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DECLARATION

I, the under signed declare that this thesis entitled ***“CAUSES AND EFFECTS OF DIMINISHING WATER VOLUME IN LAKE CHELEKLEKA, BISHOFTU, ETHIOPIA AND STRATEGY FOR CONSERVATION”*** *is my original work and has not presented for any degree in any university and all the sources of materials used for the thesis have been duly acknowledged.*

Name of candidate : **DANIEL ASSEFA GEBRE**

Signature:…………………………………………

Date:………………………………

CERTIFICATION

Here with I state that Daniel Assefa has carried out this research work on the topic entitled ***“CAUSES AND EFFECTS OF DIMINISHING WATER VOLUME IN LAKE CHELEKLEKA, BISHOFTU, ETHIOPIA AND STRATEGY FOR CONSERVATION”*** Under may supervision and it is sufficient for submission for the partial fulfillment for the award of MSc. Degree in Environmental Planning and Landscape Design.

Dr. Hailu worku

Signature : ……………………………

Date: ……………………………

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ACKNOWLEDGEMENTS

I am grateful to my advisor Dr. Hailu Worku for his appreciable suggestions and supervisions from the very beginning to the end of the thesis work. I would like to extend my appreciation to Fituma Lemessa and Abel Gezahegn for their smooth facilitation and active cooperation in the fieldwork. My thanks also go to my friends Abera Dugasa for his moral support and friendship encouragement while working the thesis.

Last but not least the special circumstance in my life in such way that no education levels would have been achieved without her support and cooperation of my dear wife Tsehay shume, thank you for your valuable support to overcome different challenges and successfully accomplish my education.

Acronyms

CSA	Central Statistical Agency
DEAT	Department of Environmental Affairs and Tourism
EPA	Environmental Protection Authority
FAO	Food and Agriculture Organization
GIS	Geographic information system
IPCC	Intergovernmental Panel on Climate Change
LULCC	Land Use and Land Cover Change
RS	Remote Sensing
TM	Thematic Mapper

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CAUSES AND EFFECTS OF DIMINISHING WATER VOLUME IN LAKE CHELEKLEKA, BISHOFTU, ETHIOPIA AND STRATEGY FOR CONSERVATION

DANIEL ASSEFA GEBRE

AAU, 2015

Abstract

This study aimed to examine Causes and Effects of Diminishing Water Volume in Lake Chelekleka, Bishoftu, Ethiopia and Strategy for Conservation. To meet the objective of the research, appropriate attention were taken to investigate the land use/cover changes, field observation, interviews with officials and horticulture farmers. Hence, the results of the study Shown, extent of the land use/cover change and its effects seen on Chelekleka Lake and its Swampy areas were very dramatic. That is, majority of the forest land use/covers during the (1973-2010) in Chelekleka Lake Water Shades and its surroundings were converted to crop land, settlement, degraded bare lands, and grass lands. This land use types covers much of the southern, western, Central and eastern parts of the Chelekleka Lake Watersheds and its surroundings. Besides, notably after 1986 land use/cover change was very tremendous and exhibited decline of forest lands, shrub lands, and swampy vegetation. Hence, during 1973-1986 deforestation and soil degradation in the Chelekleka Lake Watersheds and its surroundings was very sever, which was ultimately affected the depth of the lake. In the same period majority of the forest and shrub lands in upper water course changes to grass lands, crop lands and bare-degraded lands, i.e., markedly, degraded bare land coverage was increased because of acute increase of agricultural lands. Moreover, the land use investigation data conclude the presence of a shift in land use types, for instance, agricultural lands were converted to population settlements areas and crop lands in turn expand to shrub and uncultivable land uses. Similarly irrigated vegetations also occupied the swampy areas of Chelekleka Lake. These land use changes caused massive reduction of surface water coverage and changes its shapes from deep dark blue and compacted shapes to slant shallow and light blue color shapes. Generally study concludes, all the Chelekleka lake especially, The inner and border areas of the lake Chelekleka was dramatically changed into irrigated vegetation and grass lands and hence the dying of the lake was already starting from upper and expands to its central areas. In addition to the challenges of land use change factors like high interest of Horticulture expansion, poorly planned infrastructure developments, lack of awareness and poor attention from governments, and climate change/variability exacerbate the dying of the lake. On the basis of the study findings of the research the following recommendations forwarded undertaking appropriate resource conservation and management approaches, both the lake and its buffer zone should be demarcated and administered by concerned bodies, the silt and sedimentation filled the base of the lake should be removed, appropriately designed ditch and/or bridges to transfer the streams from upper course to the lake should be implemented.

Key words: ***Lake*** ***Chelekleka*** ***Land use*** ***land cover change***

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

Water is a prime natural resource, a basic human need and a precious national asset. The extent to which water is abundant or scarce, clean or polluted, beneficial or destructive has a major influence on our planet in its rapidly changing face brought about by rapid development on all fronts, ever increasing population and fast rate of scientific and technological advancements (Arsano, 2007).

Globally, water is an increasingly scarce resource requiring careful economic and environmental management (DEAT, 2007). In developing countries the situation is exacerbated by rapid population growth, expansion of agriculture and urbanization. As the demand for water for human use has escalated, so has the competition for water used for agriculture and industry (World Bank, 2000).

At present, sub-Saharan countries, in general, and Ethiopia in particular, are facing major challenges related to the growing competition for this precious resource and makes many lakes, reservoirs, streams, rivers etc near to die and reduced significantly their volume from year to year. Thus, the sustainable management of available water resources to meet the ever increasing needs of the growing population, industry, and agriculture is also of major concern.

Hence, effective and sustainable management of water resources like the current study site Lake Chelekleka have vital role in ensuring sustainable development. However, efforts of water resource management system seem to demonstrate inappropriate practices, especially when compared to water consumption trends in developing countries in general, and sub-Saharan Africa in particular(Dungumaro & Madulu, 2003). Poor water resource management have stimulated and sustained a number of problems related to health, socio- economic and environment, which need to be solved. These problems are accelerated and magnified by the countries', communities' and individuals' struggles for economic and social development as many development initiatives are affected by water availability and vice versa.

Moreover, deforestations, unplanned infrastructure developments, and other land-use activities can significantly alter the seasonal and annual distribution of stream flow within a watershed (Dume and Leopold, 1978). It is likely that such changes can also affect the seasonal and annual distribution of base flow. Understanding how these activities have influenced stream flow pattern may enable planners to formulate policies to minimize the undesirable effects of future land use changes. Hence, Land use data are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels.

1.2. Statement of the problem

A number of forces continue to seriously affect our natural water resources. Many of these are primarily the result of human actions and include ecosystem and landscape changes, sedimentation, pollution, over-abstraction and climate change. The removal, destruction or impairment of natural ecosystems is among the greatest causes of critical impacts on the sustainability of our natural water resources.

However, it should be emphasized that the ecosystems with which we interact are directly linked to the well-being of our natural water resources. Although it is difficult to integrate the intricacies of ecosystems into traditional and more hydrological-based water assessment and management processes but have paramount importance for ensuring the sustainability of the resources.

Hence, the recognition that each type of landscape change will have its own specific impact, usually directly on ecosystems and directly or indirectly on water resources. The magnitude of the impacts will vary according to the setting's conditions with a wide range of possible landscapes. Changes that can occur to landscapes in the study area include: forest clearance, rapid expansion of agricultural land, road and other infrastructural development, grazing lands replacing grasslands or other natural terrestrial ecosystems, urbanization (leading to changes in infiltration and runoff patterns as well to pollution), wetlands removal or reduction, stream cut off that spills the lake, and mining in quarries etc.

Moreover, Sediments occur in the Chelekleka Lake as a result of various human actions including land-use changes and agricultural practices, changing dramatically the volume of water resources. In addition, the inadequate and very little consideration was given by stakeholders especially governments to alleviate the impacts of a recently increasing high sediment loads from the construction of new roads and other infrastructures exacerbate the probability of dying on aquatic systems and downstream water supplies of Chelekleka Lake. These impediments excessively affect volume of the lake's freshwater systems and threaten its habitats, local community, income from tourists, and other natural resource endowments.

Therefore, it is crucial and appropriate to undertake scientific investigation on the watersheds of Chelekleka Lake, like the current study which aiming to explore the extent of the impacts of land use changes in upper catchments and within the surrounding, its driving forces, and analyzing the frequency and severity of the causes and its affects. This is because having the knowledge and understanding of the reality would help to take any appropriate concrete remedial and corrective actions protecting the lake from dying.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this research is to investigate Causes and Effects of Diminishing Water Volume in Lake Chelekleka, Bishoftu, Ethiopia and Strategy for Conservation.

1.3.2. Specific objectives

1. To assess the extent of the land use/cover change in the Chelekleka Lake watershed and its effects on the lake;

2. To explore the drivers of change and basic challenges aggravating water diminish;

3. To identify environmental planning gaps affects the lives of Chelekleka Lake.

1.4. Research Question

1. What are the extent of the land use/cover change and its effects on Chelekleka Lake Watersheds and its surroundings?
2. What are the drivers of change?
3. What challenges are exacerbating water diminish and move it to die Lake Chelekleka?
4. What environmental planning gaps are needed to be addressed to protect Chelekleka Lake from dying?

1.5. Significance of the study

Previously, no significant studies were undertaken to show causes and effects of water volume change and how to protect the dying Lake Chelekleka. Hence, the current study has the importance of:

- adding knowledge on the gap created i.e., about water volume diminish;
- Promising in terms of identifying drivers of change and aggravate problems water volume change;
- offered information regarding the future planning to preserve the lake;
- More importantly, the findings of this study can lead to new problems for further investigation and suggest strategies for conservation;
- Furthermore, the study is also meant to signal and motivate the various stakeholders to take appropriate actions by incorporating the issue in their policies and strategies;
- Provide policy makers, researchers, institutions etc with adequate, sufficient and reliable data so as to implement feasible and appropriate land use plan to protect the lake from dying.

1.6. Delimitation of the Study

For the sake of making the research manageable, this study has limited in scope, time, and coverage areas. Accordingly, to conduct the research on the issue of water resource managements and planning across the district's different landscapes would be comprehensive and it needs a huge amount of money and long progress. Hence, in its scope the study has limited to in analyzing land use change effects on water resources of Chelekleka Lake watersheds, its swampy and surroundings'. Hence, to substantiate land use detection data and to offer remedial environmental planning for the lake, rigorous field observations were made. Moreover, possible efforts were exerted to overcome constraints and accomplish the desired work successfully.

1.7. Methods and Materials

1.7.1. Description of the study area

Bishoftu is a town lying south east of Addis Ababa. It was formerly known as Debre Zeyit (also transliterated Debre Zeit; Ge'ez ደብረዘይት; Amharic "Mount of Olives") however since the late 1990s it has been officially known by the Oromo name, Bishoftu which was its name until 1955 (Briggs, 2009). The town is located in the Misraq Shewa Zone of the Oromia Region, and has an elevation of 1,920 meters above sea level (6,300 ft). It is a resort town, known for five crater lakes: Lake Bishoftu, Lake Hora (a base for water sport, many water birds and an annual festival), Lake Bishoftu Guda, Lake Koriftu and the Lake Chelelaka. Other lakes existing at the periphery of the town includes Cuban made lake, Hora Kilole Lake, Green Lake and Ziquala Lake.

These lakes all existed since long ago and they are all respected by culture and so existed undisturbed both by nature and human interventions. They all are serving as cultural, source of food for both animals and residents around, flood controlling mechanisms and environmental regulations. Stated lakes are the beauty of the town and all its name and fame are related to these lakes. The vision of the town, to develop as a resort town and tourist center is derived from the existence of these lakes.

Demographics

The 2007 national census reported a total population for Bishoftu of 99,928, of whom 47,860 were men and 52,068 were women. The majority of the inhabitants said they practiced Ethiopian Orthodox Christianity, with 79.75% of the population reporting they observed this belief, while 13.82% of the populations were Protestant, and 4.98% of the populations were Muslim (CSA, 2007). The town also occupied by three largest ethnic groups; the Amhara (42.86%), the Oromo (39.4%), and the Gurage (8.3%); all other ethnic groups made up 9.44% of the population. Amharic is spoken as a first language by 71.95%, and 20.12% spoke Oromiffa; the remaining 7.93% spoke all other primary languages (CSA, 2007).

Overview of Lake Chelekleka

Lake Chelekleka is situated at the gate of the town from Addis. It covered large hectare of land and can be accessed both on foot and by vehicles easily. It has been used as a food source both for animals and human and water source for vegetation. Chelekleka is a seasonally flooded shallow pan in to which fresh water seeps and flows from surrounding cultivated slopes and townscapes. Water fills the muddy depression during the rainy season and persists well in to the dry season. The high land ranges of the surrounding on the western, northern and eastern of the swamp, are the main catchments for Chelekleka. Because of its shallow nature, the lakes shoreline is wide.

The size of in undated area varies dramatically from year to year. It seems that, the amount of channeling run off entering to the lake is reduced and catchment area is filled with sediment resulting on total reduction of volume of water. The area around the lake is intensively used as the waters retreat. Though it is uncommon to see some cultivation throughout the year, but peasant farmers and agro industry developers are intensively utilizing the existing small volume of water to cultivate vegetables and citruses.

1.7.2. Methods of the study

1.7.2.1. Design of the Study

As the main purpose of the study is to investigate the root causes which made Lake Chelekleka diminish from year to year and now approaching to die, the study design include both quantitative and qualitative type. Yin (2003) has shown that, in situations where two strategies might be considered attractive, it is possible to use multiple strategies in a given study. Therefore, the quantitative data collected from extents of land use change extents and magnitudes, whereas the qualitative information was collected by using in depth interview and site observations.

1.7.2.2. Sources of Data

On the basis of the study objectives (i.e., to answer all research questions), both primary and secondary data sources was used. The primary data source includes satellite landsat images, interviews and site observations. While secondary data sources collected from extensive reviewing of literature from different sources, which includes books, reports, journals, electronic Medias and the like. To determine the study area land use samples, the researcher considers the aerial photograph taken in 1972/73 and Topographic map of the 1986/87 of the study area. Because these two sources were the only input help to determine the appropriate catchment area of the Chelekleka Lake, watersheds, and its swampy areas. After having the exact delineated study site for each category under investigation the analysis was made by considering the four different periods of 1973, 1986, 2000 and 2010 satellite images.

1.7.2.3. Land Use and Land Cover Change Analysis

1.7.2.3.1. Remote Sensing Data Acquisition

For this study, four periods of (1973, 1986, 2000 and 2010) of Landsat satellite images are downloaded from (Source: *www: Earth explores* (USGS) to begin change examinations (table 1). The downloaded satellite images are in tiff format and were stacked in ERDAS IMAGINE 2010 software, and developing function in it to stack each layer to produce one single layer composing of each band. Then from the stacked band the study area was extracted.

Table 1: Landsat Data used in Land Use and Land Cover Classification

Landsat Type	Date of Acquisition	Path & Row	Pixel Size/Resolution(m)
L1-5MSS	January 1973	P181/r054	30*30
L1-5MSS	January 1986	P168/ro54	30*30
L7ETM$^+$	January 2000	P168/ro54	30*30
L8OLI/TIRS	January 2010	P168/ro54	30*30

1.7.2.3.2. Image Analysis

1.7.2.3.2.1. Image Pre-processing

Preprocessing involve those operations that are normally required prior to the main data analysis and extraction of information. To address the objectives of the research multi-temporal satellite image such as Land sat Multispectral scanner (MSS) for 1973 with a path of 181 and row 054; Thematic Mapper (TM)/Thematic Mapper plus (TM^+) for 1986, Enhanced Thematic Mapper plus (ETM^+) for 2000 and Operational Land Image and Thermal Infrared Sensor (OLI/TIRS) for 2010 with a path of 168 and row 054; and topographic-map with the scale 1:150,000 were used to generate four decades data trends. The raw data were georeferenced and clipped with the boundary of the study area for further processing.

I. Geometric Correction

In this work, the processing of these images have been geometrically corrected with road and river intersection on the images themselves and the topographic map of the study area with scale of 1:250,000. After the raw data are georeferenced, they have been clipped with the boundary of the study area for further processing.

II. Image Enhancement

To improve the visual interpretation, image enhancement is done for increasing the apparent distinction between features in the scene (Lillesand and Kiefer, 2000). If the image is enhanced the distinct of features are clearer so that image analysis, classification and interpretation is improved. In addition, Image enhancement is used to increase the details of the image by assigning the image maximum and minimum brightness values to maximum and minimum display values, it is done on pixel values, and this makes visual interpretation easier and assists the human analyst. The original low dynamic range of the image is stretched to full dynamic range which is from 0 to 256 by using histogram equalization. Moreover, spatial enhancement of convolution of Kernel 5 by 5 of high pass filtering has been done on the images of the respective years.

1.7.2.3.2.2. Image Classification Analysis

In this study, unsupervised and supervised classification methods are used. Supervised image classification was a method in which the analyst defines small training sites on the image, which are representative of each desired land cover category. The delineation of training areas representative of a cover type is most effective when an image analyst has knowledge of the geography of a region and experience with the spectral properties of the cover classes. However the unsupervised classification technique is performed when there was little or no knowledge to the geography of the region where classification is under taken.

Hence, initially the four periods of satellite images are classified in the unsupervised classification for identification of the features in a pixel form, then after by observing and recording identifiable coordinate points of features in the Google Earth, the supervised classification using the training points are performed. For this study a simple classification scheme comprising seven land use/cover types are developed for the purpose of mapping. A combination of information collected from the field and a satellite image are effectively used in the preparation of the legend. Classification of some of the land use/cover classes are required a number of field visits and discussions with farmers, to have not only a clear understanding of the main land use/cover types but also to establish what types of changes are existed over time. Categorization of land use/cover types concluded in the production of the land use/cover legend, establishment of its characteristics, and identification and mapping of the various land use/cover types (Binyam, 2012).

1.7.2.3.2.3. Accuracy Assessment

Land use and land cover maps derived from remote sensing always contain some sort of errors due to several factors, which range from classification technique to method of satellite data capture. In order to safely use the maps the errors must be quantitatively evaluated in terms of classification accuracy and intended to produce information that describes reality. Therefore, an accuracy classification assessment was carried out to verify to what extent the produced classification is compatible with what actually exists on the ground (Congalton, 1991). It involves the production of references (samples) that evaluate the produced classification. These references were produced from Google Earth and GPS points during field work, which were independent of the ground truths used in the classification. Using this process error matrix was produced for recent image of the study area (table 2) for validation. Accordingly, the evaluation result confirms the validity of the classification with Overall Accuracy = 85.87% and and Kappa Coefficient (index) = 0.840

Table 2: Classification accuracy assessment of 2010

Land Use	Surface Water body	Swampy Vegetation	Forest land	Shrub land	Grass land	Crop land	Bare land	Settlement	Total	% Matched
Surface Water body	13	0	0	0	0	0	0	0	13	100
Swampy Vegetation	1	11	0	0	0	1	0	0	13	84.62
Forest land	0	0	10	1	0	1	0	0	12	83.33
Shrub land	0	0	0	11	1	1	0	0	13	84.62
Grassland	0	0	0	0	11	1	1	0	13	84.62
Cropland	0	0	0	0	1	11	0	1	13	84.62
Bare land	0	0	1	1	0	0	9	0	11	81.82
Settlement	0	0	0	0	1	0	1	10	12	83.33
Total	14	11	11	13	14	15	11	11	100	85.87

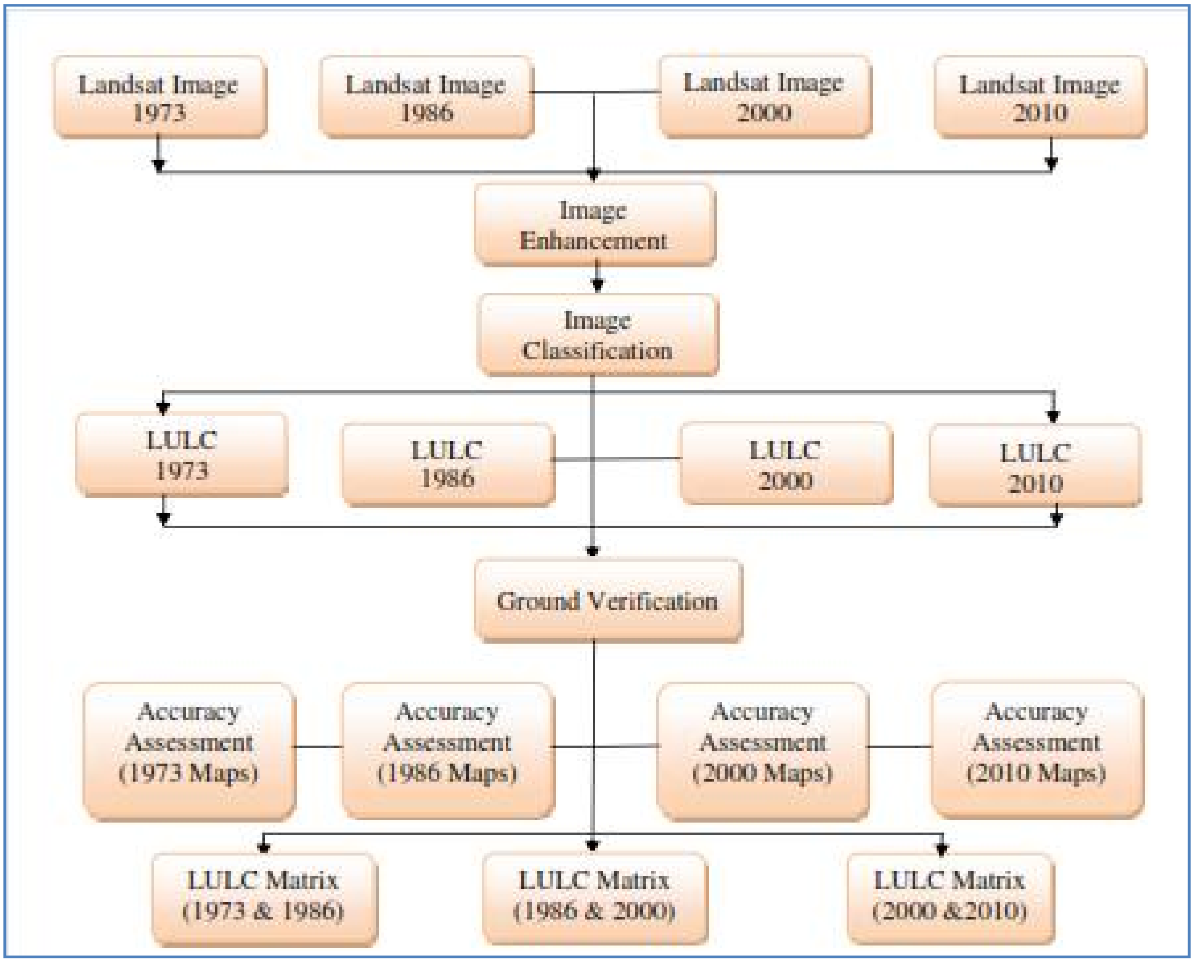
Symmetric Measures		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.840	.040	22.191	.000
N of Valid Cases		100			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

1.7.2.3.2.4. Matrix of Land Use and Land Cover Dynamics

The change matrixes are determined by overlaying two land use and land cover maps at a time in ERDAS IMAGINE 2010 software (fig. 1). The areas which were converted from each of the classes to any of the other classes are computed (Gautam *et al*., 2003).


Landsat Image 1973
Landsat Image 1986
Landsat Image 2000
Landsat Image 2010
Image Enhancement
Image Classification
LULC 1973
LULC 1986
LULC 2000
LULC 2010
Ground Verification
Accuracy Assessment (1973 Maps)
Accuracy Assessment (1986 Maps)
Accuracy Assessment (2000 Maps)
Accuracy Assessment (2010 Maps)
LULC Matrix (1973 & 1986)
LULC Matrix (1986 & 2000)
LULC Matrix (2000 &2010)

1.7.2.4. Qualitative data analysis

This is mainly composed of the interview data with key informants and observation data substantiated with document analysis. An interview data collected using semi structured interview guide. The interview designed in such a way that it is possible to react accordingly. As to Merriam (1988) this format allows the researcher to respond to the situation at hand, to the emerging world view of the respondent and to new ideas on the topic. Observation also allowed the researcher to formulate his or her own vision of what occurred independent of the land use/ cover data showing why the lake is dying. It provided an in depth understanding of what was occurring in the natural setting and hence systematic observation was made in the study to investigate the causes of Chelekleka Lake water volume change. These data were discussed after examined and synthesized the information obtained from interviews and field observation. By doing so, the researcher attempted to draw implication from the responses of participants and field observation about the causes of diminishing water volume in Lake Chelekleka and strategy for conservation.

CHAPTER TWO
REVIEW OF THE RELATED LITERATURE

2.1. Land Use and Land Cover Dynamics

Land represents an important resource for the economic life of a majority of people in the world. The way people handle and use land resource is decisive for their social and economic well-being as well as for the sustained quality of land resources (Fazal, 2013). Land use however is not only a realm of those directly using it; it is exposed to a part of the wider reality of social and economic development and change (Fazal, 2013) or defined as the way or manner in which the land is used or occupied by humans (Campbell & Wynne, 2011; Giri, 2012). Land cover refers to the observed biotic and a biotic assemblage of the earth's surface and immediate subsurface (Meyer and Turner, 1992); Land cover is the visible features of the Earth's surface included in the vegetative cover, natural and as modified by humans, its structures, transportation and communications (Campbell & Wynne, 2011).

In a nutshell, land cover represents the visible evidence of land use. In other words, land cover is the observed physical cover, whereas land use is based on function or the socioeconomic purpose for which the land is being used. A piece of land can have only one land cover (e.g., forests), but can have more than one land use (e.g., recreational, educational, and conservational) (Giri, 2012). Examples of major land-cover types are forests, shrub lands, grasslands, croplands, barren lands, ice and snow, urban areas, and water bodies (including groundwater)(Campbell & Wynne, 2011; Giri, 2012). As can be seen from the definitions and examples, the term now includes not only the vegetation that covers the land but also human structures, such as roads, built-up areas, and immediate subsurface features such as groundwater. Land resources are used for a variety of purposes which interact and may compete with one another. Land use and its transformation is therefore a highly dynamic process. Land transformation accelerated and diversified with the onset of the Industrial Revolution, the globalization of the world economy, and the expansion of population and technological capacity (Fazal, 2013).

2.1.1. Land Use & Land Cover and Change

Land use implies a human dimension or purpose for which the land is used while Land cover is the biophysical attributes of the Earth's surface and can be detected directly from aerial imagery or satellite-borne sensors. Land use can be inferred from remotely sensed data but typically must be verified by local expert knowledge or data collected in the field (FAO, 2012). Land use and land cover change has become a vital component in current strategies for managing natural resources and monitoring environmental change. Providing an accurate assessment of the extent and health of the global forest, grassland, and agricultural resources has become an important priority (Alalign, 2009). The land use and land cover pattern of a region is an outcome of natural and socioeconomic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use and land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use and land cover schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use and land cover resulting from the changing demands of the increasing population (Alalign, 2009). Land use/land cover and change involves the interaction of biophysical, social, ecological, and human behavioral attributes over time and space (Turner *et al.*, 1994). It is complex process that arises from modifications in land cover to land conversion process.

2.1.2. Cause and Effects of Land Use Land Cover Changes

Land use and land cover is a primary ingredient of ecological structure and function, with changes affecting species habitat and distribution (EPA, 2008) and can affect farmer livelihoods and farmer's livelihoods strategies (Pensuk and Shrestha, 2007). It‘s change involves the interaction of biophysical, social, ecological, and human behavioral attributes over time and space (Turner *et al.*, 1994) and complex process that arises from modifications in land cover to land conversion process. Land use change is driven by the interaction in space and time between biophysical and human dimension, moreover, there are also the potential impacts on physical and social dimensions (Veldkamp and Verburg, 2004). According to Lambin *et al*. (2003), Land-use change is driven by synergetic factor combinations of resource scarcity leading to an increase in the pressure of production on resources, changing opportunities created by markets, outside policy intervention, loss of adaptive capacity, and changes in social organization and attitudes. Due to this synergetic factor LULCCs resulting to land fragmentation, biodiversity loss, degradation of agricultural productivity, decline or improvement in economic well- being, or changes in human population. For instance, the people who live in similar land use type may have differing socio-economic characteristics because their connections with places, institutions, and available resources are different as Gyawali *et al*. 2004 cited in Turner *et al*. 1994. LULCC is one of the most important drivers of global change (Lambin *et al*., 1999) and affects many parts of human environment systems. Changes in the condition and composition of the land-cover affects climate (IPCC, 2001) changes in biogeochemical cycles and energy fluxes (Melillo *et al*. 2003) and affect thereby livelihoods (Vitousek *et al*. 1997).

LULCC are widespread, accelerating, and significant processes driven by human actions but also producing changes that impact humans (Agarwal *et al*., 2002). These dynamics alter the availability of different biophysical resources including soil, vegetation, water, animal feed and others. Consequently, land use and cover changes could lead to a decreased availability of different products and services for human, livestock, agricultural production and damage to the environment as well. Daily rural livelihood practices to fill their gap resulting LULCDs and conversely LULCDs affect rural livelihoods well being such as deforestation, soil erosion and associated problems of decline in soil fertility and loss of biodiversity have resulted in making livelihood improvement a very challenging task to countries lake Ethiopia that are highly dependent on agricultural and natural resources products (Melaku, 2008). Changes in land cover can influence climate and climate in turn, can influence land use and land cover. These land cover changes affect weather and climate variability by altering biophysical, biogeochemical, and energy exchange processes at local, regional, and global scales (USGS, 2013). LULCCs occur constantly and at many scales, and can have specific and cumulative effects on air and water quality, watershed function, generation of waste, extent and quality of wildlife habitat, climate, and human health (EPA, 2008). The effect of LULCCs on the hydrological processes is mainly contributed by the changes in vegetation interception, soil evaporation, plant transpiration, infiltration and soil water content (Liu *et al*., 2009).

2.2. Remote Sensing (RS) & Geographic information system (GIS) in LULCDs

RS is the science of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Kerle *et al*., 2001); the practice of deriving information about the Earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the Earth's surface (Campbell & Wynne, 2011), while GIS are computer-based systems that can deal with virtually any type of information about features that can be referenced by geographical location; and capable of handling both location data and attribute data about such features(Lillesand *et al*., 2004). It also a system that provide data capture, preparation, management (storage and maintenance), data manipulation and analysis, and data presentation (Rolf, 2004). RS simply measures the reflective response of the earth's surface, and so it can be used to directly observe the land cover for a given pixel. Land use must be inferred by linking the measured land cover with ancillary information such as socioeconomic data with a combination of RS observation, regional and local knowledge (including field observation) that links a given land cover in a region with a given land use (Giri, 2012; FAO, 2012) and detecting surface cover type and condition and provides a number of landscape attributes that can be used by LULC models (Campbell & Wynne, 2011).

RS data and techniques and GISs provide efficient methods for analysis of land use issues and tools for land use planning and modeling (Daniel, 2008; Nastanet, 2007). GIS databases are used to improve the extraction of relevant information from remote sensing imagery, whereas RS data provide periodic pictures of geometric and thematic characteristics of terrain objects, improving our ability to detect changes and update GIS databases (Janssen, 1993). Land-cover information at multiple spatial, thematic, and temporal resolutions has direct relevance to LULC forecast modeling (Giri, 2012). The RS data can be combined with other data to address a specific practical problem, such as LULC change, land-use planning, mineral exploration, or water-quality mapping (Nastanet, 2007). When digital RS data are combined with other geospatial data, applications are implemented in the context of GIS (Campbell & Wynne, 2011). Therefore; understanding the driving forces of LULCDs in the past and managing the current situation with modern RS and GIS tools, and modeling the futures and able to develop plans for multiple uses of natural resources and nature conservation. The knowledge about land use and land cover has become increasingly important as all nations plan to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of native forest, destruction of important wetlands, and loss of aquatic and wildlife habitats (Anderson, 2001).

2.3. Land Use/Cover Change Analysis

The expressions of land use and land cover are often exchangeable though there are some differences among them. For instance, FAO (2000), state land cover as the observed biophysical cover on the earth's surface. In similar but more detailed manner, Lambin *et al., (*2003) and Chrysoulakis *et al.*, (2004) defined land cover as attribute of the earth's land surface with vegetation, water, desert and ice and immediate subsurface including biota, soil, topography etc. and also with including land covers of created by human as a result of their activities; like mining areas and settlement covers.

Whereas, land use refers to how the land is used by human activities, mostly because of economic values, and hence, FAO (2000) defines land use as; the arrangements, activities and inputs that people under take on a certain land cover type. on the other hands, Lambin *et al., (*2003) and Chrysoulakis *et al.*, (2004) defines land use as; it is an intended employment of land use strategy placed by human agents and /or land managers to exploit the land cover and changed to compartments of land uses; like industrial zone, agricultural zone, settlement and residential zones etc. In addition, land use change is a process of any physical, biological change, etc attributable to management, conservation and/or utilization; for instance, change of forest land to agricultural lands and /or residential lands even in rare cases agricultural/residential lands are converted to forest lands, wet land and other precious ecosystem components (Quentin *et al.*,. 2006). Hence, the assessments of land use/cover change for a given country or localities have paramount importance for the selection, planning, and implementation of land use and land cover schemes offered to meet the increasing demands of basic human needs and welfare (Alemu, 2012). Besides, investigations of land use/cover change provides a lope of holes for creating polices, laws, strategies etc. to manage the natural resources including forests through controlling environmental degradations. Hence, to do the investigation of land use/cover change analysis one has to stick to appropriate land use/cover change detection methods, including image enhancement, classification, ground verification, accuracy assessments, and change detections etc. These are, design of change detection area and objectives, Selection of Remotely Sensed Data, Image Preprocessing, Image Processing (i.e., Image enhancement and/or Classification), identifying Change Detection Algorithms, and Evaluation of Change Detection Results.

2.4. Change Detection Methods

Ever since the launch of the first remote sensing satellite (Landsat-1) in 1972, land use land cover studies were carried out on different scales for various users (Opeyem, 2006), and since then, information about change is updating land cover maps and the management of natural resources. This enhanced land use/cover change detection methods prior only collected through field visit. But, the land use/cover change detections methods required the ability of quantifying temporal effects using multi-temporal data sets to adequately explore the differences in state of a phenomenon. According to, Macleod and Congation (1998) change detection should meet four basic aspects when monitoring natural resources: (1) Detecting the changes that have occurred; (2) Identifying the nature of change; (3) Measuring the area extent of the change; and (4) Investigating the spatial pattern of change.

To meet the aspects of the change detection, Lu *et al.,* (2004) described needs to base on research objectives, quality of remote sensing data, change detection algorithms, and geographical size of the study area etc., since it has tremendous effects on design of change detection techniques, procedure used, and image processing methods. Hence, to detect the land use/cover change of district and small regional areas like the current study, Landsat and Thematic Mapper (TM) images are the most widely used (Lu *et al.*, 2011), and required six successive steps. These are, Nature of Change Detection Problems, Selection of Remotely Sensed Data, Image Preprocessing, Image Processing or Classification, Selection of Change Detection Algorithms, and Evaluation of Change Detection Results.

2.4.1. Design of objectives and study area

The first step in land use /cover change detection is identifying research objectives, problem areas, delineation and/or location of the study area (Jensen, 2005). The rightly, accomplishment of appropriate problem design enhance the quality of the detection process of the next steps and hence, directly affect the type of remote sensed data used and change detection algorithms. Moreover, according to Lu *et al.*, (2011) this stage helps to answers about the accuracy of each change detection trajectory, size of study area, period of land detection, type of remote sensing data used etc.

2.4.2. Identification of Remotely Sensed Data

Identification of remotely sensed data that best suit and easy the process of land detection is another crucial stage to select suitable data sets for specific study. Since, remotely sensed data may have their own strength and weakness in spectral, radiometric, spatial and temporal resolutions, polarization, and angularity of the images (Barnsley 1999, and Lefsky and Cohen 2003) proper identification of remotely sensed data that meet the objective and nature of the study area are very important.

Besides, analyst's interest, availability of the various image data, personal experience in using the selected image etc. are also important in selecting remotely sensed data (Lu *et al*., 2004; and Lu and Weng 2007). Lu *et al.,* (2011) suggest, (1) at local level a high spatial resolution data such as, IKONOS, QuicBird, SPOT 5 HRG (High Resolution Geometric) a fine scale land cover change detection type of remotely sensed data. (2) At regional, sub regional, and district levels; medium spatial resolution data like Landsat TM and Terra Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) are used. (3) at large scale level like on global and/or continental level, coarse spatial resolution data such as AVHRR, MODIS, and SPOT VEGETATION type of remotely sensed data are frequently used as an instruments of change detection. A successful change detection investigation should required to consider remote sensor system, environmental characteristics (i.e., atmospheric condition, soil moisture, and phonological), and image processing methods (Jensen, 2005).

2.4.3. Image Preprocessing

Image preprocessing is a step in which the analyst of change detection verified geometric and radiometric correction, optimal enhancement or atmospheric calibration/standardization are obtained to improve image's interpretational ability. Correction and data enhancement and required since, the same images may have different spectral signatures in different date of image obtained broadly due to sun angles, vegetation phonological conditions, soil moisture, and atmospheric conditions (Lu *et al*., 2011). To avoid such differences the analyst and/or the expertise should required converting digital numbers to radiance/surface reflectance of quantitative multitemporal image analysis through adopting a variety of methods like relative calibration, dark object subtraction, and 6S to correct radiometric and atmospheric effect (FitzHugh 2000; Yang and Lo 2000; and Vermote *et al*., 1997). If necessary and the study area are rugged and mountainous it is possible to undertake topographic correction also (Lu *et al., 2008b).*

2.4.4. Image Processing

2.4.4.1. Image Enhancements

Image enhancement is a process notably required for the improvement of visual interpretability of an image being under consideration through increasing the apparent distinction between the features (Solaimani *et al.,* 2010). Hence, digitally enhanced images attempts to optimize the complementary effects of the understandings of the human with the downloaded land sat images. The good understanding of the human is an excellent approach to easily identifying obscure and some subtle features (Lillesand and Kiefer, 2000). Besides, contrasting the image developed with the false color composites increases its accuracy and interpretability of the images. But, initially, the false color composite should required visual interpretation using computer screen in order to easy the processes of delineation of land cover classes like in to forest lands, agricultural land , wetlands , shrub lands, grass lands, bare lands and built-up areas. For the land cover classes not easily separated because of their spectral confusions by supervised classification way, visual interpretations are required to separate those uncertainties (Solaimani *et al.*, 2010).

2.4.4.2. Image Classification

Image classification is the process of assigning and/or identifying pixels into predetermined classes, based on their data file values (Jensen, 1996). The classification process has been explained as consisting of two stages (Mather, 1999). Accordingly, the first is the recognition of categories of real world objects which includes forest lands, grasslands, shrub lands, agricultural lands and other land cover types depending geographical scale, objective, and nature of the study. The second stage in the classification process is labeling of entities which is normally called pixels, are needs to be appropriately classified. Each individual pixel often treated as an individual unit composed of values in several spectral bands, and assembled in classes/groups the identified members of similar pixels by comparing each pixel to one another. These classifications are applied to both to pre and post classification change detection approaches (Schowengerdt, 1997).

In sum, the process of classification should required two important things; the first is determination of prior number and nature of the categories in terms of which the land cover to be described; and secondly, it required to assign numerical levels to each of the identified pixels on the basis of their properties using a decision rule and/or classification rule (University of Oxford, 2013). According to University of Oxford (2013), there are three distinct types of classification that are currently in use in the field of GIS and Remote sensing includes unsupervised, supervised and hybrid classifications. Here under described a brief review of each of the classification types.

2.4.4.2.1. Unsupervised Classification

Unsupervised classification is the process of identification of natural groups or structures of multi-spectral data. The most widely used algorithm for performing unsupervised classification is Iterative Self Organizing Data Analysis, it offers results that are frequently considered to be superior to those derived from essential distance classifiers (Campbell, 2002). The ISODATA cluster algorithm is an iterative process for computing the minimum Euclidian distance[1] when assigning each candidate cell to a cluster (Richards, 1986). The ISODATA also requires the user to define/input the maximum number of classes' desired, maximum number of iterations for the algorithms, and the threshold value for the mean inter-center Euclidian distance. The process starts with arbitrary means being assigned to the closest of these means but for all the multidimensional attribute space only. New means are recalculated for each cluster based on the attribute distances of the cells that belong to the clusters after the first iteration trials. The process is repeated until the closest mean in multidimensional attribute is obtained. This may be specified through forming number-iteration for each cluster to minimize the migration of cells to one another and stabilize the clusters.

In general, unsupervised classification is a process that uses statistical clustering approaches to combine pixels into clusters /classes; based on the degree of similarities of their brightness value in each spectral band. The analyst then combines spectral classes into real land cover type using maps and field based knowledge. The analyst should understand the spectral characteristics of the terrain in the area of interest well enough to properly label certain clusters into a specific information class (land cover type).using the combination of similar spectral bands in amalgamating with field knowledge and understandings of the study area characteristics, many spectral classes can be assigned to a few land cover types (Jensen, 1996).

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[1] In mathematics, the Euclidian distance/Euclidean metric is the ordinary distance between two points in Euclidian space, and with this distance, Euclidian space becomes a metric space. But in, unsupervised classification it relies on clustering algorithms to automatically segment the training data into prototype classes, supposing of each training class is represented by a prototype (mean vector) and given by: $mj = \frac{1}{Nj \sum_{zewj} x \; for \; j=1,2,...M} = Dj\,(x) = \| x - mj \| \; for \; j = 1,2, ... M$

2.4.4.2.2. Supervised Classification

Supervised classification is the process of grouping pixels using a known identity of specific sites (i.e., pixels already assigned to informational classes) to classify pixels of unknown identity (i.e., to assign unclassified pixels to one of the several informational classes (Cambell, 2002). Knowledge of study area, aerial photography, and experience with remotely sensed data etc. are required before undergoing training samples. Thus, by using the results of the training samples/sites expand to the remainders of the image, which confirm homogeneity of the pixels able to form members of the same land use/cover types.

2.4.4.2.3. Hybrid Classification

As the name indicate hybrid classification system considers both unsupervised and supervised classification systems, and also called guided classification approaches. An unsupervised classification is initially performed to identify spectral differences within the data and then a supervised classification is performed using areas of the unsupervised classification as training data in addition to ground verifications through field survey. Using the hybrid of the two classification approaches have an advantage of offering the analyst indentifying the various spectral subclasses representing information class automatically through clustering, and hence, the process of labeling the spectral clusters is straight forward due to the developed wide information class. Hybrid classifiers have also been observed to be of particular value in the analysis where there is complex variability in the spectral response patterns of individual cover types, a condition that is quite common in vegetation mapping (Lillesand and Kiefer, 2000).

2.4.5. Selection of Change Detection Algorithms

Algorithms[2] is techniques able to solve problems following step by step procedures, and hence change detection algorithms refers to a step by step methods of offering change or non-change, and directions/matrices of changes through image differencing, image rationing,

[2] "What is a computer algorithm?"(2001). HowStuffWorks.com. http://computer.howstuffworks.com/question717.htm; accessed on 12 February 2015.

vegetation index differencing, and PCA; and post classification (i.e., detecting detailed changes *"from-to"* among the different land uses) and hybrid classifications respectively (Lu *et al.,* 2004). The detection of binary change or non-change techniques required the attainment of thresholds in both tails of the histograms representing the changed areas (Singh, 1989). The selection of thresholds is through interactive/manual trial and error procedure, and Statistical measures from which suitable standard deviations are selected from the mean (Makaio and Watts 1997).

In general, although a large number of change detection applications have been found and tested so far no single of it is suitable for all cases; and hence, the selection of which method is best suited to specific study site relies on the characteristics of the study area, analyst knowledge and skill, remotely sensed data etc. (Lu *et al,* 2011).

2.4.6. Accuracy Assessment of Change Detection Results

Accuracy assessment is the process of confirming the quality of data generated from the remotely sensed data through applying location and classification accuracy type (Congalton and Green, 1999). Location accuracy deals with crosschecking what is found on the image mapped with the reality exist on the ground, whereas, classification accuracy assessment which arise from map error need to compare map data with reference/ground data, since ground truth assumed to be 100% perfect (Congalton and Green, 1999). But, the problem is the complexity and costly nature of the verification of remotely sensed data with ground realities coupling with immature development of advanced measures of accuracy assessments affect change detection results (Lu. *et al*, 2011). Hence, Standard accuracy assessment techniques have been developed mainly for single-date remotely sensed data. Standardized single date remotely sensed data accuracy assessments includes;

- The error matrix-based accuracy assessment method- the most common and valuable method for the evaluation of change detection results;
- Accuracy Assessment curves- analyze satellite-based change detection (Morisette and Khorram, 2000);

- An area-based accuracy assessment method- analyzes change maps (Lowell, 2001); and,
- A Monograph titled "Accuracy Assessment of remotely sensed-derived change detection," (Biging *et al.* 1999) - specifically focused on the accuracy assessment of land-cover change detection.

2.5. Impact of land use changes on sustainability of natural resources

All across Sub Saharan Africa increasing population pressures have led to increases in cultivation and grazing intensity. This has led to massive deforestation and conversion of natural habitats to farmlands and settlements with implications on biodiversity and land degradation (Olson, Misana, Campbell, Mbonile, and Mugish, 2004(a)). Deforestation is one of the most pressing environmental problems faced by almost all sub-Saharan African nations including Ethiopia, from which fuel wood took a lion's share. Many sub-Saharan countries have had over three quarters of their forest cover depleted and lead to dying many of their wet lands. The highest rates of deforestation occur in areas with large growing populations such as the lake basin area and the surrounding highlands (Allen and Barnes 1985).

Productivity of farms has reduced in the intensively cultivated areas due to poor soils (Southgate 1990). In the areas where land is still available there are extensions of cultivations to replace the loss in production brought about by poor soils, but land subdivision is reducing available land slowly and the land use systems are becoming intensively managed. Farming, grazing and settlements have expanded at the expense of wet lands, dried areas of water bodies especially the lake basins. As wet lands and lake basins are lost, indigenous marine species and animal biodiversity are lost. As croplands expand, soil fertility and moisture drops and wet lands dying more easily.

Moreover, Irrigation for crops also pollutes water sources. For instance, researchers indicate that in the Lake Victoria basin non point pollution caused by agricultural chemicals in the uplands is far more significant than even pollution from municipal wastes (FAO 2001).

Furthermore, an intensive study conducted by (ICRAF, 2004) over several years has revealed a huge amount of loss of soil by erosion and sedimentation in the lake basin from the productive land. These massive soil translocations are mainly facilitated though the activities of human beings and livestock grazing systems. There is need for an urgent solution to reduce the rates of current soil erosion and land use changes in the lake basin to sustain the life span of the lakes (Olson, J, *et al*, 2004).

2.6. International Experiences on the causes of lake water volume change

Lakes are particularly vulnerable to changes in climate parameters that caused by different impacts of socio-economic activities of human beings. Notably, land use changes, agricultural expansions', sedimentation, variations in air temperature and precipitation, and other meteorological components directly cause changes in evaporation, water balance, lake level, and the entire lake ecosystem.

Under some climatic conditions, lakes may disappear entirely. There are many different types of lakes, classified according to lake formation and origin, the amount of water exchange, hydrochemistry, and so forth. An important distinction is drawn between closed (endorheic) by out flowing rivers. Endorheic lakes are very dependent on the balance of inflows and evaporation and are very sensitive to change in either (whether driven by climate change, climatic variability, or human interventions). This also means that they are very important indicators of climate change and can provide records of past hydroclimatic variability over a large area (Kilkus, 1998). Small endorheic lakes are most vulnerable to a change in climate; there are indications that even relatively small changes in inputs can produce large fluctuations in water level (and salinity) in small closed lakes in western North America (Laird *et al.*, 1996).

The largest endorheic lakes in the world are the Caspian and Aral Seas, Lake Balkash, Lake Chad, Lake Titicaca, and the Great Salt Lake. Some of the largest east African lakes, including Lakes Tanganyika and Malawi, also can be regarded as practically endorheic. Changes in inflows to such lakes can have very substantial effects: The Aral Sea, for example, has been significantly reduced by increased abstractions of irrigation water upstream, the Great Salt Lake in the United States has increased in size in recent years as a result of increased precipitation in its catchment, and Qinghai Lake in China has shrunk following a fall in catchment precipitation. Many endorheic lake systems include significant internal thresholds, beyond which change may be very different. Lake Balkash, for example, currently consists of a saline part and a fresh part, connected by a narrow strait. Several rivers discharge into the fresh part, preventing salinization of the entire lake. A reduction in freshwater inflows, however, would change the lake regime and possibly lead to salinisation of the freshwater part; this would effectively destroy the major source of water for a large area.

Exorheic lakes also may be sensitive to changes in the amount of inflow and the volume of evaporation. Evidence from Lake Victoria (east Africa), for example, indicates that lake levels may be increased for several years following a short-duration increase in precipitation and inflows. There also may be significant thresholds involving rapid shifts from open to closed lake conditions. Progressive southward expansion of Lake Winnipeg under postglacial iso-static tilting was suppressed by a warm dry climate in the mid-Holocene; when the north basin of the lake became closed (endorheic) and the south basin was dry (Lewis et al., 1998). A trend of progressively moister climates within the past 5,000 years caused a return from closed to open (overflowing) lake conditions in the north basin and rapid flooding of the south basin about 1,000 years later. Other examples include Lake Manitoba, which was dry during the warm mid-Holocene (Teller and Last, 1982).

Computations of sustainable lake area under equilibrium water balance (Bengtsson and Malm, 1997) indicate that a return to dry conditions comparable to the mid-Holocene climate could cause this 24,400-km lake draining a vast area from the Rocky Mountains east almost to Lake Superior to become endorheic again (Lewis *et al.*, 1998).

CHAPTER THREE

FINDINGS AND DISCUSSIONS

3.1. Findings

3.1.1. Land use/cover Change

3.1.1.1. Land Use/Cover types in Chelekleka Lake Water Shades and its surroundings 1973-2010

A shown in table 3, in 1973 surface water body, swampy vegetation, forest land, Shrub land, Grass land, Crop land, bare land, and Settlement covers comprised 609.9, 1085.8, 4587.1, 6479.1, 9910.4, 53297, 2000.1, and 385.2hectares from the total 78354.5 hectares in Chelekleka Lake watersheds and its surroundings respectively. Majority of the land use/cover in this period of investigation occupied by crop land (68%), which followed by grass land (12.6%) and shrub land (8.3%). The remaining land use/ covers especially like Surface Water body, Swampy Vegetation, Bare land, and population Settlement areas composed of very in significant composition in the study area for the period of 1973.

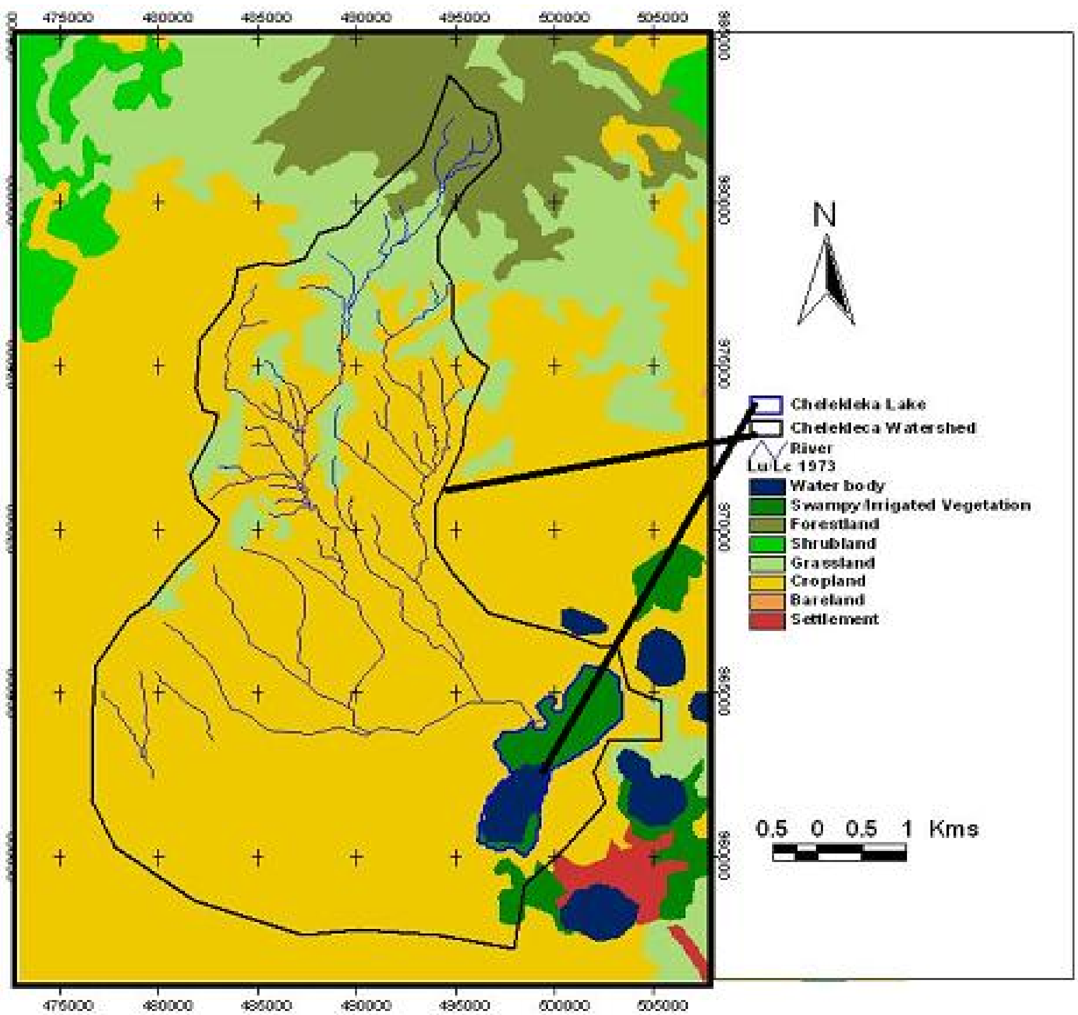
Table 3: land Use/Cover Type of the 1973

No.	Lu/Lc type	1973	
		Ha.	%
1	Surface Water body	609.9	0.78
2	Swampy Vegetation	1085.8	1.4
3	Forest land	4587.1	5.9
4	Shrub land	6479.1	8.3
5	Grassland	9910.4	12.6
6	Crop land	53297	68
7	Bare land	2000.1	2.6
8	Settlement	385.2	0.5
	Total 1973	78354.5	100

Source: satellite Image Land use/Cover Output in 1973

In addition land use/cover change analysis in fig. 2 shown, in 1973 majority of the southern, western, Central and eastern parts of the of Chelekleka Lake Watersheds and its surroundings were dominantly covered by agricultural/crop lands; whereas, most of northern areas, north eastern and western parts, and south eastern areas were broadly covered by forest lands, shrub lands, and water bodies respectively. In the same period, population settlement was only found in southern eastern parts of the watersheds and its surroundings' i.e., very near to the lakes areas (fig. 2).

Figure 2: Land use/Land cover Map of Chelekleka Lake Watersheds and its surroundings 1973



During the period of 1986 land use/cover change analysis in Chelekleka Lake Watersheds and its surroundings, tremendous decline of forest lands, shrub lands, and swampy vegetation covers compared with 1973 data, i.e., reduced from 4587.1, 6479.1, and 1085.8hectares to 3876.2, 2761.5, and 654.3 hectares in 1986 (table 4 and figure 3). This shown deforestation and land degradation in the Chelekleka Lake Watersheds and its surroundings was very sever, and exacerbate rate of sedimentation which reduce depth of the lake and inflate surface water coverage from 0.78% to 0.96%.

Table 4: Land Use/Cover type 1986

		1986	
No.	Lu/Lc type	Ha.	%
1	Surface Water body	751.1	0.959
2	Swampy Vegetation	654.3	0.8
3	Forestland	3876.2	4.9
4	Shrub land	2761.5	3.5
5	Grassland	12758.4	16.3
6	Cropland	54990.2	70.2
7	Bare land	2109.2	2.7
8	Settlement	434.1	0.6
	Total 1973	78334.9	100

Moreover, during the period of 1973 to 1986, majority of the forest lands and shrub areas from which the water streaming in to Lake Chelekleka changes to grass lands, crop lands and bare-degraded lands. As a result, the mentioned land use/cover was increased from 9910.4, 53297, and 2000.1hectares to 12758.4, 54990.2, and 2109.2 hectares of land use/covers between 1973 to1986.

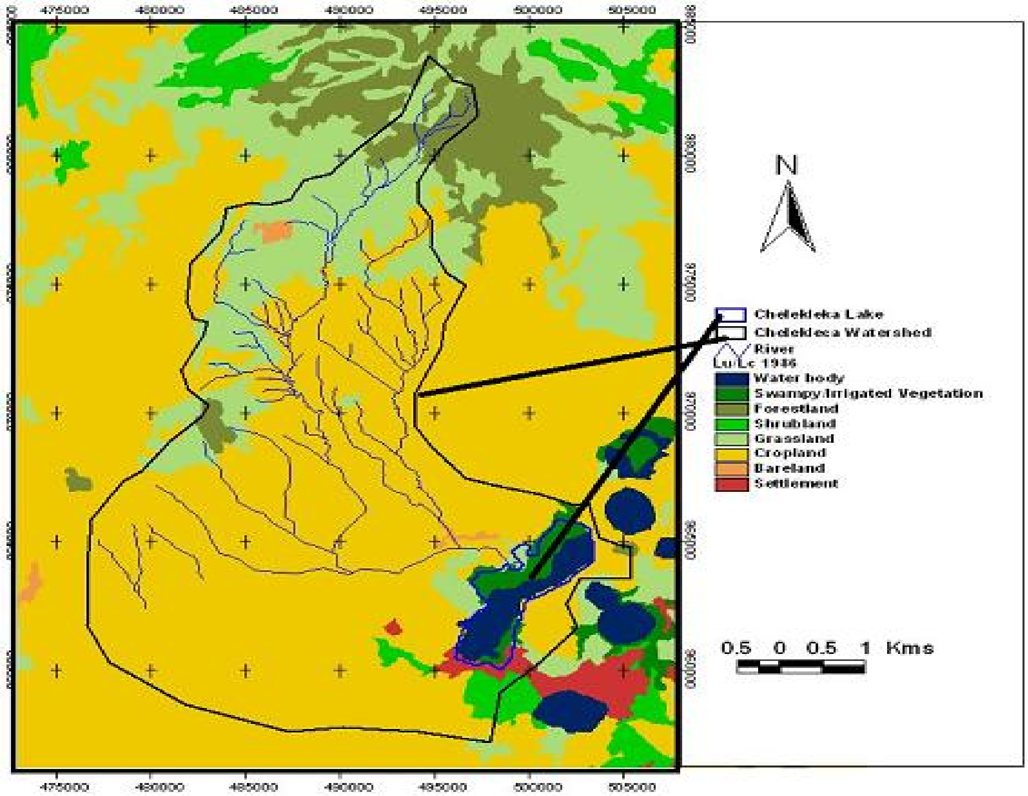


Figure 3: Land use/cover Map of Chelekleka Lake Watersheds and its surroundings 1986

Whereas, during the period of 1986 to 2000 due to the Derge Regime afforestation program forest cover areas shown progress and broadly extend to grass land use/cover areas, but degraded bare land coverage was increased because of acute land use changes in the basin and its surroundings'. Contrary, the extent of shrub land use/cover change was very drastic between 1986 and 2000 in Chelekleka Lake Watersheds and its surroundings, and converted to agricultural/crop lands and bare-degraded land use/cover areas. That is the analysis confirmed, as former crop areas occupied by population settlements, crop land areas expands to shrub and uncultivable land uses. Hence, settlement coverage was jumped to 0.6% to 2% during 1986 and 2000 (table 5).

Table 5: Land Use/ Cover type 2000

No.	**Lu/Lc type**	2000	
		Ha.	%
1	Surface Water body	843.75	1.077
2	Swampy- irrigated Vegetation	2108.2	2.7
3	Forestland	5621	7.2
4	Shrub land	854.5	1.1
5	Grassland	9259	11.8
6	Cropland	55565.6	70.9
7	Bare land	2560.6	3.3
8	Settlement	1542.2	2
	Total	78354.9	100

Moreover, in this period notably degraded bare lands were exclusively occupied much parts of North central, and western part of areas of Chelekleka watersheds, and similarly irrigated vegetations also occupied the swampy areas of Chelekleka lake (see fig 4). Crop land covers within the watersheds were aggressively occupied by settlements, degraded-bare lands, and irrigated vegetations which negatively affect the lives of Lake Chelekleka through sedimentation and siltation besides massive use for irrigation purposes following the drying catchment of the lake.

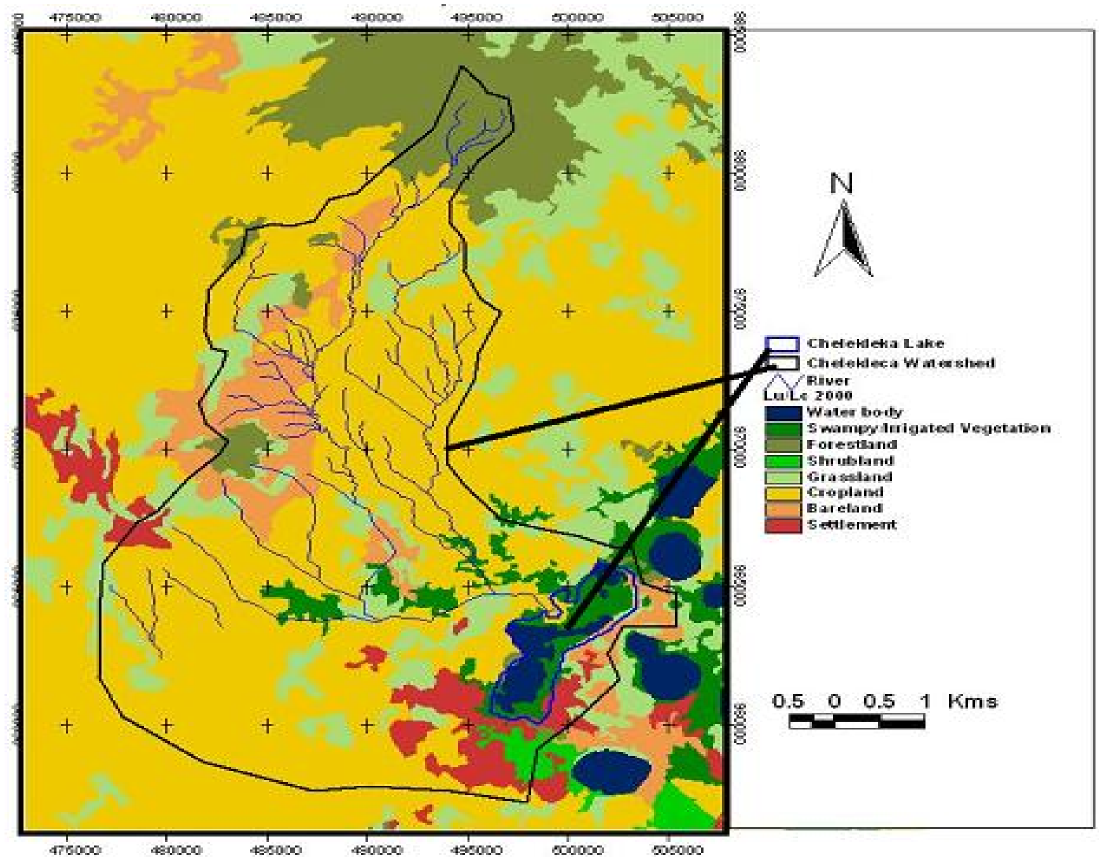


Figure 4: Land use/cover Map of Chelekleka Lake Watersheds and its surroundings 2000

Contrary to the above, during the period of 2000 to 2010 there was observed massive reduction of surface water coverage. That means there are a clear loss of water sources, as the land use changes within the basin and its surroundings are very acute. Hence, it accompanied by overwhelming increase of degraded-bare lands, rapid growth of population settlement, i.e., increased from 2560.6, 1542.2 to 3752, 2846 hectares of land (fig.5).

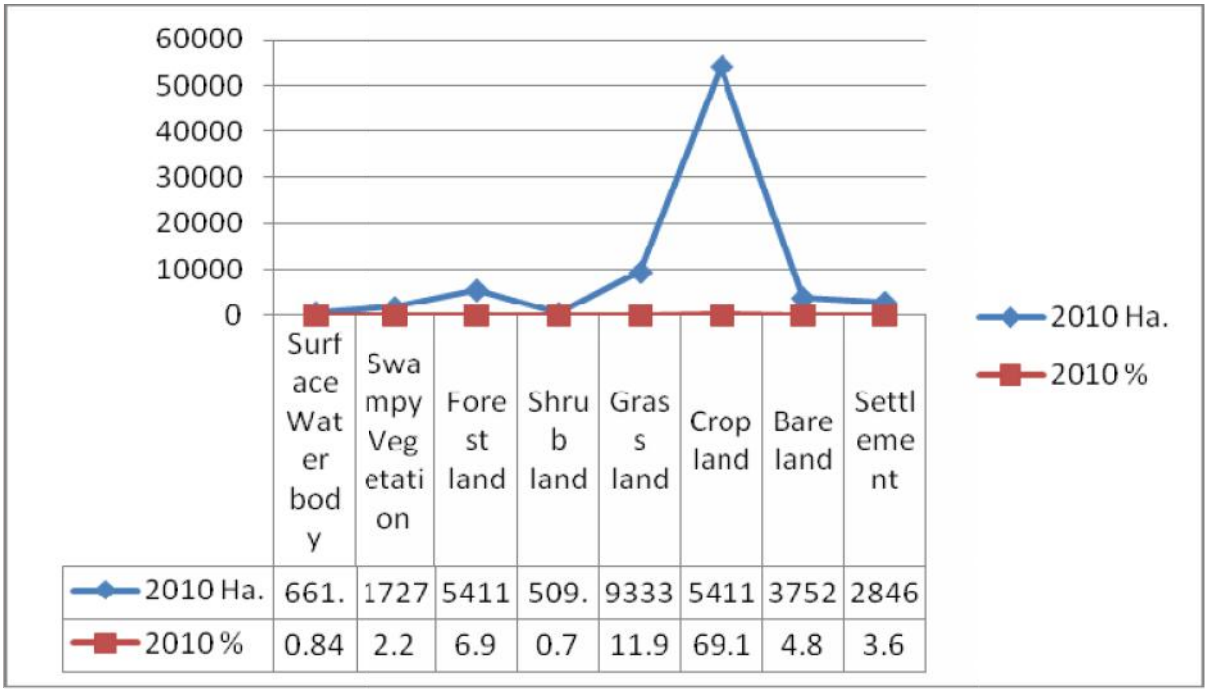


Figure 5: land use/cover types in 2011

Moreover, fig 6 displays, the major factors for the change of water volume during the period of 2000 to 2011 in the Chelekleka watersheds and its surroundings' were broadly because of:

1. Acute increase of degraded bare lands from increased from 2560.6 (3.3%) to 3752 (4.8%);
2. Rapid Population settlement coverage increase from 2846 (2%) hectares to 1542.2 (3.6%);
3. Deforestation of Forest land covers which resulted in reduction of 5621 (7.2)% hectares to 5411(6.9%) in the Chelekleka watersheds and its surroundings'.

Hence, the surface coverage found in the watershed during this period reduced from 843.75 (1.077%) to 661 (0.84%), and accompanied by loss of swampy vegetation-which found near to the lake from 2108.2 (2.7%) to 1727 (2.2%).

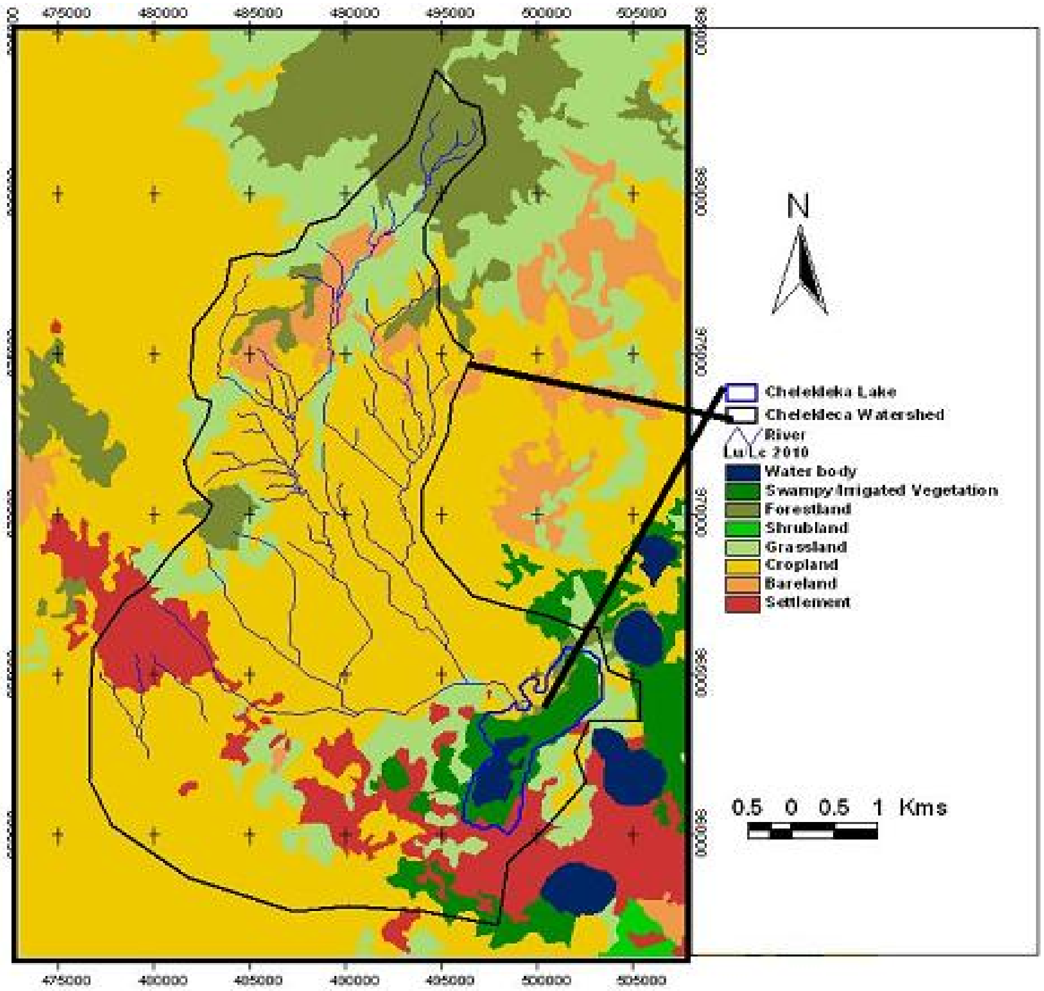


Figure 6: Land use/cover Map of Chelekleka Lake Watersheds and its surroundings 2010

3.1.1.2. Land use/cover Change Comparison in Chelekleka Lake Watersheds and surroundings During (1973 – 2010)

The results of the change comparison (table 6) with regard to water volume in the Chelekleka Lake watersheds and surroundings' verified both positive and negative changes during different periods of the land use/cover change investigations. Accordingly, it exhibited positive changes during 1973-1986, 1973-2000, 1973-2010, and 1986-2000 with increment rate of surface coverage 141.120, 233.820, 51.570, and 92.700 hectares respectively. But during the 1986-2010, and 2000 – 2010 the water surface coverage reduced by -658.350 (-24.266%), and -182.250(-21.6%) hectares respectively. The reductions of surface water were notably in the latter cases associated with;

- Forest land cover losses during 2000 – 2010 by -210.06 (-3.7%) hectares of land covers respectively;
- Shrub land deforestation during 1986-2010 to 2000 – 2010 by -4668.48 (-12.5%) and -344.97 (-40.4%) respectively;
- As a result of this acute deforestation in the basin and its surroundings' during 1986-2010 to 2000 – 2010 by degraded –bare lands were increased by 1657.89 (56.5%) hectares, and 1191.78 (465%) respectively;
- Moreover population settlements also expands to the lost resource areas during the same period and increased by 1674.1 hectares and 1304.1 hectares of land covers within the basin and its surroundings' during 1986-2010 to 2000 – 2010.

Table 6: Land use/cover Change Comparison in Chelekleka Lake Watersheds and surroundings during (1973 – 2010)

Lu/Lc type	Change 1973-1986		Change 1973-2000		Change 1973-2010		Change 1986-2000		Change 1986-2010		Change 2000 - 2010	
	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
Water body	141.120	23.137	233.820	38.336	51.570	8.455	92.700	12.343	-658.350	-24.266	-182.250	-21.600
Swampy[3] Vegetation	-431.5	-39.7	1022.4	94.2	641.0	59.0	1453.9	222.2	799.6	-58.3	-381.4	-18.1
Forest land	-710.9	-15.5	1033.92	22.5	823.86	18.0	1744.83	45.0	-2131.38	-5.4	-210.06	-3.7
Shrub land	-3717.6	-57.4	-5624.64	-86.8	-5969.61	-92.1	-1907.01	-69.1	-4668.48	-12.5	-344.97	-40.4
Grassland	2848.1	28.7	-651.33	-6.6	-577.44	-5.8	-3499.38	-27.4	-16257.8	-0.6	73.89	0.8
Cropland	1693.2	3.2	2268.63	4.3	817.56	1.5	575.46	1.0	-54414.7	-2.6	-1451.07	-2.6
Bare land	109.2	5.5	560.52	28.0	1752.3	87.6	451.35	21.4	1657.89	56.5	1191.78	46.5
Settlement	48.9	12.7	1157.04	300.4	2461.14	638.9	1108.17	255.3	1674.1	300.4	1304.1	84.6
Total	-19.6	0.0	0.36	0.0	0.36	0.0	19.98	0.0	00	0.0	0	0.0

[3] swampy Vegetation - for the year before 2000, Irrigated horticulture for the recent years

3.1.1.3. Types and extents of Land Use/Cover Changes in Chelekleka Lake Watersheds (1973-2010)

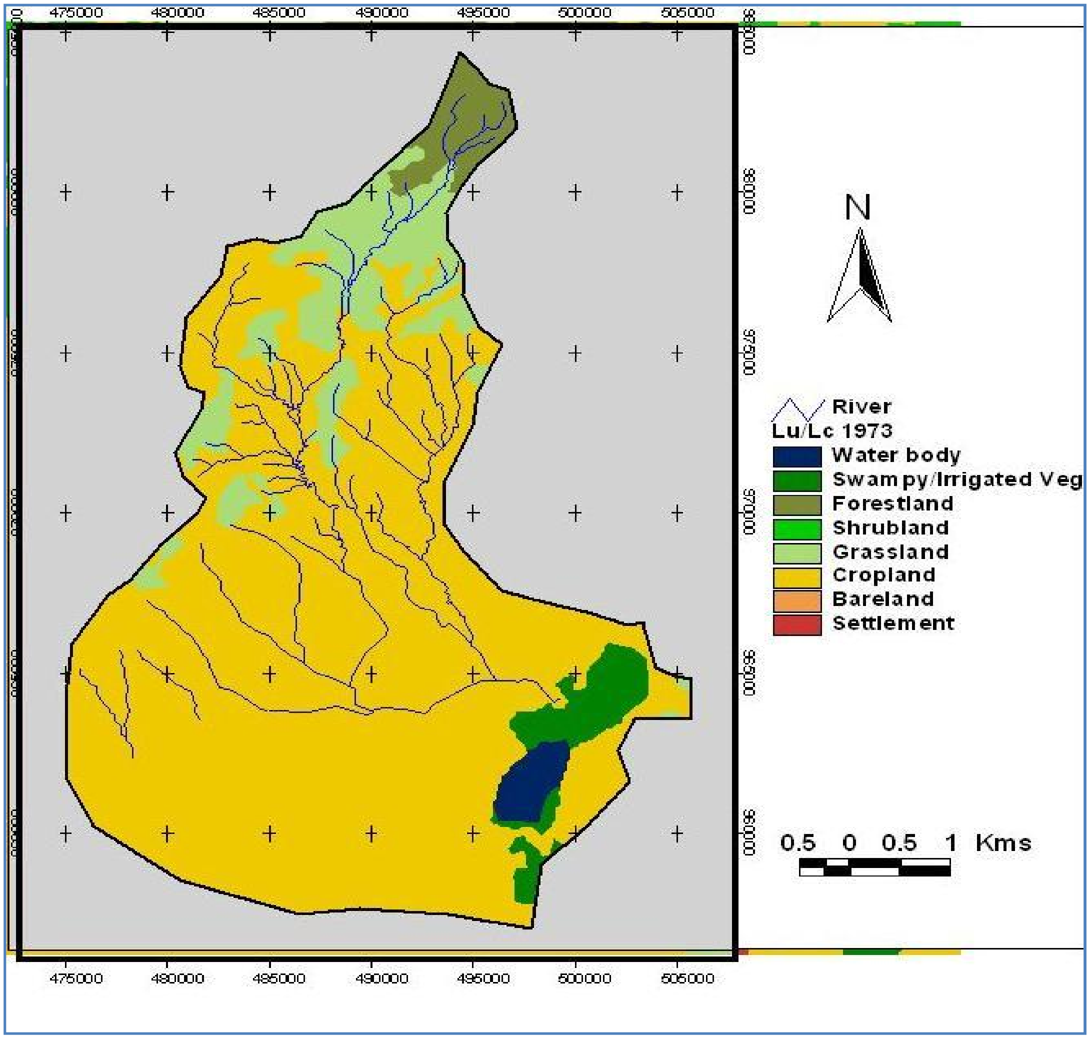
3.1.1.3.1. Types of Land Use/Cover Changes

The extent of land use/cover change in the Chelekleka watersheds during the investigation of 1973 shown, about 134.5 (1.4%), 338.0(3.6%), 286.6 (3%) 1049.2 (11%), and 7692.3 (81%) hectares of land use were covered by Surface Water body, Swampy Vegetation, Forestland, Grass land, and Crop land respectively (table 7). During the same period all most all of the land covers was occupied by crop lands, even as compared to the analysis result of Chelekleka watersheds and surrounding in the same period.

Table 7: types of Land Use/Cover Changes in Chelekleka Lake Watersheds1973

No.	Lu/Lc type	1973	
		Ha.	%
1	Surface Water body	134.5	1.4
2	Swampy Vegetation	338.0	3.6
3	Forestland	286.6	3.0
4	Shrub land	0.0	0.0
5	Grassland	1049.2	11.0
6	Cropland	7692.3	81.0
7	Bare land	0.0	0.0
8	Settlement	0.4	0.0
	Total	9500.9	100.0

Moreover, displayed fig 7 the land use /cover change investigation verified the absence of degraded-bare lands, shrub lands, and population settlements during the 1973. That means, all most no or insignificant rate of deforestation and soil degradation within the watersheds in this period though dominantly covered by crop lands.

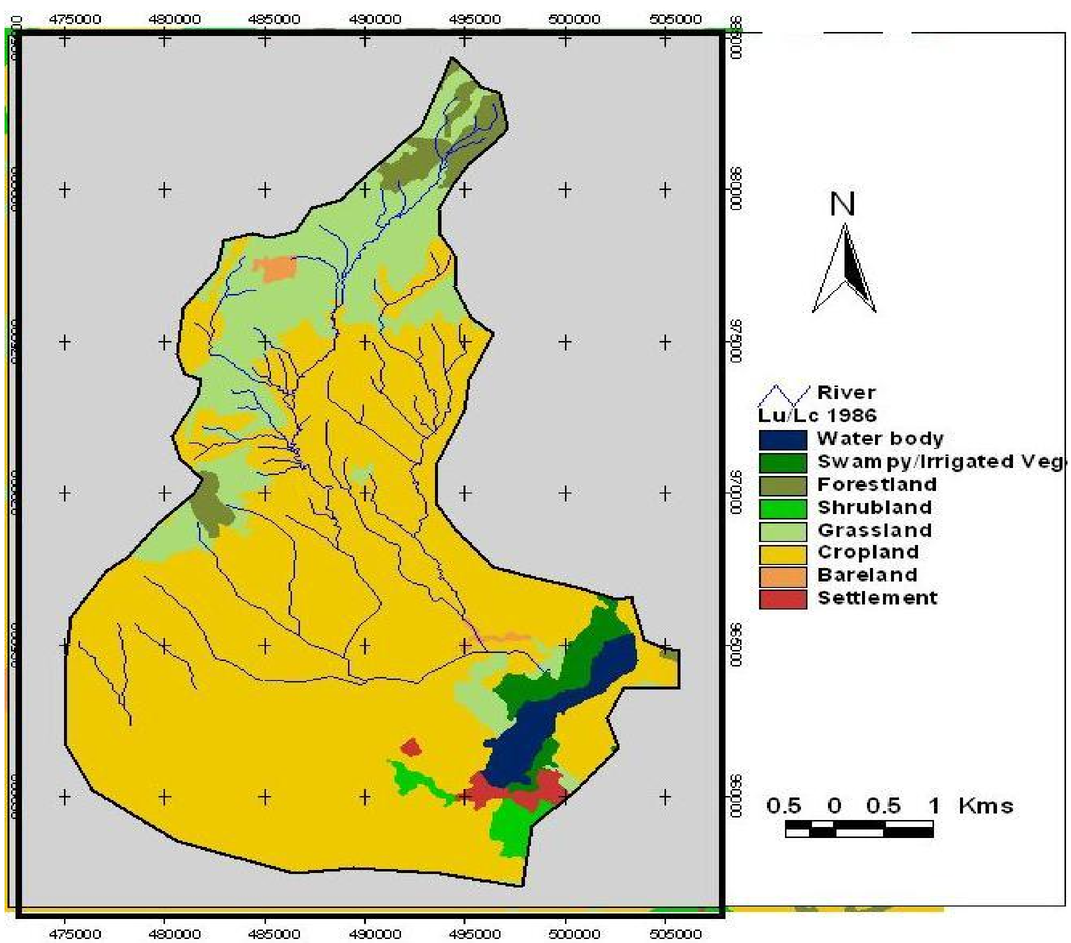

475000
480000
485000
490000
495000
500000
505000
N
River
Lu/Lc 1973
Water body
Swampy/Irrigated Veg
Forestland
Shrubland
Grassland
Cropland
Bareland
Settlement
0.5 0 0.5 1 Kms

denudation, siltation and sedimentation of eroded materials in the water bodies, which uplift its catchment areas.

Table 8: Land Use/Cover Changes in Chelekleka Lake Watersheds 1986

No.	Lu/Lc type	1986	
		Ha.	%
1	Surface Water body	230.1	2.4
2	Swampy Vegetation	200.2	2.1
3	Forestland	278.0	2.9
4	Shrub land	113.3	1.2
5	Grassland	1596.9	16.8
6	Cropland	6937.0	73.0
7	Bare land	53.9	0.6
8	Settlement	91.4	1.0
	Total	9500.9	100.0

Moreover, the north western part of the Chelekleka watersheds dominated by grass lands which was previously occupied by forest and shrub lands. The forest deforestation even aggressively seen at the upper parts of the watersheds at Yerer Mountain, which is the source of many permanent and intermittent rivers, and streams including the Dukem rivers. The exacerbated deforestation in this upper parts of water sources negatively affect the down wards swampy areas near to Bushofitu and Dukem, among these areas lake Chelekleka and its swampy is the most adversely affected sites. In addition the land use/cover change investigation results revealed in fig. 8 below confirm, around the lake Chelekleka there was noticeable initial expansion of small scale irrigated swampy land uses especially to the northern and south eastern part the lake, and also accompanied by rapid population settlement expansion in southern and south eastern parts of the Chelekleka lake.


475000
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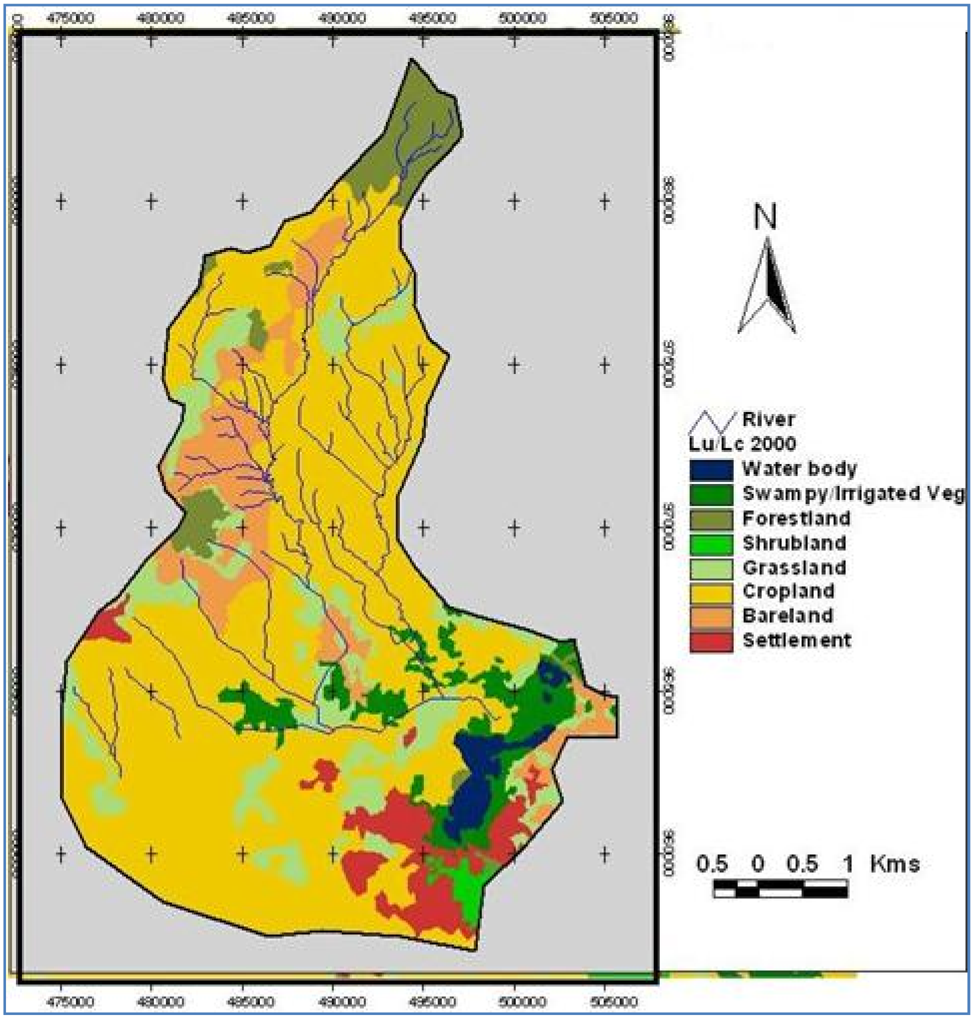
505000
N
River
Lu/Lc 1986
Water body
Swampy/Irrigated Veg
Forestland
Shrubland
Grassland
Cropland
Bareland
Settlement
0.5 0 0.5 1 Kms

Furthermore, the land use/cover change detection during the period of 2000 verified in the Chelekleka watersheds, surface water body coverage confirmed acute reduction notably near to Lake Chelekleka, i.e., decreased from 2.4% to 1.9% in the watersheds (table 9). The change in the surface water coverage during this period highly associated with dramatic land use/cover change growth in degraded bare lands and population settlements from 0.6 and 1% during 1986 to 9.5% to 5.2% respectively.

Table 9: Land Use/Cover Changes in Chelekleka Lake Watersheds 2000

No.	Lu/Lc type	2000	
		Ha.	%
1	Surface Water body	178.830	1.9
2	Swampy Vegetation	534.2	5.6
3	Forestland	481.5	5.1
4	Shrubland	71.8	0.8
5	Grassland	1129.8	11.9
6	Cropland	5709.0	60.1
7	Bareland	900.9	9.5
8	Settlement	494.8	5.2
	Total	9500.9	100.0

An expansion of the bare lands within the watersheds first start from the upper parts of the watersheds (fig. 9), and slowly expands downstream to Chelekleka Lake. This degraded bare land was caused by massive land use for agricultural purposes. Because availing the degraded land uses during this period, was formerly occupied by crop lands in 1973 and 1986 land use /cover change detection in watersheds. So it possible to generalize agricultural expansion within the watersheds played a greater role for land degradation and deforestation; which was most influential agent ultimately intensifies the dying of Lake Chelekleka and its swampy areas.

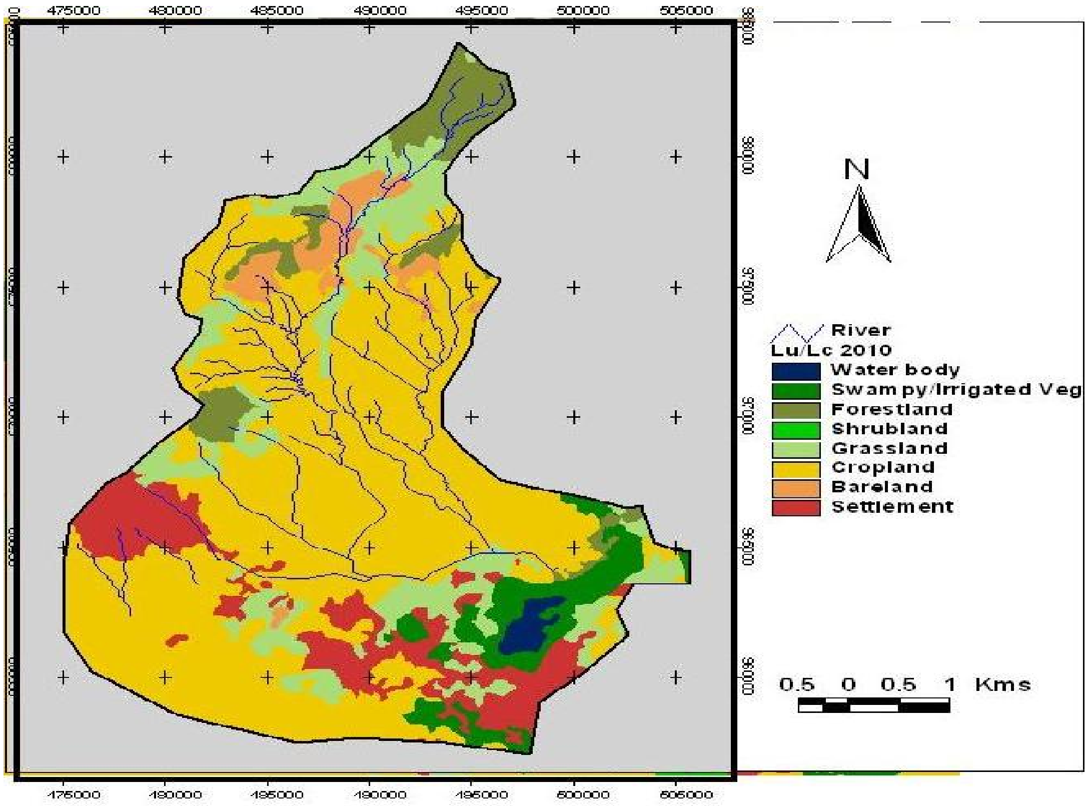


N
River
Lu/Lc 2000
Water body
Swampy/Irrigated Veg
Forestland
Shrubland
Grassland
Cropland
Bareland
Settlement
0.5 0 0.5 1 Kms
475000
480000
485000
490000
495000
500000
505000

Table 10: Land Use/Cover Changes in Chelekleka Lake Watersheds 2010

No.	Lu/Lc type	2010	
		Ha.	%
1	Surface Water body	83.2	0.88
2	Swampy Vegetation	534.6	5.6
3	Forestland	582.2	6.1
4	Shrub land	0.0	0.0
5	Grassland	1324.2	13.9
6	Cropland	5584.9	58.8
7	Bare land	356.0	3.7
8	Settlement	1035.8	10.9
	Total	9500.9	100.0

Besides, population settlements dominated the Southern, south western and western parts of the Chelekleka lake watersheds. Most of these land uses currently covered by settlements formerly covered by agricultural lands, and hence reduces agricultural lands from 60.1% during the 2000 to 58.8% in 2010 land use /cover change detection (table 10, and fig. 10).



475000
480000
485000
490000
495000
500000
505000
N
River
Lu/Lc 2010
Water body
Swampy/Irrigated Veg
Forestland
Shrubland
Grassland
Cropland
Bareland
Settlement
0.5 0 0.5 1 Kms

Table 11: Land use/cover Change Comparison in Chelekleka Lake Watersheds during (1973 – 2010)

Lu/Lc type	Change 1973-1986		Change 1973-2000		Change 1973-2010		Change 1986-2000		Change 1986-2010		Change 2000 - 2010	
	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
Water body	95.670	71.151	44.370	32.999	-51.300	-38.153	-52.300	-22.292	-281.430	-41.572	-95.670	-53.498
Swampy[4] Vegetation	-137.8	-40.8	196.3	58.1	196.7	58.2	334.1	166.9	133.9	0.2	0.4	0.1
Forest land	-8.6	-3.0	194.94	68.0	295.65	103.2	203.49	73.2	-74.52	36.2	100.71	20.9
Shrub land	113.3	#DIV/0![5]	71.82	#DIV/0!	0	#DIV/0!	-41.49	-36.6	-154.8	-63.4	-71.82	-100.0
Grassland	547.7	52.2	80.55	7.7	274.95	26.2	-467.1	-29.3	-2063.97	12.2	194.4	17.2
Crop land	-755.3	-9.8	-1983.33	-25.8	-2107.44	-27.4	-1228.05	-17.7	-8165.07	-1.8	-124.11	-2.2
Bare land	53.9	#DIV/0!	900.9	#DIV/0!	356.04	#DIV/0!	846.99	1571.1	793.08	-1010.7	-544.86	-60.5
Settlement	91.1	25300.0	494.46	137350.0	1035.45	287625.0	403.38	441.1	311.94	591.6	540.99	109.3
~~Total~~	~~0.0~~	~~0.0~~	0.0039	0.0	0	0.0	0.0039	0.0	-9500.85	0.0	-0.0039	0.0

[4]Swampy Vegetation - for the year before 2000, Irrigated horticulture for the recent years

[5] These symbols happened, when the percentage change to successive period of investigation become positive numbers but it is zero at former period of investigation, which ultimately create the denominator zero ***(undefined).*** For instance, for this column the amount of shrub land use in 1986 is 113.3 hectares of land, but it was zero in 1973 land use/cover change detection. Hence, its (113.3- 0)/0*100 = ***Undefined***

3.1.1.4. Land use/Cover Change with specific to Lake Chelekleka and Swampy Area during the period of 1973-2010

3.1.1.4.1. Land use/Cover Change types

As displayed in table 12 below during the 1973 land use /cover change detection, Chelekleka and its Swampy area composed of two land use types; namely the lakes main water body part and its surrounding Swampy dominantly in the northern and some extent southern parts. Accordingly, during this period the lake water body covers about 134 hectares of land use, and the Swampy area covered 288.5 hectares of the land use. The swampy land use occupied more than double the exact size of Lake Chelekleka (table 12). Moreover, during this period of land use/cover change investigations no other any type of land use/cover types was detected from land sat image.

Table 12: Lu/Lc change type with specific to Lake Chelekleka and Swampy Area in 1973

No.	Lu/Lc type	1973	
		Ha.	%
1	Water body	134	31.7
2	Swampy Vegetation	288.5	68.3
3	Grassland	0	0
4	Irrigated Horticulture	0	0
5	Settlement	0	0
	Total	422.4	100

Besides the above, during this period the lake's main water body had dark blue color and compact shape (fig. 11) which verified the presence of in depth water volume. Thus, it confirms presence of insignificant level of erosion from degraded bare lands and agricultural lands.

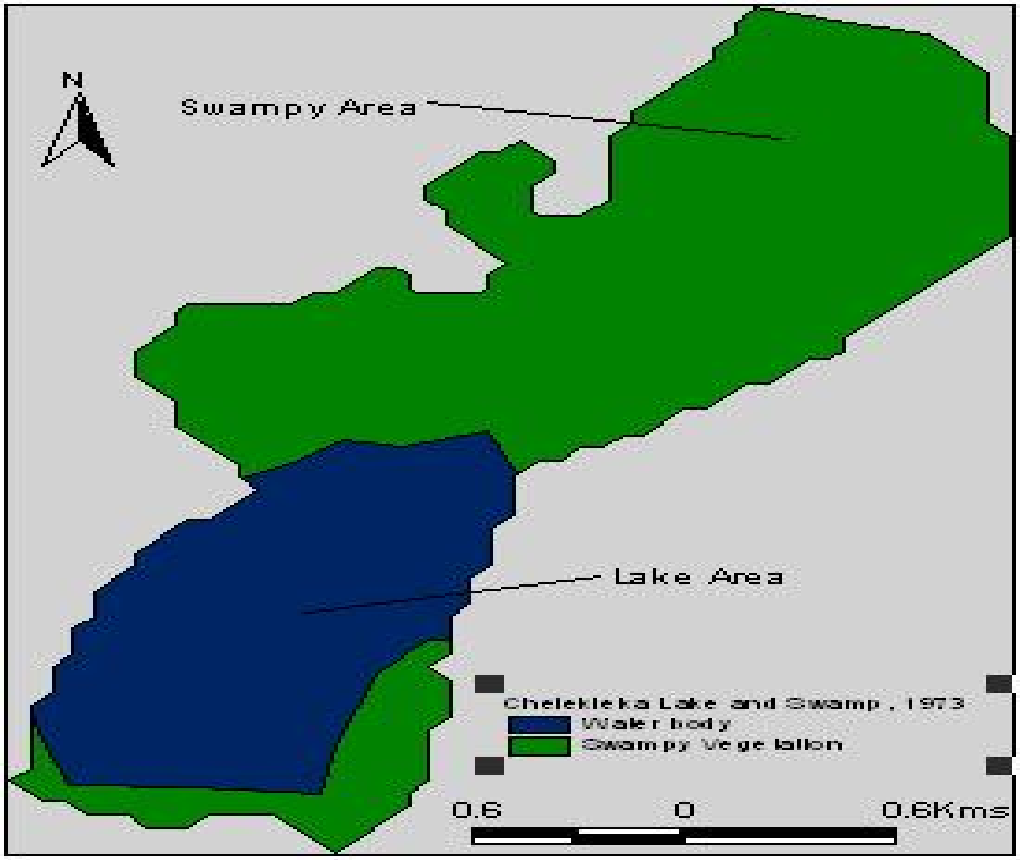


Figure 11: Land use/Land cover Map of Chelekleka & Swampy 1973

Contrary to the 1973 land use/cover change investigations, the 1986 land use/cover change detection shown Lake Chelekleka and Swampy areas characterized by five land use types. These includes, Water body, Swampy Vegetation, Grass land, Irrigated Horticulture, and Settlements which composed of 53.3%, 36.1%, 3.5%, 3.8%, and 3.3% from the total land covers during the 1986 (table 13). That means, the area of the lake's main body inflated its surface coverage areas, which arises from accumulation and sedimentation of different materials in the inner part of the lake. Hence, the lake's water expands to the nearby swampy areas, as its depth decreases during the time of considerations. Moreover, most part of the swampy vegetation cover areas during 1973 was changed to other land use/cover types, which includes Grass land, Irrigated Horticulture, and Settlements.

Table 13: Lu/Lc change with specific to Lake Chelekleka and Swampy Area in 1986

No.	Lu/Lc type	1986	
		Ha.	%
1	Water body	225.3	53.3
2	Swampy Vegetation	152.3	36.1
3	Grassland	14.6	3.5
4	Irrigated Horticulture	16.2	3.8
5	Settlement	14	3.3
	Total	422.4	100

In addition, the Land use/cover change detection for Lake Chelekleka & Swampy during the same period reveals, the presence of acute changes in the main water body of Lake Chelekleka both in shape and color. These changes made the lake to had diagonal long tail shape and light blue color, which characterize the shallowness of the lake; which obviously resulted from depth reduction of the lake (Fig. 12).

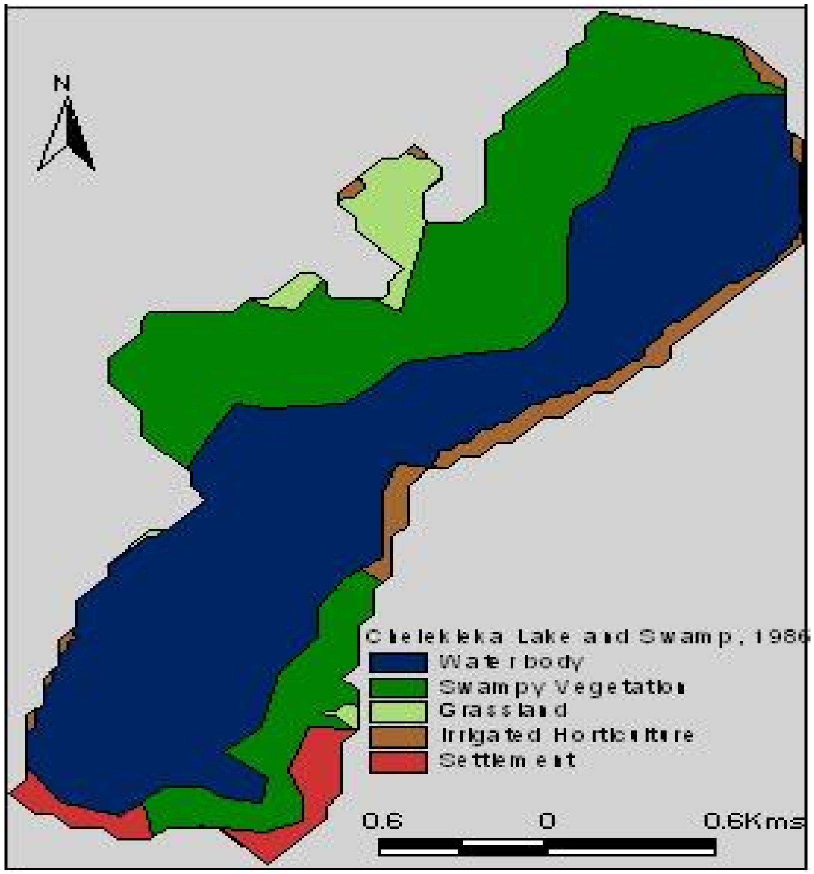


Figure 12: Land use/Land cover Map of Chelekleka & Swampy 1986

Furthermore, the surface water coverage of Lake Chelekleka and Swampy Area during the period of 2000 shown increasing but in dispatched way, and hence the surface water coverage increase was superficial not real and healthy growth (table 14). Major Factors responsible for this fact was the overwhelming expansion of irrigated horticultures in areas of previously covered by the lake's water body and its swamp's. Besides, the expansion of urban population settlement to the lake was also among the main factors which exacerbate the dying of Lake Chelekleka. Therefore, the analysis result generally confirms, unless urgent especial and timely consideration being taken by all concerned stakeholders so as to sustain the lives of the lake, the probability of losing this natural gift in very near future is not deniable facts.

Table 14: Lu/Lc change with specific to Lake Chelekleka and Swampy Area in 2000

No.	Lu/Lc type	2000	
		Ha.	%
1	Water body	232.85	55.12
2	Swampy Vegetation	94	22.2
3	Grassland	10.2	2.4
4	Irrigated Horticulture	73.1	17.3
5	Settlement	12.4	2.9
	Total	422.5	100

In conformity with the above discussions, the land use/cover change Map of Chelekleka & Swampy during 2000 (fig. 13) verified, inner and border areas of the lake Chelekleka was dramatically changed into irrigated vegetation and grass lands. Hence, during this period land use/cover change investigation, the dying of the lake was already starting from upper and expands to its central areas.

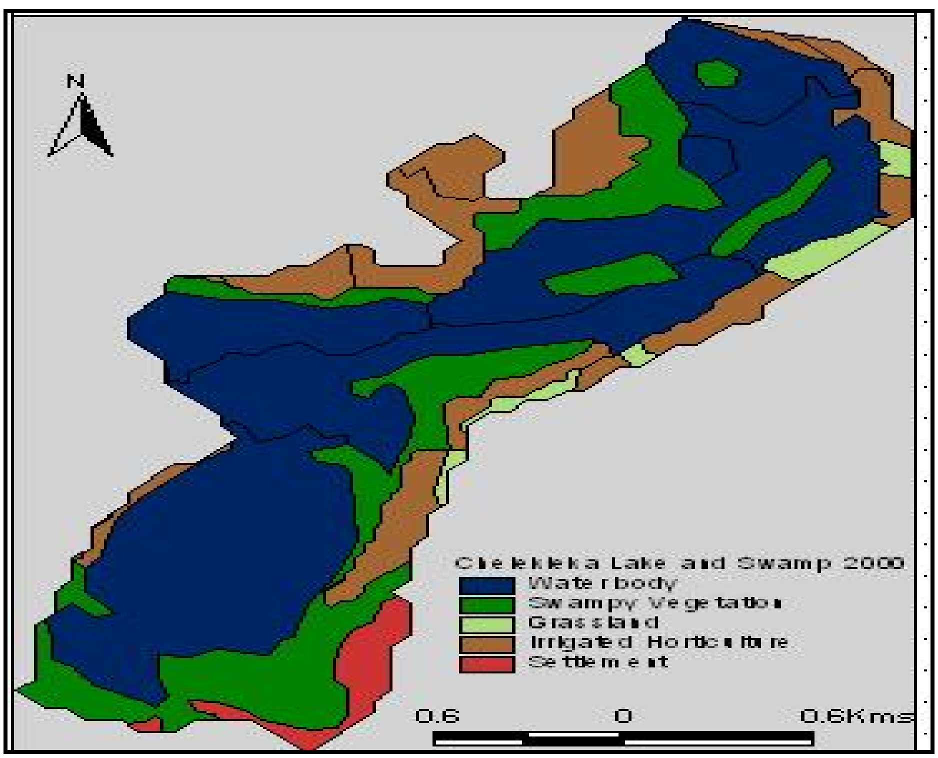


Figure 13: Land use/Land cover Map of Chelekleka & Swampy 2000

As displayed in table 15 below the water coverage of Lake Chelekleka during the land use/cover change investigation of 2010 was reduced by more than three times during 2000. The reason for this reduction was broadly associated with rapid growth and expansion of irrigated horticulture following the retreat of the lake, i.e., during this period it reached 40.2% of the catchments of Lake Chelekleka and its Swampy areas. Settlement land covers also aggressively increased and occupied much parts of the lake.

Table 15: Lu/Lc change with specific to Lake Chelekleka and Swampy Area in 2010

No.	Lu/Lc type	2010	
		Ha.	%
1	Water body	85	20.13
2	Swampy Vegetation	135.3	32
3	Grassland	9.6	2.3
4	Irrigated Horticulture	169.7	40.2
5	Settlement	22.9	5.4
	Total	422.5	100

Moreover, land use/cover Map of Chelekleka & Swampy Area 2010 (fig. 14) revealed, much part of the northern part of the lake was disappearing, and changed to irrigated horticultures, swamp vegetation and grass lands. The southern parts of the lake were also aggressively changed to settlements and irrigation areas.

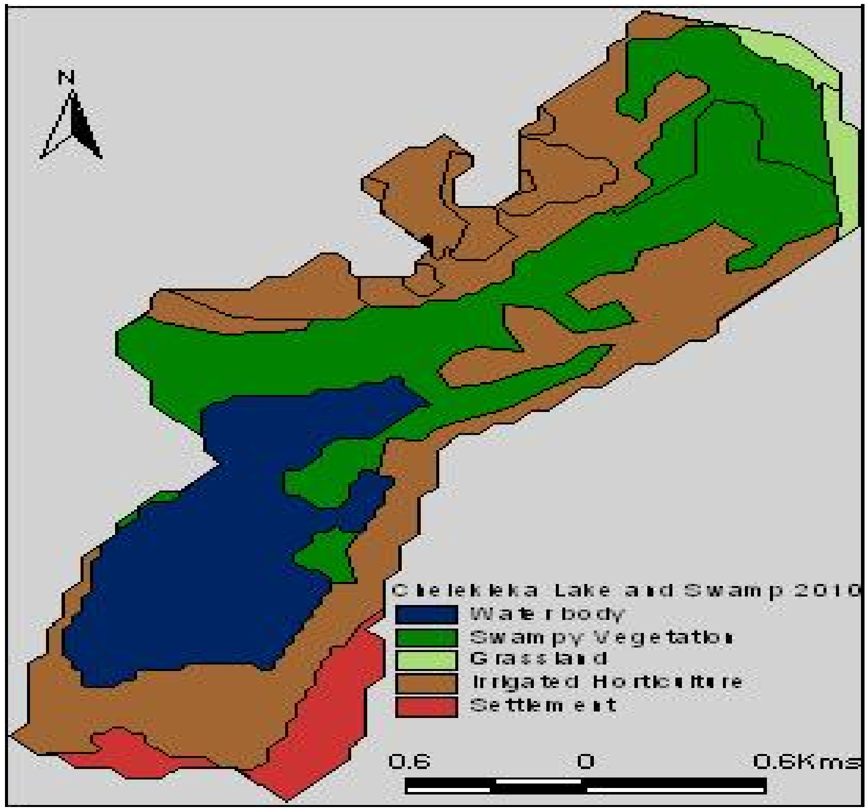


Figure 14: Land use/Land cover Map of Chelekleka & Swampy Area 2010

3.1.1.4.2. Land use/cover Change Comparison

The Land use/cover Change Comparison in Chelekleka Lake and its Swampy during (1973 – 2010) as stated in table 14 below, the surface water coverage of the lake had positive changes during the 1973-1986, 1986-2000, and 1973-2000 and increased by 91.310, 98.880, and 7.570 hectares of land covers respectively. Whereas, acute surface water body reduction during the land use change detection of 1973-2010, 1986-2010, and 2000 – 2010 with -48.940, -217.710, and -147.820 hectares of water cover lost respectively.

Table 14: Land use/cover Change Comparison in Chelekleka Lake and its Swampy during (1973 – 2010)

Lu/Lc type	Change 1973-1986		Change 1973-2000		Change 1973-2010		Change 1986-2000		Change 1986-2010		Change 2000 - 2010	
	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
Water body	91.310	68.157	98.880	73.808	-48.940	-36.531	7.570	3.360	-217.710	-65.616	-147.820	-63.483
Swampy Vegetation	-136.130	-47.2	-194.510	-67.428	-153.220	-53.115	-58.380	-38.322	-210.720	27.104	41.290	43.944
Grassland	14.620	-	10.170	-	9.590	-	-4.450	-30.438	-19.070	-3.967	-0.580	-5.703
Irrigated Horticulture	16.210	-	73.060	-	169.700	-	56.850	350.709	40.640	596.175	96.640	132.275
Settlement	13.990	-	12.420	-	22.890	-	-1.570	-11.222	-15.560	74.839	10.470	84.300
Total	0.0	0.0	0.02	0.0	0.02	0.0	0.02	0.0	-422.42	0.0	0	0.0

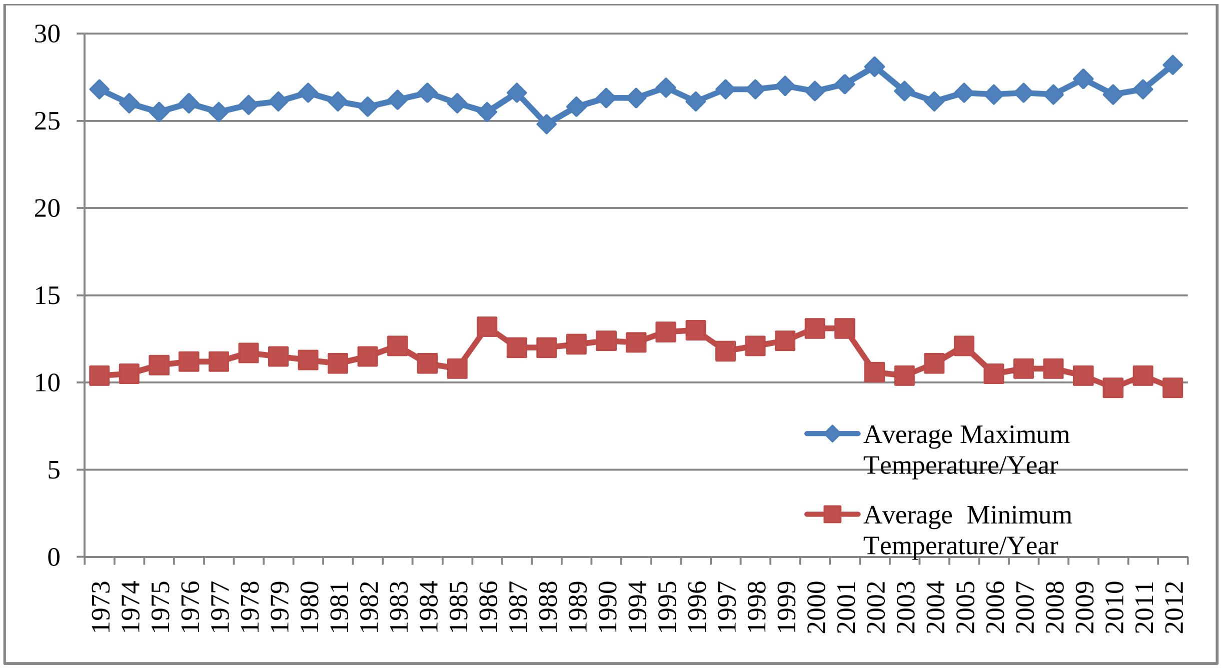










30
25
20
15
10
5
0
Average Maximum Temperature/Year
Average Minimum Temperature/Year
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
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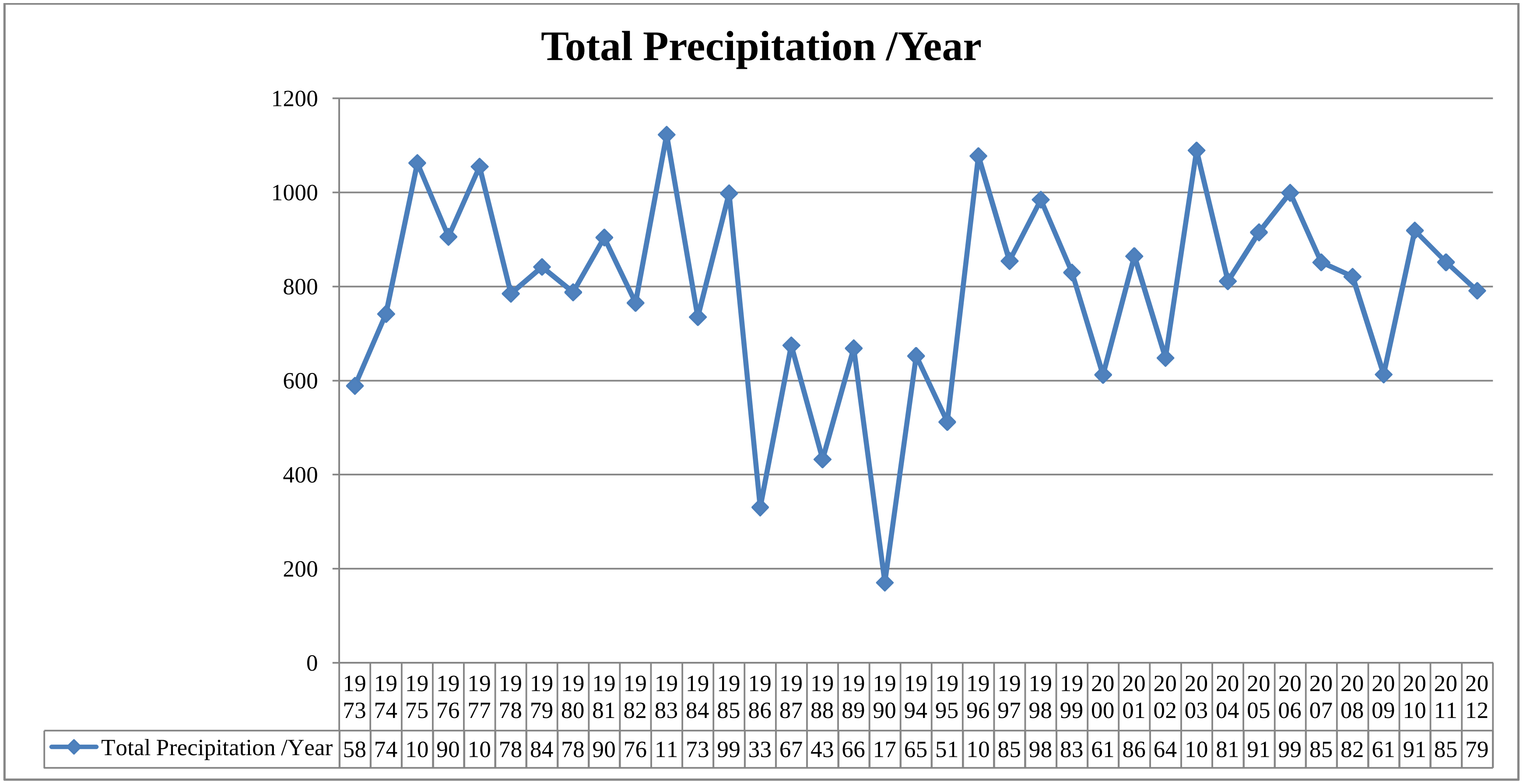

Total Precipitation /Year
1200
1000
800
600
400
200
0
1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
Total Precipitation /Year
58 74 10 90 10 78 84 78 90 76 11 73 99 33 67 43 66 17 65 51 10 85 98 83 61 86 64 10 81 91 99 85 82 61 91 85 79

3.1.3. Environmental/Landscape planning gaps

As identified in the land use/cover change investigations and major threats of the lake are large sedimentation from agricultural and urban built-up areas, and diversion of natural stream and runoff from urban built-up areas. In addition, the plan of the town (fig. 21) and existing realities around the town and the lake Chelekleka are not adequately considered. For instance, the planning lacks both the dry extended detention and buffer zone development in conformity of the plan (fig. 22 & 23). The deviation of one from the other may cause problems, since planning required what really exist in the fields without serious discrepancies.

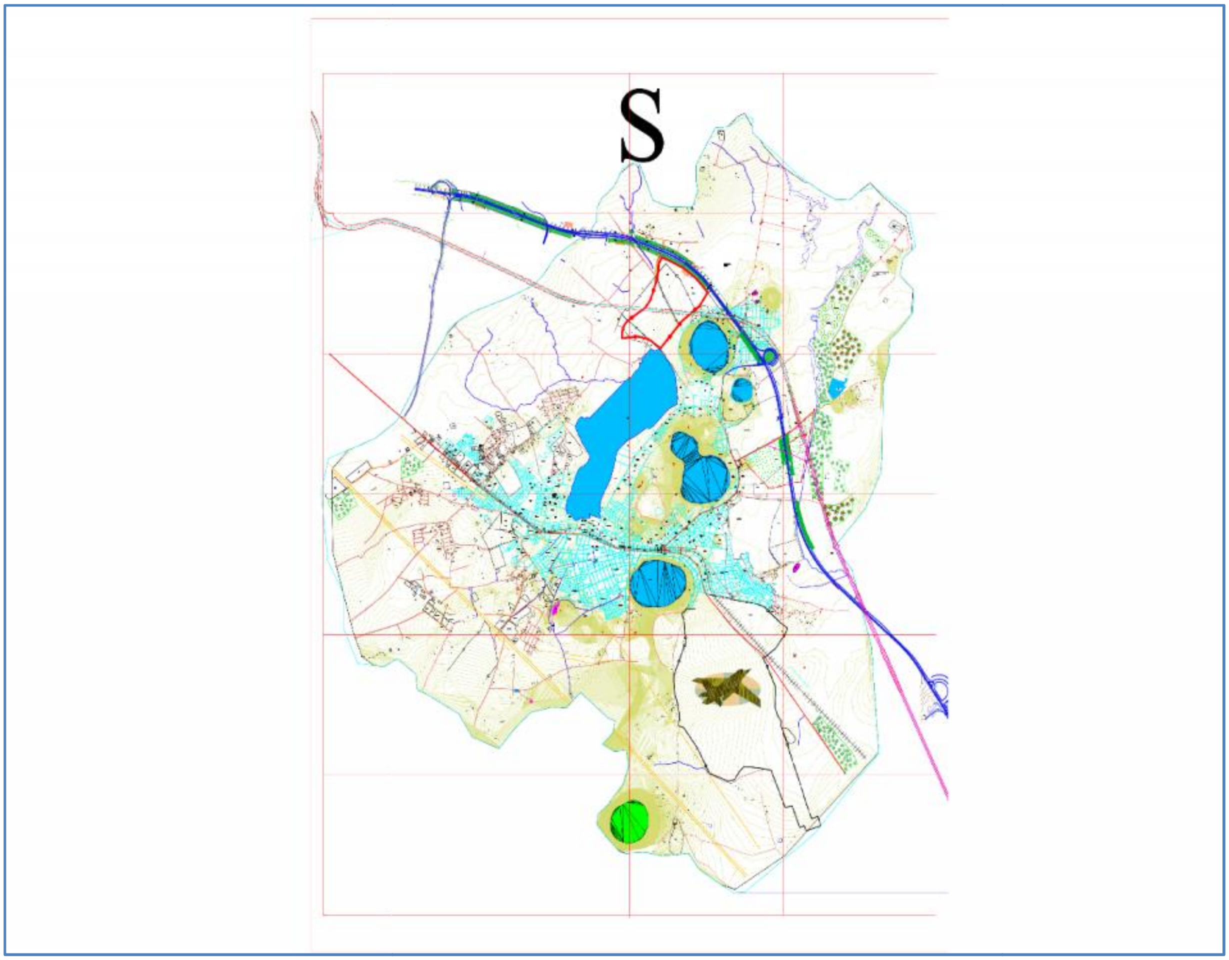


Figure 21: Bishoftu town plan

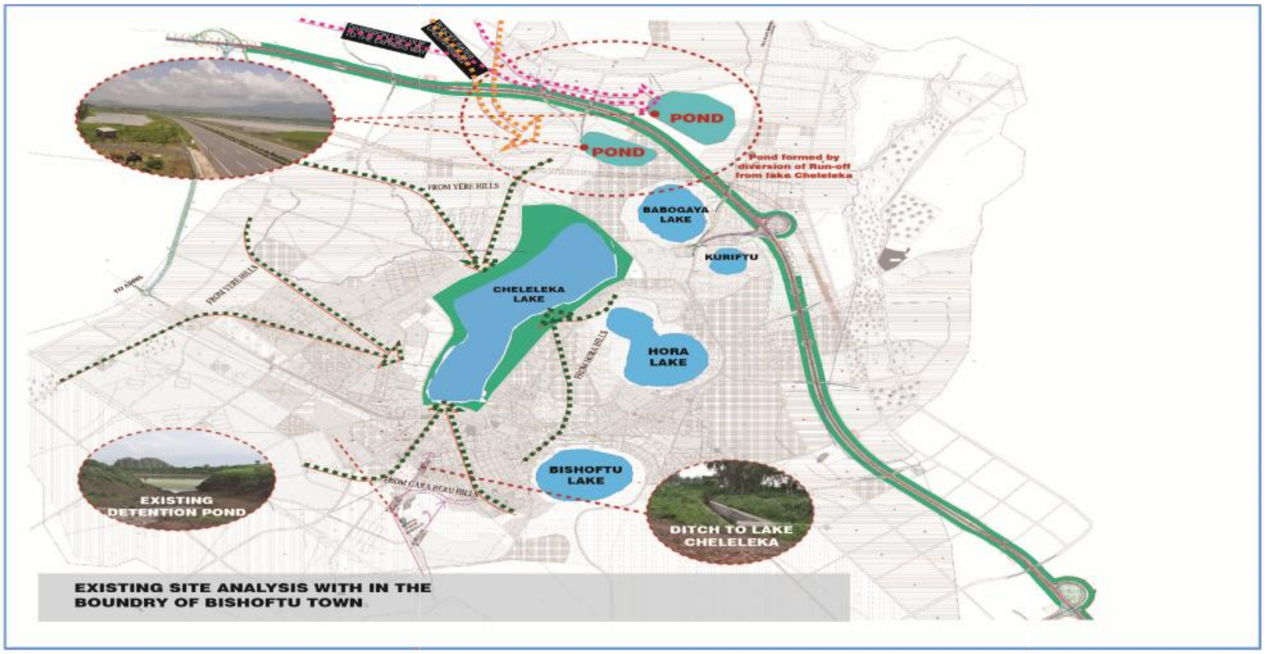


Figure 22: existing site analysis within the boundary of Bishoftu town

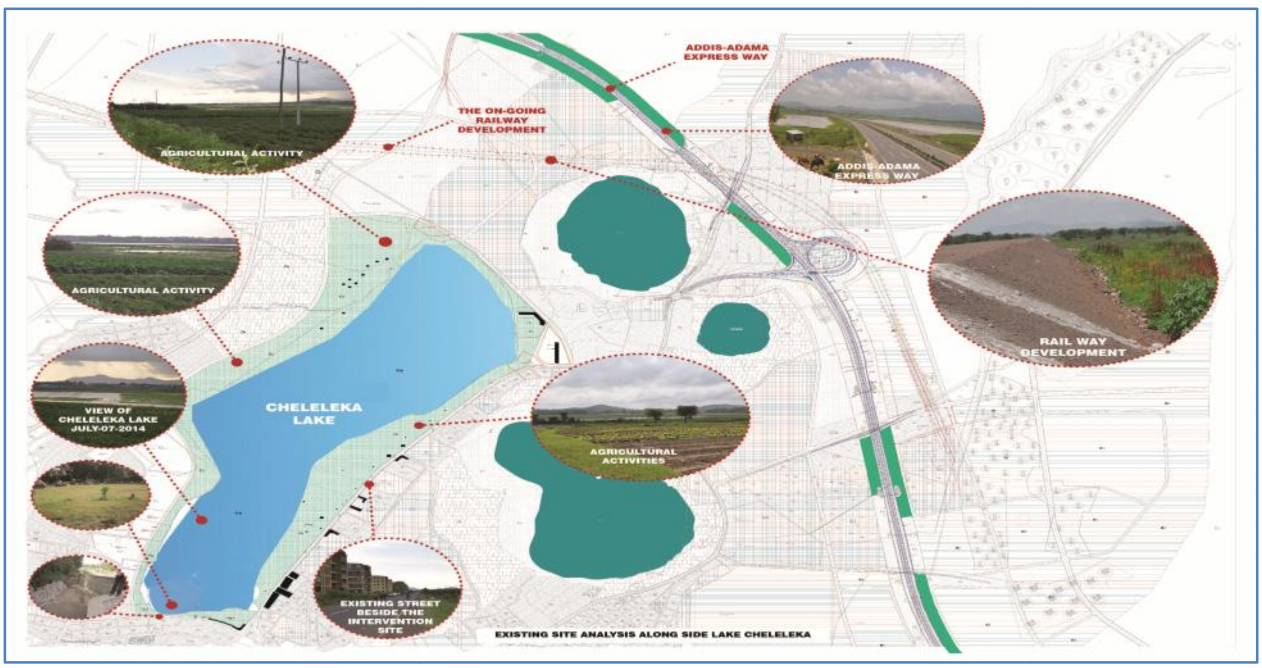


Figure 23: existing site analysis alongside Lake Chelekleka

3.2. Discussion

3.2.1.Land Use/Cover Change Dynamics of (1973 – 2010)

Change in land use/land cover may result in land degradation that manifests itself in many ways depending on the magnitude of changes. For instance, natural vegetation which may provide environmental and socio economic service becomes increasingly decline, water courses are drying up, grassland and wetlands are shrinking and soils become eroded and losses its productivity and deposited in the water courses as form of sedimentation.

All of these manifestations have potentially severe impacts on land users, existence of natural resources, and people's livelihood which rely for survival on the products from a healthy landscape. The dynamic change detected in the Chelekleka Lake Water Shades surroundings, within the Chelekleka Lake watershed, and in the catchment of the Lake and its Swampy areas during the entire periods of 1973-2010 as revealed by investigation of the land use detections. Based on classified land cover classes which revealed that forest land, shrub land, woodland , grassland, Wetland /water body were shrink and forced to be transformed into agricultural land and settlement covers during the consecutive land use detection periods of 1973 to 2010. Hence, Land use/cover Change dynamism of Lake Chelekleka Watershed and surroundings, the lake and its swampy area during (1973 – 2010) verified both positive and negative Surface water coverage changes. Surface water coverage increases by141.1hectares and 92.7hectares during 1973 to1986 and 1986 to2000 in the watersheds and its surroundings respectively, but it decreases by -182.3hecatres of land cover during 2000to 2011 in the same area.

Similarly, the land use/cover change detection of the surface water coverage within the lake watershed shown, the same pattern with 1973 to 1986 lake surrounding detection with increment of 95.67 hectares though it starts declining after 1986 by -52.3hecatres and -95.67hecatres of land covers during 1986 to 2000 and 2000to 2010 respectively. Likely, the detection of land uses with specific to the lake and its swampy area also confirmed increase of surface coverage of water bodies during 1973to 1986 and 1986 to 2000 by 91.31 hectares and 7.57hecatres of lands respectively, but declined by -147.82hecatres during 2000 to 2010.

Moreover, in the lake's watersheds and its surrounding; Forest land cover decreases by -2131.38 (-5.4%) hectares and -210.06 (-3.7%) hectares of lands during 1986-2010 to 2000 -2010. During the same period Shrub land deforested by -4668.48 (-12.5%) and -344.97 (-40.4%) during 1986-2010 to 2000 – 2010 respectively, as a result of this acute deforestation degraded bare lands were increased by 1657.89 (56.5%) hectares and 1191.78 (465%) during the same period respectively. Moreover, cropland increased by 1693.2, 451.4, and 1191.8 and hectares of land cover during 1973-1986, 1986-2000, and 2000-2011 respectively.

Furthermore, the land use detection results of Chelekleka Lake Watersheds also confirm, the acute reduction of surface water coverage loss especially during 1986-2000 and 2000-2011 by -51.3 and -95.7hecatres respectively. Following the drying of water courses especially very near to the lake Chelekleka, irrigated horticulture are massively expanding. Land use/cover change with specific to Lake Chelekleka and Swampy Area shown initially (1973) comprised of two land uses i.e., the lake part and its Swampy area. The surrounding Swampy areas are found dominantly in the northern parts. During 1973 land detection the swampy land uses are occupied more than double of the exact size of Lake Chelekleka. Due to low level of erosion and accompanied sedimentation from upper streams, during 1973 the lake's main water body had dark blue color and compact shape; which verified the high depth of water volume.

Contrary, during the 1986 land use/cover change detection the Lake Chelekleka and Swampy areas characterized by five land use types. These include Water body, Swampy Vegetation, Grass land, Irrigated Horticulture, and Settlements. As a result of these conversions and accumulation of sedimentation of different materials in the inner part of the lake, the water are expands to swampy areas. Hence, the water body of Lake Chelekleka was changed in both shape and color. The change in shape was from compact to diagonal long tail shape and the change in color comprises from dark blue to light blue color, which characterize the shallowness of the lake; which obviously resulted from sedimentation and siltation in the banks of the lake. The coverage increase of Lake Chelekleka and Swampy Area during the period of 2000 in dispatched way was superficial not real and healthy growth since it resulted from high sedimentation storage from overwhelming expansion of irrigated horticultures and crop lands in areas of previously covered by the lake's water body and its swamp areas. But, during 2000 to 2010 the water coverage of Lake Chelekleka was acutely decreasing by more than three folds. The expansion of urban population settlement to the lake areas are also exacerbating the probability of the dying of Lake Chelekleka. Therefore, if not urgent and timely consideration are taken by all concerned stakeholders so as to sustain the lives of the lake, the probability of losing this natural gift is not long taking.

The rates of change in land use/ land cover units have not been uniform across the land use classes. The variations are distinct from small scale to three fold; this is also similar to the findings of Amanuel and Mulugeta (2014), Land use/ Land cover dynamics trend in Nadda Asendabo Watershed, Southwestern Ethiopia. The increases in agricultural land and built up area due to unlimited human activity was accountable for decreases in areas covered by wetland, water body forest land, shrub land, woodland, and grassland. Besides, the study undertaken by Daniel (2014) in Southern Ethiopia shown remarkable decline in coverage of wetlands and water bodies by -1368.8 hectares, -530.4hectares, -658.7 hectares of land cover during 1973-1986, 1986-2000, and 2000-2011 of land use change detection in Odo-Shakiso District respectively. Similarly, Yoseph (2014) described from results of Land Use/Land Cover Dynamics and Rural Livelihood Perspectives in Anferara-Wadera High Forest Southern Ethiopia, coverage of wetlands and water bodies during 1973-1986 and 1986-2000 were decreased by -18 hectares and -42.71hectres of wetlands, and -13.62 hectares and -7.07 hectares of water bodies in the respective periods. Moreover, the study conducted by Gete and Hans (2001) in Northwestern Ethiopia documented a drop in natural forest cover from 27% to 0.3% (covering 27,103 ha for the period 1957–1995) while cultivated land increased from 39% in 1957 to 70% in 1982 and 77% in 1995. Similarly Gessessee and Kleman (2007) revealed that natural forest land was declined from 16 to 2.8% between the periods of 1972 to 2000 and conversely cultivated land was increased by 82% between the periods of 1972 to 2000 in the South central rift valley of Ethiopia.

3.2.2. Drivers of Change/Land Cover Dynamics

3.2.2.1. Agricultural land expansion

The agro ecological condition of Bushoftu is suitable for agriculture. Due to this, crop cultivation and livestock rearing is the basic economic activity in the area. For instance, agricultural land was accelerated during 1973-1986 and 1986-2000 by the rate of 130.2 and 41.1 hectares/ year respectively with expense of others land cover classes. For example, Shrub lands were decelerated with the rate of -286.0, -136.2, and -31.4 hectares per year respectively during the entire periods in the watersheds and its surroundings. Similarly Haile and Assefa (2012) revealed that decreased in shrub lands and grassland by 29.31% with an increase of agricultural land by 3.94% in Angereb Watershed, northern Ethiopia; and Eyayu and *et al.*, (2010). The study also elaborates that substantial expansion in cultivated land observed in the study area took place at the expense of reduction of areas under wetlands and water bodies, forest, shrub land, woodland, and grassland covers in Northwestern Ethiopia.

3.2.2.2. Built up area expansion

Due to rapid population growth and unlimited human interest forest land, shrub land, woodland, grassland , wetland and water bodies are radically decline and forced to change into built up area in the watersheds of lake Chelekleka and its surroundings. For instance, during the periods of 1973-1986, 1986-2000, and 2000-2010land detection in the Chelekleka watersheds and surroundings built up area was increased by 3.8, 79.2, and 118.6 hectares/year respectively. Inline of this, Messay and Tsetargachew (2013) study indicate that built up area was increased about 6.3% in the central Ethiopia between 1986 - 2010 with expense of shrub land, grassland and wetland; and also Tekle and Hedlund (2000) funding agreed that an increases in the size of open areas and settlements at the expense of shrub lands, wetlands and forests.

In addition, Hans *et al.* (2005) report at upper Nile Basin of Ethiopia found that changes in population densities due rapid population growth and in-migration from the adjacent area clearly had an effect on land use and land cover, resulting in shrinking forests and grassland and expansion of cultivated areas. Similarly a study in Southern Burkina Faso by Ouedraogo *et al*. (2012) indicated that migrants had larger farmlands and used environmentally harmful techniques (shifting cultivation, slash and burning techniques) in their land use systems while native population tended to take more care of land and environment by intensifying the production within the same croplands instead of cutting forest to make space for new croplands.

3.2.2.3. Overgrazing

In the watersheds of Lake Chelekleka and its surroundings', most of the farmers rear livestock and want to maintain large number with little care for their quality. According to the key informants report larger number of cattle population in a given family is both a source of wealth and status. Due to large number of livestock population grazing land was degraded and aggravate soil erosion resulting in land use/land cover dynamics of the lake regions. Therefore, overgrazing of forest land, shrub land, woodland, grassland and wetland is considered to be major primary causes for land use/land cover dynamics in the study area. In line with this finding, Diress *et al.* (2010) also indicated that livestock production is under increasing threat due to shortage of grazing land and soil degradation enhanced by natural vegetation dynamics.

3.2.2.4. Firewood collection and charcoal production

In the study areas fire wood collected from the adjacent forest and charcoal production are the most sources of energy and household Income. According to the informants over the recent years fire wood is commercialized as its demand has increased particularly in urban areas and at the village of the Kebeles. In addition to this, selling of wood and wood products are means of income for the poorest people and those landless youths and women illegally cut down trees from upper stream the forest area near to Yerer Mountain and supply large quantity of forest products for urban and rural dwellers via to nearby markets. Moreover as the key informants reported firewood collection and charcoal production as major causes of deforestation that change forest land, shrub land and woodland cover in the area. Hence, an increasing demand of forest products, in the form of fire wood and charcoal within and outside the study area has been resulting land use/land cover dynamics in watersheds of Lake Chelekleka and its surroundings. In line with this study, Meseret (2009) revealed that an increasing demand of forest products, in the form of firewood and charcoal production within and outside the forest area was the cause of deforestation in Adaba-Dodola Forest Priority Area. Similarly the study conducted by Belay (2002) in South Wello Highland confirmed that the major cause for the extensive destruction of the forest land and shrub land in the region is firewood collection and charcoal production for the surrounding markets - which exacerbate manmade calamities on open resources.

3.2.2.5. Land Tenure Arrangement

Tenure security provides the right incentives to invest or make improvements in land and natural resources. A land tenure system that ensures the holders a more secure landownership position usually results in better environmental conservation practices which, in turn, enhance the sustainability of natural resources like water and wetlands. The three most notable land tenure systems in Ethiopia are that of the *Imperial* Government (1930-1975), the *Derg* regime (1975-1991), and the Federal Democratic Republic of Ethiopia (FDRE) (1991-recent). The land policy of the *Imperial* government, though varied spatially, was favoring individual landlords to amass and possess the land indefinitely. This might have encouraged the landowners to take care their land and the resources on it which, in turn, might have resulted in relatively stable LU/LC changes for over a long period of time. Contrarily, the Military Government (*Derg)* nationalized the land and the natural resources on it under the umbrella of the renowned motto, "*Land to the Tiller*".

Consequently, land and the resources were divided into pieces among peasants or smallholding farmers, which resulted in massive deforestation of vegetated lands meant for various purposes. This, in turn, might have resulted in dramatic LU/LC changes throughout the country, in general, and the watersheds of Lake Chelekleka and its surroundings, in particular. In fact, the land use policy of the FDRE has offered the rural community the right to use land indefinitely. Although this FDRE's land tenure arrangement appears to be better compared to the previous regimes, but fear for possible confiscation, the lack of confidence and government trust complicate the land management. Their feelings of no right over their land makes land tenure arrangement as the main causes of deforestation which aggravate sedimentation and siltation in the courses of the lake.

CHAPTER FOUR
CONCLUSION AND RECOMMENDATION

4.1. Conclusion

Based on the investigation of the Causes and Effects of Diminishing Water Volume in Lake Chelekleka, and Strategy for Conservation, the following conclusions have been made.

In Chelekleka Lake Water Shades and its surroundings, within the Chelekleka Lake watershed, and in the catchment of the Chelekleka Lake and its Swampy areas shown dramatic land use/cover changes.

- Accordingly, majority of the land use/cover change during the (1973-2010) in Chelekleka Lake Water Shades and its surroundings were occupied by crop land (68%), which followed by grass land (12.6%) and shrub land (8.3%). The remaining land use/ covers especially like Surface Water body, Swampy Vegetation, Bare land, and population Settlement areas composed of very in significant composition in the study area for the period of 1973.
- in 1973 majority of the southern, western, Central and eastern parts of the of Chelekleka Lake Watersheds and its surroundings were dominantly covered by agricultural/crop lands; whereas, most of northern areas, north eastern and western parts, and south eastern areas were broadly covered by forest lands, shrub lands, and water bodies respectively. In the same period, population settlement was only found in southern eastern parts of the watersheds and its surroundings' i.e., very near to the lakes areas.
- During the period of 1986 land use/cover change analysis in Chelekleka Lake Watersheds and its surroundings, tremendous decline of forest lands, shrub lands, and swampy vegetation covers compared with 1973 data.
- During 1973-1986 forest deforestation and soil degradation in the Chelekleka Lake Watersheds and its surroundings was very sever, which was ultimately ends up in the lake. In the same period majority of the forest and shrub lands in upper water course, changes to grass lands, crop lands and bare-degraded lands. Notably, degraded bare land coverage was increased because of acute increase of agricultural lands. Moreover,

during this period former agricultural lands were converted to population settlements areas and crop lands in turn expand to shrub and uncultivable land uses. Similarly irrigated vegetations also occupied the swampy areas of Chelekleka Lake.

- During the period of 2000 to 2010 there was observed massive reduction of surface water coverage. That means there are a clear loss of water sources, as the land use changes within the basin and its surroundings are very acute. Hence, it accompanied by overwhelming increase of degraded-bare lands and rapid growth of population settlement. the major factors for the change of water volume sources during the period of 2000 to 2011 in the Chelekleka watersheds and its surroundings' were broadly because of:
    - Acute increase of degraded bare lands from increased from 2560.6 (3.3%) to 3752 (4.8%);
    - Rapid Population settlement coverage increase from 2846 (2%) hectares to 1542.2 (3.6%), and;
    - Deforestation
- These aggregated changes together with high surface runoff enhances sedimentation of soils, sands and gravels in the Chelekleka lake which changes its shapes from deep dark blue and compacted shapes during 1973, to slant shallow and light blue color shapes. Besides the lower parts, especially areas very near to the lake were taken by irrigated vegetation and urban population settlements.
- Generally study concludes, all the Chelekleka lake especially, The inner and border areas of the lake Chelekleka was dramatically changed into irrigated vegetation and grass lands and hence the dying of the lake was already starting from upper and expands to its central areas. For instance, during 2000 to 2010 it was reduced by more than three times.
- In addition to the challenges of land use change factors like high interest of Horticulture expansion, Poorly planned Infrastructure Developments which blocked the natural stream flow including the recent mega projects of country of the rail way line and the express way roads, Lack of Awareness and poor attention from governments, and climate change/variability twined with rise of temperature and rainfall/precipitation variability exacerbate the dying of the lake.

4.2. Recommendation

On the basis of the study findings and objective of the research the following recommendations were forwarded.

- The land use/cover change around and within the watersheds of the lake Chlekleka shown dramatic increase of degraded bare lands arise from forest deforestation and acute growth of agricultural lands, and hence appropriate resource conservation and management approaches should be undertaken so as to reduced the effect of siltation and sedimentation which decreased the depth of the lake.

- As one of the tragedy of the common resources is absence of appropriate ownership and administration problems, which also seen in the lake Chelekleka and in its surroundings needs more attention to reduce the challenges of common resource. Hence, both the lake and its buffer zone should be demarcated and its boundary should be fixed.

- Moreover, to promote sustenance of the lake the demarcated lakes should be transferred to responsible bodies; be it administered by the government, micro and small enterprises, and/or by participatory community management approach.

- More importantly the development projects like the express road ways and the rail lines blocked the natural stream flow to the lake Chelekleka, should be treated with appropriately designed ditch and/or bridges to transfer the streams comes from Yerer Mountain which is the major water supply for the lake.

- The construction on the buffer zone and horticulture irrigation by micro farmers should be transferred to other environmentally less sensitive areas.

- The city municipality, and urban greenery and beautification office should assigned adequate budget to make the lake to one of the best areas for tourist destination and income generating areas for the city and the community. This done through constructing the dry extended detention basins and buffer zone development.

    - Here under are stated the Proposed Planning of both the dry extended detention basins (fig. 24) and buffer zone development (fig. 25) implementations.

A) The dry detention pond

- The dry detention pond is the solution suggested at the gate of the lake where much runoff comes and stored from the town landscape;

- Since the ditch controls the speed and volume of the run-off, it easily stopping the sediment entering in to the lake.

- The provision of the dry detention pond only possible where the slope of the lands suited to easily collect the surface water runoff adequately.

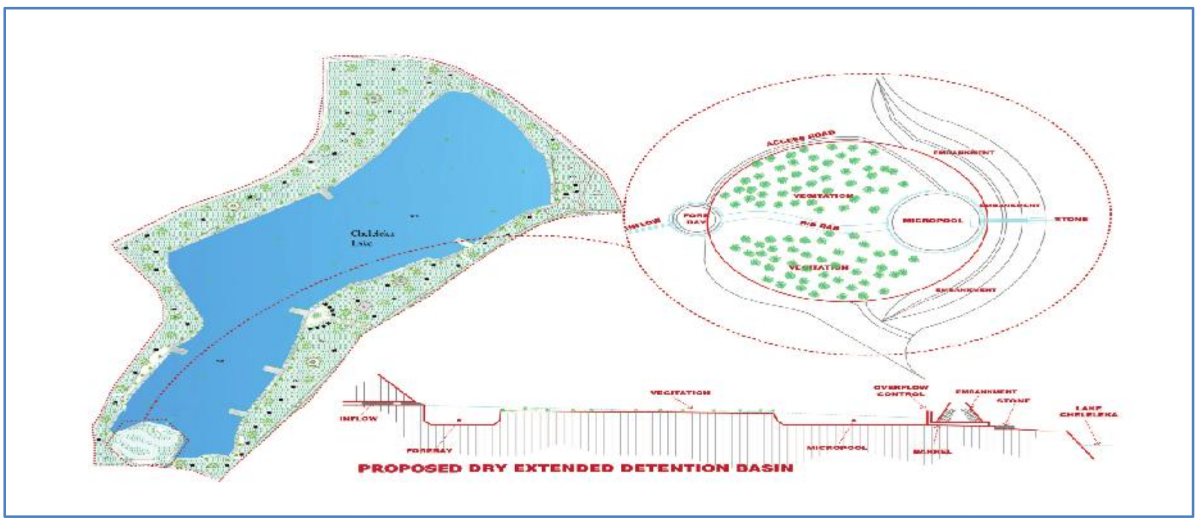


Figure 24: proposed dry extended detention basin

The design and implantation of dry detention pond for the lake Chelekleka considers the following basic activities and implementation strategies.

Basic activities

- ✓ **Pretreatment:** is highly recommended at the inlet of a dry extended detention with fore bay to trap incoming sediment. To prevent re-suspension of trapped sediment and scour during high flows, the energy of the influent flow must be controlled.

- ✓ **Treatment:** Treatment design features help enhance the ability of a storm water management practice to remove pollutants. Designing dry ponds with a high length-to-width ratio to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short- circuit the pond.

- ✓ **Conveyance/passage** of storm water runoff into and through the dry pond is a critical component. Storm water should be conveyed to and from dry ponds safely in a manner that minimizes erosion potential. In addition, an emergency spillway should be provided to safely convey large flood events.

- ✓ Maintenance Reduction: Regular maintenance activities are needed to maintain the function of storm water practices. For instance design features can be incorporated to ease the maintenance burden by constructing micro pool at the outlet to prevent re-suspension of sediment.

- ✓ **Landscaping:** conformity of choosing vegetation for a dry extended detention basin, consideration must be given to the wildflowers or grasses suitable with climate and landscapes of the study area.

Strategies for implementation of dry detention pond:

- ✓ Maintain and improve the quality of urban storm water through implementation of the Storm water Management Plan in conformity with municipal/town plans;
- ✓ Develop and implement a Development Control Plan for Water Sensitive Urban Design;
- ✓ Design and Implement Integrated Water Cycle Management Plan (storm water provisions);
- ✓ Provide an appropriate allocation of budget
- ✓ Encourage community participation and management;

B) Buffer Zone Development

The buffer area of the Lake Chelekleka should require to be covered by greenery vegetations by concerned bodies either by the government or the micro and small enterprises. As to me to boost the participatory resource management approach it better to be transferred to the local community in any form of organizations so as to sustain the lives of Lake Chelekleka. Hence, through this approach the lake is more expected to be more developed for public usage at large since it empower proper owner ship rights.

Figure 25: proposed buffer zone development

Strategies for implementation of Buffer Development

- Protect and restore the riparian zone of the lake and also consider while undergoing new development activities through the use of planning controls;

- Implement best management practices during the maintenance;
- Restore riparian lands by implementing natural resource and Management Plans;
- execute riparian zones of the lake and restore through partnerships with community groups, residents and commercial businesses;
- Engage small farmers, Micro and small enterprise operators and the local community in actively managing the riparian zone;
- Encourage natural resource, soil, and water conservation activities in the upper stream and surrounding areas of the lake with stakeholders.

4.3. Direction for Future Study

Several suggestions that may be fruitful for future research have emerged from this present study. In order to validate the findings of this study, a case study is another interesting approach that can develop by future research. In addition, the research model of this study should be grown to project approach so as to give appropriate follow up and understand positive changes appeared after the implementation recommended concepts. Moreover, attention works are needed to rehabilitate the Chelekleka Lake like that of Haromaya Lake in south east of the country.

References

Agrawal, A. (2001). Common Property Institutions and Sustainable Governance of Resources. World Development 29 (10): 1649–72.

Alelign Dessalew. 2009. Land Use Land Cover Change Detection and Vulnerability to Forest Degradation Using Remote Sensing and GIS: A Case of Borena District in North Central Ethiopia.

Alemu B., (2012). Carbon Stock Potentials of Woodlands and Land Use And Land Cover Changes In North Western Lowlands Of Ethiopia. Msc. Thesis,Hawassa University, Wondo Genet College Of Forestry And Natural Resources, Wondo Genet, Ethiopia .

Allen, J., and Barnes D. 1985. The Causes of Deforestation in Developing Countries. Annals of the Association of American Geographers 75(2):163-184.

Amanuel Abate and Mulugeta Lemenih. 2014. Detecting and Quantifying Land Use/ Land Cover Dynamics in Nadda Asendabo Watershed, South Western Ethiopia. International Journal of Environmental Sciences Vol. 3 No.1.

Arsano, Y. (2007) Ethiopia and the Nile dilemmas of national and regional hydroponics, Centre for Security Studies, Swiss Federal Institute of Technology, Zurich, Switzerland. Zurich, Phd. Thesis.

Barnsley, M. J. (1999). Digital remote sensing data and their characteristics. In Geographical Information Systems: Principles, Techniques, Applications, and Management, 2nd ed. P. Longley, M. Goodchild, D. J. Maguire, and D. W. Rhind, 451. New York: John Wiley & Sons.

Belay Tegene. (2002). Land-Cover/Land-Use Changes in the Derekolli Catchment of the South Welo Zone of Amhara Region, Ethiopia. Eastern Africa Social Science Research Review, Vol.18, No.1.

Bengtsson, L. and J. Malm, (1997). Using rainfall-runoff modeling to interpret lake level. Journal of Paleolimnology, 18, 235–248.

Best , W., J. and Khan, V.,J. (1989). Research in Education and Development. Englewood Cliffs, New Jersey: Prentice –Hall Publishers; University of Michigan.

Biging, G. S. *et al.*, (1999). Accuracy assessment of remote sensing-detected change detection. Monograph Series, ed. S. Khorram. Maryland: American Society for Photogrammetry and Remote Sensing.

Campbell, J.B (2002) Introduction to Remote sensing (3rd Ed). Taylor and Francis Ltd. London.

Chrysoulakis, N., Kamarianakis, Y ., Farsari, Y., Diamandakis, M. and P.Prastacos, (2004). Combining Sate llite and socioeconomic data for Land Use Models estimation. In G oossens, R.(Editor), Proc.Of 3rd Workshop of EARSeL Special Interest

Congalton, R., 1991. A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data. *Remote Sensing of Environment* 37: 35-46.

Creswell, J.W. (2003). Research Design, Quantitative and Mix approaches. .London: Sage Publishing Inc.

CSA, (2007). Population and Housing Census of Ethiopia: Results for Oromia Region, Vol. 1, Tables 2.1, 2.5, 3.4 (accessed 10 March 2014)

Daniel Ayalew. (2008). Remote Sensing and GIS-Based Land Use and Land Cover Change Detection in the upper Dijo River Catchment, Silte Zone, Southern Ethiopia

Daniel Ebba (2014). Land Use Change, Soil Carbon Dynamics and Rural Livelihoods in Southern Ethiopia: The Case Study of Odo-Shakiso Forest. PhD dissertation: Submitted To Center for Environment and Development Studies, College of Development Studies, Addis Ababa University, Ethiopia.

Department of Environmental Affairs And Tourism (2007). South African Environmental Outlook. A Report on the state of the environment, Department of Environmental Affairs and Tourism, Pretoria.

Diress Tsegaye, Moe, S., Vedeld, P. and Ermias Aynekulu. (2010). Land use/cover dynamics in northern afar rangelands, Ethiopia. Agriculture, Ecosystems and Environment, 139; 174-180.

Dungumaro E. W. & Madulu F. N. (2003). Public participation in integrated water resources management: the case of Tanzania; Published by Elsevier Ltd.

EPA's, 2008. Report on the Environment

Eyayu Molla , Heluf Gebrekidan , Tekalign Mamo and Mohammed Assen. (2010). Patterns of Land Use/Cover Dynamics in the Mountain Landscape of Tara Gedam and Adjacent Agro-Ecosystem, Northwest Ethiopia. SINET: Ethiop. J. Sci., 33(2): 75–88.

FAO 2001. Global Forest Resources Assessment 2000. FAO Forestry Paper 140, FAO, Rome.

FAO, (2000). The digital soil and terrain database of east Africa (sea) notes on the Arc/Info files Version 1.

FAO, (2012). Global forest land-use change from 1990–2005. FAO Forestry Paper 169.

Fazal S. 2013. Land Use Dynamics in a Developing Economy. Regional Perspectives from India

Gautam, A.P., Webb, E.L., Shivakoti, G.P., and Zoebisch, M.A., 2003. Land use dynamics and landscape change pattern in a mountain watershed in Nepal. *Agriculture, Ecosystems and Environment* 99: 83-96.

Gessesse Dessie and Johan Kleman. (2007). Pattern and Magnitude of Deforestation in the South Central Rift Valley Region of Ethiopia. Mountain Research and Development Vol 27 No 2: 162–168.

Gete Zeleke and Hans Hurni. (2001). Implications of Land Use and Land Cover Dynamics for Mountain Resource Degradation in the Northwestern Ethiopian Highlands. Mountain Research and Development Vol 21 No 2 May 2001: 184–191.

Giri. C. P. (2012). Remote Sensing of Land Use and Land Cover: Principles and Applications, CRC Press Taylor & Francis Group.

Haile G. and Assefa M. (2012). The impact of land use change on the hydrology of the Angereb Watershed, Ethiopia. International Journal Water Science, Vol. 1, 4:2012

ICRAF 2004. Improved land management in the Lake Victoria Basin: Final Report on the TransVic Project. World Agro Forestry Centre. Occasional Paper No. 07.

Janssen, L. L. F. 1993. Methodology for Updating Terrain Object Data from Remote Sensing Data: The Application of Landsat TM Data with Respect to Agricultural Fields.

Jensen, J.R., (1996). Introductory Digital Image Processing: A Remote Sensing Perspective, 2nd ed. Prentice Hall, Upper Saddle River, N.J. 316 pp.

Kilkus, K., 1998: Lakes of temperate regions as climate change indicators. In: Proceedings of the Second International Conference on Climate and Water, Espoo, Finland, August 1998. Helsinki University of Technology, Helsinki, Finland, pp. 588–596.

Koul. (1996). Method of Educational research. New Delhi; vikas Publishing, House Pvt. Ltd.

Laird, K.R., S.C. Fritz, E.C. Grimm, and P.G. Mueller, 1996: Century-scalepaleoclimatic reconstruction from Moon Lake, a closed-Basin lake in the northern Great Plains. Limnology and Oceanography, 41, 890–902.

Lambin EF, Geist HJ, Lepers E. (2003). Dynamics of land-use and land-cover change in tropical regions. Annu. Rev. Environ. Resour, 28: 205-241.

Lambin, *et al*., (1999). Land-Use and Land-Cover Change (LUCC) Implementation Strategy, IGBP Report 48.

Lefsky, M. A., and W. B. Cohen. (2003). Selection of remotely sensed data. In Remote Sensing of Forest Environments: Concepts and Case Studies, eds. M. A. Wulder, and S. E. Franklin, 13. Boston: Kluwer Academic.

Letsinger (2011). Evaluation of Riparian Buffer Zones using GIS and Remote Sensing. Indiana Geological Survey. Walnut Grove Ave., Bloomington, IN 47405-2208 2011.

Lewis, C.F.M., D.L. Forbes, E. Nielsen, L.M. Thorliefson, A.M. Telka, R.E.Vance, and B.J. Todd, 1998: Mid-Holocene Lake Winnipeg: where was it? In: Proceedings of GSA1998 Annual Meeting, Toronto, October 1998. Geological Society of America, Boulder, USA. Abstracts 30, p. A168.

Lillesand, T.M., 2000. Remote Sensing and Image Interpretation, 4th edition, John Wiley and Sons, Inc. New York.

Lillesand, T.M., and Kiefer, R.W. (2000) Remote sensing and image interpretation 4th ed. John Wiley and Sons Inc. New York.

Lillesand, T.M., and Kiefer, R.W. (2004). Remote sensing and image interpretation 4th Edition. John Wiley and Sons Inc. New York.

Lowell, K., 2001. An area-based accuracy assessment methodology for digital change maps. Int J Rem Sens 22:3571.

Lu E., Moran E., Hetrick S., and Li G. (2009). Land–Use and Land-Cover Detection. Anthropological Center for Training and Research on Global Environmental Change Publication No. 11-02: Advances in Environmental Remote Sensing Journal: Indiana University, U.S.A.

Lu E., Moran E., Hetrick S., and Li G. (2011). Land–Use and Land-Cover Detection. Anthropological Center for Training and Research on Global Environmental Change Publication No. 11-02: Advances in Environmental Remote Sensing Journal: Indiana University, U.S.A.

Lu, D. et al., (2004). Change detection techniques. Int J Rem Sens 25:2365.

Lu, D., and Q. Weng. (2005). Urban classification using full spectral information of Landsat ETM+ imagery in Marion County. Indiana Photogramm Eng Rem Sens 71:1275.

Macleod, R. D., and R. G. Congalton. (1998). A quantitative comparison of change-detection algorithms for monitoring eelgrass from remotely sensed data. Photogramm Eng Rem Sens 64:207.

Mather, P.M. (1999). Computer processing of remotely sensed images, 2nd ed. John Wiley and Sons.

Melillo, J., Field, C. & Moldan, B. (2003). *Interactions of the major biogeochemical cycles*, Island Press, Washington, DC.

Meseret Mideksa. (2009). Assessments of Forest Cover Change Using Remote Sensing and GIS Techniques: Case Study in Adaba-Dodola Forest Priority Area, Ethiopia.

Messay Mulugeta and Tsetargachew Legese. (2013). Spatiotemporal Environmental Dynamics and Its Implications on Rural Livelihoods in Wasarbi-Garba Guracha Watershed, Central Ethiopia Journal of Sustainable Development in Africa. Vol.15, No.8.

Morisette, J. T., and S. Khorram. (2000). Accuracy assessment curves for satellite-based change detec- tion. *Photogramm Eng Rem Sens* 66:875.

Netsanet Deneke. 2007. Land Use and Land Cover Changes in Harenna Forest and Surounding Area, Bale Mountains National Park, Oromia National Regional State, Ethiopia. M.Sc. Thesis.

Nissen-Petersen, E. (2006). Water from Roads. ASAL Consultants Ltd. for Danida in Kenia (Danish International Development Assistance). www.waterforaridland.com

Norman (2014). Sediment problems and solutions for the Minnesota River. West Central Experiment Station, University of Minnesota.

Olson, J., Misana, S., Campbell, D., Mbonile, M. and Mugisha, S. 2004(a). The Spatial Patterns and Root Causes of Land Use Change in East Africa

Ouedraogo Issa, Korodjouma Ouattara,Séraphine Kaboré/Sawadogo, Souleymane Paré and Jennie Barron. (2012). Permanent Internal Migration as Response to Food Shortage: Implication to Ecosystem Services in Southern Burkina Faso.

Quentin F. B., Jim, C., Julia, C., Carole, H., and A ndrew, S., (2006). Drivers of land use change, Final report: Matching opportunities to motivations, ESAI project 05116, Department of Sustainability and Environment and primary industries, Royal Melbourne Institute of Technology. Australia.

Richards, J. A. (1986). Remote Sensing Digital Image Analysis: An Introduction. Berlin: Springer–Verlag.

Rolf A.de By. (2004). Principles of Geographic Information Systems, an introductory textbook.

Singh, A. (1989). Digital Change detection techniques using remotely sensed data. International journal of remote sensing: Vol. 10. 989-1003.

Solaimani K., Arekhi M., Tamartash R., and Miryaghobzadeh M. (2010). Land use/cover change detection based on remote sensing data: A case study of Neka Basin. Agriculture and Biology Journal of North America.

Southgate, D. 1990. The causes of land degradation along "spontaneously" expanding agricultural frontiers in the third world. Land Economics 66 (1): 93-101.

Tekle, K.; Hedlund, L. (2000). Land cover changes between 1958 and 1986 in Kalu District, southern Wello, Ethiopia.

Teller, J. and W. Last, 1982: Pedogenic zones in post-glacial sediments of LakeManitoba, Canada. Earth Surface Processes and Landforms, 7, 367–379.

Turner, B. L., Meyer, W. B. and Skole, D. L. 1994. Global land-use/land-cover change: towards an integrated study. Ambio.

U.S. Environmental Protection Agency (2014). Dry Detention ponds. Available at: http://www.epa.gov/nscep/ordering.html . Accessed on February 2015.

Veldkamp, A. and Verburg. P.H. 2004. Modelling land use change and environmental impact. Journal of Environmental Management.

Vitousek, P.M., Mooney, H.A., Lubchenco, J. & Melillo, J.M. 1997. Human Domination of Earth's Ecosystems.

WORLD BANK. (2000). World Development Report, 1999/2000. The World Bank, Washington, DC. USA.

Wu Yang, Tang Ya and Chengmin Huang. (2009). Harvesting of rainwater and brooklets water to increase mountain agricultural productivity: A case study from a dry valley of southwestern China. Natural Resources Forum, 33, 1, 39 -48.

Yang, X., and C. P. Lo. 2000. Relative radiometric normalization performance for change detection from multi-date satellite images. Photogramm Eng Rem Sens 66:967.

Yin, R.K (2003). Case study Research Design and Methods (3 rd. ed.) London; Sage publications.

Yoseph Samuel (2014). Land Use/Land Cover Dynamics and Rural Livelihood Perspectives In Anferara-Wadera High Forest, Southern Ethiopia. M.Sc. THESIS: Submitted to School of Natural Resources and Environmental Studies, Wondo Genet College of Forestry and Natural Resources. Hawassa University; Wondo Genet, Ethiopia.

Annex One

Land use/Land cover change matrix in Chelekleka Area during the period 1973- 1986

	Land use/Land cover types 1973																	
Lu/Lc type	Water body		Swampy vegetation		Forest land		Shrub land		Grassland		Cropland		Bare land		Settlement		Total	
Land use/Land cover types 1986	Ha	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
Water body	508.1	83.3	175.5	16.2	12.6	0.3	0.0	0.0	11.7	0.1	38.4	0.1	0.0	0.0	4.8	1.2	751.1	1.0
Swampy Vegetation	25.4	4.2	292.9	27.0	102.0	2.2	0.0	0.0	114.6	1.2	117.1	0.2	0.0	0.0	2.4	0.6	654.3	0.8
Forestland	2.5	0.4	36.6	3.4	2458.4	53.6	202.5	3.1	811.4	8.2	352.4	0.7	12.4	0.6	0.0	0.0	3876.2	4.9
Shrub land	3.2	0.5	147.8	13.6	292.4	6.4	976.6	15.1	984.7	9.9	312.8	0.6	0.0	0.0	43.9	11.4	2761.5	3.5
Grassland	15.5	2.5	146.0	13.4	1557.3	33.9	568.3	8.8	4597.6	46.4	5601.9	10.5	236.3	11.8	35.7	9.3	12758.4	16.3
Cropland	53.8	8.8	234.1	21.6	145.7	3.2	4723.0	73.0	3309.6	33.4	44810.7	84.1	1669.6	83.5	43.3	11.2	54989.8	70.2
Bare land	0.0	0.0	0.0	0.0	18.8	0.4	0.0	0.0	48.1	0.5	1960.6	3.7	81.8	4.1	0.0	0.0	2109.2	2.7
Settlement	1.4	0.2	52.9	4.9	0.0	0.0	0.0	0.0	32.8	0.3	91.9	0.2	0.0	0.0	255.1	66.2	434.1	0.6
Total	609.9	100.0	1085.8	100.0	4587.1	100.0	6470.4	100.0	9910.4	100.0	53285.8	100.0	2000.1	100.0	385.2	100.0	78334.6	100.0

Annex Two

Land use/Land cover change matrix in Chelekleka Area during the period 1973- 2000

	Lu/Lc type	Land use/Land cover types 1973																	
		Water body		Swampy vegetation		Forest land		Shrubland		Grassland		Cropland		Bareland		Settlement		Total	
		Ha	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
Land use/Land cover types 2000	Water body	482.6	79.1	201.6	18.6	35.2	0.8	0.0	0.0	27.3	0.3	92.3	0.2	0.4	0.0	4.5	1.2	843.8	1.1
	Swampy Vegetation	51.1	8.4	481.7	44.4	0.0	0.0	0.0	0.0	97.7	1.0	1427.0	2.7	0.0	0.0	50.6	13.1	2108.2	2.7
	Forestland	25.6	4.2	34.7	3.2	3233.3	70.5	309.5	4.8	1268.7	12.8	739.0	1.4	10.3	0.5	0.0	0.0	5621.0	7.2
	Shrub land	3.0	0.5	86.4	8.0	242.4	5.3	0.0	0.0	326.5	3.3	182.0	0.3	0.4	0.0	13.9	3.6	854.5	1.1
	Grassland	42.0	6.9	80.9	7.5	600.8	13.1	323.7	5.0	2259.7	22.8	5782.1	10.9	143.4	7.2	26.3	6.8	9259.0	11.8
	Crop land	1.9	0.3	118.7	10.9	425.3	9.3	5661.6	87.5	5274.3	53.2	42434.6	79.6	1617.4	80.9	31.5	8.2	55565.3	70.9
	Bare land	3.8	0.6	30.8	2.8	26.5	0.6	120.8	1.9	569.3	5.7	1497.2	2.8	178.1	8.9	134.3	34.9	2560.6	3.3
	Settlement	0.0	0.0	50.9	4.7	23.7	0.5	63.5	1.0	86.9	0.9	1142.9	2.1	50.2	2.5	124.2	32.2	1542.2	2.0
	Total	609.9	100.0	1085.8	100.0	4587.1	100.0	6479.1	100.1	9910.4	100.0	53297.0	100.0	2000.1	100.0	385.2	100.0	78354.5	100.0

Annex Three

Land use/Land cover change matrix in Chelekleka Area during the period 1973- 2010

Land use/Land cover types 2010	**Land use/Land cover types 1973**																	
Lu/Lc type	Water body		Swampy vegetation		Forest land		Shrub land		Grass land		Crop land		Bare land		Settlement		Total	
	Ha	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
Water body	451.7	74.1	89.5	8.2	52.0	1.1	0.0	0.0	53.5	0.5	13.0	0.0	0.0	0.0	1.9	0.5	661.5	0.8
Swampy Vegetation	112.1	18.4	412.6	38.0	0.0	0.0	0.0	0.0	162.5	1.6	1033.1	1.9	0.0	0.0	6.5	1.7	1726.7	2.2
Forest land	23.4	3.8	55.3	5.1	2816.3	61.4	417.9	6.5	1091.9	11.0	951.2	1.8	55.1	2.8	0.0	0.0	5411.0	6.9
Shrub land	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	287.6	2.9	207.3	0.4	0.0	0.0	14.5	3.8	509.5	0.7
Grass land	15.4	2.5	84.7	7.8	967.2	21.1	267.6	4.1	2778.1	28.0	4985.5	9.4	227.3	11.4	7.2	1.9	9332.9	11.9
Crop land	1.7	0.3	191.6	17.6	670.8	14.6	5550.1	85.8	4501.4	45.4	41846.5	78.5	1316.4	65.8	35.7	9.3	54114.2	69.1
Bare land	0.0	0.0	0.0	0.0	80.8	1.8	202.3	3.1	815.6	8.2	2272.6	4.3	358.3	17.9	22.8	5.9	3752.4	4.8
Settlement	5.6	0.9	252.2	23.2	0.0	0.0	41.0	0.6	220.0	2.2	1987.9	3.7	43.0	2.2	296.6	77.0	2846.3	3.6
Total	609.9	100.0	1085.8	100.0	4587.1	100.0	6479.1	100.1	9910.4	100.0	53297.0	100.0	2000.1	100.0	385.2	100.0	78354.5	100.0

Annex Four

Land use/Land cover change matrix in Chelekleka Area during the period 1986- 2000

		Land use/Land cover types 1986																	
	Lu/Lc type	Water body		Swampy Vegetation		Forest land		Shrub land		Grassland		Cropland		Bare land		Settlement		Total	
		Ha	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
Land use/Land cover types 2000	Water body	583.5	95.7	138.0	12.7	15.8	0.3	2.7	0.0	70.3	0.7	33.6	0.1	0.0	0.0	0.0	0.0	843.8	1.1
	Swampy Vegetation	106.0	17.4	248.4	22.9	50.4	1.1	57.0	0.9	165.9	1.7	1406.1	2.6	10.8	0.5	63.6	16.5	2108.2	2.7
	Forest land	17.3	2.8	139.0	12.8	2721.9	59.3	196.7	3.0	1894.1	19.1	639.1	1.2	9.2	0.5	4.0	1.0	5621.0	7.2
	Shrub land	0.1	0.0	0.0	0.0	173.7	3.8	429.2	6.6	146.1	1.5	88.3	0.2	6.3	0.3	10.8	2.8	854.5	1.1
	Grass land	17.8	2.9	51.7	4.8	429.8	9.4	653.9	10.1	3054.1	30.8	4707.9	8.8	306.5	15.3	36.0	9.3	9257.7	11.8
	Crop land	16.5	2.7	63.5	5.9	391.3	8.5	1191.9	18.4	6781.5	68.4	45601.3	85.6	1503.3	75.2	0.0	0.0	55549.3	70.9
	Bare land	9.9	1.6	2.9	0.3	77.0	1.7	117.6	1.8	604.9	6.1	1335.7	2.5	273.2	13.7	137.2	35.6	2558.3	3.3
	Settlement	0.0	0.0	10.9	1.0	16.4	0.4	112.5	1.7	41.7	0.4	1178.3	2.2	0.0	0.0	182.5	47.4	1542.2	2.0
	Total	751.1	123.1	654.3	60.3	3876.2	84.5	2761.5	42.7	12758.4	128.7	54990.2	103.2	2109.2	105.5	434.1	112.7	78334.9	100.0

Annex Five

Land use/Land cover change matrix in Chelekleka Area during the period 1986- 2010

Columns: Land use/Land cover types 1986; Rows: Land use/Land cover types 2010

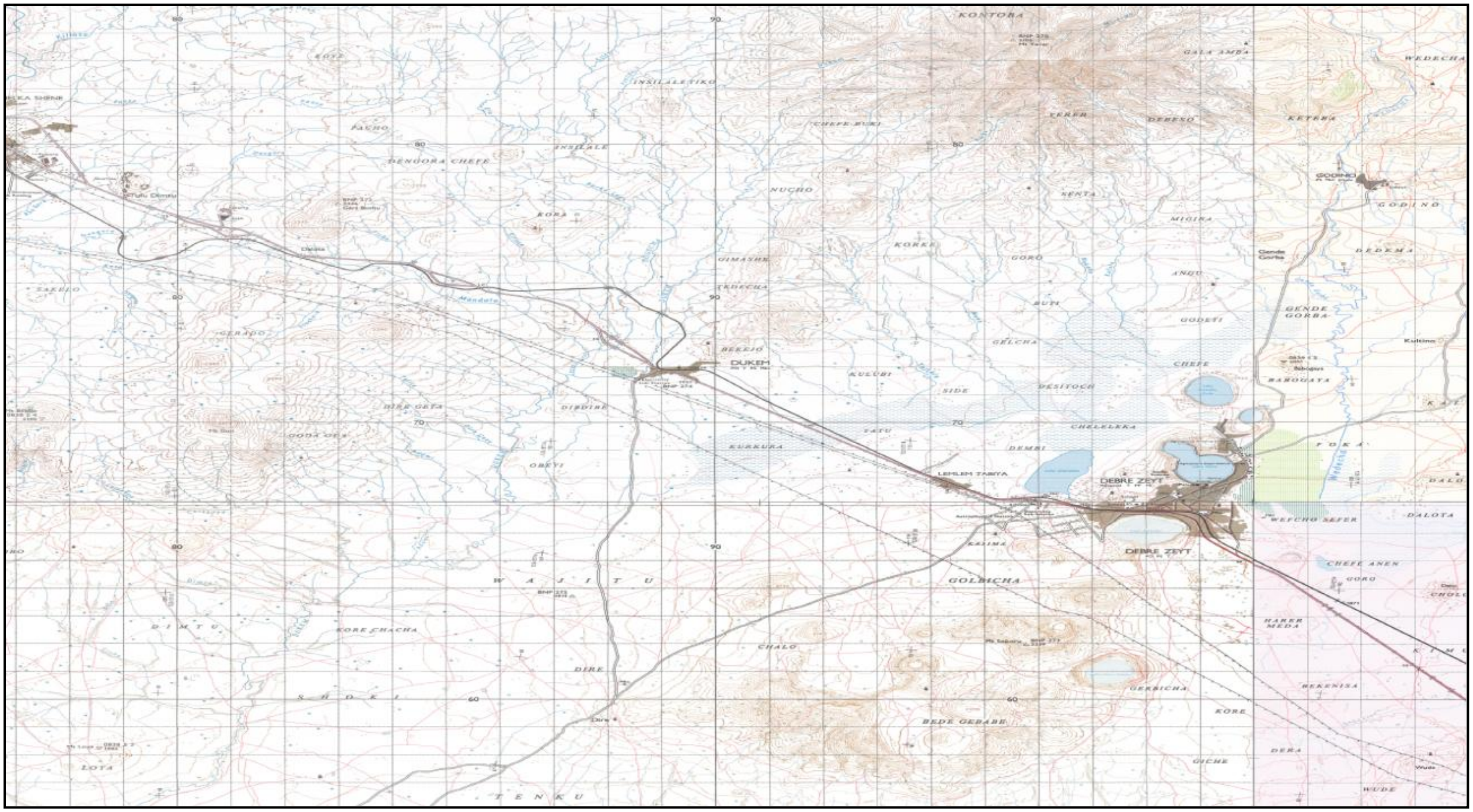
Lu/Lc type	Water body		Swampy Vegetation		Forest land		Shrub land		Grass land		Crop land		Bare land		Settlement		Total	
	Ha	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
Water body	494.6	81.1	79.1	7.3	0.0	0.0	2.6	0.0	46.1	0.5	38.8	0.1	0.0	0.0	0.3	0.1	661.5	0.8
Swampy Vegetation	187.7	30.8	182.1	16.8	52.0	1.1	4.7	0.1	311.6	3.1	955.7	1.8	0.0	0.0	33.0	8.6	1726.7	2.2
Forest land	21.2	3.5	148.7	13.7	2592.8	56.5	153.1	2.4	1597.7	16.1	893.7	1.7	3.8	0.2	0.0	0.0	5411.0	6.9
Shrub land	0.0	0.0	0.0	0.0	22.8	0.5	268.7	4.2	44.8	0.5	158.6	0.3	0.0	0.0	14.7	3.8	509.5	0.7
Grass land	5.9	1.0	85.4	7.9	580.5	12.7	826.9	12.8	3702.1	37.4	3723.8	7.0	392.2	19.6	10.7	2.8	9327.5	11.9
Crop land	33.8	5.5	95.1	8.8	580.6	12.7	1103.5	17.1	5787.7	58.4	45150.3	84.7	1348.9	67.4	0.0	0.0	54100.0	69.1
Bare land	0.0	0.0	0.0	0.0	35.4	0.8	60.0	0.9	1122.8	11.3	2172.1	4.1	362.2	18.1	0.0	0.0	3752.4	4.8
Settlement	7.8	1.3	63.9	5.9	12.2	0.3	342.0	5.3	145.7	1.5	1897.2	3.6	2.2	0.1	375.4	97.5	2846.3	3.6
Total	751.1	123.1	654.3	60.3	3876.2	84.5	2761.5	42.7	12758.4	128.7	54990.2	103.2	2109.2	105.5	434.1	112.7	78334.9	100.0

Annex Six

Land use/Land cover change matrix in Chelekleka Area during the period 2000-2010

Rows: Land use/Land cover types 2010; Columns: Land use/Land cover types 2000

Lu/Lc type	Water body		Swampy vegetation		Forest land		Shrub land		Grassland		Crop land		Bare land		Settlement		Total	
	Ha	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%	Ha.	%
Water body	559.8	91.8	24.6	2.3	3.5	0.1	1.4	0.0	6.8	0.1	63.5	0.1	2.0	0.1	0.0	0.0	661.5	0.8
Swampy Vegetation	178.1	29.2	647.1	59.6	11.4	0.2	21.4	0.3	463.2	4.7	300.2	0.6	22.8	1.1	82.5	21.4	1726.7	2.2
Forest land	20.5	3.4	64.5	5.9	3973.4	86.6	151.5	2.3	308.9	3.1	812.5	1.5	73.1	3.7	6.6	1.7	5411.0	6.9
Shrub land	0.0	0.0	50.5	4.7	0.0	0.0	262.6	4.1	90.8	0.9	72.9	0.1	2.0	0.1	30.7	8.0	509.5	0.7
Grass land	22.7	3.7	137.1	12.6	611.9	13.3	139.1	2.1	4076.6	41.1	3977.4	7.5	260.2	13.0	108.1	28.1	9332.9	11.9
Cropland	55.3	9.1	1000.2	92.1	917.9	20.0	85.3	1.3	3584.1	36.2	46693.1	87.6	1477.4	73.9	301.4	78.2	54114.6	69.1
Bare land	4.3	0.7	3.2	0.3	85.6	1.9	8.7	0.1	437.0	4.4	2497.7	4.7	556.1	27.8	159.7	41.4	3752.4	4.8
Settlement	3.1	0.5	181.0	16.7	17.3	0.4	184.5	2.9	291.6	2.9	1148.5	2.2	167.1	8.4	853.3	221.5	2846.3	3.6
Total	843.8	138.3	2108.2	194.2	5621.0	122.5	854.5	13.2	9259.0	93.4	55565.6	104.3	2560.6	128.0	1542.3	400.4	78354.9	100.0



KONTORA
GALA AMBA
WEDECHA
INSILALE TIKO
KETEBA
FACHO
CHEFE BUKI
TERER
DEBESO
DENGORA CHEFE
INSILALE
NUCHO
SENTA
GODINO
KORA
MIGIRA
KORKE
GORO
DEDEMA
GIMASHE
ANGU
SAKELO
DEDECHA
BUTI
GENDE GORBA
GERADO
GODETI
BEKEJO
GELCHA
DUKEM
KULUBI
CHEFE
SIDE
DESITOCH
BAROGATA
DIRE GETA
DIBDIBE
GODA GUS
TATU
CHELELEKA
KURKURA
DEMBI
FOKA
OBEYI
LEMLEM TABIYA
DEBRE ZEYT
WEFCHO SEFER
DALOTA
KALIMA
CHEFE ANEN
W A J I T U
GOLBICHA
GORO
HARER MEDA
D I M T U
KORE CHACHA
CHALO
DIRE
GERBICHA
BEKENISA
S H O K I
KORE
BEDE GEBABE
LOTA
GICHE
DERA
WUDE
T E N K U

Annex Eight
Interview Guide

ADDIS ABABA UNIVERSITY
ETHIOPIAN INSTITUTE OF ARCHITECTURE, BUILDING CONSTRUCTION AND CITY DEVELOPMENT (EiABC)
DEPARTMENT OF ENVIRONMENTAL PLANNING AND LAND ESCAPE DESIGN

Dear respondent

The Purpose of this questionnaire is to gather information and Opinion regarding the Causes and Effects of Diminishing Water Volume in Lake Chelekleka, Bishoftu, Ethiopia and Strategy for Conservation. This study is undertaken as academic requirements of MSc Degree in Environmental Planning and Land Escape Design. It also helps to gain practical knowledge on the topic under investigation and other prospective researchers will use it as a stepping stone to carry out further investigation. Finally, I want to assure that this study is only for academic purpose authorized by Addis Ababa University. I will be very grateful if you could take a few minutes to complete this questionnaire. Your feedback is very important and all data obtained from you will be kept confidential.

Note;

1. No need of writing your name on the questionnaire
2. Put the (√) mark for your response on the space provided.
3. Write your additional comments and suggestions on the given spaces.

Thank you

Region: Oromia
Zone: East Shewa
Woreda/District: --------------------------
Town _Bushfitu___

1. Name:..
2. Role/ employment ....
3. Education: ....
4. Which division/ area do you work in? ....
5. How long have you worked here?
6. How would you explain the management situation of Cheleleka Lake?
7. What experiences does your organization have in the past in terms of collectively managing natural resources including Cheleleka Lake and its water shade areas?
8. How are boundaries of the lake defined and preserved?
9. How are decisions made locally and nationally in accordance of preserving the sustainability of the lake?
10. Can you mention some decisions wrongly affected and make to diminish and move it to die Lake Chelekleka?
11. Do you feel that the local communities agree with the decisions?
12. How would you explain the importance of the Cheleleka Lake for the people surrounding?
13. What ecological and hydrological changes occurred in the Cheleleka Lake and its water shades?

14. In your understanding, what factors enhance water volume diminishes and moves it to die Lake Chelekleka?

15. For the future what remedial measures the government intends to sustain the life span of the lake?

Thanks