, respectively. This lake size reduction is equivalent to 2.87km$^2$ (1.59%), 64.24km$^2$ (35.69%) and 10.52 km$^2$ (5.85%) for the year 1985-1995, 1995-2005 and 2005-2015, respectively. The decline of Abiyata is very drastic in that 43.13% of its area in 1985dried up in 2015. Table 4.3 summarizes the fluctuation in the size (area) of the lake.

Table 4.3:Areas of the lake (km$^2$) from LandSat images

| Lake Name | Yea r | | | | Change in % between 1985 and 2015 |
|---|---|---|---|---|---|
| | 1985 Area (Sq.km) | 1995 Area (Sq.km) | 2005 Area (Sq.km) | 2015 Area (Sq.km) | |
| Abijata | 180 | 177.13 | 112.89 | 102.37 | -43.13→ declining trend |

Source: Computed from Satellite image and GIS

This decline in the general trend of lake size (areal) could be due to many reasons. Supplemental information extracted from a quick image shows however a dramatic reduction by 46.5% between 2000 and 2006 (Fig. 3). Similar figures mentioned in a separate study by Jansenet al. (2007). A study of old maps by Billi(2002) concluded that, at currentretreat rate, within less than 100 years Lake Abijata will be totally dried.This projection could be reduced by more than half based on the retreat rate observed between 2000 and 2006 Legesse et al. (2004) modeled explanatory factors for lake retreat. Sometimes the Soda Ash has blamed for pumping an excessive amount of water (Gebre-mariam, 1998). Nevertheless, factory officials pointed outtwo basic reasons: the decreased discharge of Bulbula River (overflow of Lake Ziway into Lake Abijata) as Lake Ziway's water is increasingly used for irrigation and climate change.

Although it calls for investigation and is not new to this time, Billi (2002) also supports the probability of Lake Abijata infiltrating to the less elevated Lake Shala. Discussions with FGD and KII also indicated the decreased discharge of Bulbula River, which is in accordance with observed large expansion of irrigated agriculture including vastly expanding floriculture (Sher Ethiopia) on Lake Ziway's shore and around Bulbula River.

Observed high water pumping for soda ash production and especially abstraction for irrigation in the upstream of Bulbula River and around Lake Zeway are two recent developments that result in reduction of the lake level. The reduction in the sizes of Lake Abijata shown pictorially in Figure below.

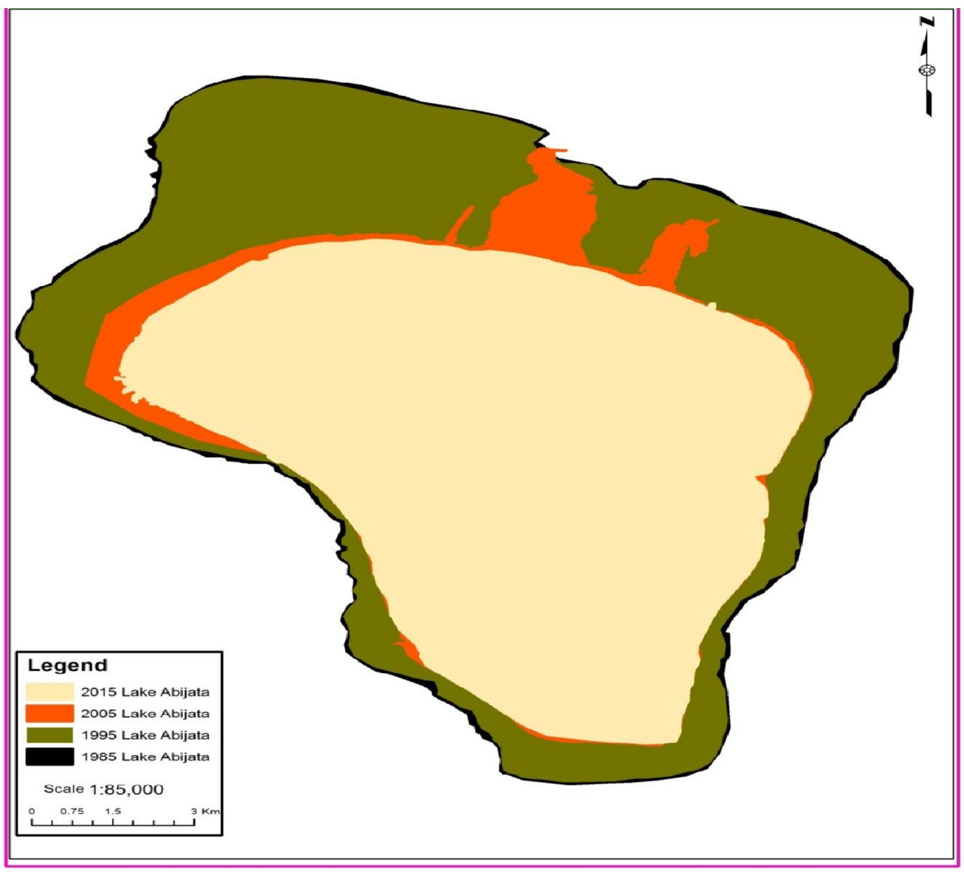


Figure 4.5: The size of Lake Abiyata during 1985, 1995, 2005 and 2015

Source: Landsat image from INSA(1985 1nd 1995) and Google Earth(2005 and 2015)

## 4.6 Impacts of Shrinking of Lake Abijata

### 4.6.1 Impact on Lake Ecosystem and Fishing Activity

Lake Abijiata is an alkaline blue colored shallow lake with depth and an area of 2.01meters and 102.37km,$^2$ respectively. Hence it is known for its large variety of birds using it as their best feeding ground of algae and fish. Its alkalinity makes fertile ground for phytoplankton, zooplankton and fish to breed. Moreover, its alkaline edge attracts a great number of arthropods. Hence, it's this nature of the lake which makes it an ideal site for bird watching (Yilma and Mengistu, 2002; RATSON, 2004).

Abijata-Shalla National Park has more than 436 bird species. However, due to drastic ecological changing conditions prevailed in the park over the last three decades, most of these valuable bird fauna are decreasing not only in terms of diversity and distribution but also in abundance (EWNHS, 1998; Dagnachew et al., 2005). The following table depicts the declining trend of bird fauna for some 31 selected types of valuable bird species based on bird census made between 1970 and 2007 on Lake Abijiata.

Table4 .1: Birds population size for some selected bird species in ASNP

| | Bird Population Size for in different fiscal year | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Common name of wet land birds | 1970 | 1971 | 1978 | 1981 | 1990 | 1991 | 1992 | 1993 | 1994 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2007 |
| Little grebe | 21 | 70 | - | - | - | - | 2 | 2 | - | 321 | 5630 | 453 | 435 | 0 | 0 | 1 | 4 |
| Great cormorant | 500 | 1000 | 9000 | 976 | - | - | - | - | - | 69 | 53 | 9 | 10 | 29 | 0 | 0 | 0 |
| Great White Pelican | 2000 | 1000 | 810 | 358 | 12 | - | 15458 | 86760 | 34000 | 27 | 66 | 48 | 1 | 104 | 0 | 0 | 0 |
| Great Flamingo | 2002 | 1000 | 818 | 1137 | - | - | 15458 | 86760 | 34000 | 3050 | 792 | 1230 | 920 | 367 | 14912 | 3697 | 7603 |
| Lesser Flamingo | - | 300 | 2550 | 94 | - | 14699 | 57227 | 235917 | 88000 | 22000 | 1517 | 2371 | 1765 | 44 | 8058 | 4427 | 15026 |
| Northern Shoveler | 206 | 500 | - | - | 350 | 5277 | 26697 | 37412 | 44000 | 347 | 1208 | 1945 | 345 | 44 | 340 | 0 | 0 |
| Southern Pochard | 12 | - | - | - | - | - | - | - | - | 10100 | 2230 | 4850 | 1780 | 5651 | 42 | 138 | 47 |
| Black winged stilt | 100 | 13 | 8 | - | 37 | 1991 | 26697 | 706 | - | 203 | 226 | 211 | 339 | 589 | 908 | 2 | 29 |
| Ringed plover | 5 | 10 | - | - | - | - | 1 | 10 | - | 16 | 42 | 4 | 36 | 47 | 70 | 23 | 5 |
| Kittliz’s plover | 20 | 10 | - | - | 17 | 609 | 3245 | 3694 | - | 843 | 233 | 334 | 250 | 777 | 232 | 82 | 106 |
| Little stint | 50 | 20 | - | - | 82 | 24302 | 24071 | 6909 | 36000 | 690 | 670 | 3762 | 1975 | 2130 | 3238 | 425 | 597 |
| Ruff | 2000 | 750 | - | - | 770 | 61502 | 6522 | 10036 | 30,000 | 3500 | 6265 | 7667 | 6695 | 6138 | 6776 | 1451 | 9305 |
| White winged black tem | 1500 | 500 | 42 | - | - | - | - | - | - | 2000 | 9710 | - | 900 | 5000 | 1322 | 0 | 81 |
| Whiskered tem | 1 | 50 | - | - | - | - | - | - | - | 23 | 0 | 8377 | 35285 | 7303 | 1000 | 0 | 0 |
| Pectoral sand piper | - | - | - | - | - | - | - | - | - | 27 | - | - | - | - | - | 0 | 0 |
| Senegal wetland plover | - | - | - | - | - | - | - | - | - | 0 | 129 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cape teal | 2 | 3 | - | - | 13 | - | 109 | - | - | 0 | 30 | 57 | 45 | 70 | 308 | 222 | 125 |
| Avocet | 54 | 350 | 13 | - | 360 | 3341 | 17172 | 11281 | - | 12 | 59 | 62 | 511 | 550 | 1714 | 50 | 2132 |
| Spur winged plover | 50 | 20 | 53 | - | 11 | - | 33 | 39 | - | 104 | 101 | 0 | 115 | 48 | 72 | 14 | 37 |
| Curlew sand piper | 30 | 3 | - | - | 5 | 62 | 381 | 495 | - | - | 117 | - | 85 | 78 | 154 | 6 | 6 |
| Grey Heron | 20 | 10 | 62 | 12 | 11 | - | - | - | - | 9 | 4 | 7 | 71 | 84 | 0 | 0 | 4 |
| Tufted Duck | - | 1 | - | - | - | - | - | - | - | 2000 | 30 | - | 0 | 79 | 0 | 0 | 0 |
| Marsh sand piper | 50 | 30 | - | - | - | - | - | 52 | 6 | 47 | 45 | 17 | 43 | 48 | 30 | 0 | 1 |
| Green Shank | 3 | 3 | - | 3 | 3 | 6 | 1 | - | - | 6 | 3 | 12 | 14 | 45 | 2 | 0 | 3 |
| Temenincks stint | 2 | 1 | - | - | 4 | - | 2 | 3 | - | 0 | 0 | 0 | o | 100 | 0 | 521 | 21 |
| 21Lesser black backed gull | 71 | 91 | 41 | - | 5 | - | 2 | - | - | 39 | 13 | 89 | 14 | 284 | 22 | 0 | 0 |
| Black headed gull | 2 | 1 | - | - | - | - | - | 3 | - | 147 | 2 | 35 | 125 | 132 | 80 | 0 | 0 |
| Grey headed gull | 300 | 200 | 130 | - | 31 | - | - | - | - | 8 | 41 | 24 | 71 | 130 | 0 | 0 | 6 |
| Egyptian gosse | 1000 | 500 | 256 | 153 | 11 | - | 50 | 10 | - | 3 | 6 | 8 | 10 | 10 | 0 | 0 | 23 |
| Sacred ibis | 50 | 30 | 90 | 29 | 16 | - | 7 | 10 | - | 18 | - | 23 | 38 | 9 | 0 | 0 | 23 |
| Africana pygmy | - | - | - | - | - | - | - | - | - | 30 | - | 0 | 0 | 0 | 0 | 0 | 0 |

Source: Mohammed, 1993: EWHS, 2007 cited in EWHS, 2010.

AS shown in the above table, there is minor variation the population size of the birds in the park generally shows declining trend over the specified period of time.

The most notable birds as mentioned by Mohammed (1993) and Stephenson (1978) are Great White Pelicans (Pelecanusonocrotalus), Storks including Abdim's Stork (Ciconiaabdimii), Lesser Flamingoes (Phoeniconaias minor), Greater Flamingoes (Phoenicopterus rubber) Egrets (Egretta spp.) and Herons(Ardeola spp.), Cormorants (Phalacrocorax spp.) andPlovers (Vanellus spp.). A great number of bird species seen in these lakes are seasonal migrants; thus, the area remains major place of attraction and serves as a paradise to ardent bird watchers (Stephenson, 1987). Accordingly, the lakes serve as important staging point and ecology for thousands of migratory birds in general and for perhaps bird of great interest to a nature lover and of concern to the world (ibid) Cited in EWHS, 2010). The pelicans breed in thousands, i.e., up to 12,000 pairs in the course of a year on Small and Pelican Islands in Lake Shalla where they find the undisturbed conditions essential to their successful breeding. According to Stephenson [1978), Lake Shalla, being too alkaline, contains no fish, the only diet of the pelican. Therefore, the bird does its fishing elsewhere, mainly in the northern waters of Lake Abijiata; then the parent birds fly the fish to small and pelican islands to feed their young birds. The Lake Shalla Pelican breeding site is the second most important of the eight regular breeding grounds in the whole of Africa (ibid)Cited in EWHS, 2010).

Recently lakeAbijjata has shrunk dramatically and no fish-eating birds were seen as before (EWNHS 1996). Declines in water levels caused by climate change will reduce fish access to the emergent vegetation of coastal marshes, which provide breeding habitat, shelter for young fish, and plenty of food in the form of vegetation and invertebrates (Keddy and Reznicek, 1986 cited in Kassaye,2010).

As stated by Tadesse(2015), the water level of Lake Abijata has significantly diminished, fishery has totally disappeared, and birds such as Lesser Flamingo and Pelican have migrated. Fish and aquatic plants now regularly occur only around the mouth of the Bulbula and Horakello rivers where the water is relatively less alkaline (Bedru,2006). In years that Lake Abyata recedes due to drought or other causes, fish dies and the algae composition changes due to the increased alkalinity of the water(HuibHengsdijk&Herco Jansen, 2006).

The lake was full of fish and commercial-scale fishing of Tilapia (Oreochromisniloticus) in Lake Abijata, using trucks and nets, was observed. However, Abdi,(1993) noted the disappearance of fish and fishing effort from Lake Abijata in 1993, some 8 years after the establishment of the soda ash company. Currently, there is no fish and fishery activity, which could be due to the declined water level of the lake, high salinity and associated effects (e.g., reduced breeding grounds of tilapia, and osmotic stress as a result of high salt concentrations). Apparently, the number of birds has been decreasing because of absence of fish at Lake Abijata. For instance, pelicans that feed on fish have been migrating. Normally, about thirteen native fish species can inhabit lakes but there barely exist species in Lake Abijata.

It is obvious that the saline water of Lake Abyata is not suitable for irrigation. At present there is no significant fishing from the lake (Jansen H. and Hengsdijk H. 2006).Regarding the impact of lake water decline on Lake Ecosystem, FGD and KII participant indicated fish and birds around Lake Abijata are decreasing from time to time and also explained that, it is obvious seeing dead fish and birds around the lake in recent years. As Abijata-Shall Soda Ash Sher Company's site manager many organization, researchers, including ASNP representatives are accusing them for the disappearance of fish from the lake. But they do not are acceptthese accusations because Lake Abijata is not the ground to bread fish.Lake Abijata's fish source is Lake Zeway through Bulbula River.

According to A/T/J/K *Woreda* Natural Resource Management expert death of fish is obvious with the increasing of alkalinity of the lake which is beyond the adaptability of fish. According to one of the guard of the Abijata-Shalla Soda Ash Share Company, many people used to fishing including himself around the lake long time ago, however due to disappearance of fish, people have change their economic activities. Some have become guards and daily laborer in the company and other has become charcoal producer.

### 4.6.2Impact on Eco-tourism

Tourism is usually called smokeless industry. Being a smokeless industry, tourism equals other competing activities in creating added value, but is much less destructive and disruptive to the natural and human environment. In actual fact, the business volume of tourism equals or even surpasses that of oil exports, food products or automobiles. Tourism has become one of the major players in international commerce, and represents at the same time one of the main income sources for many developing countries.

Tourism can be a source of economy for Ethiopia, and the government and public should work hand in hand to develop the sector as the country has historical, cultural and natural heritages. Eco-tourism is in line with the government's policies, because Ethiopia aims to achieve carbon-neutral middle-income status before 2025 while developing a green economy, which allows protecting and conserving tourism destination places such as Abijata-Shala Lakes National Park (Estifanos, 2008).

In the Park, a total of 436 bird species (among which 114 species are wetland birds) have been recorded including Lesser Flamingo (Phoeniconaias minor), Greater Flamingo (Phoenicopterusroseus), Northern Shoveler(Spatula clypeata) , Pied Avocet (Recurvirostraavosetta) , Eastern Yellow-billed Hornbill (Tockusflavirostris) , Great White Pelican (Pelecanusonocrotalusroseus). It is also a stopover site for large number of birds that migrates from Africa and Europe. The Park was absolutely a paradise (Tadesse, 2015).

Of the birds, Lesser Flamingo is a major tourist attraction. This species feed primarily on Arthrospira , algae which grow exclusively in very alkaline lakes such as Lake Abijata . Hence, Lake Abijata is a source of food (Arthrospira) while Lake Shala is a breeding ground for Lesser Flamingo,(Stephenson,1978). However the numbers of birds are decreasing around Lake Abijata. Since Lake Abijata's water is not suitable for irrigation and other domestic purpose, tourism and fishing activities are the main use of the lake next to soda ash production. At present days due to decreasing of the lake; its attraction to tourism is decreased. This can affect eco-tourism sector of the country. Regarding tourism activities, the result of FGD and KII show that there are no people who came to see the lake as a tourist rather some people came here for study.

# CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

The results of the study revealed that much of the fluctuations in the lake water levels are caused by human activities (anthropogenic factors). Lake Abijata is dramatically reduced in size to 2.87km$^2$ (1.59%), 64.24km$^2$ (35.69%) and 10.52 km$^2$ (5.85%) for the year 1985-1995, 1995-2005 and 2005-2015, respectively. The decline of Abiyata is very drastic which is 43.13% of its area in 1985dried up in 2015 (about 35.69% of its area between 1995 and 2005) due to both natural and human activities (most dominant ones).

The Rainfall trend in the area shows declining pattern and temperature trend in the watershed is shows increasing pattern. However, the impact of rainfall and temperature fluctuation on the declining of Lake Abijata has no measurable values.

The water level of Lake Abijata is declining dramatically due to large scale water abstraction for soda ash production by Abijata-Shalla Soda Ash Share Company, decreased inflow from Zeway due to large abstraction of water for irrigation around lake Zeway and Bulbula river by large floriculture and horticulture and small scale irrigation. Most of large scale agricultural investments and small scale irrigation are uses furrow irrigation system. This system is highly use water because there is high loss of water in the open irrigation ditch.

Abijata-Shalla Soda Ash Share Company is abstracting the Lake water even Lake Abijata water level is decreasing dramatically. Producing soda ash is important for the economic development but development must consider environmental sustainability. However the company planning to use Lake Shalla as the water of Lake Abijata has almost reached to a point where pumping is impossible.

Flower plantation like Sher Ethiopia at the moment of the national focus to earn foreign currency and creating job opportunity. Since investment is important for the development of the country attracting foreign investment is good with consideration of environmental sensitivity. However Sher Ethiopia's environmental impact on the lake level, water pollution, fish product and sensitivity of the area is never considered.

Declining of Lake Abijata affects the overall lake ecosystem. As a result the number of flamingos and pelicans are declining due to increasing alkalinity of the lake and decreasing of fish population in the lake due to this, Lake Abijata is became zero ground of fishing and its tourism attraction is decreasing.For instance, pelicans and flamingoesthat feed on fish have been migrating. Normally, about thirteen native fish species can inhabit lakes but there barely exist species in Lake Abijata.

## 5.2 Recommendations

As the result of unsustainable water resources utilization from Lake zeway, feeding river (Bulbula river) and Lake Abijata, the natural feature of lake Abijata seem s to lay under threat and the following recommendations are needed to restore or to sustain present condition.

- Concerned bodies need to work together to manage water use in the Ethiopian Rift Valley, particularly around Lake Zeway and Bulbula river in order to save lake Abijata from drying up like Haramaya Lake.
- Environmental impact assessment should be conducted for Sher Ethiopia and AbijataShalla Soda Ash Share Company as it describes the overall environmental impacts of the projects. To my best knowledge, Environmental Impact Assessment were not Conducted for both.
- Since Lake Abijata is seriously affected, special attention is needed to conserve the water in the lake by controlling the excessive use of water and save the lives lake ecosystem including fauna and flora.
- Awareness on the causes and consequences of excess water use and on how to manage and use wisely the water resources need to be given to large and small-scale irrigator and Abijata-Shalla Soda Ash Share Company around the lakes.
- Further studies need to be made on the Ethiopian Rift Lakes to accurately identify the additional factors that are causing Lake water level fluctuation and to find solution for the problems.

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**Appendix1: Climate Data(Rainfall inmm), maximum and minimum temperature in $^0$C)**

| Year | Rainfall in MM | | Annual max.Temperature | Annual Min. Temperature |
|---|---|---|---|---|
| | Bulbula Station | Zeway Station | | |
| 1985 | 657.7 | 659.1 | N/A | N/A |
| 1986 | 763.6 | 541.2 | N/A | N/A |
| 1987 | 782.6 | 552.9 | N/A | N/A |
| 1988 | 576.8 | 700.6 | 27.6 | 14 |
| 1989 | 951.2 | 951.5 | 26.6 | 13.8 |
| 1990 | 756.4 | 689.4 | 27.3 | 13.8 |
| 1991 | 595.3 | 801.6 | 27.5 | 14 |
| 1992 | 727.3 | 794.2 | 27.2 | 14.4 |
| 1993 | 648.0 | 958.9 | 27.6 | 14.3 |
| 1994 | 955.0 | 517.3 | 27.8 | 14.2 |
| 1995 | 639.0 | 564.0 | 27.9 | 14.3 |
| 1996 | 753.7 | 912.1 | 27.2 | 13.9 |
| 1997 | 395.5 | 848.6 | 27.7 | 14.5 |
| 1998 | 688.7 | 756.2 | 28 | 14.9 |
| 1999 | 756.1 | 545.5 | 27.8 | 12.3 |
| 2000 | 772.8 | 704.3 | 27.5 | 14.2 |
| 2001 | 698.0 | 725.7 | 27.4 | 14.5 |
| 2002 | 480.8 | 457.6 | 28.5 | 15.1 |
| 2003 | 670.7 | 850.8 | 27.9 | 14.9 |
| 2004 | 457.4 | 773.6 | 27.8 | 14.7 |
| 2005 | 769.2 | 779.1 | 27.5 | 14.4 |
| 2006 | 593.7 | 776.5 | 27.5 | 14.6 |
| 2007 | 634.5 | 836.5 | 27.5 | 13.4 |
| 2008 | 683.7 | 892.6 | 27.1 | 13 |
| 2009 | 366.8 | 728.7 | 28 | 14.6 |
| 2010 | 800.9 | 863.3 | 27.4 | 14.6 |
| 2011 | 538.5 | 672.9 | 27.8 | 14.2 |
| 2012 | 476.7 | 909.0 | 27.8 | 14.1 |
| 2013 | 481.1 | 747.4 | 27.5 | 14.3 |
| 2014 | 432.9 | 673.1 | 27.7 | 14.5 |
| 2014 | 302.6 | 470.7 | 28 | 14.7 |

Source: National Meteorological Agency Hawassa Branch(2015)

**Appendix2:Abijata Lake Level between 1985 and 2007**

| Year | Lake Level |
|---|---|
| 1985 | 5.635299 |
| 1986 | 4.483107 |
| 1987 | 4.275501 |
| 1988 | 3.65185 |
| 1989 | 3.230083 |
| 1990 | 3.513083 |
| 1991 | 3.82525 |
| 1992 | 3.77683 |
| 1993 | 4.752167 |
| 1994 | 4.457225 |
| 1995 | 4.407417 |
| 1996 | 4.716667 |
| 1997 | 5.109049 |
| 1998 | 4.878 |
| 1999 | 4.554667 |
| 2000 | 4.145083 |
| 2001 | 4.328083 |
| 2002 | 4.316083 |
| 2003 | 3.060833 |
| 2004 | 1.891333 |
| 2005 | 1.5175 |
| 2006 | 1.316917 |
| 2007 | 2.543596 |

Source: Kassaye, 2010

**Appendix3:**

Area of Lake Abijata as obtained from Google Earth and Landsat imagery 1985

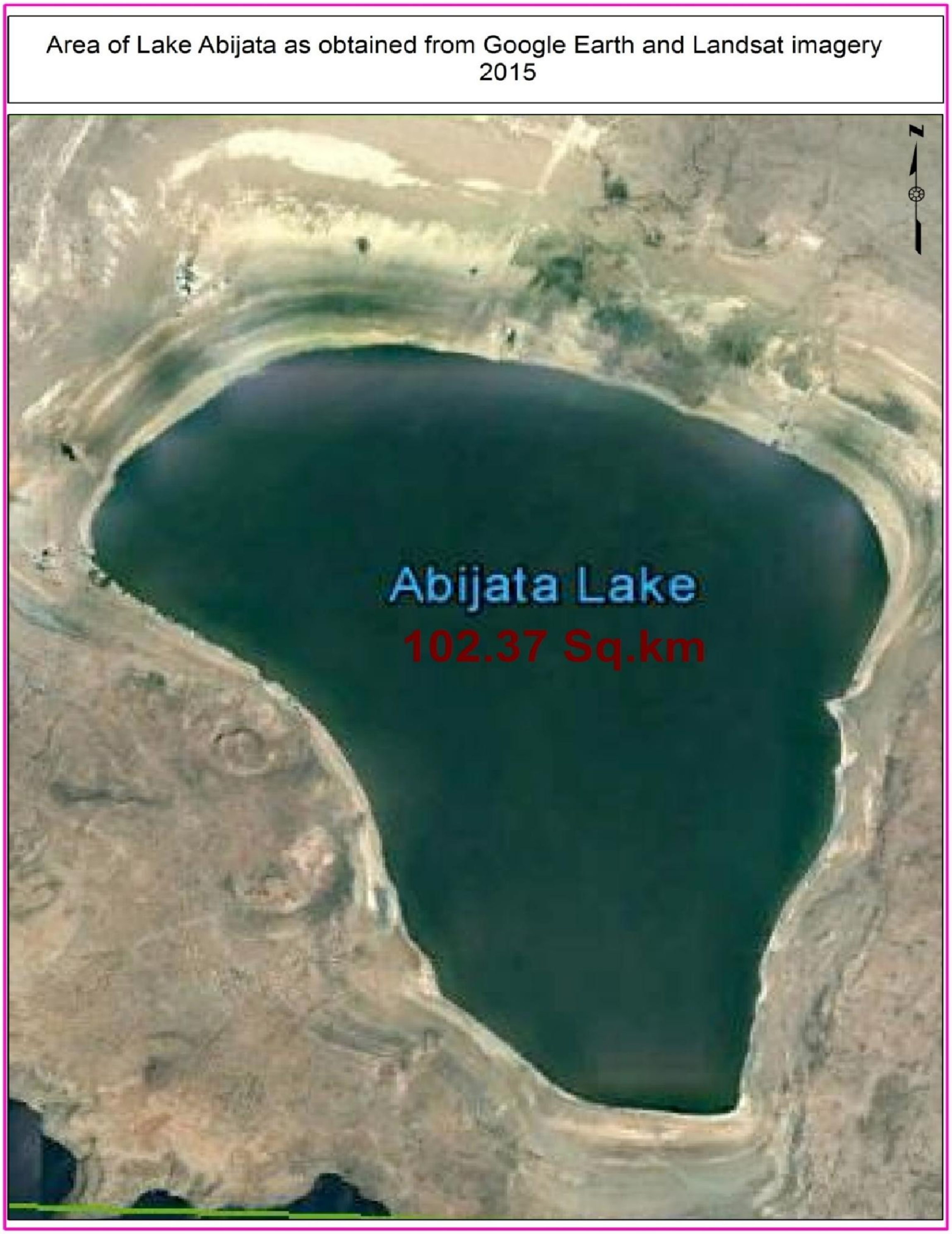
**Appendix4:**


Area of Lake Abijata as obtained from Google Earth and Landsat imagery
1995
177.13 Sq.km
N

**Appendi5:**

Area of Lake Abijata as obtained from Google Earth and Landsat imagery 2005

**Appendix6:**


Area of Lake Abijata as obtained from Google Earth and Landsat imagery
2015
N
Abijata Lake
102.37 Sq.km

**Appendix7:Interview Guide**

Dear respondent,

My name isAbdi Ibrahim Oumer. I am a postgraduate student at Adama Science and Technology University, in Land and Water Resource Management Stream of the Department of Geography and Environmental Management.

Currently, I am writing my thesis on the Cause, Extent and Consequence of Shrinking of Lake Abijata Central Rift valley of Ethiopia. You have been selected purposively from different experts in A/T/J/Kombolcha*woreda* Land and Environmental Protection Office, *Woreda* Administration, Irrigation Authority, and Agricultural office. The responses you give are valuable and will be held in utmost confidentiality and will be used only for the analysis of this research. You will not be identified by name in any case. If you accept to participate in this research, you will be doing so voluntarily and there will not be any monetary returns. You are also free to refuse to respond to any questions you do not feel comfortable answering or to withdraw from the research all together.

Thank you in advance for your cooperation

**Interview Guide**: To be administered to in A/T/J/Kombolcha*woreda* Land and Environmental Protection Office, *Woreda* Administration, Water Resources, Mineral and Energy, and Agricultural office.

1. How many years you live in this area?
2. What is your view on the shrinking of Lake Abijata?
3. Do you know the existing condition of the lake in terms of size compared with the previous years?
4. Is Lake Abijata water level rising or falling over last 30 years? What do you think the cause for this?
5. Is there any water abstraction from the Lake and its feeding rivers?
6. How you express the impact of irrigation around Lake Zeway and BulbulaRiver on Lake Abijata?
7. Is there any difference on the size and time of flow of Bulbula River?

8. Is there any precipitation difference temporally and spatially from the existing condition compared with the previous years?
9. Is the Temperature in your area increasing or decreasing over last 30 years?
10. What is your view on Abijata-Shalla Soda Ash Share Company in relation to Lake Abijata?
11. Is there any change you observe on Lake natural resources?
12. Who do you think is Vulnerable to the shrinking of Lake Abijata ?
13. Is there any Socio-economic and environmental consequence of Shrinking of Lake Abijata?
14. Is there any people who fishing around Lake Abijata in recent years?
15. Is there any people come to the area as a tourist in recent years?

**Appendix 8: Checklist for Focus Group Discussion**

- ✓ Have you noticed changes on Lake Abijata? If yes, ask for each of the changes?
- ✓ How is it different from original situation?
- ✓ What are the main changes that you observe inthe locality in the last few years? How did you measure (indicator)?
- ✓ When did it take place? What are the major causes of these water level changes?
- ✓ How do you measure (indicate) the extent of Lake water level change of Lake Abijata?
- ✓ What have been the effects of these changes on the natural ecosystem of the lake?
- ✓ What have been the effects of these changes on the socio-economic life of the community?
- ✓ Who do you think is responsible for drying of Lake Abijata?