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Trends, Drivers and Implications of Land Use Land Cover (LULC) Changes in Lake Ziway Catchment, Central Rift Valley of Ethiopia

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DECLARATION

I, Araba Jemal Ibrahim, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

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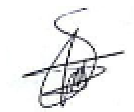

21/12/2021

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CERTIFICATION

This is to certify that the master's thesis entitled **"Trends, Drivers and Implications of Land Use Land Cover (LULC) Changes in Lake Ziway Catchment, Central Rift Valley of Ethiopia",** is a record of the original work done by Araba Jemal Ibrahim in partial fulfillment of the requirement for the award of Master of Science Degree in Water Science, Policy track, at Pan African University Institute of Water and Energy Sciences (including Climate Change)-PAUWES during the Academic Year 2019-2021.

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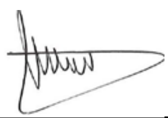

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ABSTRACT

This study aimed to examine the trends, drivers and implications of land use land cover change (LULC) in the Lake Ziway catchment, central rift valley of Ethiopia. To address these objectives, the study followed a mixed-method approach that included the use of remote sensing and geographic information system techniques, household surveys, focus group discussions and in-depth interviews. In this study a total of 120 household survey respondents were selected by simple random sampling and 15 key informants as well as 4 FGD participants were selected purposively to gather data. The study shows that the conversion of forest land into agricultural lands and settlement areas are the major detected LULC changes, over the last 30 years period (1990-2020). Cultivated land has increased by 40.60% and settlement and plantation lands have increased by 61.54% and 60%, respectively. On the other hand, forest land decreased by 54.85% and grazing land have decreased by 15.85% respectively. Water bodies and wetlands have also decreased by 8.70% and 19.32% area coverage, respectively. The main proximate driving forces of LULC change in the catchment are agricultural expansion, extraction of fuel wood, settlement expansion and overgrazing. Further, the main underlying drivers of LULC change in the catchment are population pressure, urbanization, lack of proper management of watershed resources and land degradation. The study indicates that although some local communities have taken training on catchment management, their participation in actual catchment management activities is very low. The study further indicates that the LULC changes observed in Lake Ziway Catchment have had significant environmental and socio-economic implications. Some of the observed implications of LULC change in the study area are biodiversity loss, soil degradation, forest degradation, changes in hydrological regimes and local climate, land scarcity and food shortages. Therefore, appropriate policy and strategy are required to address LULC change impacts and enhance the sustainable utilization and management of Lake Ziway.

Key words: LULC change, Drivers, Landsat images, ArcGIS, land degradation.

RÉSUMÉ

Cette étude visait à examiner les tendances, les moteurs et les implications du changement d'occupation des sols (LULC) dans le bassin versant du lac Ziway, dans la vallée centrale du Rift en Éthiopie. Pour atteindre ces objectifs, l'étude a suivi une approche à méthodes mixtes qui comprenait l'utilisation de techniques de télédétection et de système d'information géographique, des enquêtes auprès des ménages, des discussions de groupe et des entretiens approfondis. Dans cette étude, un total de 120 répondants à l'enquête auprès des ménages ont été sélectionnés par échantillonnage aléatoire simple et 15 informateurs clés ainsi que 4 participants aux groupes de discussion ont été sélectionnés à dessein pour recueillir des données. L'étude montre que la conversion des terres forestières en terres agricoles et en zones de peuplement sont les principaux changements détectés dans les LULC au cours des 30 dernières années (1990-2020). Les terres cultivées ont augmenté de 40,60 % et les terres de peuplement et de plantation ont augmenté de 61,54 % et 60 %, respectivement. D'autre part, les terres forestières ont diminué de 54,85 % et les pâturages ont diminué de 15,85 % respectivement. Les plans d'eau et les zones humides ont également diminué respectivement de 8,70 % et de 19,32 % de superficie. Les principales forces motrices immédiates du changement LULC dans le bassin versant sont l'expansion agricole, l'extraction de bois de chauffage, l'expansion des colonies et le surpâturage. En outre, les principaux moteurs sous-jacents du changement LULC dans le bassin versant sont la pression démographique, l'urbanisation, le manque de gestion appropriée des ressources des bassins versants et la dégradation des terres. L'étude indique que bien que certaines communautés locales aient suivi une formation sur la gestion des bassins versants, leur participation aux activités réelles de gestion des bassins versants est très faible. L'étude indique en outre que les changements LULC observés dans le bassin versant du lac Ziway ont eu des implications environnementales et socio-économiques importantes. Certaines des implications observées du changement LULC dans la zone d'étude sont la perte de biodiversité, la dégradation des sols, la dégradation des forêts, les changements dans les régimes hydrologiques et le climat local, la rareté des terres et les pénuries alimentaires. Par conséquent, une politique et une stratégie appropriées sont nécessaires pour traiter les impacts du changement LULC et améliorer l'utilisation et la gestion durables du lac Ziway.

Mots clés : changement LULC, Drivers, images Landsat, ArcGIS, dégradation des terres.

ACRONYMS AND ABBREVIATIONS

CRV	Central Rift Valley
CSA	Central Statistical agency
DEM	Digital Elevation Model
EPA	Environmental Protection Agency
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization of the United Nations
FDRE	Federal Democratic Republic of Ethiopia
FGD	Focus Group Discussion
GIS	Geographic Information System
GPS	Global Positioning system
GTZ	German Technical Cooperation
IWRM	Integrated Water Resource Management
LULC	Land Use Land Cover
MOA	Ministry of Agriculture
MoWIE	Ministry of Water Irrigation and Electricity
NGO	Non-Governmental Organization
OLI	Operational Landsat Image
RS	Remote Sensing
SPSS	Statistical Package for Social Sciences
TM	Thematic Mapper
USD	United State Dollar
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WFP	World Food program
WGS	World Geodetic system

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CHAPTER ONE

INTRODUCTION

1.1. Background Information

Land use land cover (LULC) change is one of the critical environmental phenomena influencing several parts of the earth's systems including biodiversity, climate, hydrology, and land resources. Land degradation caused by land-use and land-cover (LULC) change, has major environmental and social consequences (Desta and Fetene, 2020). The effects of LULC change linked to population increase, urbanization, intensified agricultural practices (e.g., enhanced fertilizer and pest management), the decreasing of grasslands, and deforestation have raised concerns about ecosystem sustainability (Sohl *et al.,* 2012).

Over half of the world's landscape is influenced by human activities or is subject to some form of anthropogenic development, and many natural resources have been overused or depleted in the worst situations in the past (Goldewijk *et al.*, 2011). Climate change, alteration of the hydrological cycle, increased water extraction, damage of water quality, degradation of soil nutrients, accelerated surface erosion, and loss of biodiversity are all effects of this extensive LULC shift on the natural environment (Turner *et al*., 2007; Paiboonvorachat, 2008; Siddhartho, 2013).

Due to high human pressures for livelihood activities, LULC changes occur on all continents, but they are more pronounced in African tropical mountain environments (Spehn *et al*., 2006). This is a particularly critical problem in Africa's Great Rift Valley System. The Great Rift Valley stretches from the Red Sea to Mozambique, the Great Rift Valley runs through Ethiopia, Kenya, Uganda, Rwanda, Burundi, Zambia, Tanzania, Malawi, and Mozambique (Wasige *et al*., 2012). Socio-economic development, population increase and human pressures on agricultural lands have all been the major causes of LULC changes in these countries (Kayhko *et al*., 2011; Muriithi, 2016; Phiri *et al*., 2019).

The driving forces of LULC change are commonly divided into proximate causes and underlying causes (Lambin *et al*., 2003). Those activities and actions that immediately affect land usage are referred to as proximate causes. The immediate (direct) causes are local people's immediate activities to meet their demands from land use. Agricultural development, wood extraction, infrastructure expansion, and other factors that alter the physical status of land cover are among these factors. The fundamental elements that activate the proximate causes, such as demographic pressure, economic policy, technological advancement, institutional, and cultural variables, are referred to as underlying causes. In Ethiopia, significant changes in land use and land cover have occurred over the last decades as a result of anthropogenic activities, population growth, and land use changes such as deforestation, overgrazing, and improper agricultural land cultivation, which resulted in accelerated soil erosion and associated soil nutrient deterioration (Bewket and Abebe, 2013; Tadele *et al*., 2019; Mesfin, 2020). To mitigate the effects of LULC change, studies on land use and land cover, its changing patterns, the proximate and underlying drivers for the observed changes are required. However, in Ethiopia, there is limited information on analyses of land use and land cover change, its trends, drivers and implications, particularly in the Lake Ziway catchment. Therefore, the assessment of land use land cover change trends, drivers and consequences in this area is very important to assist policy makers to develop effective resource management and planning strategies.

1.2. Statement of the Problem

A major challenge in environmental studies is to understand and clarify the impacts of land use land cover change on the environment and the socio-economic structures (Aklile Nigatu, 2014). For the past four to five decades, Ethiopian ecosystems have been subjected to anthropogenic intervention through land use change (Muluneh, 2010). Environmental degradation, which can be defined in terms of land and water resource degradation as well as biodiversity loss, is one of the key challenges preventing Ethiopia's sustainable development. Land degradation is contributing to reduced agricultural production and food insecurity in the country (Yakob and Fekadu, 2016).

The environment has become a major concern in Ethiopia in recent years. Water degradation, soil erosion, deforestation, loss of biodiversity, desertification, recurrent drought, flood, and water and air pollution are among the country's major environmental issues (EPA, 2012). Although various studies have been conducted around the world to estimate the potential effects of LULC change, on environmental resources (water, soil, vegetation), there are only a few studies in Ethiopia, particularly in the Lake Ziway catchment.

Lake Ziway catchment is one of the environmentally susceptible areas of the country. The expansion of agricultural land in the catchment has resulted in the degradation of water resources, forest and soil resources. This affects the ecological balance of the watershed system. The quantity and quality of water resources in the Lake Ziway catchment have deteriorated due to soil erosion, sediment deposition and pollution caused by poor management practices in Lake Ziway catchment. This has negatively impacted the catchment health and the livelihood of local inhabitants. Lake Ziway catchment has been an important source of livelihood for local communities (like, fishing) and the primary source for irrigation and domestic water supply, but it is now highly degraded. LULC change detection is therefore necessary for the assessment of land and water resource impacts and developing effective resource management and planning strategies.

1.3. Research Objectives

1.3.1. General objective

This study seeks to examine trends, drivers and implications of land use and land cover changes in the Lake Ziway catchment, central rift valley of Ethiopia.

1.3.2. Specific objectives

i. To assess the trends of land use and land cover changes on the Lake Ziway catchment from 1990 to 2020,

ii. To explore the driving factors of LULC change in the Lake Ziway catchment

iii. To assess local communities' participation in watershed management activities in the study area

iv. To examine the implications of LULC changes in the Lake Ziway catchment.

1.4. Research Questions

The following research questions are raised to address the above objectives.

i. How does the trends of land use land cover changes in the Lake Ziway catchment between 1990 and 2020?

ii. What are the driving factors of land use land cover change in the Lake Ziway catchment?

iii. What is the status of community participation in watershed management activities in the catchment area?

iv. What are the implications of land use land cover change in the Lake Ziway catchment?

1.5. Significance of the Study

Land use and land cover change is a significant aspect of the pressure on limited land resources, which is driven by a variety of biophysical and anthropogenic processes, especially population expansion. Therefore, analysis of land use and land cover changes deliver greater importance to stakeholders, urban planners, and decision-making groups to better understand the implications of these changes. In addition, information about the trends of LULC changes and driving factors could be used as input for various stakeholders and experts to make important decisions on reversing LULC changes impacts at watershed levels. Moreover, the outcome of this study would provide better information on the integrated application of GIS and remote sensing techniques and their suitability for the analysis of LULC changes. Furthermore, the analysis contributes to the general knowledge on the impacts of land use and land cover changes on the catchment so that other researchers can build on this knowledge to conduct further research.

1.6. Limitations of the Study

The present study attempted to collect the required information both from primary and secondary data sources. However, the study has encountered certain limitations. One of the limitations was that it was difficult to obtain secondary data from different organizations working on land use issues in Ethiopia. Given the remoteness of the study sites, the data collection activities were time-consuming and physically demanding. This has made it difficult to gather enough amount of data from various sources.

1.7. Thesis Chapter Outline

This thesis is divided into five chapters. The first chapter introduces the background of the problem, study area, problem statement, research questions and objectives, the significance of the research and limitations. The second chapter forms the theory base of this research and provides a literature review on LULC change. This chapter also covers the driving factors of land-use change, major concepts important in LULC and classification. Chapter three describes the materials and methods used to address the research objectives and provides information on the data analysis processes. Following that, chapter four presents the results and discussion on trends, drivers and implications of land use land cover change in the Lake Ziway catchment. The fifth chapter concludes the study by summarizing the main findings and providing key recommendations for policy and practice.

CHAPTER TWO

LITERATURE REVIEW

2.1. Land Use and Land Cover Changes: Definitions and Concepts

Land is a defined area of the earth's terrestrial surface that includes all aspects of the biosphere immediately above or below it. This may include the near-surface climate, soil and terrain types, hydrology surfaces, plants, animals, human settlements, and the physical consequences of historical and present human activities (terracing, water storage or drainage infrastructure, roads, buildings, and so on) (Mutsindikwa, 2019). Human-induced processes such as deforestation, agricultural activity, and urbanization have significantly altered the earth's surface in the past decades.

Land cover is the physical and biophysical qualities or state of the earth's surface. The immediate environment is captured in the distribution of flora, water, desert, bare soil, and other physical features of the land, including those caused only by human actions, such as settlements (Kassa and Forech, 2009). Land cover is the natural vegetative cover type that defines a specific location and land cover change is the modification or total conversion of an existing land cover to a new cover type (Aklile Negatu, 2014).

Land use refers to the planned use or administration of a land cover type by human beings. Thus, land use encompasses both the ways land's biophysical attributes are manipulated and the intent behind that manipulation (e.g., agriculture, grazing, etc). The conversion of land use owing to human involvement for diverse purposes, such as agriculture, settlement, transportation, infrastructure, and manufacturing, parks, recreation usage, mining, and fishing is known as land use change (Aklile Nigatu, 2014).

Land use change is defined to be any physical, biological or chemical alteration attributable to management, which may include translation of grazing to cropping, alteration in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, the spread of weeds and exotic species and conversion to non-agricultural uses. Land use changes are typically observed in deforested land, farmland expansion, dryland degradation, urbanization, pasture expansion and agricultural intensification (Abiy, 2014).

Land Use and Land Cover (LULC) Changes refers to changes in land use and land cover as a result of changes in intent and/or management. Land use and land cover conversions and land use and land cover modification are two types of LULC change (Lambin and Geist, 2008). Conversion refers to the transition from one form of cover or usage to another, such as in agricultural growth, deforestation, or urban expansion. Land use and land cover modification, on the other hand, entails maintaining a broad cover or use type despite changes in its characteristics. Both conversion and modifications of land use and land cover have significant environmental consequences due to their effects on soil and water, biodiversity, and microclimate (Lambin *et al*., 2003).

2.2. Drivers of Land Use Land Cover Change

Changes in land use and land cover result from the direct and indirect effects of human-induced actions on the environment to improve one's quality of life. For example, population growth has an impact on land use, particularly in developing countries. As land use and land cover change is a complex process, it can also be caused by mutual interactions between environmental and social elements at different spatial and temporal scales (Lambin *et al*., 2003). LULC change is often recognized as a function of socioeconomic and environmental factors. These factors are often referred to as ‘driving factors. The factors that drive LULC change can be classified as proximate or underlying drivers. The former refers to direct changes made by individuals on a small scale such as at individual farms, and the latter refers to indirect changes made at a regional level (Turner *et al*., 2007). Proximate (direct) driving factors are immediate activities of local peoples to meet their demands from land use. Agricultural development, wood extraction, infrastructure expansion, and other factors that alter the physical status of land cover are among these factors.

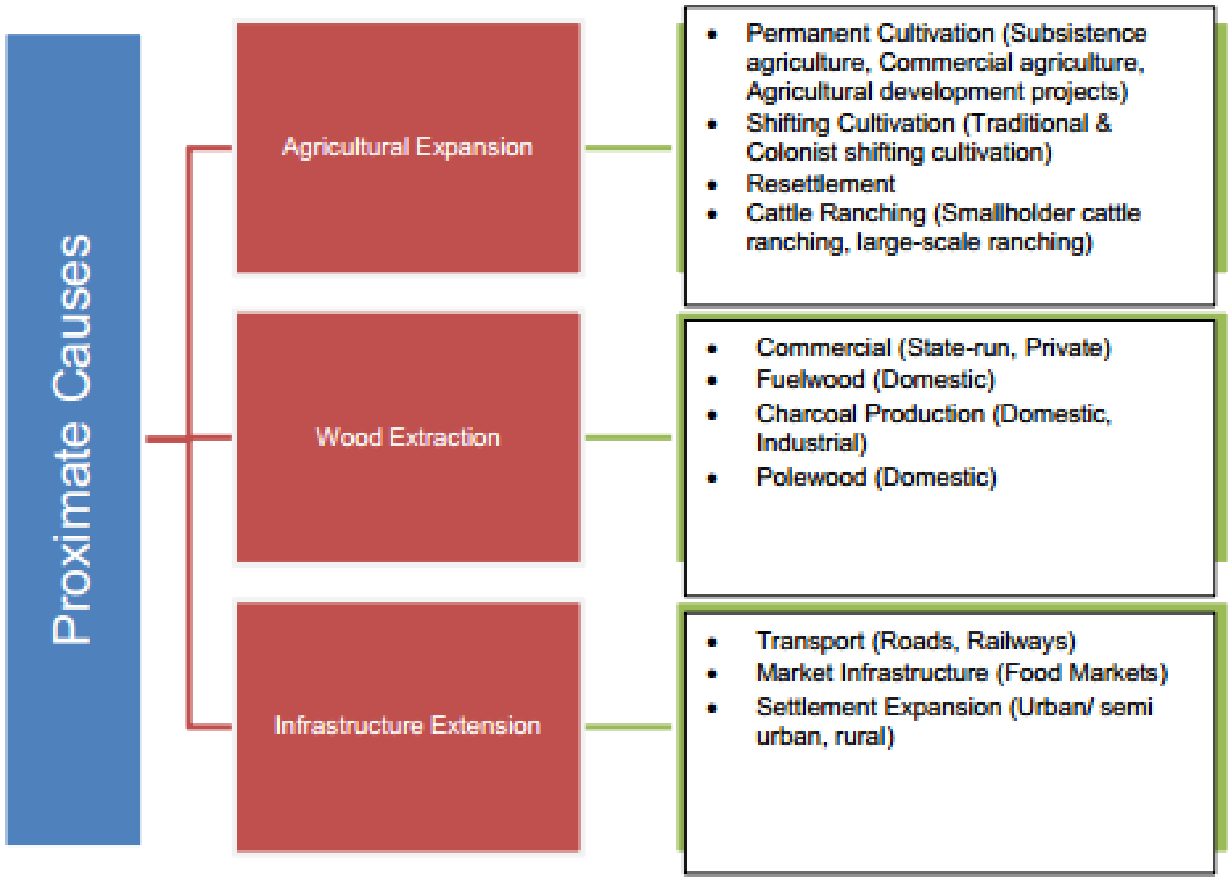

Figure 2. 1. Proximate causes of LULC change and their variables (Mutsindikwa, 2019)

Underlying (indirect) drivers are fundamental socioeconomic and political processes that push proximal causes into immediate action on land use and land cover. Land cover/use is influenced by the interaction of multiple underlying drivers such as demographic pressure, economic status, technical, and institutional elements. Underlying causes are frequently external and beyond the control of local communities (Geist and Lambin, 2002).

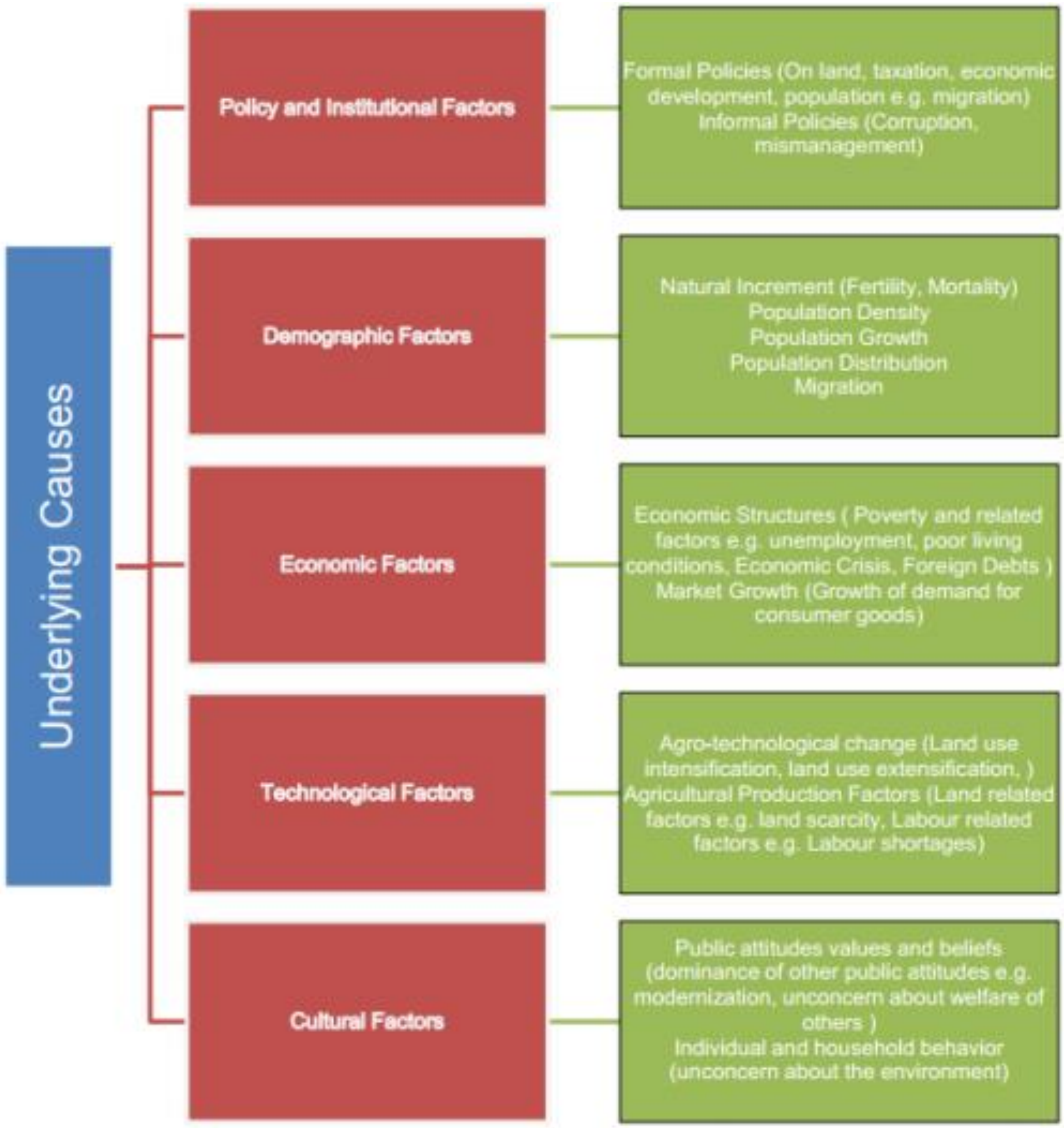

Figure 2.2. Underlying causes of LULC change and their variables (Mutsindikwa, 2019).

Land cover changes, on the other hand, can be caused by a variety of sources, which can be split into natural and human-induced or anthropogenic causes. Demographic considerations, policies, institutional factors, legislation, as well as socio-cultural diversifications, economic, technical advances, and environmental issues, are all common root causes of land use and cover changes (Milline *et al*., 2003). All of these factors show the interaction between biophysical and societal processes over time and space and reflect the economic, social and political processes as well as the physical environment. They also reflect interdependencies between scales, from local to national and international scales (Aklile Nigatu, 2014).

2.3. Population and Land Use Land Cover Change

Population growth is related to a rise in resource consumption, which causes extension and intensification of land use, overexploitation of biological resources and exploitation of marginal lands as well as the disintegration of traditional resource management systems. Changes in LULC and socioeconomic dynamics are linked. As the population grows, so does the demand for cultivated land, grazing land, and fuel wood, settlement areas to fulfil the increased demand for food and energy (Tadele *et al*., 2019). According to Aklile Nigatu (2014), the key agents between land use and land cover changes are human beings. Population growth is one of the key drivers for the observed land cover dynamics in most developing countries (Mesfin, 2020). Compared to other sources, population growth has been a more prominent factor of land use and land cover change in Ethiopia (Muluneh, 2010). Agricultural areas are expanding at the expense of natural vegetation and grasslands in response to rising food production demands (Kassa and Forech, 2009).

2.4. Land-Use and Land Cover Changes in Ethiopia

The nature of LULC dynamics significantly differs from country to country as the drivers of LULC change and land management activities vary from place to place (Negese, 2021). In Ethiopia, natural resources changes, availability and management practices vary significantly from place to place. This variability is caused by differences in climate, topography and biogeography (Eyasu *et al.*, 2019). Human actions are speeding up land-use/land-cover changes, but they are also causing changes that affect humans. The dynamics of LULC changes the availability of many biophysical resources, such as water, vegetation, soil, animal feed, and other resources (Belete, 2017). In Ethiopia, land use change is mostly driven by people's decisions, population growth, and declining income and household farm size (Mesfin, 2020).

In the country, the proximate causes of land cover change include natural forest destruction, agricultural expansion (i.e., shifting cultivation and the spread of sedentary agriculture), increasing demands for construction material, fuel wood, and charcoal. Charcoal production is widely produced in semi-arid, arid and dry sub-humid parts of the country (Hamza and Iyela, 2012). Fire is also commonly used to fumigate bees and to enable hunting, which causes forest fire and natural forest destruction (Aklile Nigatu, 2014).

Previous studies show that there have been significant LULC changes in Ethiopia due to the expansion of cultivated land at the expense of forestland (Meshesha *et al*.,2012; Tesfaye *et al*., 2014; Desta *et al*., 2017; Negese, 2021;). Forest land is being stretched into sloppy areas due to land scarcity. Agricultural practices and human settlement have a long history, especially in Ethiopia's highlands. Population pressure and unstainable activities in highland areas have depleted natural resources (Miheretu and Yimer, 2018).

In addition, research work undertaken on the spatial and temporal land use and land cover change at watershed and district level in Ethiopia has shown that there has been a significant LULC change in different parts of the country due to the expansion of cultivated land and built-up areas at the expense of natural vegetation cover, shrublands, and grasslands particularly in the highlands (Bewket and Abebe, 2013; Alemu *et al*., 2015; Hailemariam *et al*., 2016; Deribew and Dalacho, 2019; Yesuph and Dagnew, 2019; Ogato *et al*., 2021).

For example, Bewket and Abebe (2013) reported the consistent expansion of cropland and settlement at the expense of forest and dense tree cover over the period between 1957 and 2001 in Gish Abay Watershed, Blue Nile Basin of Ethiopia. A similar study by Hassen and Assen (2018) reported that farmlands and settlement areas expanded at the expense of forest area, shrublands, and grasslands over the study period between 1957 and 2014 in Gelda catchment, Lake Tana Watershed of Ethiopia. Further, Tesfaye *et al.* (2014) reported a significant increase in cultivated land and settlement and a decrease in vegetation cover between 1976 and 2008 in Gilgel Tekeze Catchment, Northern Ethiopian Highlands. According to Shawul and Chakma (2019), cropland and the urban area also replaced a large area of forest cover and shrublands in Upper Awash Basin, Ethiopia, over the years between 1972 and 2014.

2.5. Impacts of Land Use and Land Cover Changes in Ethiopia

LULC change exerts negative impacts on ecosystem services, in general, and on biodiversity, climate, soil, water, and air, in particular (Hailemariam *et al*., 2016).

Impact on soil erosion: Soil erosion is affected by LULC change. Land cover plays a significant role in controlling soil erosion by reducing the direct impacts of raindrops on the soil, enhancing the organic matter content in the soil, increasing the infiltration rate of water, reducing the velocity of runoff, and reducing the transportation of sediments on the surface (Negese, 2021). Hence, a change in land use and land cover due to anthropogenic activities significantly affects the rate of soil erosion.

Impact on hydrological cycle: Land under little vegetative cover is subject to high surface runoff and low water retention. The increased runoff causes sheet erosion to intensify and rills and gullies to widen and deepen. The masses of sedimentary materials removed from hill slopes accumulate in low-lying areas downstream, where they create problems of water pollution, reservoir siltation, and problematical sediment deposition on important agricultural lands (Mesfin, 2020).

Impact on biodiversity: Biodiversity has been diminishing considerably by land use change. When lands change from forested land to a farming type, the loss of forest species within deforested areas is immediate and huge. The habitat suitability of forests and other ecosystems surrounding those under exhaustive use are also impacted by the fragmenting of existing habitat into smaller pieces, which exposes forest edges to external influences and decreases core habitat area (Mesfin, 2020).

Furthermore, LULC change can affect soil fertility, land productivity and the sustainability of environmental service provision. Apart from these, it also contributes to global warming (Mikias, 2015). Land-use changes affect watershed runoff, groundwater tables, processes of land degradation and landscape level biodiversity (Lambin and Geist, 2008). The radical land use and land cover change effect in the Ethiopian highlands will affect countries downstream because of the water and sediment carried from Ethiopia by the transboundary Rivers especially the Blue Nile.

2.6. Watershed Management Practices in Ethiopia

The Ethiopian government has long recognized the catastrophic consequences of continuous soil erosion in terms of environmental deterioration, and in the 1970s and 1980s, large national programs were developed to address this issue. For example, the government has funded rural land restoration in Ethiopia since 1980, to implement natural resource conservation and development programs through watershed development (Desta *et al*., 2005). However, these efforts were insufficient in preventing land degradation.

Catchment/Watershed projects in Ethiopia were very scarce in number. FAO implemented the institutional strengthening project, which aimed to increase the capacity of Ministry of Natural Resources technicians, experts, and development agents in the country's highlands. To produce land use plans for soil and water conservation, the projects used the sub-watershed as the planning unit and sought input from local technicians and members of the farming community. During 1988-1991, FAO technical assistance under the MOA was used to test this strategy at the pilot level (Desta *et al*., 2005).

The participatory planning approach to watershed development took its first steps in this direction. Watershed development had become the main point for rural development and poverty alleviation by the late 1990s. Several NGOs and bilateral organizations have implemented watershed development in their intervention areas over the last decade, with the help of government partners. For example, the land rehabilitation project, which received WFP Food-for-Work funding, attempted to address food insecurity by building soil conservation structures, community forestry, and rural infrastructure. The project concentrated on selected food shortage watersheds in the country where the occurrence of chronic food insecurity is highly severe. GTZ-Integrated Food Security Program South Gondar, with Integrated Watershed. Management Approach support aimed at enhancing the nutritional food insecure households in south Gondar through natural resource management by physical and biological soil conservation practices, crops and rural infrastructure works (Tesfaye, 2011). The gully rehabilitation strategy worked well for the project. Watershed development is currently being promoted by a wide range of donors and development organizations.

Watershed management in Ethiopia was merely considered as a practice of soil and water conservation. Early watershed project success stories were noticeable as the foundation of major watershed initiatives in Ethiopia (Alemayehu, 2012). However, only technology approaches were embraced from those early successful programs, and institutional arrangements were overlooked (MOARD, 2005). The newly introduced projects did not involve or make an effort to gather people to collectively solve the problem. When village participation was tried, one or two essential people, such as village leaders, were usually included. Because of their centralized organization, restrictive technology, and lack of attention to institutional arrangements, many projects failed (Alemayehu, 2012).

2.6.1. Community participation in watershed management

The best way to reverse environmental deterioration is to carry out environmental conservation and restoration by involving local people directly with the government, transforming a common experience of conflict into cooperation. Governments and non-governmental organizations (NGOs) have recognized that watershed conservation cannot be done without the active cooperation of residents. Therefore, people's participation is critical for sustainable and successful watershed management. This is one of the lessons gained from the failures of centrally planned watershed development projects, in which local people were forced to build terracing, bunding, gully rehabilitation, and other technical measures that external specialists' thought would cure watershed degradation (Tesfaye, 2011).

Farmer participation is vital not just for the execution of soil and water conservation measures such as terracing and bunding by food for work, but also for the planning of long-term land and water resource management. Farmers are closer to the actual difficulties, and so they are conscious of issues that professionals may miss, and their aims are more practical in terms of economic development. In addition, farmers' participation in conservation efforts is also vital in increasing the adoption of the recommended technology.

In Ethiopia, soil and water conservation programs are promoted with standard technical solutions such as terracing, contour bunding, and other soil conservation measures in most centrally planned projects (MOARD, 2005; Tesfaye, 2011). The assumption is that soil conservation measures are universally applicable and local farmers are unaware of soil erosion and its causes and consequences. However, when the new conservation efforts are rarely maintained or are technically less well adapted than traditional methods, these measures, which were often imposed on the people, may cause greater erosion than their indigenous practices. The greater majority of watershed progress projects are based on conventional and rigid approaches considering solely physical planning without care to socio-economic or ecological conditions (Abiyot *et al.*, 2018). For example, in the 1980s, the large Borkena Dam in South Wollo of Ethiopia was constructed without assessing the environmental conditions of the area (Desta *et al.*, 2005).

Managing a watershed involves not solely individual plots, but also common property resources like forests, gullies, springs, roads and footpaths, and vegetation along streams as well as rivers. Each watershed has varied demands and priorities for different users. Appropriate policies and technology can be established for each watershed by gathering information from farmers about their constraints and priorities, as well as their potential for new technologies. As a result, participatory watershed management entails all stakeholders to cooperatively discuss their interests, prioritize their needs, evaluate potential alternatives and implement, monitor and evaluate the project outcomes. User participation is important for successful watershed management. A participatory approach suggests a main role for the community and encompasses partnerships with other interested groups, at all levels and with policy makers. However, the key concern is to recognize approaches that can achieve an effective, efficient and the responsible line between the community, the local governments, the state and the federal governments.

2.7. Ethiopian Lakes and Their Temporal Variation

A lake is an inland body of water, surrounded by dry land around it into which water that drains from catchment. It's a big body of fresh or salty standing water located inland. Lakes are distinguishable from other bodies of water that have an exchange with the ocean and are subject to tides, such as bays and gulfs, and some seas. Lake basins are formed by a variety of geologic processes, including the buckling (fastening) of stratified rock into enormous folds, the movement of massive amounts of rock by faults, and the obstruction of valleys by landslides. Glaciers have left their mark on lakes as well. By scooping up bedrock and spreading loose debris, glaciers carve out vast basins. The source of lake water is rainfall that falls directly on the lake as well as through springs, brooks, and surface runoff from the watershed area, all of which contribute to a specific lake.

Ethiopia’s landscapes have 11 fresh and 9 saline lakes, 4 crater lakes and over 12 significant swamps or wetlands. The Rift Valley Basin has the vast majority of the lakes. Fish abound in the vast majority of Ethiopian lakes. Most of the lakes, except lake Ziway, Tana, Abbaya, Langano and Chamo, are endorheic, meaning they have no surface water outlets. Lakes Abijata and Shala have large concentrations of chemicals and Abijata is presently exploited for the production of soda ash (Eresso, 2010). Most of the lakes in the Rift Valley of Ethiopia are situated at the lowest end of large drainage basins to obtain maximum water-collecting potential. Because of this link between watershed activities and reservoir health and stability, understanding the complex interaction between aquatic and terrestrial systems has become an important part of lake management. This leads to a watershed evaluation to define criteria for efficiently dealing with watershed-related, reservoir water quality and quantity issues.

The rest of Ethiopia's large lakes are limited to the Rift Valley bottom. Because the majority of the lakes are fed by perennial rivers that begin in the highlands, their levels fluctuate according to rainfall patterns in the surrounding highlands. Seasonal lake level changes can reach 1 m, with the yearly high occurring in October or November. Although the impact of recent tectonic activity on the hydrological regimes of the lakes has not been completely examined, some changes in lake level may be linked to rift fault opening or reactivation. For instance, alterations in the discharge of springs around lake Langano have been observed after current seismic activity run to the formation of new faults (Ayenew and Legesse, 2007).

Lake Ziway, locally known as Hara Dambal in Ethiopian Central Rift Valley (CRV), is one of the country's most important lakes. This lake has been used for agricultural, domestic water supply, and recreation since it contains fresh water from the two incoming rivers (Katar and Meki), and rainfall. Furthermore, soil adjacent to the eastern lake shore closer to Chafe Jilla is full of minerals and it is used for livestock of the area and adjacent high land community. Similar to other exorheic lakes, Lake Ziway is experiencing all processes, such as variation of lake level and volume due to anthropologic activities and climatical change. According to Eresso (2010), if all planned land area is irrigated, annual water abstraction from the Lake and main Rivers will be about 150-180 Mm^3 with 30 cm discount in the level of lake Ziway which eventually lead to a radical decrease in the level of lake Abijata and drying up of the feeder Bulbula river.

The level and area of Lake Ziway may be affected significantly by climatic change. Temperature and other environmental factors (sunshine duration, wind speed, and relative humidity of the air) are rising, while the length of the rainy season is shortening, resulting in a reduction in water input to the lake (Lijalem, 2006). This could influence the lake level decline that may reach up to 62 cm in the coming 90 years, therefore, the water surface area of the lake Ziway can also shrink to 25 km^2 (Eresso, 2010).

2.7.1. Water resources of Lake Ziway catchment

Lake Ziway, Katar, Meki and Bulbula rivers are major water resources in the watershed. There are also seasonal intermittent that originated from highland areas either feeding these major rivers or directly draining to the lake. Katar River is the biggest perennial river starting from Arsi high lands (Kakka mountain) and flowing towards the northwest and finally joins the lake. The river has a watershed area of 3350 km^2 at Habura gauging station and 1750 km^2 at Fite. The watersheds of Katar river ascend to over 4256 masl on the summits (picks) of Chilalo and Kakka mountains. Consequently, the gradient of this river is generally steep throughout its course to Lake Ziway, and it is often deeply incised up to 50 m below the ground surface. Meki river drains an area of 2433 km^2 from the Gurage mountains to the west and northwest of Lake Ziway. Although the head water of Meki river is at an altitude of about 3500 masl, the river rapidly descends the rift valley escarpment to an elevation of below 2000 m before being joined by several major tributaries, Meki river is incised in a steep-sided valley until it reaches Meki town at the head of its delta. The entire outflow from lake Ziway is through Bulbula river, which flows in the south direction to lake Abijata. Bulbula descends some 58 m over a distance of 30 km between lake Ziway and Abijata. Except during the wet season, the flow in the river usually derives from lake Ziway. During the past three decades, the mean annual discharge of Katar and Meki rivers contributed by about twice the direct rainfall inputs to the lake Ziway or about 15% of the annual rainfall of the watershed (Eresso, 2010).

2.8. Role of Remote Sensing and GIS in Land-Use and Land-Cover Change

Remote sensing and geographic information system techniques have been commonly used worldwide to study historical changes in LULC. Vegetation cover, air pollution, water bodies, bare soil, and other surface characteristics have all been identified by using remote sensing. It delivers a large variability and amount of data about the earth’s surface for comprehensive analysis and change detection. With the accessibility of historical remote sensing data, the lessening in data cost and enlarged resolution from satellite platforms, remote sensing technology seems ready to make an even larger impact on monitoring land-cover change (Belete, 2017).

A Geographic Information System (GIS) is a computer-based system for capturing, storing, manipulating, analyzing, managing and displaying spatial or geographic data. When used together, RS and GIS provide powerful tools for earth observation and data processing. Viewing the earth from orbit allows us to appreciate the cumulative impact of human activities on the natural state of the planet's surface. Capturing and analyzing this information by the RS and GIS tools offers a cost-effective record of LULC in a precise and timely manner (Siddhartho, 2013).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Introduction

This chapter presents all the techniques and methods that were used for conducting this research. First, information about the study area will be presented. Following that, the specific methods and data collection process will be described. Lastly, the data analysis techniques will be described.

3.2. Description of the Study Area

3.2.1. Location

The study was conducted in Lake Ziway catchment, central rift valley of Ethiopia. The study site is located at 163 km south of Addis Ababa. Geographically, the catchment lies between latitudes 7^0 30’0” to 8^0 30'0” N and longitudes 38^0 30’0” to 39^0 30’0” E (Figure 3.1). The area of the catchment is 7300 km^2 (ESRI, 2016).

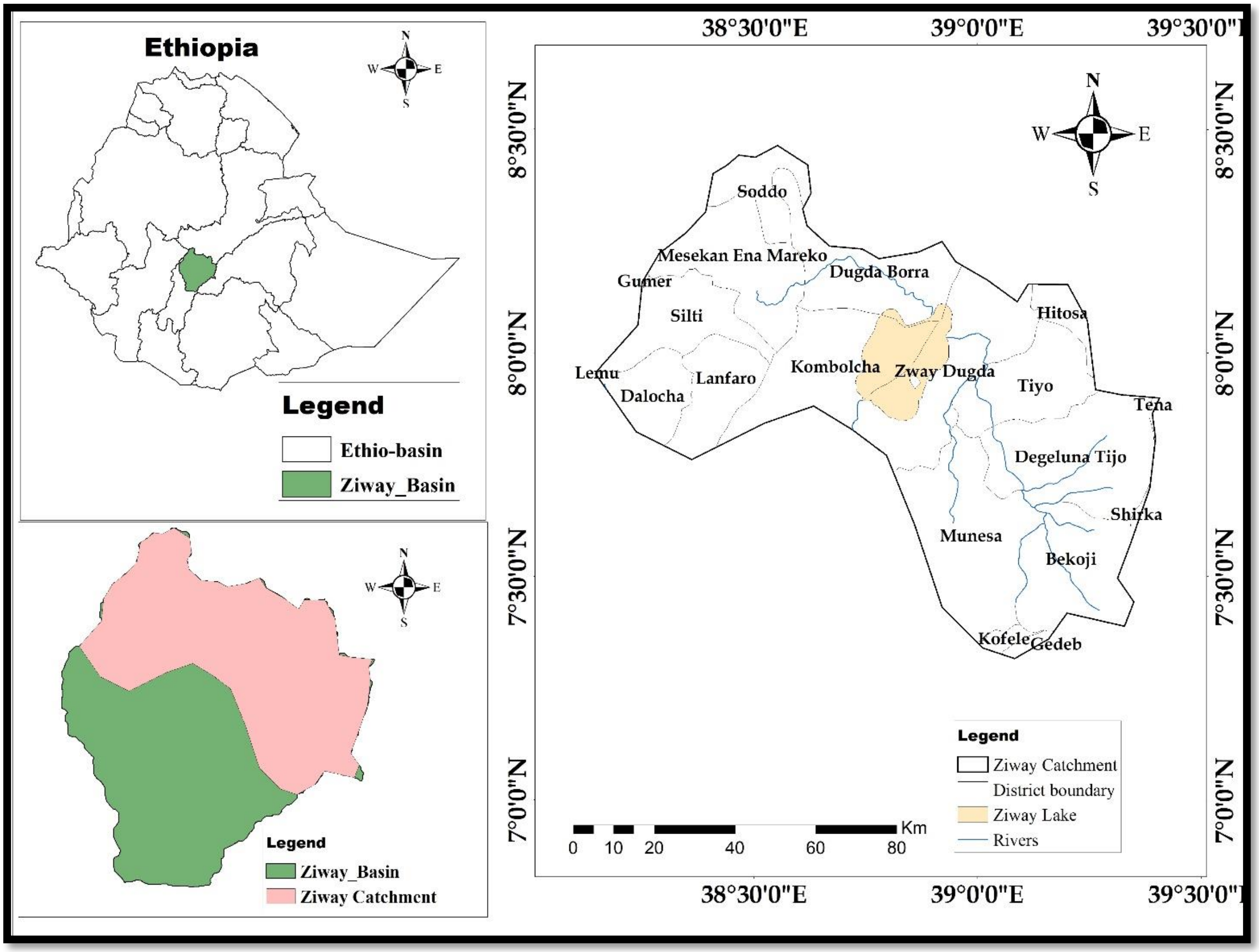

Figure 3.1. Location map of the study area

The catchment contains the Rift floor, two escarpment areas, two major river inlets - Katar and Meki Rivers - and one river outlet - Bulbula River. Lake Ziway and its surrounding lowlands are covered by the center part of the watershed (Rift Valley bottom). Lake Ziway, the most upstream of the Central Rift Valley lakes of Ethiopia, is located in the Rift floor part of the watershed. Runoff from the watershed pours into Lake Ziway via two feeder rivers that symbolize the opposite faces of the Rift escarpments, in addition to seasonal runoff and groundwater movement. It is the major freshwater lake in the central Rift Valley With a surface area of 420 km^2. The lake is relatively shallow with 9 meters depth maximum. The lake is one of Ethiopia's primary sources of commercial fish farming. In the central rift valley, Lake Ziway is the only lake used for irrigation purposes and municipal water supply (Hailesilassie and Tegaye, 2020).

3.2.2. Climate

The climate in the Lake Ziway catchment ranges from dry to humid. The lowlands around the lake are arid or semi-arid, while the highlands are humid to sub-dry humid. The climatic conditions in the catchment are not uniform. The intensity, duration, and frequency of rainfall events vary throughout the year in the watershed. The catchment has a tropical climate, with a minimum and maximum annual precipitation of 729.8 mm and 1227.7 mm, respectively (Demeke, 2018). The rainy season, which lasts from June to August, accounts for around 55% of the yearly precipitation, while the other seasons account for the remaining 45% (Desta *et al.*, 2017). The mean annual temperature is 18.5 °C (Demeke, 2018). The temperature in the Lake Ziway catchment is relatively constant throughout the year. The daily maximum temperature is 24.2 ^{o}C to 30.5 ^{o}C and the daily minimum temperature varies between 10.4 ^{o}C and 16.8 ^{o}C (Desta and Fetene, 2020).

3.2.3. Population and livelihood systems

The total population size in the Lake Ziway catchment is about 2 million (CSA, 2017). According to data obtained from the Batu district office, the catchment has 339, 000 households out of this 85% are male-headed households and 15% female-headed households. The settlement pattern is typical of rural communities. Livelihoods largely depend on smallholder agriculture and livestock production. For example, about 1.9 million livestock (Meshesha *et al.*, 2012) inhabit the Lake Ziway catchment. The fishery of the lake is also an important source of livelihood to fishermen and their families and provides the sources of food for many families within the lake basin and beyond.

3.2.4. Geology, topography and soils

The Lake Ziway catchment has the lowest and highest elevations ranging from 1601 to 4213 m above sea level (masl). It is characterized by high mountains at the edge and mostly flat landform on the Rift floor. The slope classes in the catchment are spatially distributed along with elevation. Eighty-nine per cent of the entire watershed area comprise of less than 30 percent slopes with the remaining slopes of greater than 30 percent (steep to very steep hills and mountains). Tectonic forces shaped the watershed's mountains, hills, ridges, and low-lying areas during the Cenozoic era (Desta and Fetene, 2020). Most of the eastern and western parts of the catchment have shallow to very shallow soil beds (mostly Cambisols). The dominant soil types in the Rift floor around Lake Ziway are Fluvisols and Luvisols. Agricultural activities are carried out on flat to gently sloping lands with high clay concentration.

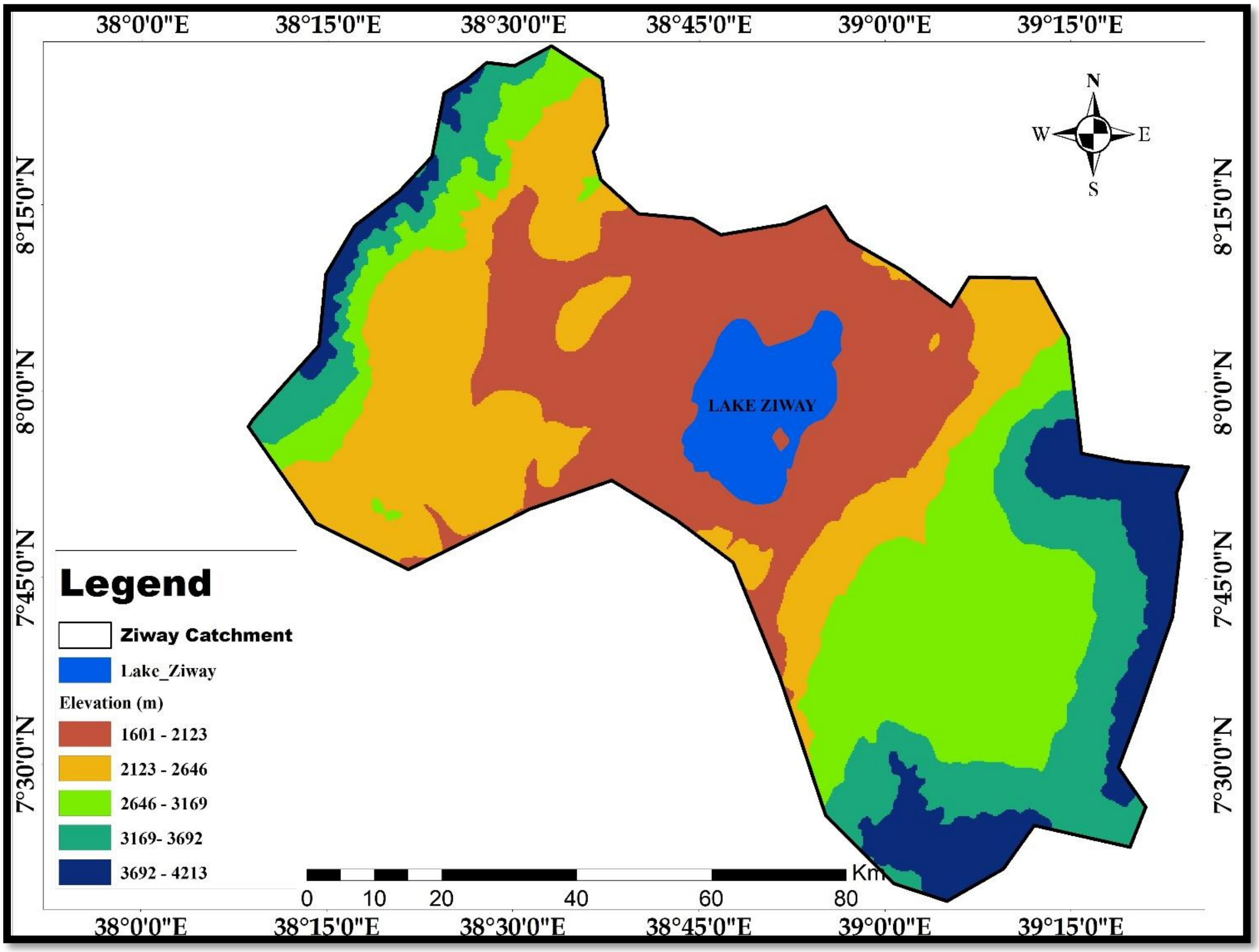

Figure 3.2. The elevation map of Lake Ziway Catchment

3.2.5. Land use types, vegetation and farming systems

The predominant land use in the watershed is smallholder agricultural land. The vegetation cover in the Rift floor is characterized by Acacia combretum open woodland, with deciduous woodlands. The farming system of the study area is agriculture with mixed crop-livestock production. The major types of crops and vegetables produced are wheat, barley, maize, tomatoes, and onions.

3.3. Methods and Data Collection

To carry out this study, both primary and secondary data sources were used. Primary data was collected by employing methods such as household surveys, in-depth interviews, and focus group discussions. Secondary data was collected from published and unpublished documents obtained from different sources such as thesis, country policy statements, reports, papers and journals on LULC changes and their drivers.

Remote sensing and GIS in land use land cover change: Remotely sensed data are vital in LULC change studies. For the purpose of this study, three periods of satellite images were used. Actual ground control coordinate points were collected for each LULC type using GPS. Trends and levels of LULC change over the last three decades were analyzed using satellite image and GIS techniques supplemented with field observations.

Household survey: The objective of the household survey was to collect socio-demographic data as well as to obtain information on drivers of LULC change, community participation in watershed management and the type of training received by the study participants. In total, 120 survey respondents were selected using a simple random sampling technique. The study was conducted between 29 August 2021 to 18 September 2021.

In-depth interview: In-depth interview is a qualitative data collection method that helps to better understand and explore research subjects, opinions, behavior, experiences, and phenomenon. In this study, in-depth interview techniques were used to collect information on the drivers and implications of LULC changes, community participation in watershed management, impacts concerning the watershed resources, current situation and future management strategies of the catchment. In total, 15 key informants were selected purposively for in-depth interviews from different social groups including elders, community leaders, agricultural experts, researchers and natural resource experts. Participants of in-depth interviews were selected purposively based on their experiences and knowledge they have about the issues in the catchment.

Focus group discussions: this technique was used to gain a detailed understanding of land use land cover issues in the catchment. A total of 4 focus group discussions were carried out. each FGD consisted of 5-10 people. A purposive sampling method was used for the selection of FGD participants based on their knowledge and experience on LULC issues in the Lake Ziway catchment. The participants included officers from the agricultural bureau, selected farmers, elders, and local natural resources managers.

3.3.1. Socio-demographic Characteristics of Sample Households

The socio-demographic characteristics of the sampled households are presented in Table 3.1. The results indicated that the respondents' ages ranged between 20 to 75 years, with an average of 40 years. In terms of gender, 70% of the respondents were male households, while 30% were female households. The majority of the respondents were married (78%). The results also revealed that household size ranged from one person to 15 people, with an average of 7 persons. The land holding size of the respondents varied from 0.25 to 9 hectares, with an average of 4.5 hectares. Based on their education status, 70 % of the respondents were literate. Out of which, 55% attended primary and secondary school and 15% attended higher education. Almost 86% of the sampled households were involved in farming activities, and a small portion of the respondents (14%), were involved in trading/business, civil services, school teachers and others. The mean household income of the respondents was 1875.67 USD or 86,506.12 ETB per year. Farming was ranked as the most important source of income in the catchment. Income from self-employment opportunities, such as businesses, handcraft, and trade, was ranked second, followed by piece works or occasional jobs, full-time government/private employment.

Table 3.1. Sample households' characteristics in the study area (N = 120)

Household characteristics	Respondents (%)
Interview gender (male, %)	70
Average household age (years)	40
Marital status (married, %)	78
Education (literate, %)	70
Main sources of household income (farming, %)	86
Mean household size	7
Mean land holding size (ha)	2.45
Mean annual household income (Birr/year)	86,506.12

Ethiopian currency: at the time of the study, 1 USD = 46.12 ETB

3.4. Data Analysis

3.4.1. Satellite image analysis

The materials employed to determine LULC change in this study was the Landsat satellite image series. To unravel the land cover dynamics of the area, cloud-free spatiotemporal data of two Landsat Thematic Mapper Plus (TM+) 30 m (1990 and 2005) images and one Landsat 8 OLI-TIRS 30 m (2020) image were downloaded from open access Landsat imagery services at https://earthexplorer.usgs.gov/. All of the raw satellite images were taken in a similar season because of the availability of cloud-free Landsat imagery across the study area during the dry season. GIS data on the administrative boundary, road network, towns, and river network were obtained from the GIS department of the Ministry of Water, Irrigation and Electricity (MoWIE), Ethiopia. A 30 m resolution Digital Elevation Model (DEM), based on Aster imagery was employed. In addition, ancillary data was also utilized during the analysis. All data were projected to the Universal Transverse Mercator (UTM) projection system zone 37N and datum of World Geodetic System 84 (WGS84), ensuring consistency between datasets during analysis. General characteristics of the multitemporal satellite data used in this study are described in Table 3.2 below.

Table 3.2. Description of image data used for LULC change study in Lake Ziway catchment

Satellite	Sensor	Path/Row	Resolution	Date of acquisition	Source
Landsat 7	ETM+	168/54	30m	16/01/1990	USGS
Landsat 7	ETM+	168/54	30m	18/01/2005	USGS
Landsat 8	OLI/TIRS	168/54	30m	19/01/2020	USGS

3.4.2. Data processing and classification

Before image processing, extraction, layer stacking, georeferencing and change detection were performed on the Landsat TM/OLI images obtained for different dates to create multi-band composite images. Then, a supervised maximum likelihood classification technique was undertaken to identify, classify and evaluate the existing LULC types in Lake Ziway catchment using ArcGIS Software Version 10.4. Training areas corresponding to each LULC type were identified from fieldwork. To evaluate and validate the classification outputs of the satellite images, the actual ground control coordinate points were collected for each LULC type using GPS. This process was supported by gathering information from elderly local people of the watershed. The catchment encompasses different land use land cover types; the major ones being cultivated land, grazing land, water bodies, forest land, wetland, plantation and settlement lands (Table 3. 3).

Table 3.3. Description of the major LULC types identified in the Lake Ziway catchment

LULC categories	Brief description
Cultivated lands	Rain fed and irrigated cultivated areas of land used for growing crop
Grazing lands	Areas with temporary or permanent grass cover privately and communally owned grazing areas for livestock.
Forest lands	Areas covered with a dense growth of trees and woody plants mainly acacia dominated species.
Water bodies	Area covered with permanent open water (mainly lakes, reservoirs, streams, canals and other shallow water.
Plantation	Area planted with eucalyptus trees
Wetlands	Areas that are wet and covered by long grasses and shrubs; most of these lands are found around the lakes and rivers and are temporarily waterlogged, marshy areas and non-forested wetlands.
Settlements	Rural settlements in the study area, small towns typical of rural communities

3.4.3. Land use land cover change analysis

Land use change analysis was conducted using the post-classification image comparison technique (Eyasu *et al*., 2019). Images of different reference years were first independently classified. The classified images were compared between each study period (1990 to 2020). Transitions between different land use/land covers were evaluated by comparing image values of one data set with the corresponding value of the second data set in each period to measure areas converted among the different land uses. Quantified values of the changes between the different LULC classes were used for statistical analysis to reveal the extent of the dynamics in the study areas. The percentage of change within the same LULC class between two-time points is calculated as follows, the values were presented in terms of kilometer squares (km^2) and percentages (%). Positive values suggest an increase whereas negative values imply a decrease in the extent of a given land-use type.

$$Change\ (\%) = \frac{Art - Apt}{Apt} * 100$$

Where, change (%): percent change in the area of specific land use land cover class between times t_n and t_{n-1}; Art is recent area extent of a given LULC type at time t and A_{pt} is previous area of LULC at earlier time t.

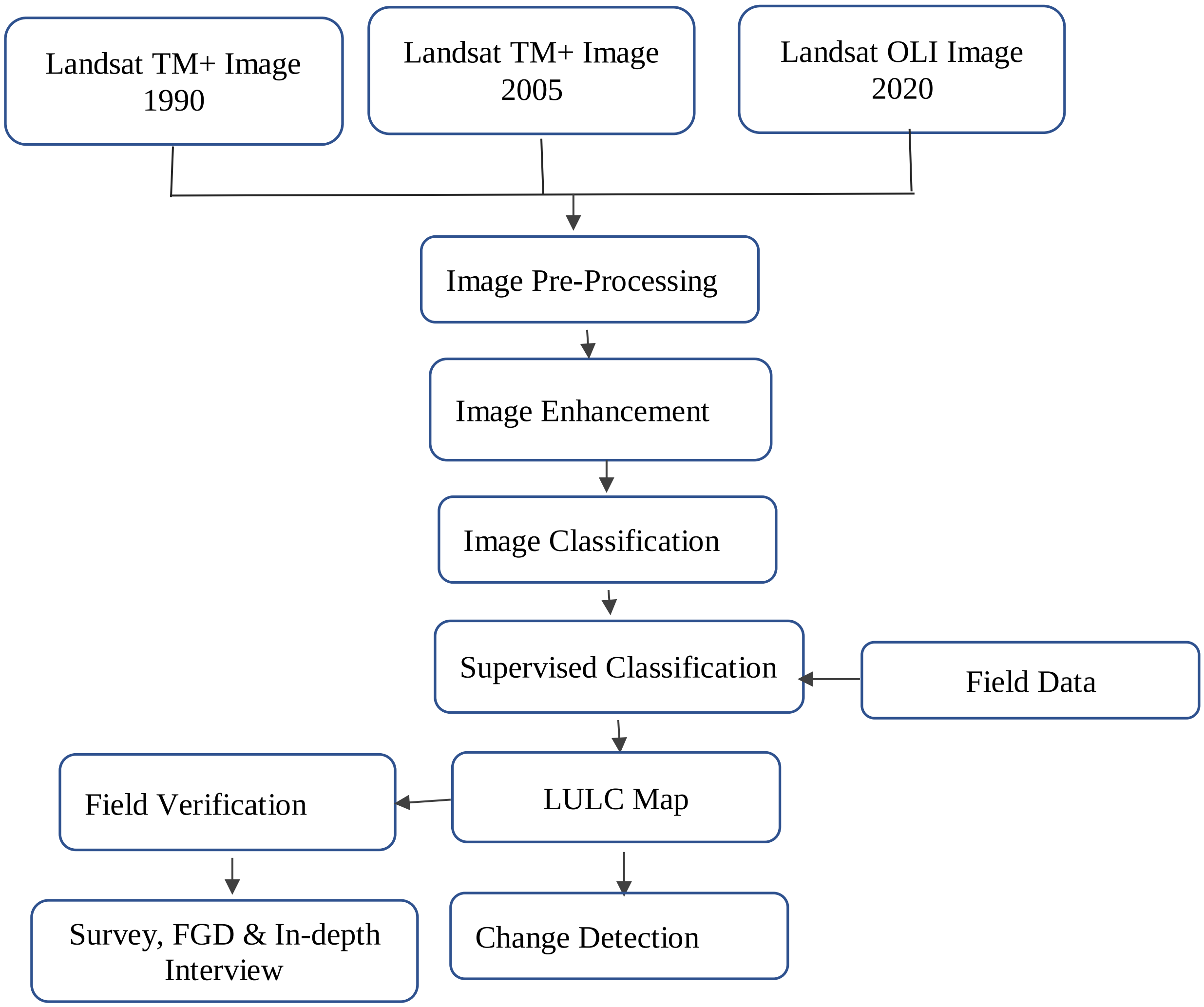

Figure 3.3. Flow chart of the general methodology followed for LULC classification

3.4.4. Quantitative data analysis

After the collection of data, ArcGIS 10.4 software was used to extract useful information in the catchment and compute the statistics. SPSS software was used for data entry and statistical analysis of quantitative data. Microsoft Excel was also used to make graphs. To analyze the qualitative data, thematic analysis techniques were employed.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

This Chapter presents the extent and trends of LULC changes which were observed in the Lake Ziway Catchment between 1990 and 2020. The chapter also explores some of the key drivers of land use land cover changes in the study area. Following this, the results of the analysis of community participation in watershed management activities and its impact on land use land cover change will be presented. Finally, the chapter discusses the implications of LULC change in the Lake Ziway Catchment.

4.1. Land Use Land Cover (LULC) Mapping and Change Analysis of the Catchment

LULC maps of the Lake Ziway catchment were prepared and presented for the three-time periods (1990, 2005 and 2020) in Figures 4.1a, 4.1b, and 4.1c below. The LULC analysis revealed a significant change from the period 1990 to 2020. The analysis was made using dominant LULC on the Ziway catchment. For the three-time periods 1990–2005, 2005–2020, and 1990–2020, areas for each of the seven categories of LULC types and the number of changes were calculated (Table 4.1). The changes in LULC were described below for each category (Cultivated lands, Grazing lands, woodlands, wetlands, plantation, settlement and water bodies).

Based on the 1990 LULC mapping (Figure 4.1a and Table 4.1), the greatest share of LULC from all classes were cultivated land and forestland. The cultivated land covers an area of 3258.34 km^2, contributing 44.63% of the total catchment area. Whereas the forestland covers 2189.64 km^2, contributing 30% of the total catchment area. Grazing lands cover an area of 1065 km^2 (14.59%) and plantations cover an area of 75 km^2 (1.03%). On the other hand, from the total area of the catchment, the area coverage of wetlands, settlement and water bodies were 122.02 km^2 (1.67%), 130 km^2 (1.78%) and 460 km^2 (6.30%), respectively. This shows that 20.89% of the total area of the watershed were covered by grazing land and water body in 1990 and the remaining 4.48% were plantations, wetland and settlements.

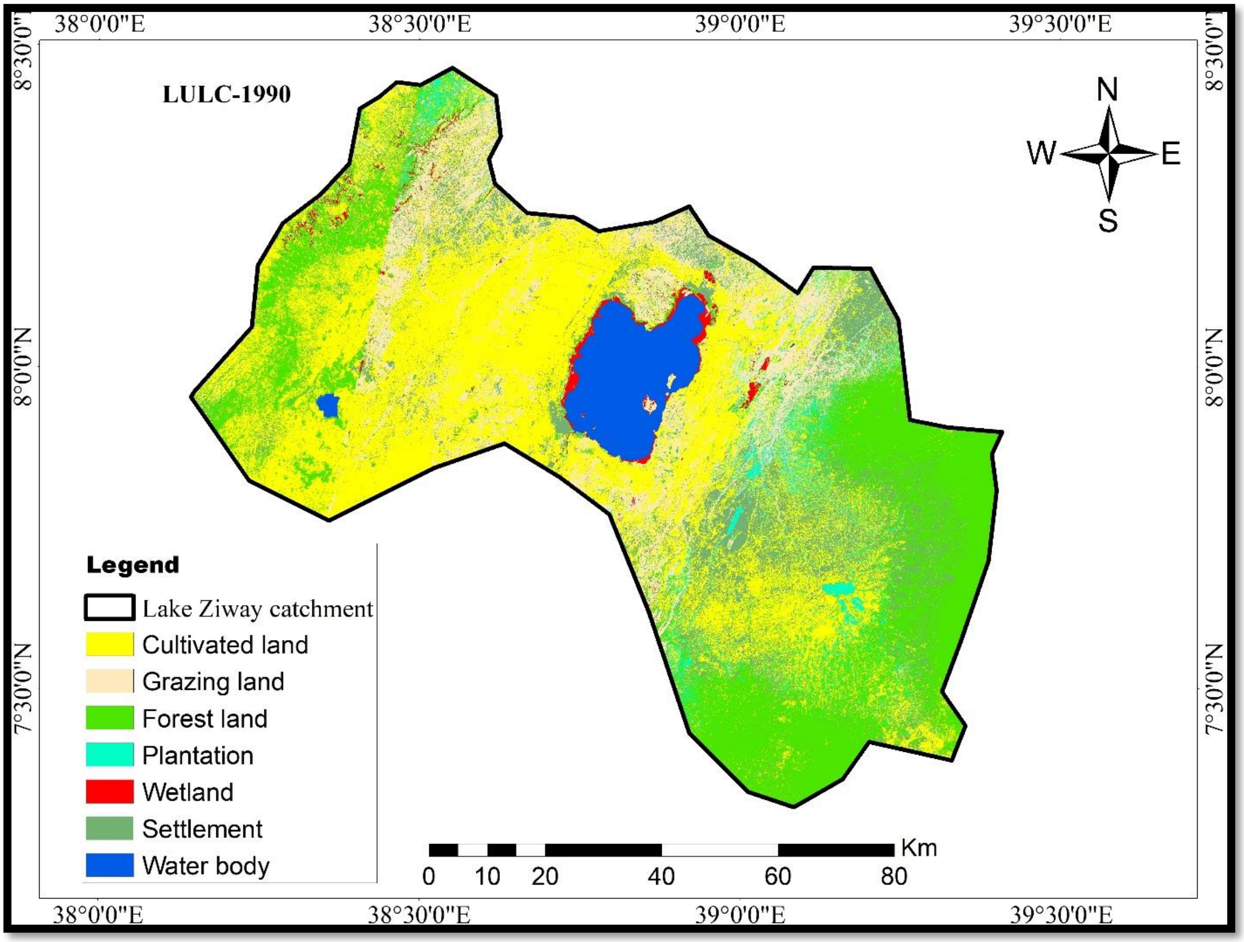

Figure 4.1a. Land use and land cover map of the Lake Ziway catchment, Ethiopia, in 1990

In the year 2005, the large area coverage of LULC from all classes was cultivated land and forest land (Figure 4.1b and Table 4.1), which covers an area of 3823.67 km^2 (52.38%) and 1677.11 km^2 (22.97%), respectively. Grazing land, settlement and water body covered an area of 975 km^2 (13.36%), 165 km^2 (2.26%) and 450 km^2 (6.16%) respectively. The lowest land area coverages were plantation and wetlands, which accounts for only 98 km^2 (1.34%) and 111.22 km^2 (1.52%), respectively. This result shows that more than half (52.38%) area of the catchment was covered by farmland (Table 4.1).

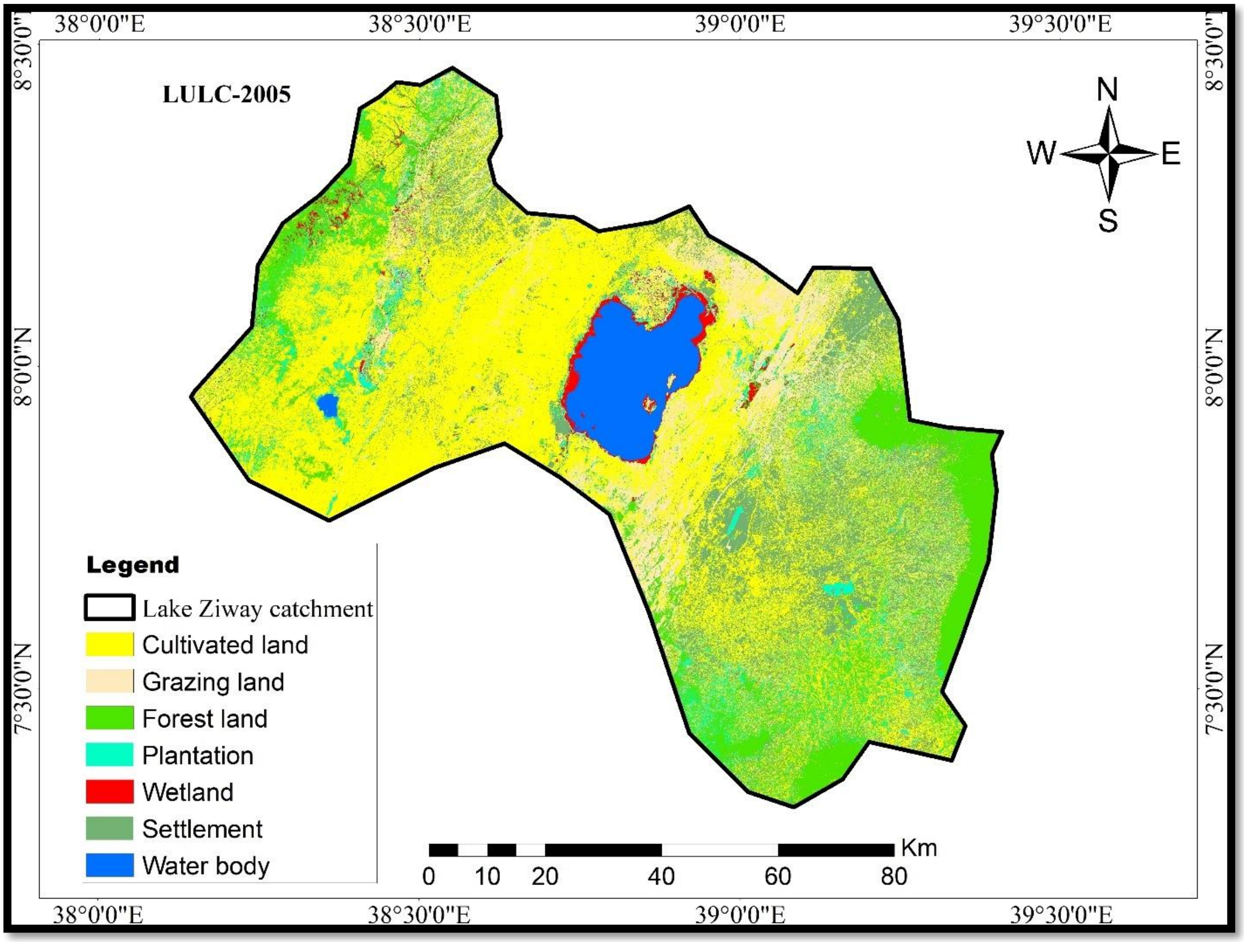

Figure 4.1b. Land use and land cover map of the Lake Ziway catchment, Ethiopia, in 2005

In the year 2020, as indicated in Figure 4.1c and Table 4.1, cultivated land cover the widespread share of LULC classes, which account for an area of 4566.76 km^2 (62.56%). This indicates more than half per cent of the catchment is covered by agricultural land and agricultural expansion is rapidly expanding in the study area. Forest land covered an area of 988.64 km^2 (13.54%) and grazing land cover an area 896.15 km^2 (12.28%). The area coverage of settlement was 210 km^2 (2.88%), while the water body covered 420 km^2 (5.75%). The smallest areal coverages were plantation and wetlands, which account for only 120 km^2 (1.64%) and 98.45 km^2 (1.35%), respectively from the total area of the catchment.

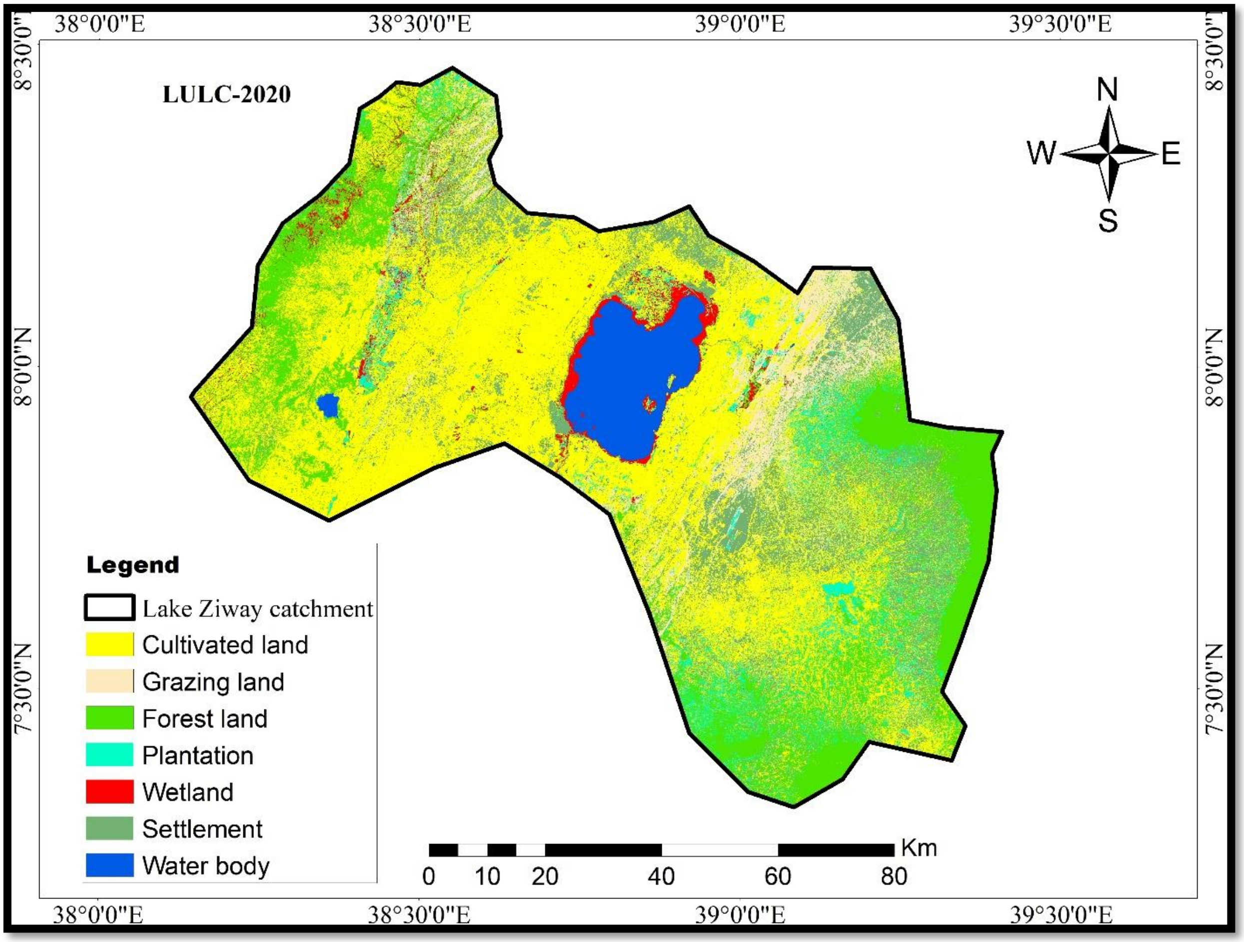

Figure 4.1c. Land use and land cover map of the Lake Ziway catchment, Ethiopia, in 2020

4.1.1. LULC change trends and rate in the Lake Ziway catchment (1990–2020)

The LULC changes varied in their existence between the three-time periods: 1990–2005, 2005–2020 and 1990-2020. The rate of LULC change in the Lake Ziway catchment throughout 1990–2020 is presented in Table 4.1. The major LULC changes observed in the catchment include the decline of forest land, grazing land, wetland and water bodies, and the expansion of agricultural land as well as the increase of settlements and plantations. Huge areas of the catchment were transformed from natural to anthropogenic LULC types in the study period. In agreement with this result, Olumana *et al*. (2019) reported that some of the factors for agricultural land expansion were due to rapidly increasing population growth and deteriorating soil productivity.

Between 1990 to 2005 period, the area coverage of forest and grazing lands decreased by 512.53 km^2 (23.41%) and 90 km^2 (8.45%), respectively. In addition, water bodies decreased by 10 km^2 (2.17%) and wetland decreased by 10.80 km^2 (8.85%). On the other hand, both cultivated and settlement lands have increased by an area coverage of 565.33 km^2 (17.35%) and 35 km^2 (26.92%), respectively (Table 4.1 and Figure 4.2). This was due to the conversion of forest and grazing lands, to cultivated lands and settlements. Relatively plantation area increased by 23 km^2 (30.67%). As indicated in Figure 4.2, cultivated lands increased during this period at the expense of all the other 6 LULC types, but mostly at the expense of forest lands. It is noted that the expansion of cultivated land and settlement occurred mostly at the expense of forest and grazing lands during this period.

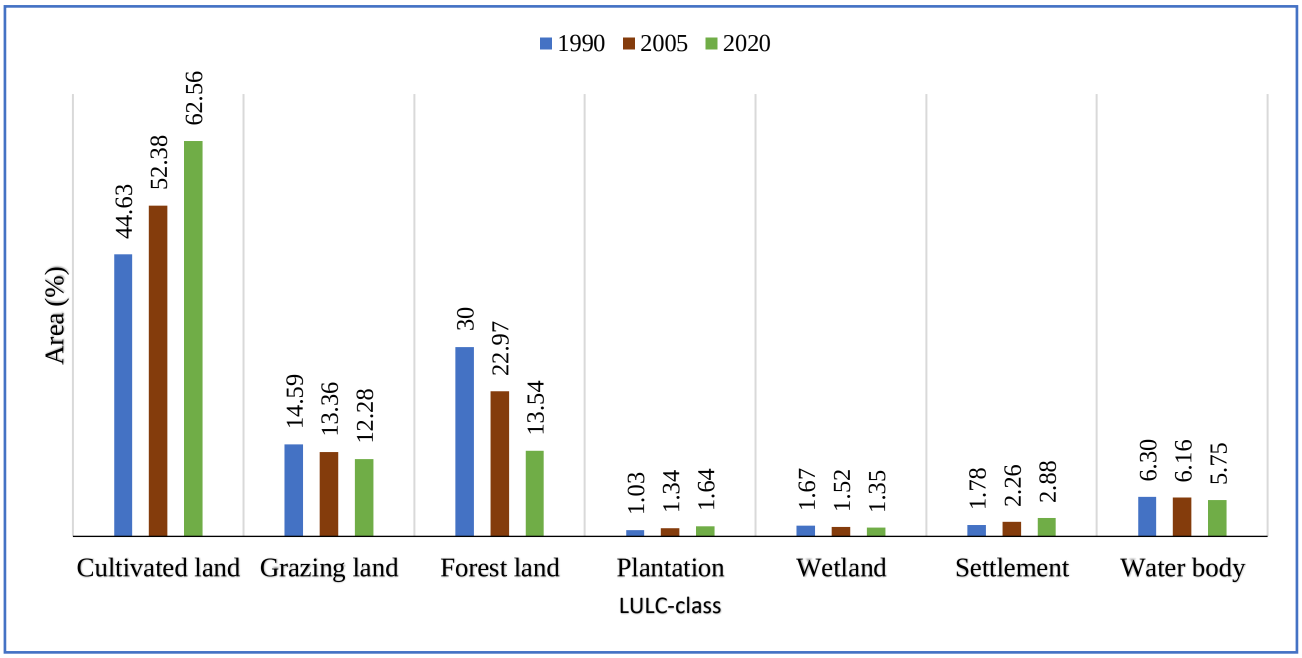

Figure 4.2. Percentage area trends of LULC change in the Lake Ziway catchment

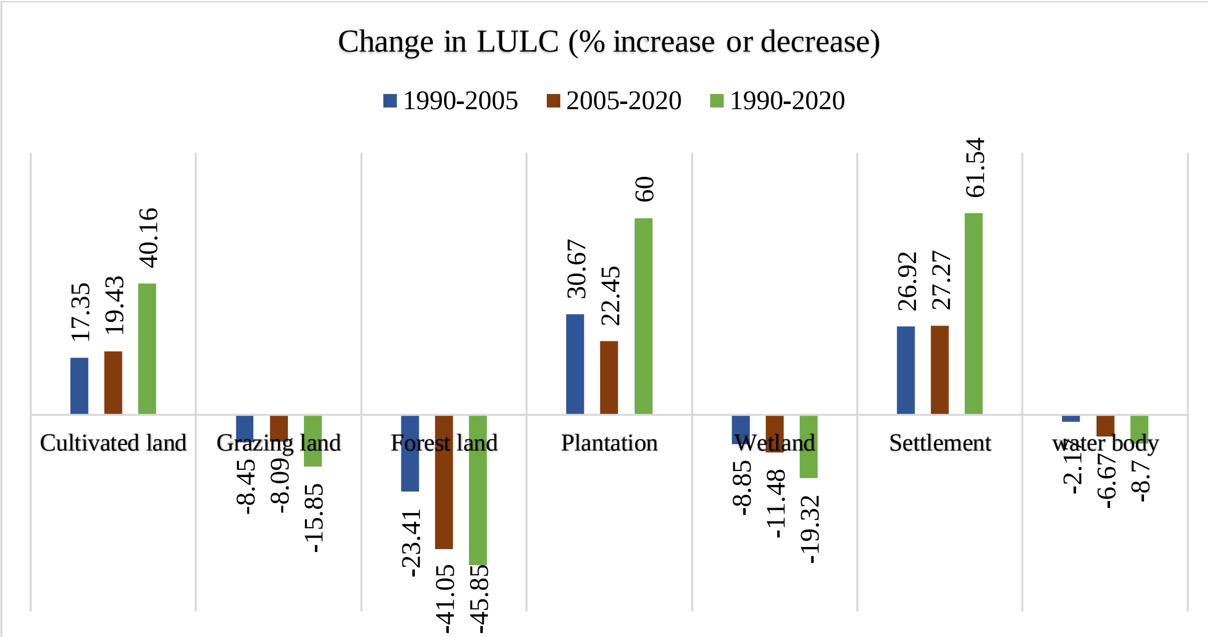

Figure 4.3. Rate of LULC change in the Lake Ziway catchment

From 2005 to 2020, the area coverage of cultivated land increased by 743.09 km^2 (19.43%). This significant increment was due to more demand for lands for agricultural expansion in the catchment. During this period (i.e., 2005 -2020), Settlement land increased by 35 km^2 (27.27%) and plantation land increased by 22 km^2 (22.45%), respectively. However, forest land decreased by 688.47 km^2 (41.05%) and grazing land decreased by 78.85 km^2 (8.09%). As shown in Table 4.1 and Figure 4.3, water bodies decreased by 30 km^2 (6.67%) and wetlands also decreased by 12.77 km^2 (11.48%). These changes show the decline of natural vegetation cover, grazing and water body in the catchment as the population size and area demand for cultivation and settlement are rising.

In the period between 1990 to 2020, 1201 km^2 (54.85%) of the forest land and 168.85 km^2 (15.85%) of grazing lands were converted to other land use types, particularly cultivated and settlement lands (Table 4.1 and Figure 4.3). Water bodies decreased by 40km^2 (8.70%) during this period. Wetland also decreased by 23.57km^2 (19.32%) area coverage. On the other hand, cultivated land increased by 1308.42 km^2 (40.16%) area coverage and the dominated land use type in the catchment. As indicated in Table 4.1 and Figure 4.3, settlement land increased by 80 km^2 (61.54 %) and plantation increased by 45 km^2 (60%). These results suggest that different factors contribute to this trend and rate change including population pressure, demand for fuel wood and construction materials, which lead to the continuous decline of natural forest resources for different uses.

In general, the major trends of LULC change in this catchment reveal that the expansion of agricultural lands is being undertaken at the expense of other land-use types, mainly forest/ woodlands at the Rift floor. This could be due to the increasing trend of human population size in the catchment. According to key informants, inadequate enforcement and control of the forest resources are also contributing to the degradation of the forest land. In addition, the change of forest land could also be due to increased demand for more fuelwood and charcoal along with the 3% population growth (CSA, 2017). Mainly, fuelwood accounts for more than 80% of households' energy supply in rural Ethiopia (FDRE, 2012). The demand for fuelwood and charcoal consequently place an additional burden on the catchment acacia woodlands (Desta and Fetene, 2020). Overall, the trend detected in the study area suggests a loss of forestland and an increase in agricultural areas and settlements. Rising population pressure, continued LULC change, combined with unstable climatic conditions, would significantly impact people's livelihoods in the catchment and puts the agropastoral production system under stress.

Table 4.1. Land use/land cover (LULC) change in Lake Ziway catchment throughout 1990–2020

LULC-class	LULC Area in (km^2 and %)						LULC change in (km^2 & %)					
	1990		2005		2020		1990-2005		2005-2020		1990-2020	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Cultivated land	3258.34	44.63	3823.67	52.38	4566.76	62.56	565.33	17.35	743.09	19.43	1308.42	40.16
Grazing land	1065.00	14.59	975.00	13.36	896.15	12.28	-90.00	-8.45	-78.85	-8.09	-168.85	-15.85
Forest land	2189.64	30.00	1677.11	22.97	988.64	13.54	-512.53	-23.41	-688.47	-41.05	-1201.00	-54.85
Plantation	75.00	1.03	98.00	1.34	120.00	1.64	23.00	30.67	22.00	22.45	45.00	60.00
Wetland	122.02	1.67	111.22	1.52	98.45	1.35	-10.80	-8.85	-12.77	-11.48	-23.57	-19.32
Settlement	130.00	1.78	165.00	2.26	210.00	2.88	35.00	26.92	45.00	27.27	80.00	61.54
Water body	460.00	6.30	450.00	6.16	420.00	5.75	-10.00	-2.17	-30.00	-6.67	-40.00	-8.70
Total	7300	100	7300	100	7300	100						

4.2. Drivers of Land Use Land Cover (LULC) Changes

Information on the drivers of LULC change is important for understanding human-environment interactions. As indicated in Tables 4.2 and 4.3, survey respondents identified both the proximate and underlying drivers of LULC change in the Lake Ziway catchment. The proximate drives of LULC change as identified and ranked by survey respondents included agricultural expansion (60%), demand for fuel wood and construction materials (55%), settlement expansion (54%) and overgrazing by livestock pressures (45%) respectively (Table 4.2). Similar results were also indicated during in-depth interviews and FGDs in which agricultural expansion, firewood collection and demand for wood construction, settlements, and overgrazing were recognized as the main causes of LULC in the study area.

Table 4.2. Perceived proximate drivers of LULC changes in the study area

LULC proximate drivers	**Household farmers response (%)**	**Rank**
Agricultural expansion	60	1
Demand for fuel wood & construction	55	2
Settlements	54	3
Livestock pressure/Overgrazing	45	4

Source: Household survey (N = 120)

Regarding the underlying drivers of LULC change in the study area, the drivers identified by survey respondents include population pressure (65%), urbanization (42%), poverty (35%), lack of proper management of watershed resources (35%), land degradation (29), poor marketing structure (25%), inadequate law enforcement (23%), and topography (22%) (Table 4.3).

Table 4.3. Perceived underlying drivers of LULC changes in the study area

LULC underlying drivers	Household farmers response (%)	Rank
Population growth	65	1
Urbanization	42	2
Poverty	35	3
Lack of proper mg't of watershed resources	30	4
Land degradation	29	5
Poor marketing structure	25	6
Inadequate of law enforcement	23	7
Topography	22	8

Source: Household survey (N=120)

According to CSA (2017), the human population has almost increased by half (50%) in the Lake Ziway catchment since 1970. Population growth in the catchment demands more new lands for agricultural expansion and settlements, leading to deforestation and land degradation (FDRE, 2012). Rapid population increase with mismanagement of land resources would destructively affect water resources and biodiversity in a watershed (Al-kalbani *et al*., 2014). Topographic drivers such as slope, aspect and elevation have also roles in the distribution and dynamics of LULC types in the study area. Lake Ziway catchment slope classes are spatially distributed and around 86% of the total area of the catchment is found within slope classes of 0 to 30% while the remaining area passes greater than 30% slopes (steep to very steep mountains and hills). Since cultivation lands are expanding due to rapid population growth in the area, it is leading to the expansion of the upslope areas of the watershed whose natural land covers have been removed. Therefore, for sustainable watershed management addressing them is fundamental.

4.3. Community Participation in Watershed Management Activities

Community participation in catchment management of the study area was low based on information obtained from key informants, FGD participants and survey respondents. For example, around 60% of households responded that there was low community participation in the study area. One of the reasons for low participation in those activities is due to the top-down nature of the catchment management activities. Another reason is due to a lack of good local leadership for organizing farmers, mobilizing their resources, promoting and sustaining the organization. The catchment management interventions do not consider farmers interests, prioritizing their needs.

In addition, only a few of the sampled respondents (13%) received soil and water conservation training in the catchment. This indicates that most of the study participants may not know the appropriate watershed management techniques. Further, as shown in Figure 4.4, only 2% of the surveyed respondents received climate change training. Climate change is currently one of the major problems that affect natural resources like water, soil, vegetation etc. According to key informants, there is no continuous training delivered for farmers from time to time on watershed management activities. Therefore, awareness creation and continuous training should be provided to the local community to improve the management of the catchment and its sustainability. Such kind of measure will protect Lake Ziway from deterioration as the lake is very important in the catchment.

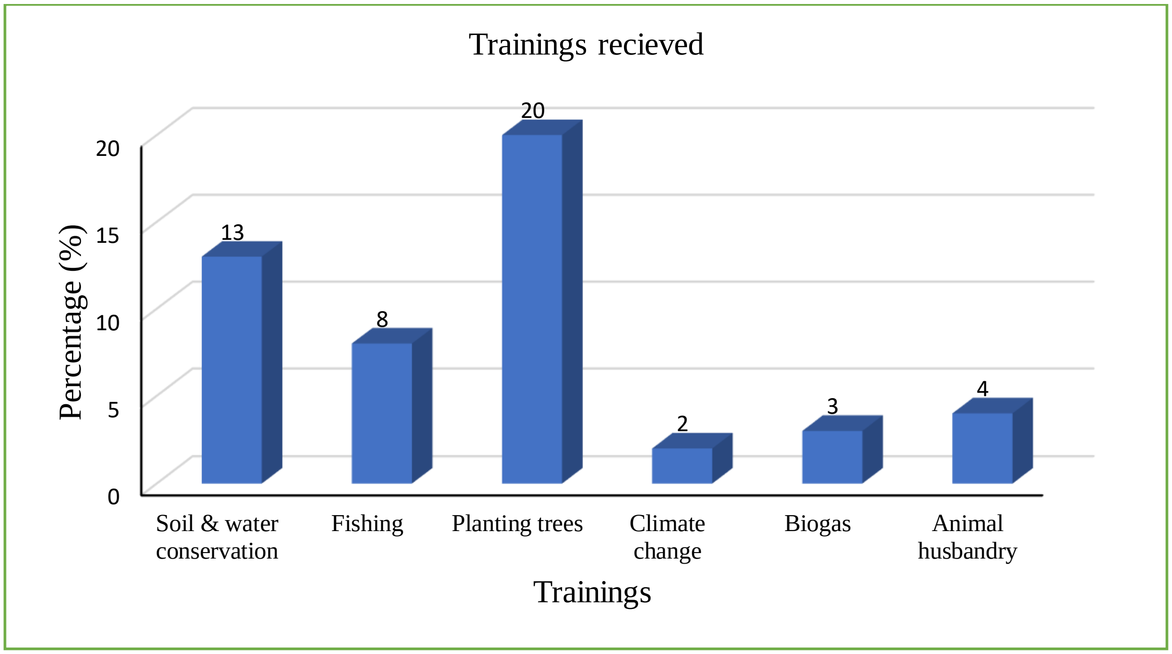

Figure 4.4. Types of training received by household farmers

4.4. Human Activities that Influence Resources in Lake Ziway Catchment

There are many activities taking place in Ziway catchment that affect the sustainability of soil, water and forest resources, which needs attention to conserve the resources in the catchment. For example, agricultural activities, demand for fuelwood and construction material and water abstraction are commonly practiced by the community. This in turn contributing to forest and soil degradation and water resource destruction in the catchment. To overcome these challenges, the communities need to receive proper training.

Agricultural activities

Subsistence rainfed agricultural and livestock husbandry are the main livelihoods of rural communities in the Lake Ziway catchment. Key informants noted that the most widespread force of LULC relates to smallholder agricultural land expansion at the expense of other land covers. In addition, FGD participants stated that increasing livestock population and density along with the expansion of the free-grazing system, are key drivers of LULC change and land degradation. Furthermore, there is a flow of fertilizers from agricultural land to the Lake Ziway which is leading to Lake eutrophication in the catchment.

Demand for fuelwood and construction materials

The majority of the household (80%) in the catchment area use wood for cooking, sale, heating and as a source of light. These activities contribute to the destruction of forests in the catchment. Participants of the FGD and key informants expressed that the forest which is found in the Ziway catchment is not only used for the fulfilment of their energy needs but also as a means of additional income. The timber obtained from the catchment was also used for sale in the nearby urban areas as construction and fuelwood materials. Therefore, the expansion of the adjacent towns puts pressure on the available resources of the catchment. The rising number of populations which is directly linked to the shortage of cultivated land has also enforced farmers to depend on selling charcoal and firewood for supplementary income, and this has also led to the destruction of the woody biomass and bushland.

Water abstraction

Results of in-depth interviews and FGDs suggest that there is over abstraction of water practice in the Lake Ziway catchment. The current level of water abstraction of the lake Ziway is estimated at around 612×10^6 l/day. Local communities extract water from the lake for irrigation, domestic water, and recreation. As compared to other lakes, water abstraction from Lake Ziway catchment is too much. Such extreme water abstraction has now become a common practice. Irrigation from feeder rivers has also become more common in both the lower and upper sub-watersheds. This is because all water resources are public property, allowing any one to use them (FDRE, 2000). This extreme water abstraction is contributing to the decrease of water levels in the Lake Ziway catchment. The finding is in agreement with other studies (Legesse and Ayenew, 2006; Ayenew and Legesse, 2007; Desta *et al*., 2017). The present agricultural expansion in the Lake Ziway catchment and the increasing urban population size of the area will further increase water abstraction for irrigation and municipal water supply.

In addition to human impacts, evapotranspiration may have an impact on the Lake's water levels. The potential evapotranspiration of Lake Ziway was found to be high throughout the year, with the highest values occurring in February and March. If the present LULC change trends and water abstraction of the catchment continue, it might highly influence the sustainability of the Lake.

The production of fish has decreased as compared to the last few decades due to the decline of lake water levels and water quality, water hyacinth and fishing activities. In the study area, fish contributes to livelihood security by both serving as a major food item and by providing cash income for fisheries. The below figure indicates survey respondents' responses regarding reasons for the decline of the production of fish in the catchment.

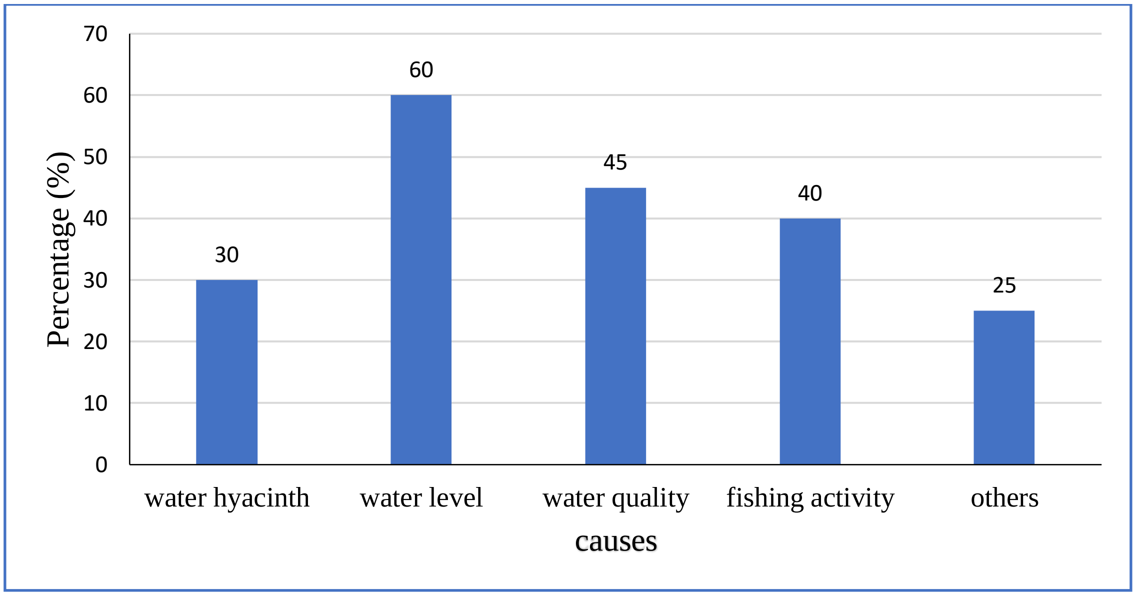

Figure 4.5. Causes that led to decrease fish production in Lake Ziway catchment

In general, the major cause of water quality and quantity changes in the lake was recognized to be the influence of human activities in the catchment. These include the removal of vegetation cover, irrigation, diversion of inflows and industrial use. This has a direct effect on the present change in fish composition and abundance. This result agrees with the study of Abera and Lemma (2018). Therefore, sustainable utilization and conservation measures are needed to reduce the causes that affect the water resources of the lake and the lives in the lake. Overall, training would be required for the community to avoid harmful activities that negatively impact resources in the catchment.

4.5. Consequences (Implications) of Land Use Land Cover Change in Lake Ziway Catchment

LULC changes have long-term impacts on environmental processes that possibly compromise the fundamental functioning of ecosystems. These changes are inevitable with multi-faceted biophysical and socio-economic implications. Understanding the implication of past and current patterns of LULC change is imperative for the sustainability of land management planning. Some of the consequences of LULC changes recognized by the study participants are discussed below.

Biodiversity loss

Land use land cover changes are recognized as key drivers of biodiversity depletion in Ethiopia (Yesuph and Dagnew, 2019). Half of the survey respondents (50%) indicate that the loss of biodiversity in the catchment is common especially around Lake Ziway. According to FGD participants, the area under natural vegetation and woodlands has declined over the past three decades. This has resulted in the loss of biodiversity in both flora and fauna. These changes and losses exert significant challenges for achieving biodiversity conservation aims and targets (Verburg *et al.*, 2011; Jewitt *et al.*, 2015). LULC changes are also responsible for the disintegration of the landscape which in turn leads to biodiversity loss and change.

Soil erosion and degradation

LULC change is one of the main factors that determine the rate of soil erosion, surface runoff and sediment yield from the Catchments (Kidane and Alemu, 2015; Gebremedhin *et al.*, 2017). In the study area, 65% of the survey respondents stated the exposure of the local area to high soil erosion and degradation (Figure 4.6). Conversion and removal of natural vegetation cover into cultivable and grazing lands are common practices in the study catchment. Reduction of these vegetation covers then decreases protection cover of the soil surface and leaves the upper soil susceptible to raindrop impacts. This contributes to the degradation of land and dramatic deteriorations in land productivity (Yesuph and Dagnew, 2019).

The quantitative evidence gained through interpretation of satellite images and ground survey showed that the catchment has undergone significant LULC changes since 1990. This LULC combined with the steep slope landscape of the catchment aggravated soil erosion. Runoff, as well as associated soil erosions, are higher in agricultural lands as compared to forest lands in

Ethiopia (Hurni *et al.,* 2016).

As noted by key informants and FGD participants, removal of the upper fertile soils and the formation of the wide and deep gully is common particularly in the margin of cultivated land and at the escarpment of the catchment in almost all portions of the catchment. This was also observed during the field transect walk. During intensive rainfall, runoff flow over agricultural land and grazing land, results in the deposition of top fertile soil, making the land unsuitable for cultivation and grazing. In the study area, there has been extensive clearance of natural vegetation cover. As a result, key informants reported that land area that is exposed to soil erosion has increased.

Hydrological regimes implications

A study conducted in Ethiopia shows that LULC changes influence rainfall conditions. (Sultan *et al.,* 2017). Since the hydrological system in a given catchment is partially depends on LULC characteristics of the area, change in land use land cover alters the hydrological fluctuations such as runoff response and sediment load relationships of the catchment (Gebremedhin *et al*., 2017). Empirical studies have also confirmed that LULC change exerts an impact on the energy balance within the hydrologic cycle due to its impact on evaporation, transpiration and solar radiation interception (Yesuph and Dagnew, 2019).

Some of the survey respondents (45%) indicated that LULC changes had a prominent impact on the surface runoff, infiltration, water retention, sediment deposition in the Lake Ziway catchment (Figure 4.6). These conditions were observed in some parts of the study catchment during field observation. This implies that LULC changes have direct implications on the hydrological cycle, runoff magnitude and base flow in the catchment. This reasonably calls for the need for more effort on stabilization of the land use/cover change in general and investments in sustainable land management activities in particular to regulate the hydrologic related turmoil occurring in the watershed.

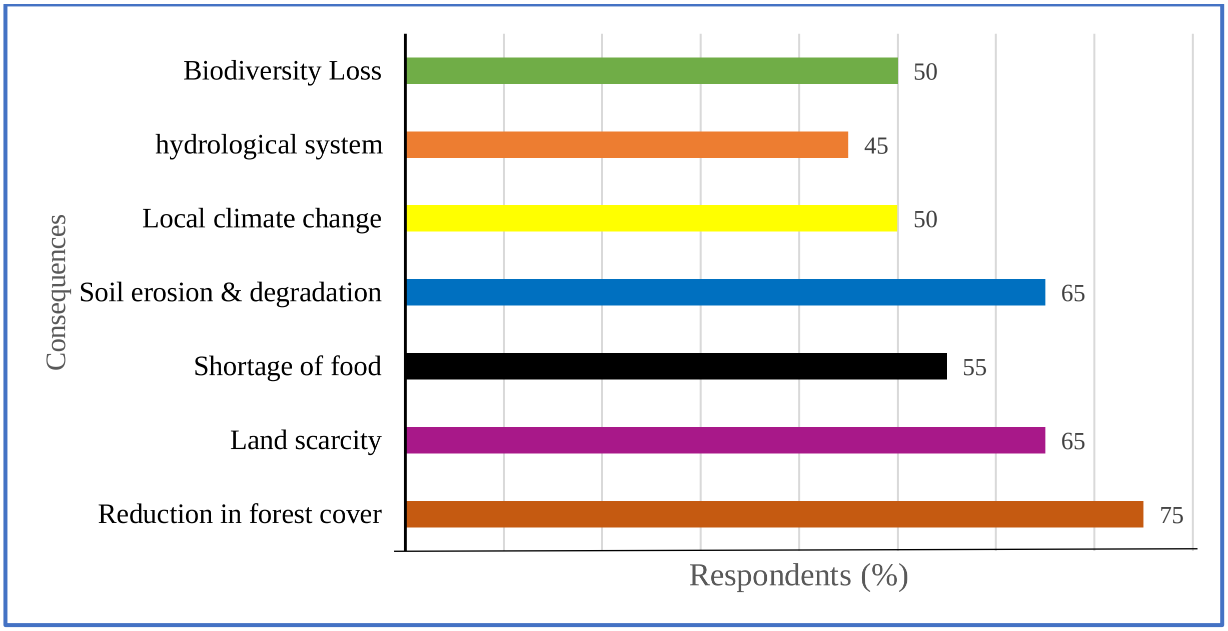

Figure 4.6. Consequences of LULC in Lake Ziway catchment

Changes in local climate

Ethiopia is highly exposed to the impacts of climate change and variability (Kassie *et al.*, 2013). LULC change is connected to climate and weather in multifaceted ways and plays a critical role in the interaction between the atmosphere and the land (Bekele *et al.*, 2015). At a range of spatial and temporal scales, LULC change can induce climate change (IPCC, 2013). For instance, LULC change affects the exchange of sensible heat between the surface of the land and the atmosphere. LULC change affects local climate through absorption/emission of greenhouse gases as well as by modifying the physical properties of the surface of the land (Yesuph and Dagnew, 2019).

According to the household survey (50%) and key informants, clearing of forests for agricultural expansion has a significant effect on evapotranspiration rates, which is increasing the frequency of climate extremes such as droughts. This finding is similar to that of Yesuph and Dagnew (2019). Changes in LULC also contribute to global warming as the carbon locked up in biomass will be released into the atmosphere. Therefore, the observed LULC change in the catchment of Lake Ziway most likely had brought such consequences.

Reduction in forest cover

In Lake Ziway catchment, there is a reduction in forest resources, which was reported by the majority (75%) of the survey respondents. Factors such as rapid population growth and demand for agricultural land, wood extraction and settlements are leading to forest degradation. Findings of in-depth interviews and FGD results also suggest that socioeconomic factors have caused a reduction in forest cover in the catchment. Hence, the improvement of current agricultural activities and the introduction of appropriate forest conservation measures are vital for mitigating forest degradation and improving the well-being of the community in the catchment.

Land scarcity

Land scarcity is also another implication of land use land cover change in the lake Ziway catchment (reported by 65% of the survey respondents). In the catchment population density is very high that leading to the scarcity of land. FGD participants revealed that due to population pressure, most peoples in the catchment have less than one hectare of land per household.

Shortage of food

Rapid population growth in the study area has increased demand for more agricultural land and left less land per person. The pressure on the land aggravated land degradation and negatively impacted crop productivity. During household surveys, 55% of the respondents perceived the decline of crop yields due to land degradation. The number and productivity of livestock have also decreased due to inadequate grazing land. All these issues have led to a shortage of food in the study area.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to examine the trends, drivers and implications of land use land cover change in the Lake Ziway catchment, central rift valley of Ethiopia. To address these objectives, the study followed a mixed-method approach that included the use of remote sensing and geographic information system techniques, household surveys, focus group discussions and in-depth interviews. This chapter concludes the study by summarizing the key findings and providing key recommendations for policy and practice.

5.1. Conclusions

The trends of land use land cover changes in the Lake Ziway catchment show major LULC changes in the Lake Ziway catchment over the last thirty years period (1990-2020). The major changes observed are an expansion of agricultural and settlement lands, and a reduction of forest and grazing lands. For example, over the last three decades, cultivable and settlement lands have increased by 40.60% and 61.54%, respectively. On the other hand, forest and grazing lands had decreased by 54.85% and 15.85% area coverages, respectively.

The findings revealed that both proximate and underlying drivers have contributed to the observed LULC changes in Lake Ziway Catchment. The main proximate drivers of LULC change were found to be agricultural expansion, extraction of fuelwood, settlement expansion and overgrazing. In addition, the underlying drivers of LULC change included population pressure, urbanization, lack of proper management of watershed resources and land degradation.

The overall survey result shows that half of the respondents have taken training on watershed management such as on soil and water conservation, tree planting and climate change. Despite this, the participation of local communities in actual catchment management activities is very low.

The study further indicates that the LULC changes observed in Lake Ziway Catchment have had significant environmental and socio-economic implications. Some of the observed implications of LULC change in the study area are biodiversity loss, soil degradation, forest degradation, changes in hydrological regimes and local climate, land scarcity and food shortages.

5.2. Recommendations

To overcome the negative consequences of LULC and sustain the livelihoods of local communities residing in the Lake Ziway catchment, the Ethiopian government should initiate catchment management and sustainable land management programs by participating local communities in the process. The expansion of agricultural and settlement lands should not be allowed to increase at the expense of mountain ecosystems and marginal lands. Overall, based on the findings of this study, the following recommendations are provided:

- Local communities should receive technical training on catchment management to practice best land and water conservation efforts, address LULC change impacts, and enhance sustainable utilization and management of Lake Ziway.

- The Ethiopian government should follow a bottom-up approach to enable the active participation of local communities in the catchment management and encourage them to use Lake Ziway sustainably. Particularly, catchment rehabilitation through afforestation and soil and water conservation activities are highly required. Reforestation programs need to be devised to counteract the deteriorating forest/shrub and avoid further destruction of forest resources.

- To reverse the current impacts of LULC change in the study area, the government should collaborate with other key stakeholders to support local communities with various livelihood options (e.g., non-farm diversification) and support them to implement appropriate resources conservation practices.

- The underlying drivers of LULC should be recognized and integrated into land-use policies and strategies to make informed decisions on land management and to overcome the consequences of land use and land cover change.

- Since one of the key drivers of land use land cover change in the catchment is rapid population growth, local communities need to be aware of family planning approaches.
- More studies should be done focusing on the consequences of LULC change, alternative strategies of minimizing the pressure on the remaining natural resources and ways of correcting bad practices in the catchment area.

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APPENDIX

Appendix 1. Questionnaire /checklist for discussion

This questionnaire is prepared for farmers to collect data about land use and land cover changes, their drivers, impacts and implications for management from lake Ziway catchment. It is expected to generate and provide helpful information for policy makers and development practitioners about magnitude and trends of land use and land cover change and its impact on water resources. Therefore, your inputs as a stakeholder to fill this questionnaire is highly appreciated and information provided will stay confidential and your right to involve is respected.

A. Socio-demographic details of the household head

Gender	Male ☐ Female ☐
Age	----------------
Marital status	Single ☐ Divorced ☐ Married ☐ Widow/ widower ☐
Educational level	Don't read and write ☐ Primary education ☐ Read and write ☐ Secondary education ☐ Higher education ☐
How many children do you have?	------
Main source of household income?	Farming ☐ Trading/ business ☐ Civil service /official ☐ School teacher ☐ Household/ domestic/ housewife ☐
Average household size	--------------------------------
Average land hold size	---------------------------------
Average annual household income	----------------------------------

B. Community participation in watershed management activities

1) How is community participation in watershed management of your area?

A. Very low B. low C. medium D. high E. very high

2) Have you ever received trainings/awareness on watershed management?

A. Yes B. No

3) In question no. 2 your choice is A, what types of trainings have you received?

a. Soil & water conservation
b. Planting trees
c. climate change
d. fishing
e. Biogas
f. Animal husbandry

4) What was the production of fish after 1990? A. increasing B. decreasing

5) If your answer in question no.4 is B what causes that leads to decrease fish production?

a. water hyacinth
b. water level
c. sedimentation
d. water quality
e. fishing activity
f. others

6) Is there water abstraction in your catchment?

A. Yes B. No

8) If your answer to question no 6, is yes, what are the ways of water abstraction?

a. Irrigation
b. Urbanization
c. Domestic water supply
d. Evapotranspiration recreation

C. Land use land cover change related issues

1. What are the most significant LULC changes that have occurred in Lake Ziway catchment in the last 30 years?

2. What are the causes/drivers for land use/land cover change in Lake Ziway watershed?

a. Population growth
b. environmental factors (Topography, climate...)
c. Lack of proper management
d. Urbanization
e. Deforestation/Demand for fuel wood and construction material
f. expansion of agricultural activities
g. Overgrazing

3) Have you noted any change in land use land cover in your watershed over the past 30 years? A. yes B. No

4) If your answer to question no.7 is yes, what change did you observe?

a. change in agricultural land
b. change in forest land
c. change in water level
d. change in grazing land
e. Change in settlements F. others
f. change in grazing land
g. change in settlement/infrastructure
h. others

5) What are the consequences of LULC change in the study area?

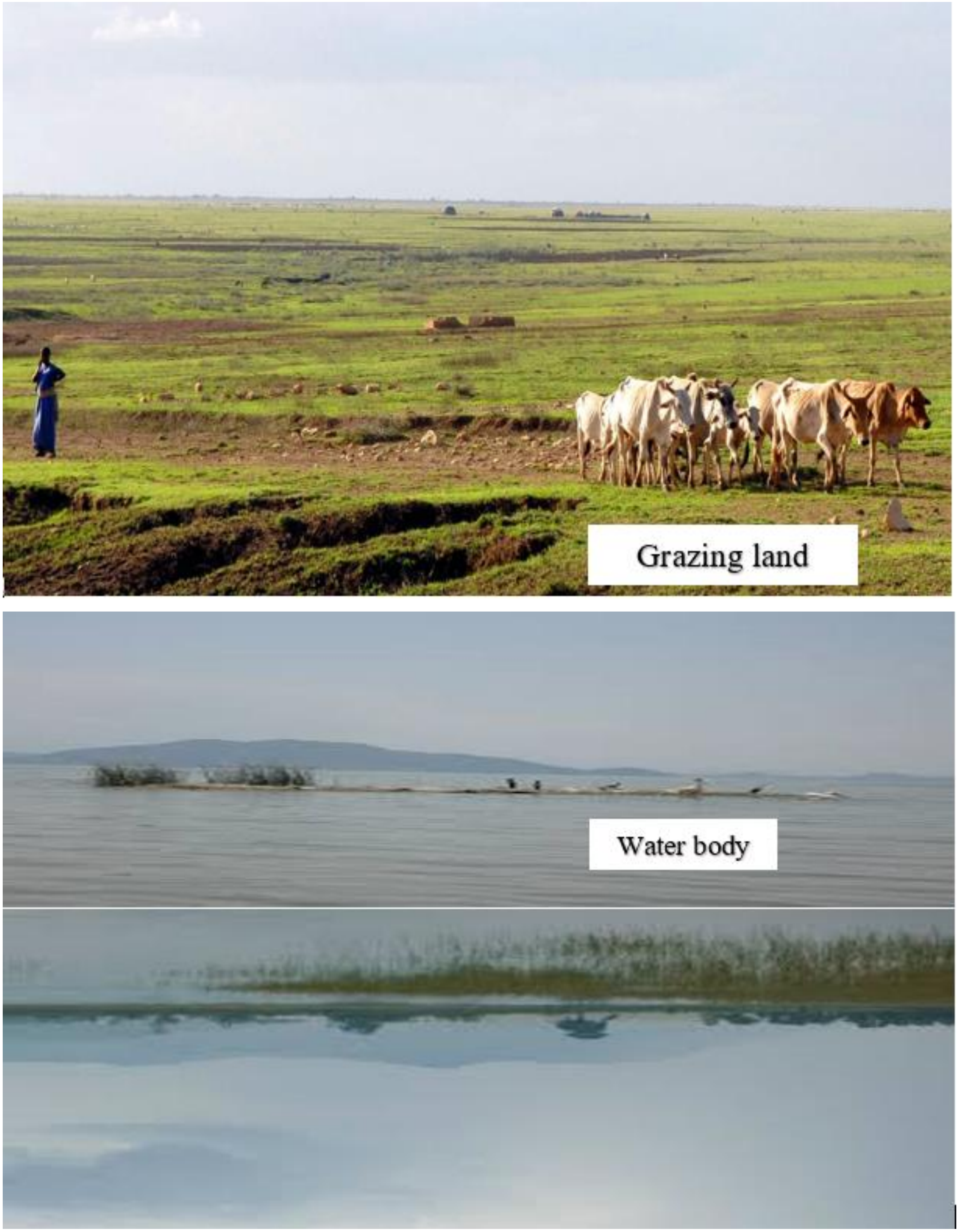
a. soil erosion b. hydrologic regime disturbance c. climate change d. biodiversity loss
e. others

Thank you in advance for your cooperation and time!

Appendix 2. Table 1: Land use land cover change in Lake Ziway catchment between 1990 to 2020

LULC-class	Change in (km^2 and %)					
	1990-2005	2005-2020	1990-2020	1990-2005	2005-2020	1990-2020
	Km^2			%		
Cultivated land	565.33	743.09	1308.42	17.35	19.43	40.16
Grazing land	-90.00	-78.85	-168.85	-8.45	-8.09	-15.85
Forest land	-512.53	-688.47	-1201.00	-23.41	-41.05	-54.85
plantation	23.00	22.00	45.00	30.67	22.45	60.00
Wetland	-10.80	-12.77	-23.57	-8.85	-11.48	-19.32
settlement	35.00	45.00	80.00	26.92	27.27	61.54
Waterbody	-10.00	-30.00	-40.00	-2.17	-6.67	-8.70

Appendix 3. Figure 1: Sample of different LULC photographs




Agricultural lands


Forest land
Settlements

Appendix 4. Figure 2: Different photos during data collection

Appendix 5. Figure 1: Composite Satellite images

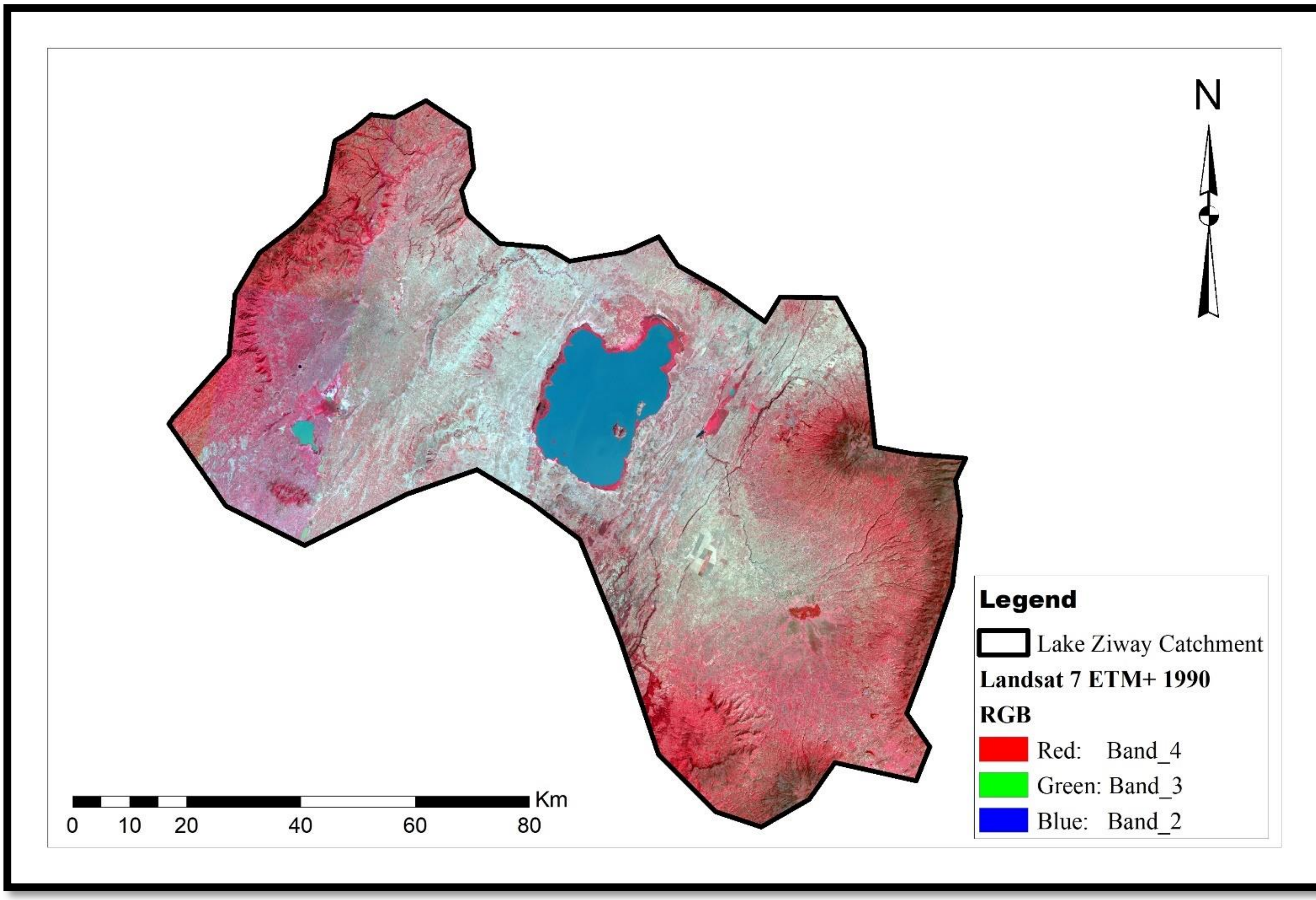


Figure.1a. Composite Landsat 7 ETM+ of 1990 satellite image of the study area

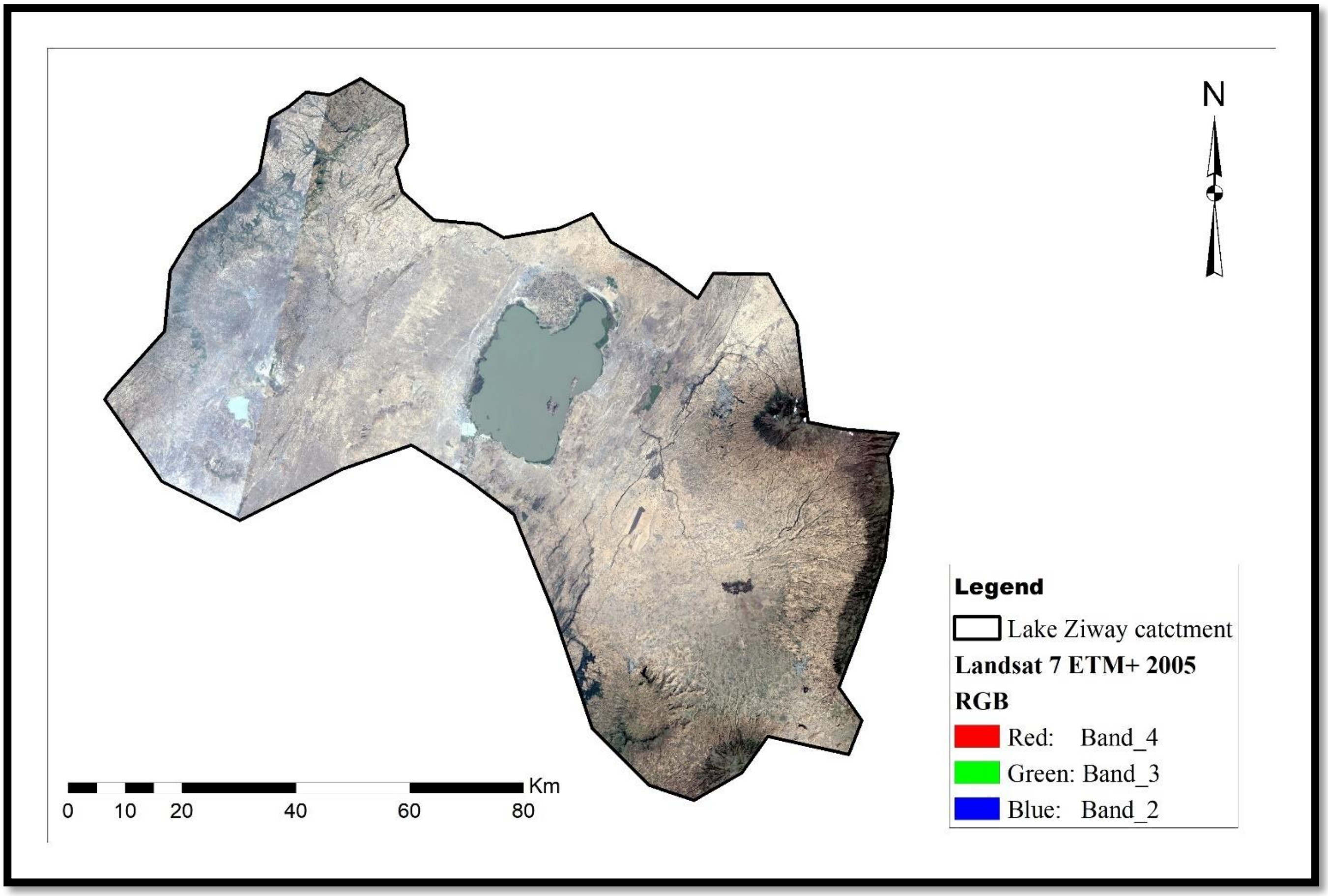


Figure.1b. Composite Landsat 7 ETM+ of 2005 satellite image of the study area

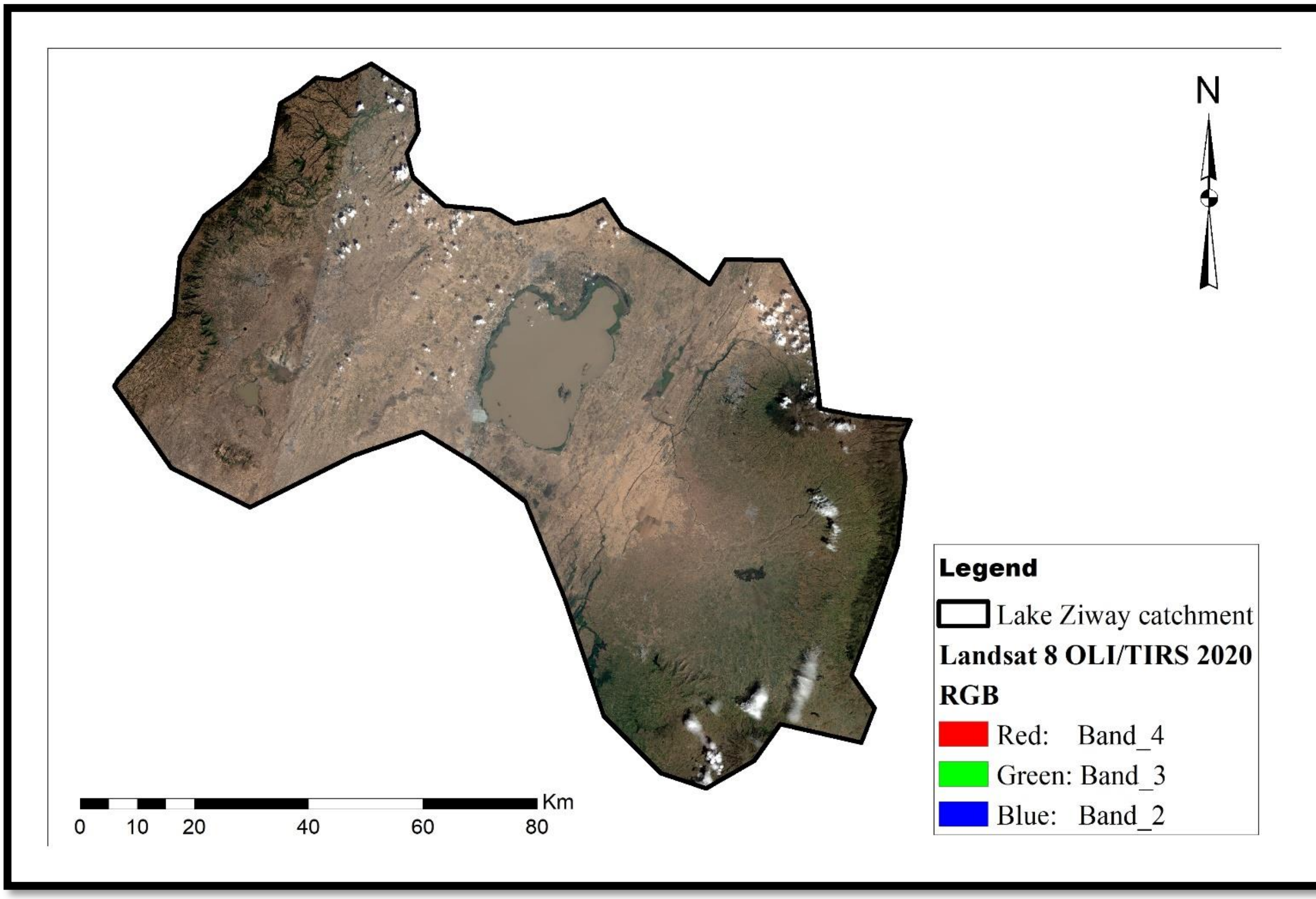


Figure.1c. Composite Landsat 8 OLI/TIRS of 2020 satellite image of the study area