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IMPACT OF LAND USE/ LAND COVER CHANGES ON THE ENVIRONMENT AND SOCIO-ECONOMY OF THE SMALLHOLDER FARMING COMMUNITY: THE CASE OF LUDE HITOSA DISTRICT, OROMIA REGION, ETHIOPIA

By

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Advisor:

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DISSERTATION APPROVAL

This is to certify that the thesis prepared by Dawit Solomon Esubalew entitled: Impact of land use/ land cover changes on the environment and socio-economy of the smallholder farming community: the case of Lude Hitosa district, Oromia region, Ethiopia and submitted to the department of Environment and Development Studies in partial fulfillment of the requirements for the Master of Arts Degree in Environment and Sustainable Development Studies complies with the regulation of the University and meets the accepted standards with respect to originality and quality.

Approved by the Board of Examiners

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DECLARATION

I, the undersigned, declare that this thesis is my original work, has never been presented for any degree at any University, and that all the resources and materials used for it are duly acknowledged.

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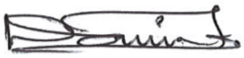
Signature: 

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ACRONYMS

CART: Classification and Regression Trees

CSA: Central Statistical Agency

ERDAS IMAGINE: Earth Resource Development Assessment System

ESSGI: Ethiopian Space Science and Geo-spatial Institute

FAO: Food and Agriculture Organization

FGD: Focus Group Discussion

GCP: Ground Control Point

GEE: Google Earth Engine

GII: Geospatial Information Institute

GIS: Geographic Information system

GPS: Global Positioning System

KII: Key Information Interview

LULC: Land use Landcover

SPSS: Statistical Package for the Social Sciences

TM: Thematic Mapper

USGS: United State Geological Survey

ABSTRACT

Understanding the process of land use/ land cover (LULC) change and its implications has paramount importance for the sustainable management of natural resources. This study assessed the trends of LULC change and its implications on the environment (land, forest, and water resources) and livelihoods of the people in the Lude Hitosa district, central-eastern parts of Ethiopia. Remote sensing data (Landsat imageries) and socio-economic surveys were used to unveil the LULC dynamics in the study area. A socio-economic data was obtained through a questionnaire survey, focus group discussions (FGDs), field observations, and key informant interviews (KIIs). As a source of Landsat imaginers, the Ethiopian Space Science and Geo-spatial Institute (ESSGI) and online archives of the United States Geological Survey (USGS) from 1984 to 2022 were used. The LULC change analysis was made using ArcMap 10.8, R studio Rstudio-02.2-4, quantum GIS (Q GIS), and Microsoft office software. The socio-economic data collected through a questionnaire survey were analyzed using SPSS (v. 20). The LULC change analysis revealed significant changes in the LULC change between 1984 and 2022. Forest cover, grassland, and shrub decreased by 12.77%, 22.23%, and 1.78%, respectively. Crop/agricultural land, settlement, and bare land had increased by 21.86%, 10.18%, and 4.75%, respectively. LULC change has significantly impacted land, forest, and water resources, thereby affecting people's livelihoods. The communities face severe food insecurity, scarcity of land, shortage of animal feed, reduction of water sources, etc. Therefore, appropriate measures that ensure the wise use of natural resources and efficient land utilization are critical.

Keywords: Land use/Land cover change, trends, impacts, GIS, Remote sensing

CHAPTER ONE: INTRODUCTION

1.1. Background of the study

Land use/ land cover (LULC) change is the term used for the human modification of the earth's terrestrial surface because of the different human activities (FAO, 2016). Land is the physical resource which is the foundation for economic, social, infrastructural, and other human activities (Lambin et al., 2003). It is a fundamental factor of production, and its basic function is supporting human and other terrestrial ecosystems through most human activities, including agriculture, industry, forestry, energy production, settlement, recreation, and water catchment and storage (FAO, 2011). The agricultural land provides a wide range of goods and services, including food and fiber. Whereas land cover refers to the physical and biological cover over the surface of the land, and land use is the human use of land for different activities. Since time immemorial, LULC has been changing at various scales, and its ecosystem functions and services have been altered (Geist et al. 2006). Changes in LULC and their implications for the global environment are becoming a challenge for the very existence of various global ecosystems (Turner et al., 2007).

On a global scale, LULC change is one of the major drivers of ecosystem destruction (Kubiszewski et al., 2017). Since humankind came into existence, anthropogenic caused land use/ land cover changes have significantly modified the earth's surface (Molders, 2012). Unsustainable uses of the environment and its resources have severely altered the ecological processes (Maro, 2011). Humans have modified the earth for resources, which contribute to their livelihoods and provided essential materials for thousands of years (Hassan et al., 2016). For example, the use of land for agriculture provides a wide range of goods and services, including the provision of food and fiber. LULC dynamics are important manifestations of human-environment interactions (Sharma et al., 2018). The drastic changes in LULC observed in different parts of the world adversely affected the environment and hampered their capability to provide ecosystem functions and services (MEA, 2005). The human-induced LULC change emerged as a global environmental issue (Woldeamlak, 2002), which has manifested in the form of the destruction of biodiversity and fragmentation of natural habitat (Steffen and Tyson, 2001). Currently, understanding LULC change, its drivers, and implications have considerable significance in policy making in monitoring environmental changes and managing natural resources.

A change in LULC usually occurs by a complex interaction of several biophysical, socioeconomic, and institutional factors (Lambin et al., 2001; Lambin and Geist, 2006), and these drivers of LULC change can be grouped into proximate (direct) and underlying (root) drivers (Lambin et al., 2003). The proximate drivers comprise the expansion of diversified agricultural activities, extraction of wood, and infrastructure expansion. On the other hand, the underlying causes encompass a complex of political, economic, demographic, technological, and cultural causes that constitute initial conditions in human-environment relations (Geist et al., 2006). In many areas of developing countries, rapid population increases have often led to LULC changes and caused deforestation (Maitima et al., 2009).

LULC change has several implications for the functioning of the socio-economic and environmental system (Lesschen et al., 2005). LULC change affects the ability of biological systems to support human needs by altering ecosystem services (Vitousek et al., 1997). It alters the fluxes of mass and energy in the ecological system, which has consequences for ecological structure, functioning, and the flow of ecological goods and services (Bockstael and Irwin, 1999). It further affects key aspects of Earth's System functioning (Lambin et al., 2001), can stress living conditions, and threaten the livelihood of society (Bimal et al., 2017). Additionally, LULC change is the primary source of soil degradation (Tolba et al., 1992). The most proximate implication and negative consequences of land use/ land cover changes are related to land degradation issues (Shan et al., 2007). It causes soil quality deterioration through loss of vegetation cover, soil moisture, and soil organic matter and affects natural regeneration capacity (Khormali et al., 2009).

For instance, the clearing of forests and subsequently converting into croplands can lead to soil erosion, reduce water holding capacity, damage structural stability and compactness, nutrient supply, storage, and biological life (Wairiu and Lal, 2003; Rasiah et al., 2004). The removal or destruction of areas of forest cover results in a degraded environment with reduced biodiversity. Forests support biodiversity, providing habitat for wildlife and fostering medicinal conservation. With forest biotopes being an irreplaceable source of new drugs, deforestation destroy genetic variations (such as wild crop varieties) irretrievably (Hance and Jeremy, 2008).

Like many other developing countries, Ethiopia has been experiencing environmental change owing to LULC change-driven soil erosion, loss of biodiversity, and water resource degradation (MoARD and WB, 2007). National-level detailed investigation regarding the magnitude of LULC change and its environmental implication is inadequate; however, micro-watershed level land-use change studies using remotely sensed images were carried out in different parts of Ethiopia (Aklilu et al. 2007; Bezuayehu and Sterk 2008; Mohammed and Tassew 2009). Many studies have reported that LULC change has been and is still very intense in the highlands[1] of Ethiopia (Amsalu, 2006; Garedew et al., 2009; Nyssen et al., 2009; Tsegaye et al., 2010). The expansion of cultivation, grazing land, and urban and rural settlements are typical reasons for this LULC change (MoARD and SLM Secretariat 2008). Besides, too much reliance on woody biomass for fuel, the expansion of agricultural activities at the expense of vegetation cover, and the demand for wood for construction materials contributed to uncontrolled land cover change and deforestation in Ethiopia (Mekonnen and Damte, 2011).

Deforestation, coupled with the traditional farming system in the Ethiopian highlands, activated the processes of soil erosion (Mekuria 2005), which leads to irreversible damage to the natural resource base (Hurni, 1988). Several studies indicated that cultivated land had expanded considerably at the expense of vegetation cover (Berihun et al., 2019). However, the drivers, patterns, and impacts of these changes in the smallholder farming system are not observed in the Lude Hitosa district, the study area, in centraleastern Ethiopia. Therefore, it is essential to collect comprehensive and up-to-date information on the pattern of LULC change and its impacts on the natural environment and socioeconomic of the smallholder farming system to set options for sustainable land use management practices.

The LULC change in the Lude Hitosa district is not investigated so far; as a result, the extent of such change, its driving forces, and its effects are poorly understood. Hence, a thorough understanding of the extent of LULC change and its implications is crucial for designing appropriate land management strategies. Therefore, the main objective of the study was to analyze the LULC changes from 1984 to 2022, its driving forces and consequences in the Lude Hitosa district, and to evaluate the coherence of community perception to the changes observed through the interpretation of remote sensing images in the study area.

[1] *In Ethiopia, the highlands are defined as areas above 1,500 meters above the mean sea level.*

1.2. Statement of the problem

LULC changes have been recognized globally as fundamental constituents of global environmental change drivers (Butchart et al., 2010). LULC changes are also a major environmental challenge in Ethiopia (Gashaw et al., 2017). Previous studies have shown notable LULC changes in different parts of the country through deforestation and reforestation activities since the late twentieth century (e.g., Woldeamlak, 2002; Gebrehiwot et al., 2014). The LULC conversions were mainly from vegetation cover to agricultural land (Assefa and Bork, 2014; Alemu et al., 2015). This implies that the rising demand for agricultural land has contributed to vegetation degradation in the country (Wogderes, 2014). Although the estimated figure lacks consistency from literature to literature, FAO (2015) revealed that the forest cover of Ethiopia declined from 15.11 million ha in 1990 to 12.5 million ha in 2015. Deforestation has been the main cause of forest cover change in Ethiopia (FAO, 2010). Other studies also reported the reduction of natural vegetation due to the conversion of land use and expansion of settlements (Alemu et al., 2015; Emiru, 2014). In contrast, some studies (e.g., Woldeamlak and Solomon, 2013) conducted in the northern part of Ethiopia reported improved vegetation cover due to plantation and enclosure of the previously degraded areas since the 1980s.

The expansion of farmlands and the widespread conversion of vegetation cover have implications for land degradation in Ethiopia (MoARD and WB, 2007). Although LULC change and land degradation are not a new phenomenon in Ethiopia, the speed and scale of the change, irrespective of the efforts done by different stakeholders on conservation actions, have been accelerated in the last 3-4 decades of the 21st century (Hailemariam et al. 2016). This is due to the increasing population and the corresponding demand for agricultural expansion to feed the growing population (Wondie et al., 2016). A rising population aggravates land degradation because of very high pressure on land resources. Ethiopia has a population of more than 100 million, with a growth rate of 2.7%. Of this, about 80% of the population solely depends on agricultural practices as a source of employment and income (CSA, 2015). According to Hurni (1988), nearly 27 million hectares of the Ethiopian highland were significantly eroded, and over 2 million hectares of the land were beyond reclamation. These problems have aggravated due to unsustainable land resource management strategies coupled with population pressure (Haregeweyn et al., 2017).

The expansion of cultivated land at the expense of natural vegetation has significantly affected the natural environment (Tolessa et al., 2019). This continuous expansion of cultivated land is also a major cause of land degradation, which imposes a greater threat to soil fertility. As reported by Belay (2002), LULC changes towards agricultural land aggravate soil erosion problems and reduce soil quality unless proper land management practices are implemented. Water-induced soil erosion is the dominant and major degradation process and occurs on cultivated land, with average annual soil loss rates of 42 tones ha-1 (Hurni, 1993).

Most studies conducted in Ethiopia focused on the drivers and the impacts of LULC change on some aspects of land degradation. For instance, some studies (Temesgen et al.,2017; Sahle and Yeshitela, 2018) focused on the pattern and drivers of LULC change. Some others emphasized the impacts of LULC change on soil erosion potential (Ebabu et al., 2018; Esa et al., 2018).

The study area suffers from deforestation and severe land degradation. However, it is less researched, and no literature is available concerning the pattern, drivers, and implications of LULC change. This study, therefore, seeks to contribute to the available empirical literature on patterns of LULC dynamics and its impacts on the environment and socio-economy. The study also fills the available literature gap by investigating the perception of farmers on the LULC change and environmental degradation.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this study is to assess the LULC change and its implications on the surrounding environment and socio-economy of the smallholder farmers in the study area.

1.3.2. Specific objectives

This study specifically aims:

1. To analyze the spatiotemporal land use/ land cover changes over the past 38 years (1984 – 2022) in the study area;
2. To examine the major driving forces of land use/ land cover changes in the study area;
3. To assess the implication of the LULC changes on the livelihoods of the farming community and their surrounding environment (land, forest, and water) in the study area.

1.4. Research questions (or Hypothesis)

The following research questions were formulated based on the specific objectives outlined above.

1. What are the major changes in LULC that occurred between 1984 to 2022?
2. What are the perceived drivers of land use/ land cover change?
3. How have these changing dynamics affected the livelihood of the farming community and their surrounding environment (land, forest, and water resources)?

1.5. Significance/Rationale of the study

This research was undertaken for academic purposes and targeted a single district, Lude Hitosa, in the Arsi Zone of Oromia National Regional State, Ethiopia. However, the results of the study are beneficial to understand the spatiotemporal dynamics of the land use/ land cover change. It will contribute to the academic community with the value that adds to the empirical literature representation appearing on the pattern of spatiotemporal analysis of LULC change effects in rural areas that actually occur at present. Hence, this research is vital to make the problems visible to policy makers and development practitioners and used by government bodies and non-governmental organizations at the district and regional levels. It helps to plan for specific rural land use planning and land use advancement plans of action to accomplish a specific objective, thereby supporting the communities to improve their surrounding environment and livelihoods.

A deeper understanding of the drivers of the LULC change and its environmental and socio-economic implications is crucial to inform policy makers and thus promote sustainable land use and management to combat land degradation and improve environmental resource management. The result of the study is supposed to have paramount importance for the agricultural sector, environmental planning, and management of natural resources. Especially, NGOs and concerned governmental bodies at district and regional levels can make use of this research output to plan for specific rural land use planning and land use advancement plans of action intended to accomplish specific objectives. Besides, it is instrumental in going through vegetation cover dynamism along with land use/ land cover change to supply basic information for those who intend to design effective and timely actions on highly degradable land resources.

The study will also contribute towards the understanding of the magnitude of change from the point of view of resource degradation, economic activity dynamics, and livelihood change, thereby indicating directions on how smallholders could come up with these problems. Furthermore, the outcome of the study will generate relevant information that will contribute to the development plans of the district in terms of land use and sustainable land management system for its local community.

It is crucial to conduct an integrated study that reveals the complete picture of the problem to design and implement measures that mitigate LULC changes. Linking information obtained through Earth observation with human perception is significant in understanding the pattern of LULC changes, driving forces, and consequences (Bürgi et al., 2017). There were various studies conducted on LULC changes in Ethiopia. However, this study is the first in the Lude Hitosa district. Hence, this study attempts to contribute to the limited literature about the major drivers and the effects of LULC changes on the surrounding environment and socio-economy of the farming communities in the study district.

The work experience of the researcher was another convincing reason for selecting LULC change as a topic. The researcher is a development practitioner with different thematic focuses in the Horn of Africa region, with a prime emphasis on the countries' major challenges, i.e., natural resource management, agriculture, climate change, food security and sovereignty. Moreover, the study area is one of the development project areas where the researcher works with partners, which implies better exposure and familiarity with the study area.

1.6. Scope and Limitations of the study

The study is limited and was undertaken in the Lude Hitosa district, central-eastern parts of Ethiopia. The study is conducted only in a single district. The study was conducted based on a cross-sectional research design, where data were gathered by a single contact through field observation, KII, FGDs, and secondary sources to investigate the drivers and implications of land use/ land cover change. Although LULC dynamics have several implications, the study was focused on the drivers and effects of LULC change on the surrounding environment and livelihood practices of the farming community. Farmer’s perception of LULC change and its implications on the environment and socio-economic practices were examined.

Despite this, the study was not free from limitations, explicitly arising from data collection problems like the unwillingness of some respondents to supply the correct data. This challenge was dealt with by contacting additional respondents. The other one is the problem of satellite image accessibility, quality, and resolution power. LULC change analysis was conducted using Landsat images of medium (30m) spatial resolution. This is due to the limited access and expensiveness of the very high-quality images. However, different data confirmation and validation methods were employed to reduce the limitations of this study to some extent. Reference points in different land use/land cover types were randomly recorded during the field survey using a hand-held Global Position System (GPS) for the 2022 images, the same as the procedure followed by (Tilahun and Teferie, 2015). Supervised classification with a maximum likelihood algorithm was used to classify the individual images independently using the ground control points collected from each LULC category (Rawat et al., 2013).

1.7. Organization of the thesis or paper

The paper is organized into six chapters, whereby the first chapter deals with the introduction, statements of the problem, research objectives, research questions, ethical considerations, the significance of the study, the scope and limitation of the study, and the organization of the paper. The second part contains a review of related literature about an overview of LULC change, the theoretical framework of land use/ land cover change, an empirical review of land use/ land cover change, driving forces of land use/ land cover changes, and implications of land use/ land cover changes.

The research methods and materials, general description of the study area, research design, instruments of data sources, and methods of data analysis are presented in chapter three. The fourth chapter deals with the result and discussion, which contains land use/ land cover maps of 1984 to 2022, accuracy assessment of classification, trends of land use/ land cover change rate, the main driving forces, and impacts of land use/ land cover change. Then the conclusions and recommendations of the study are presented in the fifth chapter. The sixth chapter contains the references. The reference is the secondary data used to describe the issues under the topics of the study. Finally, appendices that contain questionnaires, methods of accuracy assessment, pictures from FGD, and field observations, have been placed as the last sections of the thesis.

CHAPTER TWO: REVIEW OF LITERATURE

2.1. Spatio-temporal LULC dynamics

LULC change is a major global challenge for sustainable development (Lambin et al., 2001). It contributes significantly to earth–atmosphere interactions, forest fragmentation, land degradation, and biodiversity loss (Maitima et al., 2009). Multiple factors are responsible for LULC changes, either from humans, biophysical attributes, or a combination of the two (Degife et al., 2019). Different studies (e.g., Quintero-Gallego et al., 2018; Wieland et al., 2019) have shown the expansion of cultivated land at the expense of woodland, forestland, wetland, and grassland is the leading cause of LULC change. Population pressure and agricultural investment in response to economic development are the main drivers for the expansion of cultivated land (Berihun et al., 2019).

Globally, LULC change is as old as a human activity. However, the current rate of change is different from earlier dynamics (Gebrselassie, 2014) because of major changes in societal development and population growth. The extent of arable land on a global scale has grown by more than 45%, increasing from 3 million square kilometers to 15 million square kilometers between 1700 and 2000 (Klein et al., 2011). On the other hand, forest cover has been shrinking due to the expansion of agricultural land and urbanization. About 37% of the world's forest degradation was attributed to agricultural expansion and infrastructural development (Geist and Lambin, 2001). In developing countries, especially in sub-Saharan Africa, the increased population has caused the rapid expansion of cultivated land at the expense of vegetation covers (Berihun et al., 2019; Degife et al., 2019) and wetland resources. Although different interventions have taken place, LULC deterioration is still a widely happening phenomenon (MEA, 2005) in many sub-Saharan African countries.

In East Africa, LULC change is pervasive. It remains a cause of significant environmental challenges, where much of the economy is derived from agricultural activities (Berihun et al., 2019), thus making rural livelihoods highly vulnerable to the negative impacts of LULC changes. Studies indicate that increases in the population and the demand for economic development in East African countries have escalated the pressure being exerted on LULC types (Gebremicael et al., 2018). Specifically, LULC changes in this region's countries have been associated with the massive conversion of vegetation cover into cultivated land (Degife et al., 2019). Livestock, coupled with poor land management, has also significantly contributed to LULC changes in the region (Gebremicael et al., 2018).

Like the rest of the East African countries, Ethiopia is not an exception to these LULC dynamics. LULC changes are also a major environmental challenge in Ethiopia (Gashaw et al., 2017), where agricultural activity serves as the backbone of the economy. The problem is more serious in the highland part of the country (Hurni et al., 2005), where a large population exists due to the suitable climatic and ecological conditions for crop and animal production. The expansion of agricultural land at the expense of vegetation cover and too much reliance on wood for fuel and construction materials has contributed to extensive LULC change in the country (Mekonnen and Damte, 2011). The change in LULC in Ethiopia has implications for land degradation (MoARD and WB 2007), which leads to the reduction in ecosystem services (Kindu et al., 2016).

According to FAO (2015) report, forest cover in Ethiopia accounts for only 11-15.5% of the total area. According to the same report, Ethiopia lost 28,180 km2 (18.6% of its forested area) from 1990 to 2015. This huge loss of forest cover was attributed to agricultural and grazing land expansion, urbanization, and the increasing demand for fuelwood and construction materials (FAO, 2015). Such dramatic changes in LULC, along with ecological disturbance and unsustainable land management practices, seriously affected Ethiopia's rich biodiversity, crop, and livestock productivity and have implications for the land degradation problem (MoARD and WB 2007).

Hence, it is possible to conclude that Land use/ land cover change is a major issue of concern intimidating the local, regional, and global environment (Prakasam, 2010). It is also one of the major environmental challenges in Ethiopia (Berhan, 2010). In such cases, the land cover and land use information gain a significant added value through the analysis, identification, and description of ongoing processes.

2.2. Drivers of LULC Changes

The land use/ land cover change analysis revolves around two central and interrelated issues: the drivers and the environmental and socio-economic impacts of land use change (Briassoulis, 2008). Theorists in social and earth system sciences hypothesized that the interaction of anthropogenic and biophysical driving forces triggers LULC dynamics. One of the fundamental theories in the study of land use/ land change is the force that causes land change, /or called the driving force (Burgi et al., 2004). There are two main driving forces of land change, namely biophysical forces (Lambin et al., 2003) and socio-economic or anthropogenic drivers (Su et al., 2011). These drivers are a complex mixture of political, social, economic, and biophysical factors that add force to environmental changes (Geist et al. 2006) and intensify through high population growth (UNEP 2000). The driving forces of LULC change can also be grouped into proximate and underlying factors (Lambin et al., 2001). The expansion of diversified agricultural activities, wood extraction, and infrastructure extension are clusters of proximate (direct) causes of LULC changes. As opposed to proximate causes, complexes of technological, economic, demographic, political, institutional, and socio-cultural factors are grouped under underlying (root) causes of LULC changes. Thirdly, biophysical triggers such as topography, landslides, droughts, and natural fires are considered biophysical factors that underpin LULC changes (Lambin et al., 2003; Geist et al., 2006).

Some studies disclosed that the relationship between land change and its causative factors is complex, dynamic, strongly related to socio-economic factors, and may occur at various temporal and spatial scales (Long et al., 2007; Reid et al., 2000). As a result of a complex interaction between several biophysical and socio-economic conditions (Reid et al., 2000), it constantly changes in response to the dynamic interaction between underlying drivers (indirect or root) and proximate causes (direct) (Lambin et al., 2003). Generally, physical driving factors are limited, static, and easily quantified, while anthropogenic factors are diverse and reflect landscape change accurately; however, it is hard to analyze them quantitatively (Su et al., 2011).

Many theories of land use change intend to describe the structure of the change in land use from one type to another and explain why these changes occur, what causes these changes, and the mechanisms of changes. The what and the why of land use change are closely related, although existing theories rarely address both (Briassoulis, 2000). Several theories of land use change are set in the more general theoretical framework of the discipline studying economic, environmental, and spatial change (transformation). Theories of land use change can be classified into three main categories (Briassoulis, 2008): the urban and regional economic theories, the sociological (political economy) theories, and the nature-society (human-nature) theories, which address mainly the human role in causing global environmental change. Some theories and models have been conceived simultaneously, in which case the terms theory and model are used interchangeably to denote a set of theoretical and operational statements about reality (Briassoulis, 2008).

2.3. Impacts of LULC change

2.3.1. Biodiversity loss

Changes in environmental conditions and the natural setting of the land and its cover can greatly affect the life cycle and the survival of various plants and animals (Angelica and Richter, 2008). Changes in land cover and land use impact biodiversity by altering habitat, ecological processes, biotic interactions, and human disturbance (Hansen et al., 2005). These mechanisms act on the population dynamics of individual species via changes in rates of birth, death, and movements. The aggregate responses of individual species define patterns of community diversity.

According to the Ethiopian Biodiversity Institute (EBI) report, Ethiopia is endowed with many native plant and animal species within its diverse climate and topography (EBI, 2014). Currently, around 320 species of mammals, including 39 endemics, 918 species of birds with 19 endemics, 240 species of reptiles (16 endemics), 71 species of amphibians (30 endemics), and 172 species of freshwater fishes with 38 endemics and more than 1225 species of insects are scientifically recorded in Ethiopia (Teketay 2001; EBI 2014; Amare 2015a). As a result, Ethiopia is among the few countries with the most diverse mammalian fauna in Africa and is blessed with the great attractions of its wildlife heritage. Similarly, the country is also endowed with floral diversity with more than 6500 species of vascular plants (with 625 endemic and 669 near-endemic species and one endemic plant genus). So, it is ranked as the fifth-largest floral country in tropical Africa (Birhan and Gebreyes 2015).

There are different National parks, wildlife reserves, and sanctuaries in the country used to manage and protect wildlife resources. So far, the Simian Mountains and Gambella national parks are gazettes notified, while the others listed together with the national forest priority areas are not gazettes notified (Marino 2003). Hence, many of the protected areas in the country are closely hemmed in and largely exploited by the nearby agrarian and pastoralist communities (Birhan and Gebreyes 2015). This situation is largely making inhabited resources susceptible to degradation.

These days, the wildlife resource in Ethiopia is facing serious threats. The wildlife populations and their management are constrained by different proximate and underlying factors, such as political, economic, social, and biological constraints. Among these, habitat destruction, fragmentation, political instability, policy defects, poaching, lack of commitment from government officials, scarcity of funds, expansion of large-scale agriculture, illegal exploitation of available resources, and lack of skilled manpower in the field are the main ones (Tefera 2011). In addition, there exists a lack of an effective and sound institutional framework and legal bases for ecotourism development in the country (Teshome et al., 2020). This is attributed to the less emphasis and recognition given to eco-tourism and the lack of cohesiveness, integrity, and cooperation among the stakeholders (Eshetu 2014).

Most of the national parks, communal lands, and protected areas of the country have always been entangled in many problems. They are exposed to frequent fires that disturb habitats and wildlife. Due to this, Ethiopia now has the world's second-largest wildlife migration (Amare 2015a). They are also under pressure from the surrounding communities in search of arable land, pastureland, or wood for fuel and other purposes. In general, all the aforementioned factors are continuously degrading the biodiversity resources in Ethiopia.

2.3.2. Soil degradation and erosion

Soil erosion is the degradation of land that could occur through water and wind erosion (Seifu and Elias 2018). Worldwide, water erosion is accountable for 56% of land degradation, followed by wind erosion, causing 28%. Land degradation attributable to soil erosion by running water is the most intimidating environmental problem in Ethiopia (Bewket and Abebe, 2013). The removal of the original cover of land without taking any mitigation measures results in the physical, chemical, and biological loss of soil. The loss of the natural land covers, the steepness of the slope, and bad farming practices all together exacerbate soil erosion (Wubie et al., 2016). Furthermore, the removal of land cover accelerates runoff and soil erosion along steep slopes, the formation of gullies in many cultivated, grasslands around the hills, and water logging in plain areas (Warra et al., 2013). On top of that, in the lower areas of gentle slopes, the gullies get narrower and smaller in depth due to the accumulation of sediments transported from higher grounds (Wubie et al., 2016).

The major components of climate that affect soil erosion are rainfall and wind. Erosive processes are set in motion by the energy transmitted from rainfall, wind, or a combination of these forces (Tibebe and Bewket 2011). The rainfall power to produce erosion is related to rainfall amount, intensity, and distribution. On the other side, the rate of wind erosion could be accelerated when soil becomes dry, weakly aggregated (less cohesive), and bare. As a result, various parts of the northwestern, central, and southeastern highlands of Ethiopia are suffering from the highest erosion rates every year (Asfaw and Neka 2017).

2.3.3. Deforestation

Forests are one of the vegetation biomass dominantly covered by trees of different species that inhabit several biotic lives (Mekonnen et al. 2018). Land spanning more than 0.5 ha with trees higher than 5m and a canopy cover of more than 10% can be called a forest (FAO 2010). In the Ethiopian context, a forest is an area with natural mosaics, dense agroforestry, acacia woodlands, shrub lands, and state and private plantations of about a *timad* or more (*timad* is local land area measurement = 0.25 ha) (Mekonnen et al., 2018). Forest plays an indispensable role in the upkeep of an environment that facilitates sustainable development. Forests, apart from their short to long-term positive effects on weather and climatic conditions, are instrumental in controlling soil erosion, land degradation, and desertification. However, due to economic and social changes, the interaction between humans and forests has changed over time in the world (FAO, 2012).

Deforestation is the clearing of forests to make the land to be usable for other purposes or to make it bare land (FAO, 2012). It causes paramount changes on the surface of the earth. The global increment in the growth rate of the human population necessitates the tragedy of global deforestation. But the pace of global deforestation before 1950 and afterward has been more rapid than the population growth (FAO, 2012).

The ever-present poverty and rapid population growth are considered as the main causes fueling the rate of deforestation to intensify and forest degradation to worsen in Ethiopia (Lemenih and Woldemariam, 2010). Rapid population growth has not only led to land clearance for agricultural purposes but also overgrazing in a dominant mixed cereal-livestock production system. It also urges increased pressure on existing forests because of the increasing demand for fodder, fuelwood, and building materials (Kassa et al. 2009). At a national level, biomass energy offers over 99% of the total domestic energy consumption (92% for households and the remaining being consumed by small-scale industries and food enterprises). From this, about 78% is derived from woody biomass, whereas around 12 and 9% are from animal dung and crop residue, respectively (Nune et al., 2013).

Forest resources are also used as cash income sources through selling wood logs, fuelwood, and charcoal. During the last 50 years, charcoal production increased from one million tons to more than three million tons yearly. Within this period, fuelwood consumption also increased from 40 to 100 million cubic meters in a year (Asfaw and Demissie 2012). These all had been done at the expense of forests. Encroachment of farmland and pasture into the natural forests has also been a common practice in many parts of Ethiopia. Such deforestation activities and overgrazing have led to soil erosion resulting in land quality deterioration, biodiversity loss, and impact on the overall climate system posing a serious problem in every aspect of human life (Kassa et al. 2016).

2.3.4. Climate change

Climate change is the permanent transformation in the climate features of a place. Its signals are a rise in global temperature, the prevalence of recurrent drought, floods, shortages of rainfall, a decrease in glacial cover over mountains, and rising sea levels (Kinfe, 2011). Henderson et al. (1994) stated that climate and land exploitation by humans are closely interrelated. Mainly, local or small-scale change in climate as a result of the land cover change is widely observed and recorded. Moreover, Cook et al. (1975) indicated that the conversion of vegetation cover could affect the climate condition on small or large scales. The changes can further stretch to grave environmental threats for humankind today, like climatic change, loss of biodiversity, and water, soil, and air pollution.

As Kinfe (2011) cited, LULC intertwines climate and weather in subtle and complex ways. The interaction between land cover and climate change encompasses the exchange of greenhouse gases (water vapor, carbon dioxide, methane, and nitrous oxide) between land and the atmosphere. Moreover, the amount of insolation, be it solar or terrestrial, influences land use/ land cover and climate, thermal exchange between the ground and atmosphere, the nature of the land surface, and its uptake of the momentum from the atmosphere (U.S. climate change science program, 2004) cited in Kinfe (2011).

2.3.5. Hydrological impacts

Hydrological responses to LULC changes are complex under various climate and geographical conditions. It is due to complicated inter-relationships between various hydrological components such as precipitation, evapotranspiration, infiltration, and runoff (Dwarakish and Ganasri, 2015). Different researchers show that land use changes like deforestation, reforestation, change of forested to agricultural lands, the conversion of grasslands by trees, drought, and increasing urbanization affect surface and sub-surface hydrology of river basins at local and regional levels (Tayler,1977; Bannister, 1979) cited in Muluneh, (2005). Changes in the hydrological cycle of a river basin can result in variations in the rate of flooding and its amount, reduction or increase in basin yield, and groundwater recharge (runoff). Furthermore, it can cause a decrease in water quality with an increase in sediment transportation and soil erosion (Walkinson, 1992), cited in Muluneh, 2005.

Moreover, land use/ land cover change highly affects the hydrological condition of the watersheds, water resources, and the environment at small and large scales (Batra et al., 2007). Human activities like deforestation and intensive cultivation can decrease the amount of water percolates into the ground and recharges streams, springs, and underground water (Warra et al., 2013). Besides, Warra et al. (2013) pointed out the volume of locally available streams and rivers reduction over time in the Kasso catchment area of Bale Mountain. The drying up of these springs and streams has affected the socio-economic life of farmers in the Kasso catchment area.

2.4. The Land Use Policy in Ethiopia

Different scientific studies undertaken in various parts of Ethiopia reveal that, except in urban centers with master plans and zoning in effect, the land has been used for a very long period in an unplanned and uncontrolled manner (Hailemariam et al., 2016; Gashaw et al., 2017; Miheretu and Yimer, 2017). It is used without due regard to its potential use and due consideration for conserving natural resources and safeguarding the environment (ibid). Consequently, land degradation has been one of the country's severe environmental problems, which requires great effort and resources to ameliorate (Hurni et al., 2005; Adgo et al., 2013). The problem is more severe in the highlands (above 1500 m above sea level and covering 45% of the total area), where roughly 90% of the population lives and 95% of the regularly cultivated lands are found (ibid).

To this end, the Ethiopian government needs to consider how it can modify land policy and administration to encourage farmers to improve their land management and produce more without reducing their livelihood security. A multi-step process involving a national land policy conference and establishing a land policy task force that will continue the land policy refinement can address this issue (USAID, 2004). As recommended by Zemen et al. (2017), the Ethiopian government must pay attention to formulating a national land use policy and preparing national integrated land use plans.

CHAPTER THREE: THE STUDY AREA AND RESEARCH METHODS

3.1. Description of the Study Area

3.1.1 Geographical Location

This study was conducted in the Lude Hitosa district, one of the districts in the Arsi zone of the Oromia National Regional State of Ethiopia. The administrative center of the district is Huruta town, which is located southeast of Addis Ababa at about 160 km and 40 km from northeast of Asella, the capital of the Arsi Zone or 65 km from Adama. The district has a total area of 485.7 km² or 48,570 ha and is located geographically between 7°55'0"–8°15'0" N latitude and 39°15'0"– 39°35'0"E longitude. It shares boundaries with Dodota in the northwest, Hitosa district in the south and southwest, Sire district in the north and northeast, and Diksis district in the east and southeast. The district is located entirely within the Ethiopian Rift Valley and has three climatic zones.

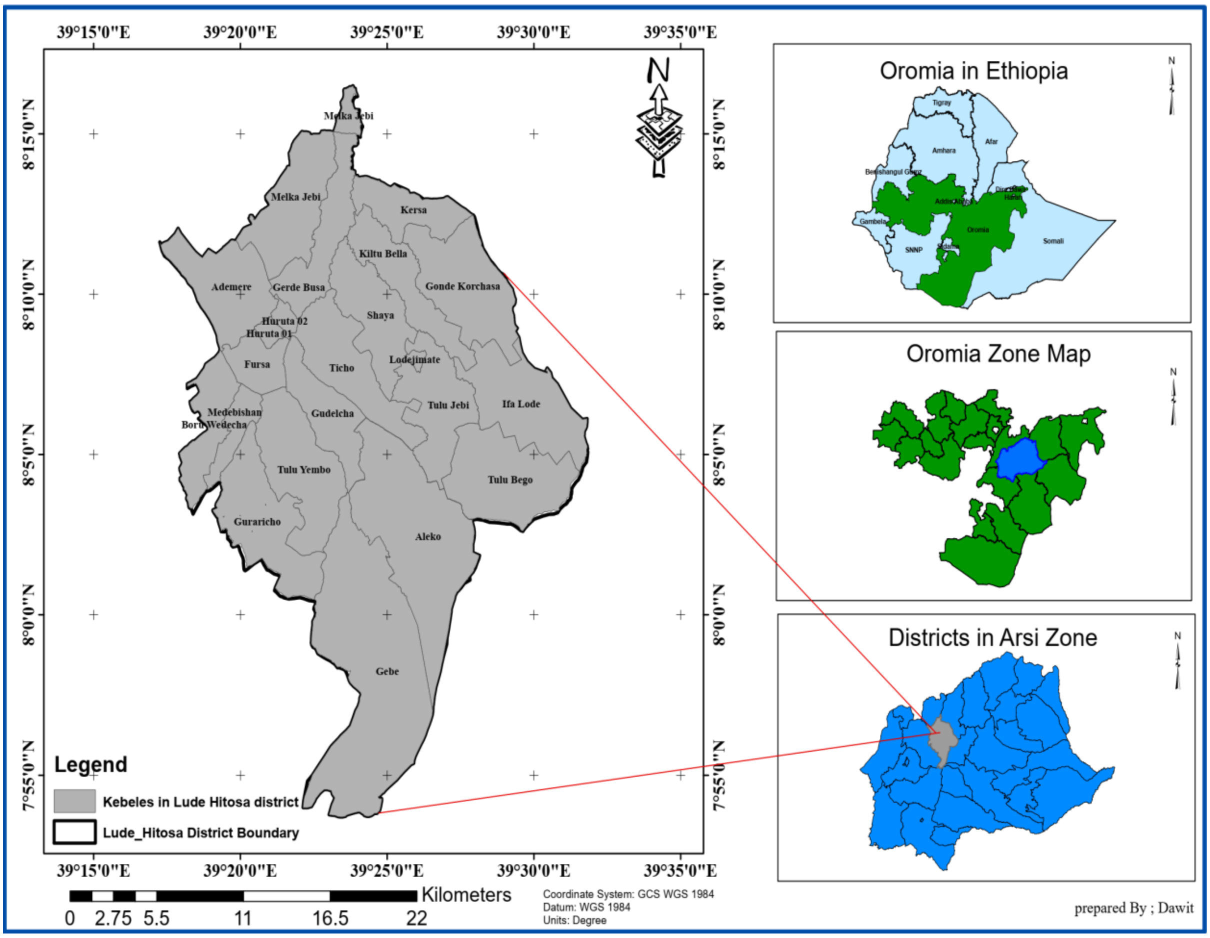

Figure 3.1. Location Map of Lude Hitosa District in Central-eastern Ethiopia

3.1.2 Populations and their Livelihoods

The study area is inhabited by a total of 160,132 people located across 19 rural kebeles and three urban kebeles in the district. Out of which, 80,700 are female (CSA 2022 prediction). The three urban kebeles in the district contain 30,600 people or 13.6% of the total population. In comparison, the remaining rural kebeles hold about 130,300 people or 86.4% of the total population of the district. The earliest available population data for the district is the 2007 national census report. It shows that the total population for the district was 107,133 people, i.e., 53,522 were men and 53,611 were women. The primary livelihood system of the people in the district is mixed agriculture. The leading smallholder subsistence crops are wheat, barley, teff, and bean; the principal cash crop is onion, and livestock is cattle, shoats, and donkeys.

3.1.3 Topography, Climate, and Land distributions

The topography of the district consists of 51% highland (dega), 44% middle altitude (weyena dega), and 5% lowlands (kola). The physiographic characteristics of the study area include altitude 1800 – 2500 m.a.s.l, annual rainfall 800-1400 mm, mean annual temperature 19^{o}C, mean maximum annual temperature 30^{o}C, and mean minimum annual temperature 10^{o}C. The rainfall in the study area is bimodal. The long rainy season extends from June to September, supporting major crop production. While the shorter rainy season comes in March and April, allowing minor crop production.

The majority of the land in the district is used for crop production (53.4%) (district agriculture office (2022)). Grazing land is 9.7%, forestland is 7%, rangeland, bare land, and others (including settlements) account for 18.3%, 5.3%, and 6.3%, respectively. The information from the district shows severe soil erosion, soil infertility, and a remarkable decline in agricultural productivity in the area. The smallholder farmer's response to the problem shows that they highly utilize external inputs like chemical fertilizers to improve agricultural production and productivity, which negatively affects soil and human health (Agrihunt, 2016; Serpil Savci, 2012; Menale and Zikhali, 2009).

3.2. Research Methods

The study design was conducted based on a mixed approach specifically, the concurrent triangulation approach was selected as the research method. As pointed out by Crestwell

(2009), the mixed method enables one to understand the problem better and more comprehensively and is the most popular method for conducting research. The procedure is preferred because it can substantiate, cross-validate, or confirm findings within a single study, as the research requires it to be examined from various angles (Gay et al., 2009). Besides, it demands the employment of diverse data collection instruments to capture the most important factors that impact land use/cover in sufficient detail. Furthermore, this strategy enables the researcher to collect data in a short period of time (Creswell, 2003; Gay et al., 2009). The quantitative and qualitative methods are combined and integrated to add value to the arguments from different perspectives and answer research questions more deeply.

In the study, data were drawn from both primary and secondary sources. The main data sources were questionnaires, observations, interviews, and focus group discussions (FGDs) and supported with remote sensing imageries, Global Positioning System (GPS), and other supportive data such as related literature.

i) Primary data sources:

The primary data was collected through a questionnaire, field observations, focus group discussions, and key informants. It was conducted with the farm household heads, elders, district experts like land management officers, agricultural experts, natural resources and forest protection office experts at the kebele and district level, and rural development agents.

Questionnaires: Questionnaire surveys were provided to households to collect information on household characteristics. A questionnaire was prepared in English and submitted to the research advisor for review and feedback. After revisions, the research advisor approved the questionnaire and allowed the collection of the required data. Then the questionnaire was translated into Afaan Oromo and Amharic, as the selected areas are inhabited by speakers of both languages. The questionnaire covered information pertaining to the socio-economic and demographic background, farmers' perception of land degradation, land management practices implemented by farm households, and perceived challenges. A preliminary test was conducted by administering the questionnaire to ten selected respondents. The necessary modifications were made based on the feedback obtained from the pre-test during the pilot survey in May 2022. Then, the questionnaire was administered by well-trained interviewers who understood the local language. The enumerators were introduced to the concepts of the research and the questionnaire to understand and help respondents during the survey.

Focus Group Discussions (FGDs): FGDs create an opportunity for participants to feel at home and express their behaviors, attitudes, and opinions freely (Berg, 2001). Three FGDs were held in three selected kebeles (i.e., Ademere, Gerdebusa, and Guraricho kebele) of the Lude Hitosa District, comprising 8 to 12 people of both sexes and different ages. The discussions were carried out with farmers, elderly, and community representatives with very good knowledge of the study area on issues like the history of land use/ land cover change, its driving forces, and its consequences. The FGDs aimed to acquire detailed information about people's perceptions of land degradation and their land management practices.

Physical observations: In this study, the researcher has conducted a physical observation of the target kebeles to assess the nature of land degradation and the land management practices (state of the land use/ land cover dynamics) of the study area. The structured observations were undertaken to physically observe the current state of the natural environment and socio-economic activity. The pre-determined research objective, schedule, and variables have guided the physical observations.

Key informant interviews: Other primary data were gathered through key informant interviews using semi-structured questions. Purposive sampling was employed to select government sector officers (agriculture officers, land managers) for the interviews. Accordingly, semi-structured informant interviews were conducted with ten key informants (agriculture, natural resources, forest protection office experts, land management and rural development office experts/officers/agents, elderly, and land speculators). They were selected purposively with their ability to inform and describe the LULC changes and land management practices in their areas. Purposive types of questions were asked to get relevant information about the causes, impacts, and types of land use/ land cover change in the study area. Such information has been used to triangulate information generated from remotely sensed data.

ii). Secondary data sources:

The secondary data were obtained from the Lude Hitosa District Agriculture Office, Rural Land Management and Environmental Protection Office, Central Statistical Authority, Ethiopian Space Science and Geo-spatial Institute (ESSGI), satellite image website, and development bureaus. Remote sensing data (Landsat imageries) were employed to quantify land use change and assess this change's impact in the study area. Furthermore, published, unpublished documents and reports from different offices in the Lude Hitosa district, as well as books, scientific journals, and proceedings, were used to substantiate and explain the study's findings. The study used mixed methods to complement each other since the methods have their weaknesses and strengths. Crummey (1998) emphasized the importance of using the mixed method as “future studies will have to have a solid grasp on the intentions and strategies of local farmers, which will mean an integration of image analysis with historical and socio-economic information."

3.2.1. Remote sensing data and LULC change assessment methods

The LULC change distribution varies in space and time. This variation is because the physical and social characteristics of communities vary in space and time, and so do land-use choices, resulting in a spatial pattern of land-use types (Canute et al., 2015). The study of land use/ land cover patterns is essential for selecting, planning, and implementing land use schemes to meet the increasing human needs and welfare. The result also provides information for managing the dynamics of land use and meeting the demands of the rising human population (Yadav et al., 2010). Therefore, showing the results of land use land cover in the form of maps and statistical data is very important for concerned bodies like planning, management, and utilization of land for different purposes (Roy and Giriraj, 2008).

Land use/ land cover analysis can be done from processed aerial photographs, satellite images (Landsat image, Sentinel), and Google Earth (Dash, 2005). Since remotely sensed data from the earth's orbit can be obtained repeatedly over the same area, they have been very useful in monitoring and analyzing LULC in various regions of the earth. It greatly contributes to the planning and management of available resources, especially in developing countries where other kinds of background data are often lacking (Dash, 2005; Fakeye et al., 2015).

While searching the remotely sensed data that suites the study objective, the researcher has considered the essential properties of the spatial resolution (the size of the grid cells), the temporal resolution (the return time or frequency that data is collected, and the availability of historical images, and for a particular moment in time), spectral resolution (the parts of the electromagnetic spectrum (wavelengths) for which measurements will be made), radiometric resolution (sensor sensitivity; ability to measure small differences), quality issues (such as the presence of cloud-cover or artifacts in the data), and availability of the image on a required period of time.

There are numerous sources of remotely sensed data from satellites. Very high spatial resolution data is available, but it is a commercial product and costly. Lower spatial resolution data is freely available from NASA (National Aeronautics and Space Agency), ESA (European Space Agency), and other organizations. Accordingly, the researcher has used the NASA data server link, http://earthexplorer.usgs.gov/, to access the freely available satellite imageries like Landsat 9, Landsat 7, and Landsat 5 imageries. The Landsat imageries used for this study were Landsat 5 Shortwave Infrared (SWIR) 2 with 30m resolution for 1984, Landsat 7 Cirrus band with 30m resolution for 2000, and Landsat 9 OLI TIRS (Operational Land Imager Thermal Infrared Sensor) with 30m resolution for 2022. Since the aim is to study the land use/ land cover trend of Lude Hitosa District for the past nearly four decades, the following satellite images are downloaded:

- For 1984 from Landsat 5 “LT05_L1TP_168054_19840421_20170220_01_T1”
- for 2000 Landsat 7 “LE07_L1TP_168054_20000205_20170213_01_T1(4)”
- And for 2022 Landsat 9 “LC09_L1TP_168054_20220305_20220305_02_T1”.

The images were downloaded by path 168 and row 054 to get the images for the target required area of interest, Lude Hitosa District. The images were obtained from the USGS (United State Geological survey).

Table 3.1. Remote sensing data sources and collection process

Satellite images	Path/ row	Date of acquisition	Spatial resolution/Grid cell size (m)	Cloud cover percentage	Number of Band	List of bands
Landsat 5	168/54	1984/04/21	30m	0.01	7	(1, 2, 3, 4, 5, 6, 7)
Landsat 7	168/54	2000/02/05	30m	0.01	9	(1, 2, 3, 4, 5, 6, 7,8,9)
Landsat 9	168/54	2022/03/05	30m	0.01	11	(1, 2, 3, 4, 5, 6, 7,8,9,10,11)

Source: US Geological Survey, 2022.

The remote sensing data used in this study were Landsat imageries and ground measurements (using GPS Receiver). For the simplicity of analysis, dry season and cloud-cover-free images were used, and all the images (1984, 2000, and 2022) were obtained for the months of February, March, and April. The satellite images of 1982 (40 years ago) were not used due to quality issues (unavailability of quality images due to cloud cover or artifacts in the data). The dates for remote sense data were determined based on historical events of structural land use dynamics (Dereje, 2018; Desalegn, 2011). Therefore, the Landsat-5 image of 1984 (after the introduction of large-scale state farms). Whereas the Landsat-7 image of 2000 (after the introduction of large-scale private agriculture, whereby the state farm was banned, and small-scale farmers were allowed to use the land for almost a decade). Lastly, the Landsat-9 image of 2022 (the current situation of LULC) was used.

The remote sensing data acquired from different sources were analyzed using different software. These softwares are ArcMap 10.8 (for training the samples by the six land use classes of bare-land, cropland, forestland, grassland, settlement, and shrub), R studio Rstudio-02.2-4 (for stacking the images, cropping the satellite image by the study area-Lude Hitosa and for analysis and visualization), quantum GIS (Q Gis) (for pixel counting and area analysis) and Microsoft office.

ArcMap 10.8 were used to visualize the satellite image and to consider the area. Then, high-resolution spot images and google earth were referred to for a better understanding of deciding the land use type. R studio is like ArcMap desktop-based software, which can work on windows and operating systems. It allows the user to compute a complicated statistical and graphical analysis and has a high visualizing capacity. Unlike ArcMap, R studio works using an R programming language and is free software. Conversely, Q Gis is again like ArcMap, but it is open-source software with many optional toolboxes. Its application is like ArcMap, but the only difference is the latter is licensed, whereas Q Gis is free software.

The Flowchart of the LULC change assessment is as follows.

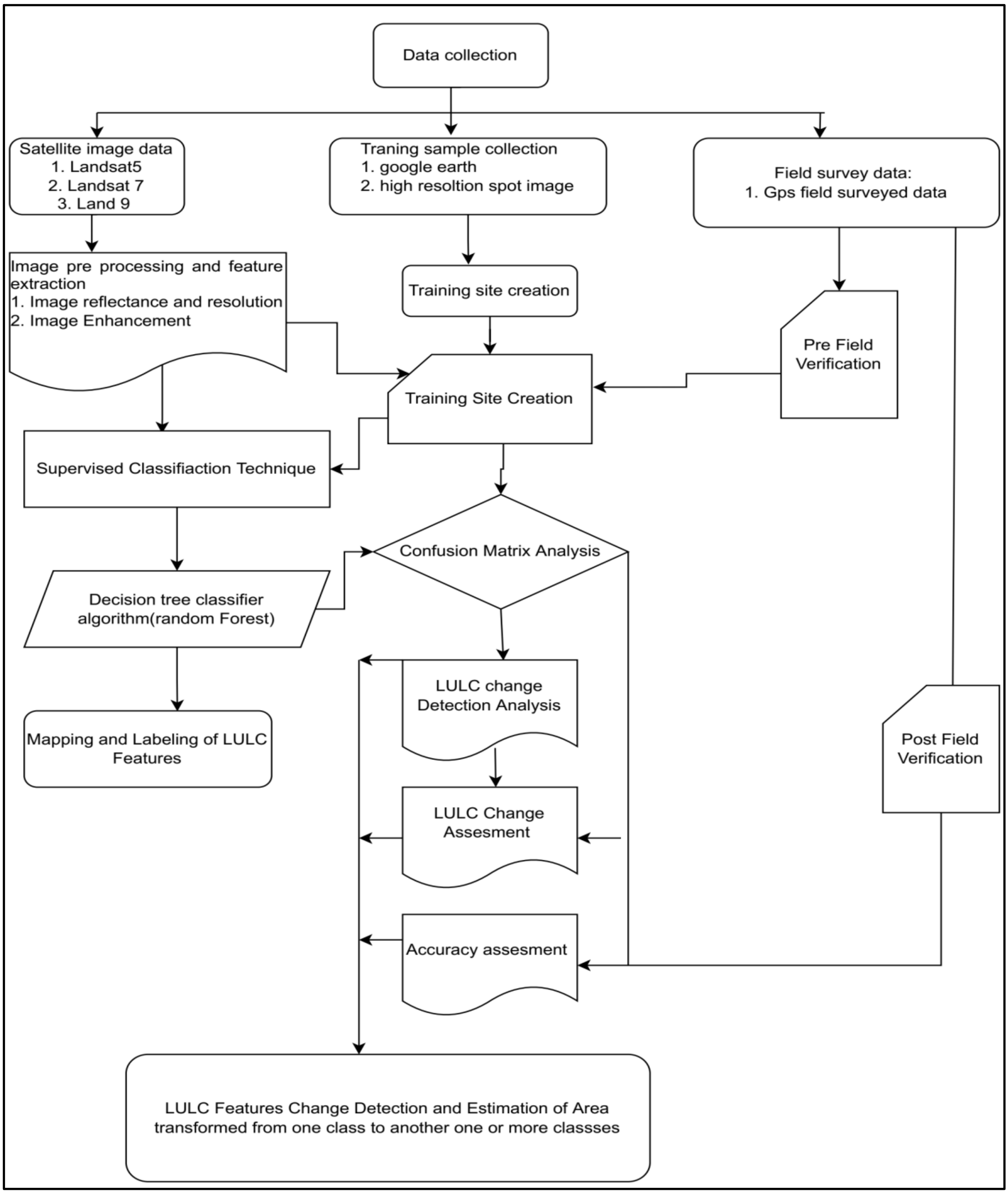

Figure 3.2. Flowchart of the LULC change assessment

A supervised classification was performed with the help of Google Earth and high-resolution spot images. A random forest/ decision tree classifier algorithm was employed to assign each pixel within the image to a discrete class. Finally, six dominant LULC classes were identified for the subsequent Spatio-temporal LULC analysis. To compose the classified LULC maps, ArcMap 10.8 was employed because it is relatively simple and convenient to produce maps.

During the classification process, natural forests and plantations were considered as forestland since it was difficult to differentiate natural vegetation from a plantation in medium-resolution images. Similarly, scattered rural dwelling units were grouped with crop/agricultural land, while fallow plots were taken as grassland. Since they had the same spectral nature on such medium-resolution images, it wasn't easy to differentiate those features. The LULC Change detection was conducted using machine learning algorithms/random forest. A post-classification comparison was applied from the various change detection algorithms, which required rectification and classification of each remotely sensed image.

3.1.1 Image processing and Classification methods

The procedure in the image preprocessing stage included detecting and restoring bad lines, geometric rectification or image registration, atmospheric correction, and topographic correction. Accurate geometric rectification or image registration of remotely sensed data is a prerequisite for a combination of different source data in a classification process (Mahendra et al., 2015). The main relevance of image processing is to get non-distorted image data with coordinates, projection, and datum.

The study used Landsat imageries to identify changes in LULC distribution for nearly four decades from 1984 to 2022. To avoid a seasonal variation and to minimize cloud cover, the selection of dates of the acquired data had made in the dry season and with the same annual season of the acquired years. All the input satellite images had composed using the RGB color composition to view and discriminate the surface features. Furthermore, the images provided complete coverage of the study area, and mosaicking, stacking of bands, and sub-setting of the images had done using R programming in R studio software.

The geometric correction was conducted to process remotely sensed data so that individual picture elements (pixels) are in their proper planimetric (x, y) map locations. This geometric correction was important because aerial photos and satellite imagery are not free from geometrical errors. Geometric Correction is done for the conversion of the data to real-world coordinates. This correction is carried out by analyzing well-distributed Ground Control Points (GCPs).

Conversely, the atmospheric correction was employed to quantify (i.e., remove) the effect of the atmosphere at the time an image was acquired. The general goal of absolute (atmospheric) correction was to turn the digital brightness values (or DN) recorded by a remote sensing system into scaled surface reflectance values.

3.2.1 Image enhancement

Image Enhancement was conducted to modify images or increase the visual appearance and interpretability of imagery. Image enhancement makes the interpretation of complex data easier for the operator. The goal of digital image enhancement was to produce an approached image suitable for a given application. The enhancement makes important features of raw, remotely sensed data more interpretable to the human eye. Image enhancement is tasked with image reduction, image magnification, transect extraction, contrast adjustments (linear and non-linear), band rationing, spatial filtering, principal components analysis, texture transformations, and image sharpening.

3.3.1 Training sample collection

Reference points in different land use/land cover types were randomly recorded during the field survey using a hand-held Global Position System (GPS) for the 2022 images, the same as the procedure followed by (Tilahun and Teferie, 2015). The researcher used Google Earth and 2016 high-resolution spot images from Ethiopian Space Science and Geospatial Institute (ESSGI). The high-resolution spot images are 1.5-meter resolution images which enabled the researcher to cover the areas that were not accessible during the field visit to identify the land use class and train the samples. Different land cover features such as water, soil, vegetation, cloud, and snow reflect visible and infrared light differently. Hence, 300 sample points for six classes (50 sample points per class) were taken from satellite images, google earth, high-resolution spot images, and GPS – to assist the samples.

In the study, the researcher has collected 30% of the 300 sample points from the field observation (using a hand-held GPS receiver) – for 2022 and 70% of the 300 samples through satellite images, google earth, and 2016 high-resolution spot image. The 30% of GPS collected points were used for the accuracy assessment and testing sample, and 70% of the sample points were consumed to train the model – on machine learning.

The machine learning (ML) technique was used in this study since it has good accuracy for image classification. It is a new trend whereby literature suggests using it for research, especially its random forest algorithm. Machine learning is a branch of artificial intelligence (AI) that focuses on using data and algorithms to adaptively improve the performance of machines from experience as the number of samples available for learning increases. It is a technique or method that uses a machine to get the best products out of it. The Random Forest algorithm is a famous machine learning algorithm that uses supervised learning methods. It can be applied to both classification and regression problems.

3.4.1 Random Forest Algorithm

A machine Learning approach (random forest (RF) algorithm) was followed for image analysis, which is a statistical learning technique used to conduct land cover classification from multispectral (multi-band) imagery. Machine learning (ML) techniques have the capacity to predict and are able to present linear and nonlinear relationships between pixels.

The RF algorithm for the image classification works first by selecting the random samples from the dataset provided, and then the algorithm creates a decision tree for each sample selected. Afterward, it gets a prediction result from each decision tree created, followed by the voting performed for every predicted result using the mode. Finally, the algorithm selects the most voted prediction result as the final prediction.

The random forest is representative of the so-called "ensemble learning" methods. The word ensemble means a group in the image classification context. After the training of the algorithm, each of those decision trees (DTs) is capable of mapping input data X to an output response Y (e.g., class labels, like urban, water, and forest). The Random Forest algorithm listens to all the responses of the DTs and makes its final prediction based on the most frequent given response (majority vote). Significant improvements in classification accuracy have resulted from growing an ensemble of trees and letting them vote for the most popular class. In order to grow these ensembles, often random vectors are generated that govern the growth of each tree in the ensemble. After a large number of trees is generated, they vote for the most popular class.

In the study, image classifications were carried out by sorting pixels into a finite number of individual categories of data based on their data file. Once the sample points were collected from google earth, high-resolution spot images, and hand-held GPS, the sample was trained using supervised learning methods. Then, to classify the image, the researcher used a random forest/decision tree (DT) algorithm by splitting the sample points into 30% for testing and accuracy and 70% of the data/samples for training the satellite images. To elaborate more, all pixels in an image were placed into LU/LC classes to draw out useful thematic information. The training sites were selected based on image interpretation keys during the field survey and interviews with the local inhabitants. Reference points in different land use/land cover types were randomly recorded during the field survey using a hand-held Global Position System (GPS) for the 2022 images. ArcGIS 10.8 and Quantum GIS (QGIS) v 3.0 software were used for overall image processing. The classification was adopted in a way that suits the purpose of the study.

3.5.1 Classification Accuracy Assessment

The Maximum likelihood supervised image classification methodology was applied to categorize LULC categories. After verifying that each categorized images have an appropriate accuracy value, an image differencing technique identifies and quantifies LULC dynamics in the research region. Fieldwork (GPS), Google Earth, and high-resolution spot image were used to validate classification findings, and accuracy assessment was assessed by using the Kappa statistics.

Accuracy Assessment of the Classification: Accuracy assessment refers to a process employed to estimate the accuracy of image classification by comparing a classified map with a reference map. The LULC change statistics were performed using relative change detection mechanisms. The technique is important to evaluate trends of area and percentage change of one land use/land cover to others to determine their spatial increase or decrease through time intervals because of natural and humanmade factors. For example, accuracy assessment is an integral part of any image classification process since image classification using different classification algorithms could classify pixels or groups of pixels into wrong classes. As classified LULC maps from remotely sensed imageries may contain some errors, an accuracy assessment was employed to find out those errors to ensure the reliability of the produced LULC maps. Therefore, the classified maps were assessed and compared with referenced data and ground truth using an error matrix. A total of 300 sample points for the three study periods were taken from satellite images, google earth, high-resolution spot images, and a hand-held GPS to assist the samples. The 30% of the 300 sample points from the field observation were collected using a hand-held GPS receiver for 2022 and were used for the accuracy assessment and testing sample.

3.2.2. The Socio-Economic Survey and Methods of Data Collection

The socio-economic data were collected through a questionnaire survey, focus group discussion (FGD), field observations, and key informant interviews (KII). Sampling for the socio-economic survey was done in two stages. The first stage was selecting the sample kebeles. The second stage was estimating the sample sizes and selecting farm households, elders, experts, and development workers from the local government offices and developmental agencies operating in the selected Kebeles.

The selection of kebeles and respondents was carried out in collaboration with the key persons known to the researcher from the district agriculture office and the development organization working in the district. The researcher has prior exposure to the area and worked on development projects that support agricultural practice improvement. Accordingly, three target kebeles (Ademere, Gerdebusa, and Guraricho kebeles) were purposively selected from the district based on the severity of the natural resource degradation (forest, land, and water) with the massive population pressure and change in agricultural lands and practices. These criteria were used mainly due to their qualifications to indicate the LULC changes and their implications towards an environment and socio-economic situations in a given area.

The sampling procures then followed with the estimation of the number of farm households residing in the three study kebeles. Thus, again with the help of district administrators and agricultural extension workers, the total number of farm households residing in the three selected kebeles was found to be 2,111 households. The next step was to determine the sample size or households required for the study, which was carried out using the formula provided by Yamane (1967).

$$n = N / (1+N (e)^2)$$

$n = 2,111/ (1+2,111 (0.095)^2)$

$= 2,111/ (1+2,111 (0.009025)$

$= 2,111/ (1+19.05)$

$= 2,111/20.05$

= 105

Where, *n* is the required sample size, *N* is the population size, *e* is the significance level (0.095), and the confidence level is 95%. The total sample size required for the study was found to be 105 households. Then representative samples were drawn proportionally from each rural kebele as the household sizes are different in each kebele (Table 3.2).

Table 3.2: The distribution of sampled households in three selected kebeles

Kebele	Households in the target kebeles	Sample households	Percent
Ademere	862	35	40.8
Gerdebusa	374	33	17.7
Guraricho	875	37	41.5
Total	2,111	105	100.0

Then, the sampling procedure continued, and the target respondents of the study were selected from those selected three kebeles of the district. The majority of the kebele residents are economically homogeneous and work in agriculture. This situation has made it convenient to apply probability sampling procedures and to identify the targets from the sampled kebeles, who have a better experience in the ecological and livelihood systems and expertise on the issues. In probability sampling, all people within the research population have an equal chance of being selected. These types of samples are used if the researcher wishes to explain, predict, or generalize to the whole research population (Saunders et al., 2016).

Accordingly, simple random sampling techniques were used to select sampling units that appear to represent the population and explain the existing situation relating to the aim of the study. As the study has the objective of studying the long-term or nearly four decades of LULC change and its impacts in the targeted area, the households or research population, the people who worked in land-related activities, like farmers and elders who live longer in the area, are selected in the sample randomly.

3.2.3. Methods of data analysis

To analyze the remote sensing data, ArcGIS 10.8 were used for data analysis and map preparation, and machine learning algorithms for remote sensing application to process satellite images, including image processing, enhancement, and classification for land use land cover. In addition to the geospatial software, Google Earth Engine was used as a geospatial tool in a cloud computing platform to acquire, store, manipulate, filter, visualize satellites images (Landsat), and classify land use and land cover dynamism through different years of the saga.

The socio-economic data collected through a questionnaire survey were analyzed using SPSS (v. 20), employing descriptive analysis (like frequency, percentage, etc.). Descriptive analysis procedures were used to check, edit, and clean the data set and to identify essential variables for further analysis—this involved computation of simple frequency tables, correlations, and contingency tables.

The qualitative information gathered through interviews, FGDs, and field observations were used to substantiate the quantitative analysis of the questionnaire data. Both qualitative and quantitative data analysis methods were used in the study. Despite this, thematic data analyses were employed in the study to analyze the data collected from semi-structured interviews and informal interviews. The analysis was conducted by thematically organizing and transcribing the collected data, then relating them (data) to each other depending on their similarities and differences. "Classification is concerned with identifying coherent classes and connection, on the other hand, involves the identification and understanding of the relationships and association between different classes" (Kitchin and Tate, 2000:235).

CHAPTER FOUR: LAND USE/LAND COVER CHANGES, DRIVING FORCES, AND IMPACTS

4.1. LULC classification and analysis

LULC changes are dynamic, widespread, and accelerating processes, mainly driven by natural phenomena and anthropogenic activities, which in turn derive changes that impact the natural resources and socio-economic activities of human beings. Sufficient information was obtained on land use/land cover changes by interpreting satellite images of 1984, 2000, and 2022. The period of 1984 was taken as a base year to analyze LULC change in the study area. This section presents the land cover maps resulting from the classification of satellite images, assessment of map accuracy analysis of the trend, rate, and nature of the land cover change. The classified land use/land cover types of the study district and the results of each LULC change are presented below.

The analysis identified six categories of LULC classes (Figure 4.1), and the annual rate of change (1984 – 2022) is presented in Table 4.1. The six LULC classes are cropland, bare land, grassland, shrubland, forestland, and settlements. The spatiotemporal LULC change analysis was made to compare the changes in the Lude Hitosa District for the last four decades. The post-classification change detection was made for three study periods 1984, 2000, and 2022. In the initial study period (1984), about 48.44% (26,221.86 ha) of the district was covered by vegetation (grassland, forest, and shrub), and only 5.10% (2,758.41 ha) of the total area had been bare land.

During 1984, bare/degraded land was limited to some parts of the district and later expanded and dominated the northern and southern parts (Figure 4.1). The LULC proportions of cropland, grassland, forest, shrub, and settlement were 46.17%, 23.59%, 19.64%, 5.21%, and 0.29%, respectively (Table 4.1). After about four decades (in 2022), the cropland, settlement, and bare land increased to 68.03%, 10,47%, and 9.85%, while forest cover, grassland, and shrub declined to 6.87%, 1.36%, and 3.43%, respectively. The findings of this study show that the proportion of cropland and bare land has steadily increased over the study periods.

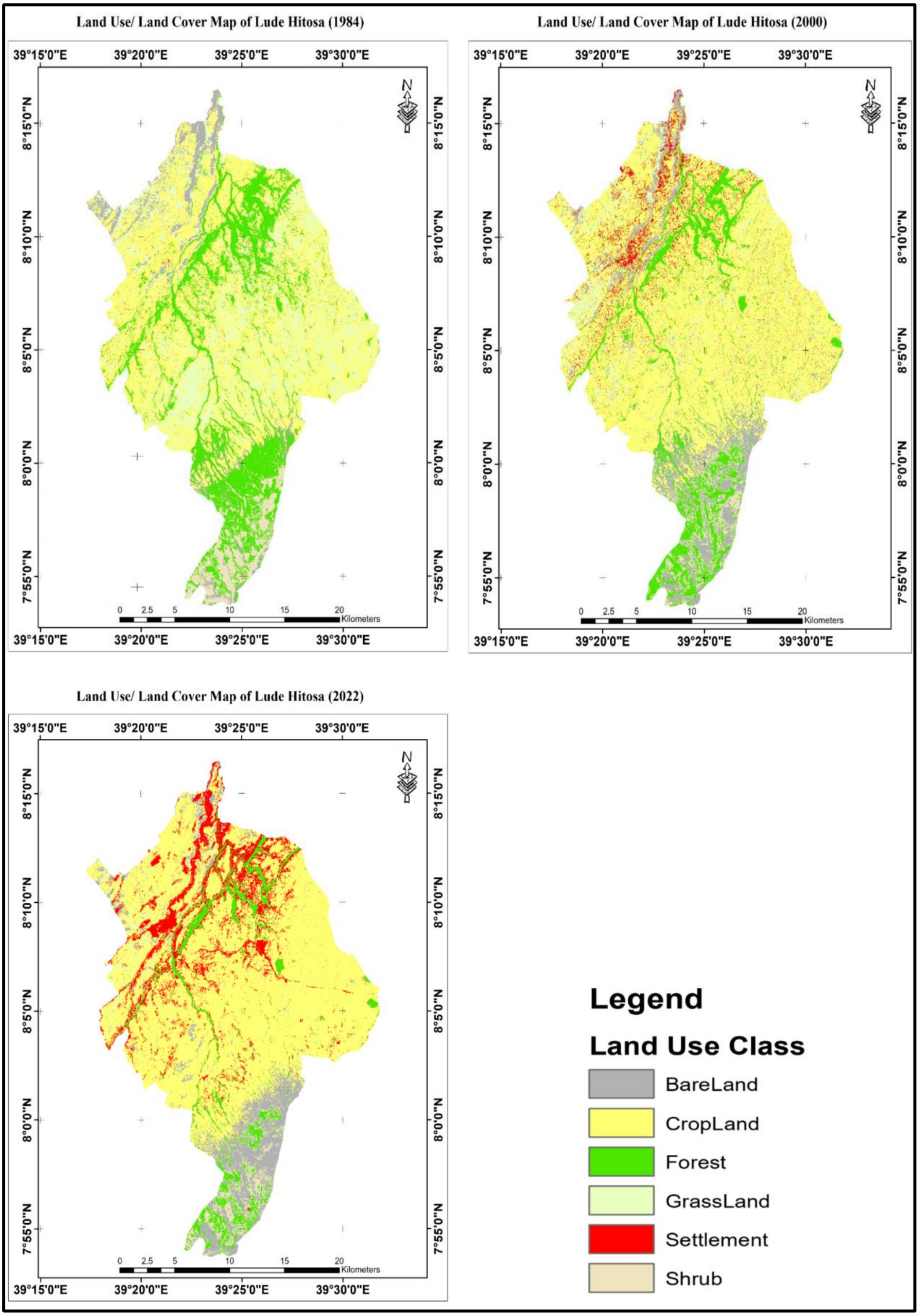

Figure 4.1 LULC classification maps of the study area in the three different periods

The LULC change trends and analysis were conducted for three study periods (1984, 2000, and 2022), and the outcome is presented as an area (hectare) and percent change. The Ethiopian Mapping Agency (EMA) standard was followed on color coding the different land use classes. The actual change area in hectares and percent change of LULC for the study periods are depicted in Table 4.1. In the district, cropland covers were the highest coverage of the study area throughout the study periods.

Table 4.1. LULC change trends and analysis of Lude Hitosa district for the study periods

ID	LULC classes	Study area						Change of LULC in the study area					
		1984		2000		2022		1984 - 2000		2000 - 2022		1984 - 2022	
		Area (Ha)	LULC class (%)	Area (Ha)	LULC class (%)	Area (Ha)	LULC class (%)	Area (Ha)	Percent (%)	Area (Ha)	Percent (%)	Area (Ha)	Percent (%)
1	Bare land	2758.41	5.1	5094.54	9.41	5330.61	9.85	2336.13	4.31	236.07	0.44	2572	4.75
2	Crop land	24996.87	46.17	33745.59	62.34	36829.71	68.03	8748.72	16.17	3084.1	5.69	11833	21.86
3	Forest	10634.04	19.64	6804.99	12.57	3717.54	6.87	-3829.1	-7.07	-3087.5	-5.7	-6917	-12.77
4	Grass land	12768.39	23.59	4145.49	7.66	735.21	1.36	-8622.9	-15.93	-3410.3	-6.3	-12033	-22.23
5	Settlement	158.58	0.29	2195.55	4.06	5667.93	10.47	2036.97	3.77	3472.4	6.41	5509	10.18
6	Shrub	2819.43	5.21	2149.56	3.97	1854.72	3.43	-669.87	-1.24	-294.84	-0.54	-964.7	-1.78
SUM		54135.72	100	54135.72	100	54135.72	100						

Source: Satellite imageries interpretation

During the initial study period (1984 – 2000), major changes were detected for cropland (16.17%) and grassland (-15.93%) over the other land use/land cover category. Conversely, in this period, the amount of forest and shrubland shrunk by 7.07% and 1.24%, respectively, while the bare land and settlement increased by 4.31% and 3.77%. This result indicates the expansion of cropland, settlement, bare land, and a reduction in the other plots of land or an area of non-cultivable lands, such as forests, shrubs, and grass.

In the second period (2000 – 2022), the forest, shrub, and grassland reduction were observed, respectively, by 5.7% (-3,087.5 ha), 0.54% (-294.84 ha), and 6.3% (-3,410.3 ha). The reduction in the vegetation covers (forest, shrub, and grassland) suggest the speed of deforestation, overgrazing, and land use change in the study area. It exceeds the rate of environmental management/conservation schemes like afforestation, reforestation, closure, etc. Conversely, cropland, settlement, and bare land areas increased by 5.69% (3,084.1 ha), 6.41% (3,472.4 ha), and 0.44% (236.07 ha), correspondingly.

In general, from 1984 – 2022, the cropland and settlement have increased by 21.86% and 10.18%, respectively, at the expense of the vegetation cover (forest, shrub, and grassland). The area of forest cover declined from 10,634.04 ha (19.64%) in 1984 to 3,717.54 ha (6.87%) in 2022 (Table 4.1). The proportion of shrub and grassland also showed a reduction of 1.78% (lost 964.7 ha) and 22.23% (lost 12,033 ha) between 1984 and 2022. The loss in the grass cover was related to its conversion to cropland, rural settlement, and bare land. Between 1984 and 2022, a remarkable change was observed in bare land, which showed an increment of 2,572 ha (4.75%). It grew from 2,758.41 ha (5.1%) in 1984 to 5,330.61 ha (9.85%) in 2022 (Table 4.1). This LULC type markedly increased because of continuous land cultivation without fallow periods and appropriate land management. The information obtained from Kindu et al. (2013); and Demissie et al. (2017) states that most areas were eroded and converted to bare grounds due to improper agricultural practices, termite infestation, and topographic effects.

As indicated by FGD, the incidences of the regime and major state policy changes on land use have contributed to these changes between 1984 – 2022. During these study periods, the three regimes occurred and set up different ideologies and differing land policies. The FGD discussants reflected on these regimes' contribution to LULC changes in the study area. All the FGD participants agreed that before 40 years (during Emperor Haile Selassie) – vegetation cover was broader and denser. Land use/land cover change in the area began after the fall of the imperial regime. The first was after the decree of “land to the tiller” during the Dergue regime. Every citizen got a farm and residential land and started cultivating their land. At that time, there was no clear land ownership, and everybody encroached on forest land and grazing land to expand their farmland and use wood for construction.

After 2000, the land started to shrink per family; at the same time, more and more unemployed and landless youth in rural and urban areas increased. Small rural villages become small towns by swallowing farmlands. They also began using chemical fertilizer application at farm cooperatives and introducing it to individual farmers. All environmental crises strengthened and became a big challenge for the environment and human survival. Now, vegetation cover is restricted to steep slopes, homestead areas, and church yards. The water course is reduced by size and length. Land holding is not only shrinking but also changing into settlement areas. Agrobiodiversity is totally declined into a limited number of varieties, i.e., barley and wheat.

As indicated by (Biazin & Sterk 2013; Hassen & Assen 2018), the policy and institutional changes are also other important drivers of LULC changes in Ethiopia. For instance, the 1974 government change has followed by radical land use policy reforms in Ethiopian history in which land held by the monarchic system for centuries had been handed over to peasants (‘land to tillers') through the 1975 proclamation for the first time in Ethiopia (Nega et al. 2003). This was followed by a massive settlement (villagization) program in 1979, which in turn led to extensive clearance of previously natural forest-covered areas and subsequent expansion of plantation forest and cultivated land in the country (Nega et al. 2003). The next government change in 1991 was also followed by subsequent policy changes that favored significant investment and infrastructural expansion in the country, further accelerating LULC change (Nega et al. 2003).

4.2. Accuracy assessment of the LULC classification

The overall accuracy gives the overall results of the confusion matrix. It is calculated by dividing the total number of correct pixels (diagonal values) by the total number of pixels in the confusion matrix. According to (Anderson, 1976), the minimum accuracy value for reliable land cover classification is 85%. On the other hand, the Kappa statistic had used to measure the agreement between two sets of categorizations of a dataset. It is used to estimate the accuracy of predictive models by measuring the agreement between the predictive model and a set of field-surveyed sample points (Moriasi et al., 2007).

Table 4.2 Results of Accuracy Assessment

LULC Category	**1984**		**2000**		**2022**	
	Producer accuracy (%)	User accuracy (%)	Producer accuracy (%)	User accuracy (%)	Producer accuracy (%)	User accuracy (%)
Bare land	77.67	100.00	77.27	100.00	78.00	97.50
Cropland	86.29	76.47	95.83	76.67	90.24	74.00
Forest	94.29	89.19	91.18	93.94	89.66	89.66
Grassland	93.75	93.75	100.00	86.36	80.00	80.00
Settlement	66.67	100.00	62.50	83.33	91.67	93.62
Shrub	72.73	80.00	75.00	60.00	83.33	62.50
Overall accuracy (%)	87.64		87.50		86.59	
Kappa coefficient	83.50		84.08		82.69	

Accordingly, the overall accuracy for the three study periods: 1984, 2000, and 2022 are 87.64%, 87.50%, and 86.59%, with the Kappa coefficient of 83.50%, 84.08%, and 82.69%, respectively (Table 4.2). The Kappa coefficient value greater than 80% represents a strong agreement, and a value between 60% and 80% represents a substantial agreement (Landis and

Koch, 1977). Hence, the maps met the accuracy requirements for change detection analysis (Anderson, 1976), and there is a positive correlation between the remotely sensed classified samples and the reference data.

4.3. The trends of land use/land cover change

The trends of LULC change were assessed using a LULC conversion matrix (Table 4.3). Accordingly, between 1984 and 2022, cropland gained 2.82%, 2.51%, 6.28%, 4.07%, and 0.26% from forestland, settlement, grassland, bare land, and shrub, respectively. On the other hand, 2.82%, 5.54%, 0.076%, 0.97%, and 1.65% of the forest cover was converted into cropland, settlement, grassland, bare land, and shrub, respectively. The reduction in forest cover, in turn, led to several socio-economic and environmental consequences, such as a reduction in biodiversity (such as loss of plant species), soil erosion, watersheds degradation, and a change in micro-climate.

Table 4.3 LULC Change Detection Matrix from 1984 to 2022 in percentage

		LULC Change to in % 2022						
		Forest	Cropland	Settlement	Grassland	Bareland	Shrub	Grand Total
LULC Change from in %	Forest	1.5561	2.8297	5.5464	0.0076	0.9790	1.6513	12.5702
	Cropland	2.1662	52.0658	0.2768	0.6497	7.1582	0.0185	62.3352
	Settlement	0.1285	2.5160	0.0118	0.0637	1.3350	0.0007	4.0556
	Grassland	0.4725	6.2870	0.0073	0.5067	0.3769	0.0071	7.6576
	Bareland	3.7487	4.0714	0.2575	0.1303	0.6176	0.5850	9.4107
	Shrub	1.7747	0.2622	0.7672		0.0032	1.1634	3.9707
	Grand Total	9.8468	68.0322	6.8671	1.3581	10.4699	3.4261	100.0000

Between 1984 and 2022, about 52.06% persisted as cropland, and the remaining 2.16%, 0.27%, 0.64%, 7.15%, and 0.0185% were converted into forestland, settlement, grassland, bare land, and shrub, respectively. Conversely, this LULC type gained 2.82%, 2.51%, 6.28%, 4.07%, and 0.26% from the forest, settlement, grassland, bare land, and shrub, respectively (Table 4.3). These conversions or expansions of croplands to other LULC classes are mainly due to population growth and the subsequent reduction in lands for cultivation. The highest (6.28%)

contribution to the expansion of cropland was made by grassland, followed by bare land (4.07%) and forest (2.82%).

From 1984 to 2022, settlement land was mainly converted into cropland (2.51%) and bare land (1.33%). In contrast, the settlement land gained 5.54% from forest land, 0.25% from bare land, and 0.76% from shrub land (Table 4.3). This change implied that while some settlement areas were converted into agriculture and bare ground, quite a higher percentage of settlement land was gained or changed from the forest land because of population growth and settlement demand.

The area of bare land increased from 5.12% in 1984 to 9.85% in 2022 (Table 4.1). The maximum (7.15%) contribution to the expansion of bare ground was made by cropland, followed by settlement (1.33%). Forest (0.97%) and grassland (0.37%) contributed a tiny proportion to degraded land (Table 4.3).

4.4. The drivers of land use/ land cover (LULC) changes

Land use is anthropogenic activities, and the varied uses which are carried out on land and land cover refer to natural vegetation, water bodies, soil, artificial cover, and others on land (NRSA, 1989). Land cover is the things that are natural and human-made features that cover the surface of the earth, while land use describes how the land cover is modified (Esubalew, 2014). Land use/land cover change is a dynamic process taking place on the biophysical surface that has taken place over a period, and space is of enormous importance in natural resource study. LULC change is the major challenge for ecology and sustainable development.

Land use/land cover change is caused by multiple driving forces controlling environmental, social, and economic variables. The variety of LULC changes results from different driving forces which may occur naturally or by human activities. The major land use/land cover change has been observed in our country over the last four decades. The socio-economic study data presented in Table 4.4 revealed that both proximate and underlying factors were key in triggering the LULC change in the Lude Hitosa district. The leading causes of LULC change in the Lude Hitosa district are population pressure, expansion of agricultural land, deforestation, overgrazing, demand for fuel wood and construction materials, government policy, and weak law enforcement.

The proximate LULC change understood by the respondents or farmers were the expansion of agricultural land (96.2%), deforestation (94.3%), overgrazing (81.0%), Illegal cutting of trees

(92.4%), and over-cultivation (66.7%). These immediate actions and activities directly affected the LULC of the study area. Conversely, the perceived underlying factors of LULC change that push proximate causes into immediate action (as per Geist and Lambin, 2002) were population increment (96.2%), land use change (91.4%), and Government policy (71.4%).

Table 4.4. Perceived drivers of LULC changes by local farmers in the Lude Hitosa district

Drivers of LULC dynamics	Responses		Percent of Cases
	N	Percent	
Population increase	101	16.1%	96.2%
Expansion of agricultural land	101	16.1%	96.2%
Deforestation	99	15.8%	94.3%
Government policy	75	11.9%	71.4%
Illegal_cutting_of_trees	97	15.4%	92.4%
Overgrazing	85	13.5%	81.0%
Repeated cultivation	70	11.1%	66.7%
Total	628	100.0%	598.1%

** Total number of valid cases was 105, and multiple counts were possible*

4.4.1. The proximate factors of LULC change

***Expansion of agricultural land*:** Agriculture is the deliberate effort to modify a portion of the earth's surface through the cultivation of crops and the raising of livestock for sustenance or economic gain (Rubenstein, 2003). Agriculture has contributed to the nation's economy and provides food and materials, a foundation for the livelihoods of over 85% of the rural population. However, unsustainable practices have affected nature and the surrounding land cover.

As shown in Table 4.4, 96.2% of the respondent farmers identified that the expansion of agricultural activities and accompanying problems were one of the major proximate factors or drivers of LULC changes. According to the key informant discussants, the expansion of agricultural land is mainly caused by rapid population growth, lack of job opportunities in the non-agricultural sector, lack of modern agricultural practices, problems with natural resource management, and weak agriculture extension services of the district to support farmers.

The remote sensing data analysis also revealed that 11,833 hectares (21.86%) of the land area was added to agricultural land between 1984 and 2022 at the expense of other LULC types. This outcome shows that the expansion of agricultural land forms a driver of LULC changing aspects in the study area as in the other parts of Ethiopia (Berhan and Woldeamlak, 2014). This LULC type has shown a reduction in its pace (changing aspects), losing its ground to bare land during the study period due to the prevalence of land degradation mainly observed on agricultural land. The participants of focus group discussions and key informant interviews have also confirmed agriculture's expansion towards hilly forested areas, steep slopes, river valleys, and wetlands areas.

***Overgrazing*:** Ethiopia is known for the largest livestock population in Africa, having 30.6 million Tropical Livestock Units (TLU), and also ranked the 10th largest in the world (Teketay 2001). According to the CSA report, the country is endowed with 30 million head of cattle, 22 million sheep, 17 million goats, 7 million equines, and 1 million camels. From this amount, about 70 to 80% of the livestock is hosted in highland areas of the country. The remaining livestock populations are grazing in the lowland areas of Afar, Borena, and Somali (CSA, 2015).

Attributable to the huge livestock population, there is high pressure on animal fodder in Ethiopia. Nationwide, livestock density data revealed that the current stocking rates on grazing/pasturelands are well above the optimum rates (Berry 2003). According to Sonneveld et al. (2010) grazing demand calculation, livestock needs to consume 2.5% of its body weight for sustained growth, resulting in a consumption of 6.25 kg of dry forage matter daily for each TLU. This consumption rate implies about 191.25 million kilograms of forage is needed each day nationwide, putting immense pressure on poorly managed grazing lands and other livestock fodders commonly used. Thus, livestock pressure on pasturelands and poor stock management systems are found to be the major sources of land degradation through soil erosion and deforestation. It has, therefore, been estimated that about 20% of the total soil erosion in Ethiopia is from degraded pasturelands (Yirdaw et al. 2017).

The expansion of grazing beyond the land’s carrying capacity evidently occurs at the cost of the available natural vegetation, such as forests, bushlands, and woodlands (Abdelgalil and Cohen, 2010). It is mainly because forest grazing and browsing are major feed sources for the vast livestock population. In Ethiopia, fodder derived from forested areas provides 10% and 60% of the livestock feed during the wet and dry seasons, respectively (Lemenih 2009). On the other hand, such kind of uncontrolled browsing of trees and shrubs is another aspect of overgrazing and a bald-faced cause of deforestation, leading to intensive soil erosion, flooding, and associated damages (Zegeye 2018). The scarcity of grazing lands and derived livestock feed has forced the widespread use of crop residue to feed livestock. When crop residues are removed for feed and cow dung issued for fuel, the soil will lose organic matter and nutrients (Berry 2003; Belay et al. 2015). This contravenes the natural soil nutrient cycle, seriously depletes soil quality, intensifies erosion, and eventually reduces soil productivity (Tesfa and Mekuriaw 2014).

Although livestock density was not a problem in the study area, the abandoned farm plots had been exposed to free grazing due to the prevailing land degradation, which facilitates soil erosion and bare land expansion. Overgrazing as a driving force of LULC dynamics was also reported by 81.0% of the sample respondents.

Many of the interviewed farmer households and focus group discussants acknowledged that they partially abandoned their original farmland and migrated seasonally into marginal areas by withdrawing conservation practices from the degraded plots. In general, the FGD discussants emphasized that the overgrazing or expansion of grazing land as one of the main factors next to cultivation land, deforestation, and settlement has caused the alteration to the LULC and degradation of the natural environment.

Deforestation and illegal cutting of trees**:** Forests are one of the vegetation biomes dominantly covered by trees of different species that support several biotic lives (Mekonnen et al. 2018). Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10% can be called a forest (FAO 2010). In the Ethiopian context, as Mekonnen et al. (2018) stated, *"forest is an area with natural mosaics, dense agroforestry, acacia woodlands, and shrub lands, state, and private plantations of about a timad or more (timad is a local land area measurement = 0.25 ha)".* Hence, forest resources may be those which exist naturally or made by man through plantation (Danano et al. 2018).

The term 'deforestation or forest degradation' refers to a reduction in the capacity of a forest to provide expected goods and services (FAO 2011). Deforestation or forest degradation in Ethiopia takes the lead among the major problems that forest resources encounter. Forest degradations are accelerated mainly by fuelwood extraction and agricultural expansion (Kassa et al. 2016; Alemu 2017). The rate of deforestation has been increasing year after year, with an estimated average of 160,000–200,000 ha/year, and fertile topsoil is lost at an estimated rate of one billion cubic meters per year (FAO 1981; UNEP 1983; Yirdaw 1996). This, in turn, results in massive environmental degradation and constitutes a serious threat to the sustainability of agriculture and forestry (Bishaw 2009).

According to Reusing (1998), a 1% deforestation rate yearly was estimated from 1986 to 1990 all over Ethiopia (163,600 woody plants/ha/year). FAO (2005) also indicated a deforestation rate of 0.93–1.04% per year between the years 1990 to 2005 in Ethiopia. WBISPP (2004) again analyzed deforestation rates in areas with high natural forests and reported a loss of 1.33 million hectares between 1990 and 2020. This loss was equivalent to over 1% annual forest resource decline in the country and contributed to socio-environmental problems.

About 94.3% of study respondents have confirmed the highest rate of deforestation within the study periods, which caused the current LULC changes in the district. Furthermore, the remote sensing data analysis confirms that the district forest coverage has declined from 19.64% to a minimum of 6.87% between 1984 and 2022. This shows that the study area has lost 6917 hectares (12.77%) of its woody biomass through deforestation. These land cover changes or reductions of forest biomass were reflected in the bare land, cultivation land, and settlement lands.

Conversely, fuel wood is a source of energy for cooking and lighting and serves as a source of income for people in the country. With the need for construction materials, people in rural and urban areas exploit natural forests and plantation trees (FAO, 2012). About 92.4% of the study respondents confirmed that the main energy source in the district is fuel wood, firewood, and charcoal, which is the leading cause of deforestation next to agricultural expansion in the district. As the FGD discussants have alluded, the number of people has been increasing from time to time, contributing to the need for shelter and construction materials, resulting in deforestation in the study area.

Repeated cultivation**:** About 66.7% of the sampled households responded that due to the population increment, land scarcity, and agricultural intensification initiatives promoted by the government in the country have contributed to the over-cultivation of lands and caused land degradation and loss of forest resources. This has contributed to the LULC change in the study areas. The Arsi zone is well known for its wheat and barley production. The study district, which is in the same zone, produces those crops. The expansion of the beer factories and the agricultural intensification with high external inputs and cluster farming have contributed the lion's share to the LULC changes in the study area, according to the FGD discussants. Furthermore, it was observed that crop production is expanding and intensifying mainly at the expense of forest and shrubland.

4.4.2. Underlying drivers of LULC change

Population growth: Population growth and pressure disturb the traditional systems of land use in each area, negatively affecting the local population's livelihoods and environment. As indicated by Agidew and Singh (2017), induced population pressure tended to alter the existing local land use patterns. About 96.2% of the surveyed farm respondents confirmed that the population increment has contributed to the LULC dynamics in the study area. The population data for the district for the base year 1984 is unavailable in CSA and the district data sources. The 1994 data has only been found for the Hitosa district, which used to be the big district that included Lude Hitosa until their separation in 1995 E.C or 2002 G.C. The earliest available data for the Lude Hitosa district is the 2007 national census report. It shows that the total population for the district is 107,133 people, i.e., 53,522 were men and 53,611 were women. However, as per the CSA prediction, the district's total population has shown a tremendous increment in 2022 to 160,132 people, of which 79,432 are male, and 80,700 are females. Population growth increases the demand for land and contributes to farming on marginal lands (steep lands, fragile soils), leading to soil erosion. It also increases the demand for biomass as a fuel source, leading to deforestation and the burning of dung and crop residues, thus increasing the problems of erosion and nutrient depletion.

According to the focus group discussions and key informants, population increment over time puts tremendous pressure on fragile and degraded resources. The increase in human and animal population numbers has led to a demand for more food crops, timber, settlement land, and feed resources. For this reason, as discussed above, forest, shrub, steep slopes, and other marginal lands were turned into cultivation, settlement, and grazing lands. Despite these, rapid population growth is the main driving force of LULC change in the study area.

Government policy and weak law enforcement: As confirmed by the focus group discussants and key informants, the farm households have been using land in an uncontrolled and unplanned manner without identifying the best potential use and without safeguarding the natural environment. Except in urban areas having master plans, no land use plan was incorporated in the rural areas. The lack of awareness and weak law enforcement on forest resources, the complicated certifying of farmers on the land ownership, inadequate supervision of forest resource use, and lack of demarcation of forest land has facilitated deforestation in addition to population density.

Furthermore, 71.4% of the surveyed farm households in the sampled kebeles responded that the absence of land use policy in Ethiopia had contributed to the LULC dynamics, particularly to the expansion of degraded areas. The country could not prepare an integrated land use plan, which helps to identify and allocate land for different purposes based on suitability, productivity, and sustainability.

4.5. Impacts of the Land Use/ Land Cover Change

Land use/land cover changes have a wide range of effects at all spatial and temporal scales. Because of these effects, LULC change has become one of the major problems for environmental change as well as natural resource management. The conversion of forest cover into crop/agricultural land in the study area has significant ecological consequences. Respondents have mentioned soil erosion and fertility decline, loss of biodiversity, change in the local climate, scarcity of grazing land, the decline in quality and availability of water, and food shortage to be the major consequences of land use/land cover change in the study area.

Table 4.5. Perceived impacts of LULC changes in the Lude Hitosa District

Implications of LULC dynamics	Responses		Percent of Cases
	N	Percent	
Soil erosion/infertility	98	17.6%	93.3%
Lack of local tree and animal species	95	17.1%	90.5%
Lack of enough grazing land	96	17.2%	91.4%
Change in the local climate	97	17.4%	92.4%
Degradation of watersheds	80	14.4%	76.2%
Food shortage	91	16.3%	86.7%
Total	557	100.0%	530.5%

** Total number of valid cases was 105, and multiple counts were possible*

4.5.1. The environmental implications of LULC change

***Soil erosion/infertility*:** Land degradation refers to soil degradation through water erosion and loss of vegetation cover, leading to reduced land productivity in densely settled or exploitatively used regions (Nyssen et al. 2004). Land degradation occurs in all kinds of landscapes over the world. It is one of the serious global environmental issues increasing in severity and extent in different areas of the world (Jamal et al. 2016). Latin America, Asia, and Africa are said to be the world's major soil degradation hotspots (Gessesse et al., 2015). In terms of land use types, over 20% of all cultivated areas, 30% of forests, and 10% of grasslands are undergoing degradation. Land degradation is also a widespread problem in Ethiopia, with over 85% of the land moderately to very severely degraded (Gashu and Muchie 2018) and about 75% affected by desertification (Gebreselassie et al. 2016).

Soil erosion is the degradation of land that could occur through water and wind erosion (Seifu and Elias 2018). Land degradation attributable to soil erosion by running water is the most intimidating environmental problem in Ethiopia (Desta et al. 2000; Amare and Belay 2015). The major components of climate that affect soil erosion are rainfall and wind. Therefore, it is not surprising to hear areas in various parts of the northwestern, central, and southeastern highlands of Ethiopia suffer from the highest erosion rates every year (Hurni et al., 2016; Asfaw and Neka, 2017).

One of the adverse effects of land use/land cover change in the study area was soil erosion/degradation. About 93.3% of the respondents indicated that soil erosions/infertility as the environmental impacts of the LULC changes. Some observed visual indicators of soil degradation (loss) in the study area were intensive erosion and infertility. The participants of the key informant interview and focus group discussion indicated that soil erosion by water is becoming a major threat in the study area. The problem is worsening due to the loss of vegetation cover and the expansion of agricultural fields into steep slopes and mountainous areas. The change in land use/land cover, particularly from natural vegetation to agricultural land, caused severe soil erosion and loss of topsoil. The LULC change analysis revealed that forest cover and grassland showed a declining trend from 1984 to 2022. During the field observation, the researcher observed low vegetation cover and gully erosion in steep slope areas.

Conversely, land use changes, especially cultivation in deforested and unsuitable lands, may rapidly diminish the soil quality. The FGD participants indicated that when the symptoms of land degradation and crop failure occur, the local farmers attempt to increase productivity by utilizing chemical fertilizers. As understood by the focus group discussants, the major reasons for soil infertility were over-cultivation, which was associated with the shortening of the fallow period and the cultivation of steeper slopes. Continuous cultivation in the absence of soil fertility management has led to soil degradation that forced farmers to abandon their exhausted fields.

***Loss of biodiversity*:** Another consequence of the LULC change was the loss of biodiversity. Changes in environmental conditions and the natural setting of the land and its cover significantly affect the life cycle and the survival of various plants and animals. About 90.5% of the respondents said that some species of plants and animals previously found in the study area disappeared mainly because of unregulated deforestation and agricultural expansion (Table 4.5). The respondents believed that the diversity of both plants and animals disappeared or declined in the study area.

According to the focus group and key informant interview participants, the majority of indigenous tree species and animals disappeared, and the remaining few plants and animals are in danger. They explain that deforestation is the main cause of the loss of plants and animal species in the study area. As a result of deforestation, many wild animals, such are lions, leopards, foxes, hyenas, etc., disappeared and fled the area due to shortages or lack of food and water. As forests and their area serve as a home for wild animals, cutting trees for different purposes makes life difficult for wild animals, and they remain homeless.

***Change in the local climate*:** Many of the respondents (92.4%) mentioned that the local climate change (erratic rain and drought) is caused by the ongoing land use/land cover change (Table 4.5). Moreover, the interviewees indicated that LULC change and associated climate change over time directly affect the livelihood of the subsistent farmers by affecting crop production since most of them are completely dependent on rain-fed agriculture.

As the FGD participants have also alluded to, the local temperature has increased in their localities. The destruction of the forest and grasslands has contributed to the desertification of the areas with bare ground. This destruction has contributed to the reduction in the rainfall amount, pattern, and temperature increment.

Degradation of watersheds (impact on water resources)**:** The decline in water quality and availability was also mentioned as the implication of LULC change in the study area. Most farm respondents indicated that LULC changes from forest to intensively cultivated land increased the overall immediate surface runoff and sediment concentration in rivers. About 76.2% of the interviewed farmers indicated that the drying up of springs and declining river water quality and quantity are major problems caused by land use change (unsustainable land management practices) (Table 4.5). Besides, the FGD and key informant interview participants confirmed that the amount of water in the rivers, seasonality of the springs, changes in rainfall patterns, distance to water collection points, and depth of water wells as indicators of changes in water quantity.

4.5.2. The socio-economic implications of the LULC change

Food shortage or insecurity**:** About 86.7% of the surveyed respondents reported that food shortage/insecurity was the main socio-economic implication of the LULC change in the study areas. The expansion of degraded land will have direct and indirect effects on rural livelihoods by causing an increased risk of crop losses and food insecurity (UNCCD, 2017). Even though the study area and Arsi zone have massive potential as one area having relatively better agricultural lands in the region, the information obtained from the Lude Hitosa district agricultural office revealed that the severity of soil erosion increased in the last 20 years. It was suffering from loss of topsoil and extensive gullies. A complete decline in agricultural productivity was observed during the early 2000s. In response to the prevailing food insecurity and unbalanced population growth, the government has been forcing the use of chemical fertilizers and intensification of the farmlands.

Lack of enough grazing land/animal feed**:** The livelihoods of the economically active people in the Lude Hitosa district are dependent on farming and livestock rearing. However, about 91.4% of local respondents confirmed a lack of enough grazing land for livestock in the study area. This has occurred due to anthropogenic activities like agricultural land expansion, settlement, and deforestation due to rapid population growth in the district. The focus group discussants from the three sample kebeles revealed that 40 years ago, on average, one household owned more than 20 livestock. However, currently, the average number of livestock one household owns is 1 to 4 on average. This has resulted from the shortage of grazing land, decrease in the volume of water, and clearance of big trees, which were used as a shadow for livestock.

Consequently, different socio-economic problems, such as a decrease in quantity and quality of livestock, including a decline in milk and milk products, meat, hide, and skin, a lack of animal manure to increase soil fertility, and a reduction of household income from the sale of live animals. In general, a shortage of animal feed is one of the main challenges for local people in the study area. Hence, ensuring food security, livelihood improvement, and improving the natural resource bases of the rural community in the district require special consideration.

4.6. Measures to minimize the adverse impacts of LULC dynamics

The LULC dynamics had various social and environmental implications in the study area. Increased soil erosion, soil fertility decline, bare/degraded land expansion, shortage of grazing land, deforestation, and food insecurity were the major socio-environmental impacts of LULC dynamics. If these problems persist, the sustainability of natural resources could be at risk and can seriously affect agricultural production and the livelihoods of the people.

Therefore, as part of the measures, the government, NGOs, and other concerned bodies should introduce off-farm income-generating activities to release the high pressure on the available land resource. The LULC policy must be devised to prevent further degradation and save the fragile marginal ecosystem; participatory watershed management programs to rehabilitate the degraded areas. Further, intensive deforestation, agricultural land expansions, and lack of inappropriate land management practices have negative environmental implications. Without effective land use plans and improved land management practices, it degrades the newly acquired land resources and affects the surrounding ecosystem. Hence, a land use plan should be prepared to protect such marginal areas from further degradation.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

It is essential to understand the process of land use/ land cover change and its implications on the environment and socio-economy of the people to identify and sustainably utilize the ecosystem services. Thus, this study assessed the pattern of LULC dynamics and its impact on land, forest, and water resources in the Lude Hitosa district, the central-eastern part of Ethiopia.

The study employed a mixed method and thus collected both qualitative and quantitative data from primary and secondary sources to achieve the intended objective. To assess the long-term LULC change (1984 – 2022), satellite imageries, google earth, and high-resolution spot images were obtained from the Ethiopian Space Science and Geospatial Institute (ESSGI) and the online archives of USGS. Ground truth data collected using a hand-held GPS receiver was also used to assist the LULC classification. Conversely, socio-economic surveys were conducted through questionnaires, Focus Group Discussions (FGDs), Key informant Interviews (KIIs), and field observation. In the study, the socio-economic surveys were the main data source, while the remote sensing data (Landsat imageries) served as the supplementary data sources.

The result of the LULC change analysis revealed that there had been remarkable changes in the LULC between 1984 and 2022. Forest cover, grassland, and shrub decreased by 12.77%, 22.23%, and 1.78%, respectively. Crop/agricultural land, settlement, and bare/degraded land had increased by 21.86%, 10.18%, and 4.75%, respectively. In general, the LULC dynamics observed in the area remarkably aggravated soil erosion, loss of biodiversity, overgrazing, and food insecurity.

The LULC pattern of change observed in the six classes of land use/ land cover has shown different trends and magnitudes in three different periods (1984, 2000, and 2022). From 1984 to 2000, 2000 to 2022, and from 1984 to 2022, a comparison was made to understand the land use/land cover change. Accordingly, cropland, settlement, and bare land are expanded throughout the three periods with different patterns, trends, and magnitude. Forest cover, grassland, and shrub were alarmingly decreased throughout the three consecutive periods.

This result shows that forest, grassland, and shrub reduced while the remaining three LULC types (cropland, bare land, and settlement) increased at the expense of other LULC classes. As displayed by the LULC change trend analysis table, bare land gained more land during the study period. This remarkable increase in bare land was at the expense of agricultural, grassland, shrub, and forest cover. However, the significant contribution to bare land was from cropland, settlement, and forest.

The direction of LULC changes perceived by the respondents was consistent with the result obtained from remote sensing image interpretation. The perceived drivers and impacts of the LULC dynamics were discussed based on the findings from the surveyed respondents, FGD, and key informant interview participants. Expansion of agricultural land, deforestation, illegal cutting of trees, overgrazing, and over-cultivation were proximate/direct drivers of LULC change. In contrast, population growth, lack of effective land use policy, and weak law enforcement were the major underlying/root driving factors identified in the Lude Hitosa district.

Conversely, the study further revealed that the LULC change had various social and environmental implications. Environmental implications are soil erosion, loss of biodiversity, change in local climate, and degradation of watersheds. Whereas the socio-economic impacts of the LULC change are food shortage or insecurity and lack of enough grazing land/animal feed in the study area. If this tendency of LULC change continues, it will have serious environmental and economic consequences with a severe impact on the people's livelihood.

5.2. Recommendations

Based on the study's findings, the following recommendations are forwarded to enhance sustainable management and solutions for land use/ land cover change in the district.

1. Land use/land cover dynamics in the study area results from smallholder farmers' struggle to sustain themselves. The livelihood of the people of the district is dependent on natural resources. On the other hand, the number of populations is growing alarmingly, and the shortage of farming land has become prevalent. Hence, to balance the gap between population growth and land use, the district should devise alternative options by introducing appropriate environmentally friendly farming practices (e.g., mixed farming/crop diversifications, crop rotations, adopting agroforestry practices, integrating livestock and crops, practicing organic farming, applying integrated pest management (IPM) techniques, etc.) and providing necessary extension services for farmers to get large productivity from

a small plot of land. Moreover, a joint measure (s) needs to be taken to reduce existing and future natural resources-related degradation. Thus, as part of the solution, the government, NGOs, and other concerned bodies should introduce alternative sources of livelihood (e.g., beekeeping, horticulture production, poultry production, fattening, dairy farm productions with forage productions, etc.) to ease the high-pressure on the available land resource.

2. As confirmed by the remote sensing data and socio-economic survey, the district's settlement rate and population growth have the lion's share in land use/ land cover change. Population growth has happened because of uncontrolled birth and an increment of immigrants from time to time. Therefore, the concerned government sector must educate the people about family planning and set a controlling mechanism for illegal movements.
3. The current situation regarding natural resource management and use is fragile. For instance, deforestation, overgrazing, and land degradation were and are very intense in the area. To avoid its impact, which has the highest potential to affect the district's and the country's socio-economic profile, concerned stakeholders (the government, NGOs, community structures, and the community themselves) should take the initiative to protect (area closures, abandoning, fencing, etc.) and enhance the resource base through physical and biological measures. Resources management inherently demands the involvement and genuine commitment of all actors. This, in turn, requires awareness creation, education, and collaboration among the community and different government and non-governmental institutions working around natural resource management.
4. Given the severity and magnitude of the problem following LULC dynamics, the study recommends a design of proper land use policy and sustainable management of land resources to reverse the prevailing land degradation in the study area. Oromia Regional State, Arsi zone, and Lude Hitosa district administrations should take the responsibility to implement land and natural resources conservation tenure policy and demarcate unprotected forest lands. The designed land management options need to consider the socio-demographic, biophysical, and institutional factors in the study area.

   As a final point, the result of this study should be taken as indicative rather than conclusive. Thus, appropriate measures that ensure the wise use of natural resources and efficient land utilization are critical.

CHAPTER SIX: REFERENCES

Abdelgalil EA, Cohen SI (2010) Modelling livestock activities and environmental sustainability: the African case. J Environ Prot (Irvine, Calif) 1:1–9. https://doi.org/10.4236/jep.2010.11001

Adgo E, Teshome A, Mati B (2013) Impacts of long-term soil and water conservation on agricultural productivity: the case of Anjenie watershed, Ethiopia. Agr Water Manag 117:55–61

Aduah, M. S., & Baffoe, P. E. (2013). Remote sensing for mapping land-use/cover changes and urban sprawl in Sekondi-Takoradi, Western Region of Ghana. The International Journal of Engineering and Science (IJES), 2(10), 66-72.

Agidew, A. M. A., & Singh, K. N. (2017). The implications of land use and land cover change for rural household food insecurity in the Northeastern highlands of Ethiopia: the case of the Teleyayen sub-watershed. Agriculture & Food Security, 6(1), 1-14.

AgriHunt. (2016). How to harvest index relates to crop yield.

Ahmad, A., & Quegan, S. (2013). Comparative analysis of supervised and unsupervised classification on multispectral data. Applied Mathematical Sciences, 7(74), 3681-3694.

Aklilu Amsalu, Stroosnijder, L., and De Graaff, J., 2007. "Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highland Ethiopia." Journal of Environmental Management, 83: 448-459.

Alemu, B., Garedew, E., Eshetu, Z., and Kassa, H. (2015). LULC and land cover changes and associated driving forces in the North-western Lowlands of Ethiopia. International Research Journal of Agricultural Science and Soil Science, 5(1):28–44.

Alemu MM (2017) Current trends of investment effect on land-use practices of Ethiopia. Open Access Libr J. https://doi.org/10.4236/oalib.110332

Amare A (2015) Wildlife resources of Ethiopia: opportunities, challenges, and future directions: from ecotourism perspective: a review paper. Nat Resour 6:405–422

Amare A, Belay S (2015) The environmental implication of population dynamics in Ethiopia: review. Int J Res Agric Sci 2:2348–3997

Amsalu, Aklilu. 2006. Caring for the land: Best practices in soil and water conservation in Beressa watershed, Highlands of Ethiopia. Tropical Resource Management Papers 76, Wageningen University. pp 85.

Anderson, J.R. (1976). Aland use and land cover classification system for use with remote sensor data (vol.964). US Government printing office.

Angelica.W. and S. Richter. (2008). Rural 21; the international Journal for Rural Development DCG verlage. GMBH. Frankfurt, Germany.

Arild Angelsen, David Kaimowitz, (1999). "Rethinking the causes of deforestation: Lessons from economic models". The World Bank Research Observer, 14:1. Oxford University Press, pp. 73-98.

Asfaw A, and Demissie Y (2012) Sustainable household energy for Addis Ababa, Ethiopia. J Sustain Dev 8:1–11

Asfaw D, Neka M (2017) Factors affecting adoption of soil and water conservation practices: the case of Wereillu District (District), South Wollo Zone, Amhara Region, Ethiopia. Int Soil Water Conserv Res 5:273–279. https://doi.org/10.1016/j.iswcr.2017.10.002

Assefa, E., and Bork, H. R. (2014). Deforestation and forest management in Southern Ethiopia: Investigations in the Chencha and Arbaminch areas. Environmental Management, 53, 284–299.

Ariti, A.T., van Vliet, J., Verburg, P.H. (2015). Land-use and land-cover changes in the Central Rift Valley of Ethiopia: Assessment of perception and adaptation of stakeholders. Appl. Geogr. 2015, 65, 28–37.

Batra R C, Porfiri M and Spinello D 2007 Vibrations of narrow microbeams predeformed by an electric field J. Sound Vib. available online (doi:10.1016/j.jsv.2007.07.030)

Belay K, Van RA, Poesen J, Van BS, Deckers J, Amare K (2015) Spatial analysis of land cover changes in Eastern Tigray (Ethiopia) from 1965 To 2007: are there signs of a forest transition? L Degrad Dev 26:680–689

Belay, T. (2002) Land-Cover/Land-Use Changes in the Derekolli Catchment of the South Welo Zone of Amhara Region, Ethiopia. Journal of Eastern Africa Social Science Research, 18, 143-157.

Berg, Bruce, L.(2001). Qualitative Research Methods for the Social Sciences. California State University, Long Beach: USA.

Belgiu, M., & Drăguţ, L. (2016). Random forest in remote sensing: A review of applications and future directions. *ISPRS journal of photogrammetry and remote sensing*, *114*, 24-31.

Berhan G (2010). The role of Geo-information technology for predicting and mapping of forest cover spatio-temporal variability: Dendi District case study, Ethiopia. Journal of Sustainable Development in Africa, 12(6): 9-33.

Berhan G and Woldeamlak B (2014). Drivers and implications of land use and land cover change in the central highlands of Ethiopia: Evidence from remote sensing and socio-demographic data integration. Ethiopian Journal of the Social Sciences and Humanities, 10 (2), pp.1-23.

Berihun, M. L., Tsunekawa, A., Haregeweyn, N., Meshesha, D. T., Adgo, E., Tsubo, M., ... & Yibeltal, M. (2019). Exploring land use/land cover changes, drivers, and their implications in contrasting agro-ecological environments of Ethiopia. *Land Use Policy*, *87*, 104052.

Berry L (2003) Land degradation in Ethiopia: its extent and impact

Bezuayehu Tefera and Sterk, G., 2008. "Hydropower-induced land use change in Fincha' watershed, western Ethiopia: analysis and impacts." Mountain Research and Development, l28: 72-80.Bewket, W., Abebe, S. (2013). Land-use and land-cover change and its environmental implications in a tropical highland watershed, Ethiopia. Int. J. Environ. Stud. 2013, 70, 126–139.

Biazin, B. & Sterk, G. 2013. Drought vulnerability drives land-use and land cover changes in the Rift Valley dry lands of Ethiopia. Agr. Ecosyst. Environ. 164: 100-113.

Bimal Kanti, P., & Harun, R. (2017). Land Use Change and Coastal Management in Climatic Hazards in Coastal Bangladesh.

Birhan M, Gebreyes G (2015) Review on problems, prospects and economic contribution of wildlife management and ecotourism in Ethiopia. J Vet Sci Technol. https://doi.org/10.4172/2157-7579.1000257

Bishaw B (2009) Deforestation and land degradation in the Ethiopian highlands: a strategy for physical recovery. Ethiop Res Innov Foresight 1:5–18

Bockstael, N. E., & Irwin, E. G. (1999). *Economics and the land use-environment link* (No. 1667-2016-136205).

Boori, M. S., & Vozenilek, V. (2014). Remote sensing and land use/land cover trajectories. J. Geophys. Remote Sens, 3(3).

Briassoulis, H. (2000) Environmental Impacts of Tourism: A Framework for Analysis and Evaluation. In Tourism and the Environment: Regional, Economic, Cultural and Policy Issues, H. Briassoulis and J. van der Straaten, eds., pp. 21–37. Dordrecht: Kluwer Academic Publishers

Briassoulis, H. (2008). Land-use policy and planning, theorizing, and modelling: lost in translation, found in complexity. Environment and Planning B: Planning and Design, 35(1), 16-33.

Bryman, A., 2004. Social Research Methods, 2nd ed. Oxford University Press.

Bürgi, M., Hersperger, A., Schneeberger, N. (2004). Driving forces of landscape change—current and new directions. Landscape Ecology 8, 857–868.

Bürgi, M., Bieling, C., von Hackwitz, K., Kizos, T., Lieskovský, J., Martín, M. G., ... & Printsmann, A. (2017). Processes and driving forces in changing cultural landscapes across Europe. Landscape Ecology, 32(11), 2097-2112.

Butchart, S. H., Walpole, M., Collen, B., Van Strien, A., Scharlemann, J. P., Almond, R. E., et al. (2010). Global biodiversity: Indicators of recent declines. Science,328(5982), 1164–1168. https://doi.org/10.1126/science.1187512.

Canute Hyandye, Christina Geoffrey Mandara, John Safari. (2015). GIS and Logit Regression Model Applications in Land Use/Land Cover Change and Distribution in Usangu Catchment. American Journal of Remote Sensing.Vol. 3, No. 1, pp. 6-16. doi: 10.11648/j.ajrs.20150301.12.

Commission of the European Communities, Organisation for Economic Co-operation and Development, Statistical Office of the European Communities, United Nations. Statistical Division, & World Tourism Organization. (2001). *Tourism Satellite Account: Recommended Methodological Framework*. Commission of the European Communities, Eurostat.

Cook, C.W., and P.L. Sims. 1975. Drought and its relationship to dynamics of primary productivity and production of grazing animals. p. 163- 168. In: Proceedings, Evaluation and Mapping of Tropical African Rangelands. Addis Ababa, Ethiopia.

Crestwell, J. W. (2009). Research design: Qualitative, quantitative, and mixed methods approaches.

Crummey, D. 1998. Deforestation in Wällo: Process or Illusion? Journal of Ethiopian Studies, XXXI, (1):1-41.

CSA (2015) Key findings of the 2014/2015 agricultural sample surveys. Addis Ababa, Ethiopia

CSA (2015). Statistical Abstract of Ethiopia. Addis Ababa. Central Statistical Agency. Danano KA, Legesse A, Likisa D (2018) Monitoring deforestation in South Western Ethiopia using geospatial technologies. J Remote Sens GIS 7:1–5. https://doi.org/10.4172/2469-4134.1000229

Dash, P. (2005). Land Surface Temperature and Emissivity Retrieval from Satellite Measurements, Institut fur Meteorologie und Klimaforshung.

Degife, A., Worku, H., Gizaw, S., & Legesse, A. (2019). Land use land cover dynamics, its drivers, and environmental implications in Lake Hawassa Watershed of Ethiopia. *Remote sensing applications: society and environment*, *14*, 178-190.

Demissie, F., Yeshitila, K., Kindu, M., and Schneider, T. (2017). Land use/Land cover changes and their causes in Libokemkem Districtof South Gonder, Ethiopia. Remote Sensing Applications: Society and Environment, 8(April), 224–230. https://doi.org/10.1016/j.rsase.2017.10.001

Denboba, M. A. (2005). *Forest conversion-soil degradation-farmers perception nexus: implications for sustainable land use in the southwest of Ethiopia* (Vol. 26). Cuvillier Verlag.

Dereje, H. (2018). Agriculture and Environment in the Angar-Dhidhessa Valley, Western Ethiopia (c.1840-2010). Addis Ababa University.

Desalegn, R. (2011). Land to investors: Large-Scale Land Transfers in Ethiopia. Land Governance for Equitable and Sustainable Development, 0–36. Addis Ababa: Forum for Social Sciences.

Desta L, Kassie M, Benin S, Pender J (2000) Land degradation and strategies for sustainable development in the Ethiopian highlands: Amhara Region. (International Livestock Research Institute), Nairobi, Kenya

Dwarakish, G.S., Ganasri, B.P., 2015. Impact of land use change onhydrological systems: A review of current modeling approaches, Cogent Geoscience, 1:1, 1115691. doi: 10.1080/23312041.2015.1115691.]

Ebabu, K., Tsunekawa, A., Haregeweyn, N., Adgo, E., and Tsegaye, D. (2018). Effects of land use and sustainable land management practices on runoff and soil loss in the Upper Blue Nile basin, Ethiopia Science of the Total Environment Effects of land use and sustainable land management practices on runoff and soil loss in the Upp. *Science of the Total Environment*, *648*(August), 1462– 1475. https://doi.org/10.1016/j.scitotenv.2018.08.273

EBI (2014) Government of the Federal Democratic Republic of Ethiopia Ethiopia's Fifth National Report to the Convention on Biological Diversity. Addis Ababa, Ethiopia

Emiru, T. S. (2014). Population Dynamics and Its Impact on Land Use: The Case of Mandura District of Metekel Zone, Benshangul-Gumuz Regional (Doctoral dissertation, University of South Africa).

Engida, T. G., & Teshoma, A. J. (2012). The socio-economic effects of community forest management: evidence from Dendi District, Ethiopia. *Int. Aff. Glob. Strategy*, *4*, 15-22.

Esa, E., Assen, M., & Legass, A. (2018). Implications of land use/cover dynamics on soil erosion potential of agricultural watershed, northwestern highlands of Ethiopia. Environmental Systems Research, 7(1), 1-14.

Eshetu AA (2014) Ecotourism as a viable strategy for livelihood diversification and sustainable natural resource management in Ethiopia (from eco-development paradigm point of view). J Environ Sci Water Resour 3:40–52

Esubalew Nebebe Mekonnen (2014). GIS and Remote sensing techniques application to the spatio-temporal climate variability analysis the case of Ziway Dugda and Dodota District, Arsi Zone, Oromia region, Ethiopia. A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in partial fulfilment of the requirement for the Degree of Master of Arts in Geography and Environmental Studies Specialization in Geographic Information System (GIS), Remote Sensing (RS), and Digital Cartography.

Fakeye, A. M., Aitsebaomo, F. O., Osadebe, C. C., Lamidi, R. B., & Okonufua, E. O. (2015). Digital Modeling of Land Use Changes in Some Parts of Eastern Nigeria. American Journal of Remote Sensing, 3(3), 37-42.

FAO Forestry Paper 7. Rome: FAO.--. 1981. Forest Resources of Tropical Africa, Part 2, Country Briefs.

FAO (2005) State of the World's forests, deforestation rate in Ethiopia. Rome

FAO (2010) Global Forest Resources Assessment 2010: Country Report, Ethiopia. FRA2010/065 Rome, 2010

FAO (2011). The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome, and Earthscan, London.

FAO. (2015). *Global Forest Resources Assessments*; Food and Agriculture Organization of the United Nations: Rome, Italy.

FAO. (2016). *State of the World's Forests 2016. Forests and agriculture: land-use challenges and opportunities*. Rome, Italy.

Feng, X., Tustison, N., Meyer, C. (2018): Brain tumor segmentation using an ensemble of 3d u-nets and overall survival prediction using radiomic features. BrainLes 2018, Springer LNCS 11384 (2019) 279–288

Fleiss, J. L., Levin, B., & Paik, M. C. (2003). Statistical methods for rates and proportions (3rd ed.). Hoboken, NJ: Wiley.

Food and Agriculture Organization of the United Nations (2012). State of the World's Forests: Rome, Italy

Foody, G. M. (2002). Status of land cover classification accuracy assessment. Remote sensing of environment, 80(1), 185-201.

Garedew, Efrem., Sandewall, M., Söderberg, U. and Campbell, B. M. 2009. Land-Use and Land- Cover Dynamics in the Central Rift Valley of Ethiopia. Environmental Management, 44: 683-694.

Gashaw, T., Tulu, T., Argaw, M., & Worqlul, A. W. (2017). Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Environmental Systems Research*, *6*(1), 1-15.

Gashu K, Muchie Y (2018) Rethink the interlink between land degradation and livelihood of rural communities in Chilga district, Northwest Ethiopia. J Ecol Environ 42:1–11. https://doi.org/10.1186/s41610-018-0077-0

Gay, L. R., Mills, G. E., and Airasian, P. W. (2009). Educational research: Competencies for analysis and applications. Merrill/Pearson.

Gebrehiwot, S. G., Bewket, W., Gärdenäs, A. I., & Bishop, K. (2014). Forest cover change over four decades in the Blue Nile Basin, Ethiopia: comparison of three watersheds. *Regional Environmental Change*, *14*(1), 253-266.

Gebremicael, T. G., Mohamed, Y. A., van Der Zaag, P., & Hagos, E. Y. (2018). Quantifying longitudinal land use change from land degradation to rehabilitation in the headwaters of Tekeze-Atbara Basin, Ethiopia. *Science of the Total Environment*, *622*, 1581-1589.

Gebreslassie, H. (2014). Land Use-Land Cover dynamics of Huluka watershed, Central Rift Valley, Ethiopia. International Soil and Water Conservation Research, 2(4), 25 33. doi:10.1016/s2095- 6339(15)30055-1

Gebreselassie S, Kirui O, Mirzabaev A (2016) Economics of land degradation and improvement in Ethiopia. In: Nkonya Ephraim, Mirzabaev Alisher, Braun Joachim von (ed) Economics of land degradation and improvement—a global assessment for sustainable development. Springer, New York Dordrecht London, pp 401–439

Geiß, C., Leichtle, T., Wurm, M., Lakes, T., & Taubenböck, H. (2017). Unsupervised change detection in VHR remote sensing imagery–an object-based clustering approach in a dynamic urban environment. International Journal of Applied Earth Observation and Geoinformation, 54, 15-27.

Geist, H. J., & Lambin, E. F. (2002). Proximate Causes and Underlying Driving Forces of Tropical DeforestationTropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. BioScience, 52(2), 143-150.

Geist H, Lambin E, Palm C, Tomich T (2006). Agricultural transitions at dryland and tropical forest margins: Actors, scales, and trade-offs. In: Brouwer F, McCarl BA (eds) Agriculture and climate beyond 2015: A new perspective on future land use patterns (Environment & Policy Vol. 46). Springer, Dortrecht, pp 53–73

Gete Zeleke and Hurni, H., 2001. "Implications of land use and land cover dynamics for mountain resource degradation in the Northwestern Ethiopian Highlands." Mountain Research and Development, 21:184–191.

Gessesse B, Bewket W, Bräuning A (2015) Model-based characterization and monitoring of runoff and soil erosion in response to land use/land cover changes in the Modjo Watershed, Ethiopia. L Degrad Dev 26:711–724. https://doi.org/10.1002/ldr.2276

Guteta, D., and Abegaz, A. (2017). Dynamics of selected soil properties under four land uses in Arsamma watershed, Southwestern Ethiopian Highlands. Physical Geography, 38(1), 83–102. https://doi.org/10.1080/02723646.2016.1251734

Hailemariam, S.N., Soromessa, T., Teketay, D. (2016). Land Use and Land Cover Change in the Bale Mountain Eco-Region of Ethiopia during 1985 to 2015. Land (5) 41: doi: 10.3390/land5040041.

Hance, Jeremy (2008). "Tropical deforestation is 'one of the worst crises since we came out of our caves'". Mongabay.com / A Place Out of Time: Tropical Rainforests and the Perils They Face. http://news.mongabay.com/2008/0515-hance_myers.html.

Hansen, A. J., Knight, R. L., Marzluff, J. M., Powell, S., Brown, K., Gude, P. H., & Jones, K. (2005). Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. *Ecological applications*, *15*(6), 1893-1905.

Haregeweyn, N., Tsunekawa, A., Poesen, J., Tsubo, M., Meshesha, D.T., Fenta, A.A., Nyssen, J., Adgo, E. (2017). Comprehensive assessment of soil erosion risk for better land use planning in river basins: case study of the upper Blue Nile River. Sci. Total Environ. 574, 95-108.

Hassen, E.E. & Assen, M. 2016. Land use/cover dynamics and its drivers in Gelda catchment, Lake Tana watershed, Ethiopia. Environmental Systems Research 6(1): 4.

Henderson-Sellers, A. and Gornitz, V. (1984) Possible Climatic Impacts of Land Cover Transformations with Particular Emphasize on Tropical Deforestation. Climatic Changes, 6, 231-258. https://doi.org/10.1007/BF00142475

Hurni, H., (1988). Degradation and conservation of the resources in the Ethiopian highlands. Mt. Res. Dev. 123-130.

Hurni, H. (1993). Land degradation, famine, and land resource scenarios in Ethiopia.

Hurni H, Berhe W, Chadhokar P, Daniel D, Gete Z, Grunder M, Kassaye G (2016) Soil and water—conservation in ethiopia: guideline for development agents, 2nd Edition. Bern Open Publishing (BOP), Bern, Switzerland

Hurni, H., Tato, K., & Zeleke, G. (2005). The implications of changes in population, land use, and land management for surface runoff in the upper Nile basin area of Ethiopia. *Mountain research and development*, *25*(2), 147-154.

Jamal S, Javed A, Khanday Y (2016) Evaluation of land degradation and socio-environmental issues: a case study of semi arid watershed in Western Rajasthan. J Environ Prot (Irvine, Calif). https://doi.org/10.4236/jep.2016.78102

Kassa H, Campbell B, Sandewall M, Kebede M, Tesfaye Y, Dessie G, Seifu A (2009) Building future scenarios and uncovering persisting challenges of participatory forest management in Chilimo Forest, Central Ethiopia. J Environ Manage 90:1004–013. https://doi.org/10.1016/j.jenvman.2008.03.009

Kassa H, Dondeyne S, Poesen J, Frankl A, Nyssen J (2016) Transition from forest-to cereal-based agricultural systems: a review of the drivers of land-use changes and degradation in southwest Ethiopia. Press

Khormali, F., Ajami, M., Ayoubi, S., Srinivasarao, C., & Wani, S. P. (2009). Role of deforestation and hillslope position on soil quality attributes of loess-derived soils in Golestan province, Iran. *Agriculture, ecosystems & environment*, *134*(3-4), 178-189.

Kindu, M., Schneider, T., Teketay, D., & Knoke, T. (2016). Changes of ecosystem service values in response to land use/land cover dynamics in Munessa–Shashemene landscape of the Ethiopian highlands. *Science of the Total Environment*, *547*, 137-147.

Kindu, M., Schneider, T., Teketay, D., and Knoke, T. (2013). Land Use/Land Cover Change Analysis Using Object-Based Classification Approach in Munessa-Shashemene Landscape of the Ethiopian Highlands. Remote Sensing, 5, 2411–2435. https://doi.org/10.3390/rs5052411

Kinfe Gebre, (2011). The impact of land use and land cover dynamics on the vegetation and soil characteristics of south omo rangelands: the case of malle woreda, Ethiopia. A Thesis Submitted to the School of Animal and Range Sciences School of Graduate Studies haramaya university, In Partial Fulfillment of the Requirements for the Degree of masters of Science in agriculture (range ecology and management)

Kitchin, R., & Tate, N. J. (2000). Conducting Human Research into Human Geography: Theory, Methodology and Practice.

Kitchin, R., & Tate, N. (2013). Conducting research in human geography: theory, methodology and practice. Routledge.

Klein Goldewijk, K., Beusen, A., Van Drecht, G., & De Vos, M. (2011). The HYDE 3.1 spatially explicit database of human-induced global land-use change over the past 12,000 years. *Global Ecology and Biogeography*, *20*(1), 73-86.

Kubiszewski, I.; Costanza, R.; Anderson, S.; Sutton, P. (2017). The future value of ecosystem services: Global scenarios and national implications. Ecosyst. Serv. 2017, 26, 289–301.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., ... & Xu, J. (2001). The causes of land-use and land-cover change: moving beyond the myths. *Global environmental change*, *11*(4), 261-269.

Lambin, E. F., Geist, H. J., and Lepers, E. (2003). Dynamics of Land-Use and Land-Cover Change in Tropical Regions. In Annual Reviews of Environmental Resources (pp. 205–241). https://doi.org/10.1146/annurev.energy.28.050302.105459

Lambin, E. F., and Geist, H. (Eds. (Eds.). (2006). Land use and Land cover Change: Local Processes and Global Impacts. Springer.

Landis, J. R.,& Koch, G. G. (1977).The measurement of observer agreement for categorical data. Biometrics.

Lemenih M (2009) Current and prospective economic contributions of the forestry sector in Ethiopia. In: Heckett T, Aklilu N (eds) Ethiopian forestry at crossroads: the need for a strong institution. Forum for Environment, Addis Ababa, pp 59–82

Lemenih M, Woldemariam T (2010) Review of forest, woodland, and bushland resources in Ethiopia up to 2008. In: Edwards S (ed) Forum for environment: Ethiopian environment review. Eclipse Printing Press, Addis Ababa This, pp 131–173

Lesschen, J. P., Verburg, P. H., & Staal, S. J. (2005). *Statistical methods for analysing the spatial dimension of changes in land use and farming systems* (pp. 81-81). Kenya: International Livestock Research Institute.

Long, H., Tang, G., Li, X., & Heilig, G. K. (2007). Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta economic area of China. *Journal of Environmental management*, *83*(3), 351-364.

Maitima, J. M., Mugatha, S. M., Reid, R. S., Gachimbi, L. N., Majule, A., Lyaruu, H., ... & Mugisha, S. (2009). The linkages between land use change, land degradation and biodiversity across East Africa. *African Journal of Environmental Science and Technology*, *3*(10).

Marino J (2003) Threatened Ethiopian wolves persist in small isolated Afroalpine enclaves. Oryx 37:62–71. https://doi.org/10.1017/S0030605303000139

Maro, P. (2011). Environmental Change in Lesotho: An Analysis of the Causes and Consequences of Land-Use Change in the Lowland Region. Springer Scence and Business Media.

MEa, M. E. A. (2005). Ecosystems and human well-being: synthesis. *Island, Washington, DC*.

Mekonnen, A., & Damte, A. (2011). *Private trees as household assets and determinants of tree-growing behavior in rural Ethiopia* (No. dp-11-14-efd).

Mekonnen Z, Taddese H, Woldeamanuel T, Asfaw Z (2018) Land use and land cover changes and the link to land degradation in Arsi Negele District, Central Rift Valley, Ethiopia. Remote Sens Appl Soc Environ 12:1–9. https://doi.org/10.1016/j.rsase.2018.07.012

Menale Kassie and Precious Zikhali (2009). Brief on Sustainable Agriculture Prepared for the Expert Group Meeting on "Sustainable Land Management & Agricultural Practices in Africa: Bridging the Gap between Research & Farmers" Gothenburg, Sweden, April 16 – 17, 2009.

Miheretu, B. A., and Yimer, A. A. (2017). Land use / land cover changes and their environmental implications in the Gelana sub- watershed of Northern highlands of Ethiopia. Environmental Systems Research. https://doi.org/10.1186/s40068-017-0084-7

Ministry of Agriculture and Rural Development and World Bank (MoARD and WB). (2007). Ethiopia: Thematic papers on land degradation in Ethiopia. Ministry of Agriculture and Rural Development and World Bank publication, Addis Ababa

MoARD and SLM Secretariat (2008). Ethiopian strategic investment framework for sustainable land management. MoARD, Addis Ababa, Ethiopia. 105 pp (unpublished project document).

Mohammed Assen and Tassew Nigussie. 2009. "Land use/Land cover changes between 1966 and 1996 in Chirokella micro watershed, southern Ethiopia." East African Journal of Sciences, 3: 1-8.

Molders, N. (2012). Land-Use and Land-Cover Changes. Atmospheric and Oceanographic Sciences Library. doi:10.1007/978-94-007-1527-1

Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE, 50(3), 885-900.

Muluneh Weldetsadik. 2005. Impact of population pressure on land use and land cover changes, agricultural system and income diversification in west Gurague land, Ethiopia. PhD dissertation. Norwegian university of science and technology (NTNU).Trondheim.

National Remote Sensing Agency (1989). Manual of Nationwide Land use/Land covers Mapping using satellite imagery, Part I. NRSA, Hyderabad.

Nega, B., Adenew, B. & Gebre Sellasie, S. 2003. Current land policy issues in Ethiopia. Land Reform, Land Settlement, and Cooperatives 11(3): 103-124.

Nune S, Kassie M, Mungatana E (2013) Forest Resource Accounts for Ethiopia. In: Hassan RM, Mungatana ED (eds) Implementing environmental accounts: case studies from Eastern and Southern Africa, eco-efficiency in industry and science 28. pp 1689–1699

Nyssen J, Poesen J, Moeyersons J, Deckers J, Haile M, Lang A (2004) Human impact on the environment in the Ethiopian and Eritrean highlands—a state of the art. Earth-Sci Rev 64:273–320. https://doi.org/10.1016/S0012-8252(03)00078-3

Nyssen, J., Simegn, Getachew and Taha, Nurhussen. 2009. An upland farming system under transformation: Proximate causes of land use change in Bela-Welleh catchment (Wag, Northern Ethiopian Highlands). Soil and Tillage Research, 103:231–238.

Pallant, J. (2020). SPSS survival manual: A step by step guide to data analysis using IBM SPSS. Routledge.

Prakasam, C. (2010). Land use and land cover change detection through remote sensing approach: A case study of Kodaikanal taluk, Tamil nadu. *International journal of Geomatics and Geosciences*, *1*(2), 150.

Quintero-Gallego, M. E., Quintero-Angel, M., & Vila-Ortega, J. J. (2018). Exploring land use/land cover change and drivers in Andean mountains in Colombia: A case in rural Quindío. *Science of The Total Environment*, *634*, 1288-1299.

Rasiah, V., Florentine, S. K., Williams, B. L., & Westbrooke, M. E. (2004). The impact of deforestation and pasture abandonment on soil properties in the wet tropics of Australia. *Geoderma*, *120*(1-2), 35-45.

Rawat, J. S., Biswas, V., & Kumar, M. (2013). Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, districtNainital, Uttarakhand, India. The Egyptian Journal of Remote Sensing and Space Science, 16(1), 111-117.

Reid, R. S., Kruska, R. L., Muthui, N., Taye, A., Wotton, S., Wilson, C. J., & Mulatu, W. (2000). Land-use and land-cover dynamics in response to changes in climatic, biological, and socio-political forces: the case of southwestern Ethiopia. Landscape Ecology, 15(4), 339-355.

Reis, S. (2008). Analyzing land use/land cover changes using remote sensing and GIS in Rize, North-East Turkey. Sensors, 8(10), 6188-6202.

Roy, P.S. and Giriraj, A. (2008). Land Use and Land Cover Analysis in Indian Context. Journal of applied science, Vol. 8(8): 1346-1353.

Rubenstein, J.M. (2003). The Cultural Landscape: An Introduction to Human Geography. 7th ed. Upper Saddle River, NJ: Pearson Education, Inc. p. 496.

Rwanga, S. S., & Ndambuki, J. M. (2017). Accuracy assessment of land use/land cover classification using remote sensing and GIS. International Journal of Geosciences, 8(04), 611.

Sahle, M., & Yeshitela, K. (2018). Dynamics of land use land cover and their driver's study for management of ecosystems in the socio-ecological landscape of Gurage Mountains, Ethiopia. Remote sensing applications: society and environment, 12, 48-56.

Saunders, T.J., Gray, C.E., Poitras, V., Chaput, J.-P., Janssen, I., Katzmarzyk, P.T., et al. 2016. Combinations of physical activity, sedentary behaviour and sleep: relationships with health indicators in school-aged children and youth. Appl. Physiol. Nutr. Metab. 41: This issue.

Serpil Savci, (2012). An Agricultural Pollutant: Chemical Fertilizer. International Journal of Environmental Science and Development, Vol. 3, No. 1, February 2012

Shan, C., Tan, T., & Wei, Y. (2007). Real-time hand tracking using a mean shift embedded particle filter. *Pattern recognition*, *40*(7), 1958-1970.

Sharma, A., Hamlet, A. F., Fernando, H. J. S., Catlett, C. E., Horton, D. E., Kotamarthi, V. R., Wuebbles, D. J. (2018). The need for an integrated land-lake-atmosphere modeling system, exemplified by North America's Great Lakes region. Earth's Future. doi:10.1029/2018ef000870

Seifu W, and Elias E (2018) Soil quality attributes and their role in sustainable agriculture: a review. Int J Plant Soil Sci 26:1–26. https://doi.org/10.9734/IJPSS/2018/41589

Solomon Abate. 1994. Land use dynamics, soil degradation and potential for sustainable use in Metu Area, Illubaor Region, Ethiopia. Thesis (PhD), University of Berne, Berne.

Sonneveld S, Pande S, Georgis K, Keyzer MA, Ali AS, Takele A (2010) Land degradation and overgrazing in the Afar Region, Ethiopia: a spatial analysis. In: Zdruli P, Pagliai M, Kapur S, Cano AF (eds) Land degradation and desertification: assessment, mitigation and remediation. Springer, Dordrecht, pp 97–110

Steffen W, Tyson P (2001). Global Change and the Earth System: A planet under pressure. Environmental Policy Collection, UNT Digital Library, USA, p: 33

Stehman, S. V. (1997). Selecting and interpreting measures of thematic classification accuracy. Remote sensing of Environment, 62(1), 77-89.

Su, S., Jiang, Z., Zhang, Q., & Zhang, Y. (2011). Transformation of agricultural landscapes under rapid urbanization: a threat to sustainability in Hang-Jia-Hu region, China. Applied Geography, 31, 439e449.

Tefera, M. M. (2011). Land-use/land cover dynamics in NONO District, Central Ethiopia. Journal of Sustainable Development in Africa, 13(1), 123–141.

Teketay D (2001) Deforestation, wood famine and environmental degradation in highland ecosystems of Ethiopia: urgent need for actions. In: International Conference on African Development Archives. Paper 3. Western Michigan University ScholarWorks at WMU, Center for African Development Policy Research

Temesgen, A., & Tufa, A. (2017). Analysis of coffee farm productivity in Darolabu District, West Hararghe Zone, Ethiopia. American Journal of Environmental and Resource Economics, 2(4), 158-161.

Tesfa A, Mekuriaw S (2014) The effect of land degradation on farm size dynamics and crop-livestock farming system in Ethiopia: a review. Open J Soil Sci 4:1–5. https://doi.org/10.4236/ojss.2014.41001

Teshome E, Shita F, Abebe F (2020) Current community-based ecotourism practices in Menz Guassa community conservation area. Ethiopia GeoJournal. https://doi.org/10.1007/s10708-020-10179-3

Tibebe D, Bewket W (2011) Surface runoff and soil erosion estimation using the swat model in the Keleta watershed, Ethiopia. L Degrad Dev 22:551–564. https://doi.org/10.1002/ldr.1034

Tilahun, A., & Teferie, B. (2015). A GIS based slope analysis for recommended soil and water conservation techniques in Sekela District, Amhara State, Ethiopia. International Journal of Advance Agriculture Research, 3, 45-54.

Tolba, M. K., & El-Kholy, O. A. (1992). Deforestation and habitat loss. In *The World Environment 1972–1992* (pp. 157-182). Springer, Dordrecht.

Tolessa T, Dechassa C, Simane B, Alamerew B, Kidane M (2019) Land use/land cover dynamics in response to various driving forces in Didessa sub-basin. Ethiopia GeoJournal. https://doi.org/10.1007/s10708-019-09990-4.

Tsegaye, Diress., Moe, S. R., Vedeld, P. and Aynekulu, Ermias. 2010. Land-use/cover dynamics in Northern Afar Rangelands, Ethiopia. Agriculture, Ecosystems and Environment, 139:174-180.

Turner, B. L., Lambin, E. F., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. Proceedings of the National Academy of Sciences, 104(52), 20666–20671. doi:10.1073/pnas.0704119104

UNCCD (2017) Global land outlook: secretariat of the United Nations Convention to Combat Desertification, First Edit. Bonn, Germany www.unccd.int

United Nations Environmental Programme (UNEP) (1983). Ecology and Environment: What Do We Know About Desertification? Desertification Control 3: 2-9

United Nations Environmental Programme (UNEP) (2000). Global environmental outlook 2000. http://www.unep.org /geo2000 /English /index.htm. [Accessed 4 November 2012].

Vitousek, P. M., D'antonio, C. M., Loope, L. L., Rejmanek, M., & Westbrooks, R. (1997). Introduced species: a significant component of human-caused global change. *New Zealand Journal of Ecology*, 1-16.

Wairiu, M., & Lal, R. (2003). Soil organic carbon in relation to cultivation and topsoil removal on sloping lands of Kolombangara, Solomon Islands. *Soil and Tillage Research*, *70*(1), 19-27.

Warra H.H, Mohammed AA, Nicolau MD (2013) Spatio-temporal impact of Socio-economic practices on land use/land cover in the kasso catchment, Bale Mountains, Ethiopia. Scientific Annals of "Alexandru Ioan Cuza" University of IAŞI, Volume LIX, no.1, S. II C, Geography series, 1–26

Wieland, R., Lakes, T., Yunfeng, H., & Nendel, C. (2019). Identifying drivers of land degradation in Xilingol, China, between 1975 and 2015. *Land Use Policy*, *83*, 543-559.

Woldeamlak B (2002). Land cover dynamics since the 1950s in Chemoga Watershed, Blue Nile Basin, Ethiopia. Mountain Research and Development 22: 263-269.

Woldeamlak Bewket & Solomon Abebe (2013) Land-use and land-cover change and its environmental implications in a tropical highland watershed, Ethiopia, International Journal of Environmental Studies, 70:1, 126-139, DOI: 10.1080/00207233.2012.755765

Wondie, M., Schneider, W., Katzensteiner, K., Mansberger, R., Teketay, D. (2016). Modeling the dynamics of landscape transformations and population growth in the highlands of Ethiopia using remote-sensing data. *International Journal of Remote Sensing* **37(23):** 5647-5667.

Wogderes, A. (2014). Detecting land use/land cover change using remote sensing & GIS techniques and analysis of its causes, consequences, and trends. In Ofla district, tigray region, Ethiopia. Addis Ababa University.

Wubie, Mohammed Assen, & Melania D.Nicolau. (2016). Patterns, causes and consequences of land use/cover dynamics in the Gumara watershed of Lake Tana basin, north-western Ethiopia. Department of Geography and environmental studies, Bahir DarUniversity, Bahir Dar, Ethiopia

Yadav, P., Kapoor, M. and Sarma, K. 2010. Land Use Land Cover Mapping, Change detection and conflict Analysis of Nagzira-Navegaon Corridor, Central India Using Geospatial Technology. International Journal of Remote Sensing and GIS, Vol. 1(2): 90-98.

Yamane, Taro (1967). Statistics: An Introductory Analysis, 2nd Edition, New York: Harper and Row.

Yirdaw, E. (1996). Deforestation and Forest Plantations in Ethiopia. In Sustainable Forestry Challenges for Developing Countries, edited by P.

Yirdaw E, Tigabu M, Monge A (2017) Rehabilitation of degraded dryland ecosystems—review. Silva Fenn 51. https://doi.org/https://doi.org/10.14214/sf.1673

Zegeye H (2018) Climate change in Ethiopia: impacts, mitigation, and adaptation. Int J Res Environ Stud 5:18–35

Appendices

APPENDIX I

SURVEY QUESTIONNAIRE FOR HOUSEHOLDS

Addis Ababa University
School of Graduate Studies
College of Development Studies
Department of Environment and Sustainable Development

SURVEY QUESTIONNAIRE FOR FARM HOUSEHOLDS

The purpose of this questionnaire is to gather data on the land use/ land cover change and its effect on the environment and socio-economy of smallholder farmers in the Lude Hitosa District of Arsi Zone, Oromia National Regional state, Ethiopia.

The result of this study will provide helpful information for policymakers, land users, and development practitioners about the magnitude and trends of land use and land cover change and its implication on ecosystem services. Your responses will remain confidential, and your name will be anonymous unless you are willing to disclose them. Therefore, you are kindly requested to provide genuine responses. Your right to be involved or not is also highly respected.

Household head information

- Name of respondent (if possible): ___________________Code No.______________
- Kebele Name: __________________________________Village: ________________
- Date of interview: __________________________
- Name and Signature of the Enumerator: _________________________________

Part I. GENERAL CHARACTERISTICS OF THE FARM HOUSEHOLDS

(Please, encircle your choice for the questions with alternatives)

1.1 Demographic Characteristics

1) Sex of the household head 1) Male 2) Female

2) Age of the household head: __________________

3) Marital status of the household head 1) married 2) single 3) divorced 4) widow 5) separate

4) Family size: Total _____________1-15 years old: ______16-65: ______above 65: _______

5) Years of schooling: 1. Illiterate; 2. Elementary; 3. Junior; 4. High school complete; 5. College and above

6) Years of experience as a farmer: _______________________

7) Do you have off-farm income? 1) Yes, 2) no

8) If your response to question No. 7 above is "yes" please specify the types of the off-farm activity, average monthly income, and use of the income earned:

____

____

2.1. Economic background of the household

2.1.1. Farmland ownership

9) Do you have farmland? 1) Yes 2) no
10) If yes, please would you tell me the total size of your farmland in timad. Private: ______; Rented: _______ Share cropped: ________

11) How many plots do you have? ___________
12) Means of farmland acquisition (*more than one response is allowed*):

1) 1st distribution; 2) Redistribution; 3) Inheritance; 4) Inheritance and Redistribution; 5) Gift; 6) Renting; 7) others, specify _________________________

13) Please indicate the size of land you had in *timad* at different periods of time.

Time Interval	Size of Each Parcel of Land			
	Homestead	Cropland	Private grazing land	Plantation
Current				
10 years ago				
20 years ago				
30 years ago				
40 years ago				

14) Is your farm holding. 1) Smaller currently 2) bigger currently 3) no change. If there are changes, what is the reason for the change of land holding ________________________

____

15) Is the farmland your household currently owned: 1) Adequate 2) not adequate
16) If "not adequate", what coping mechanism do you use to solve the problem?
1) Intensification of the existing farm plot; 2) expansion toward forest area;
3) cultivation of steep slope and valley areas; 4) cultivation of wetlands;
5) Engage in to non-farming activities; 6) Others: ________________________

2.1.2. Livestock ownership

17) Do you own livestock? 1) Yes 2) No
18) If "yes", how many livestock do you own? Fill in the table below.

No.	Livestock Type	Quantity in Number
1	Cow	
2	Oxen	
3	Calf	
4	Heifers	
5	Goats	
6	Sheep	
7	Horses	
8	Mule	
9	Donkeys	

10	Poultry	
Others…		

19) What are the significances of livestock to your households? 1) _______________ 2) _____________ 3) _______________________ 4) _________________ 5) ____________

20) What are the major sources of animal feed? 1) Crop Straw; 2) Grazing private pasture 3) communal grazing land 4) Grazing around homestead 5) Private fallow 6) others, specify: ___________________________

21) Has your number of livestock been increasing or decreasing over the past years? 1. Increasing; 2. Decreasing; 3. No change: 4. I do not have

22) If you say decreasing to Q 21, would you tell us the reasons for the above trend in the order of importance? 1) Lack of fodder 2) Shortage of grazing land 3) Disease prevalence 4) Lack of veterinary services 5) Shortage of water 6) other, specify_______________________

23) If the number of livestock is decreasing, do you think it impacts your livelihood? 1) Yes 2) no

24) If yes to question 23, what are these implications 1) income decline 2) malnutrition problem 3) shortage of animal labour for farm activity and transportation 4) any other______________

25) Do you have a problem of grazing land? 1) Yes 2) no

2.1.3 Crop Production

26) List the major crops that you frequently grown in the order of their importance: 1) _____________ 2) ___________________ 3) ____________________ 4) __________________ 5) ______________

27) How do you state the trend of yield on your farmland over the past years? 1) Increasing 2) no change 3) decreasing 4) I don't know

28) If you say decreasing for Q27, what are in your opinion, the major causes of crop yield reduction **orderly**: 1) erratic rainfall__ 2) scarcity and the high price of improved seed ___ 3) unaffordable price of fertilizer____ 4) shortage of ploughing oxen___ 5) soil degradation (erosion, low fertility, etc.)____ 6) pest prevalence (parasite, diseases, weed, etc.) 7) other, specify______________________________________

29) What is the crop diversity at the household level over the years?

	Crop diversity per household over the years			
No.	In 1980s	1990s	2000s	2010s
1				
2				
3				
4				

Part II. Land use/ land cover change: its pattern, drivers, and impacts

30) Have you noticed any change in the land use/land cover in your locality over the past 40 years or so? 1. Yes 2. No

31) If "yes" to Q30, what major changes occurred in your locality in the past 40 years? Give your opinion as (*increasing, decreasing, no change and don't know*).

Land use type	**1980s**	**1990s**	**After 2000**
Cultivation land			
Grazing land private			
Grazing land communal			
Natural vegetation			
Plantation forest			
Fallow			
Abandoned land			
Closed area			
Volume of streams			
Number of wildlife			

32) What factors prompted the alterations in land use/land cover? 1) Market prices and availability 2) Population increase 3) Expansion of agricultural land 4) Introduction of new development projects 5) Deforestation 6) climate change 7) Government policy 8) Others, specify________

33) What problems do you face due to the land use/cover change. List them in order of importance. 1) Soil erosion/infertility 2) lack of local tree species 3) lack of enough grazing land 4) change in the local climate 5) deforestation 6) other, specify ____________________

____

34) Following the land use/land cover change, which environmental problems have become very common in your area? 1) Soil erosion 2) degradation of watersheds 3) change in local climate 4) lack of grazing land 5) lack of trees around homesteads 6) water availability; 7) lack of land for social services; 8) others, specify______________________

Part III. Land Degradation and Management

35) Have you noticed the problem of land degradation in your locality? 1) yes 2) no

36) Which symptoms of land degradation did you observe in your locality? 1) Soil erosion 2) desertification 3) deforestation 4) others, specify _____________

37) Which land management practices do you implement in your landholding?

- ➢ Drainage furrows ➢ Crop rotation ➢ Coffee-based Agroforestry
- ➢ Diversion ditches ➢ Manure application ➢ Changing plant species
- ➢ Soil bunds ➢ Compost use ➢ Grass strips
- ➢ Stone bund ➢ Fallowing ➢ Tree planting
- ➢ Terrace construction ➢ Area closure ➢ Area closure ➢ others, specify)

______

Part IV. Environmental Degradation and Management

38) Have you noticed the problem of environmental degradation in your locality? 1) yes 2) no

39) If your answer is "yes", how do you explain the degradation process? (in relation to vegetation, soil, local climate, water bodies, wildlife, etc.)

____

____

40) What crises did your household face due to the problem? *You can underline more than one answer.* (health crises, food shortage, crop failures, loss of cattle, death, lack of capital, soil fertility decline, insects and pests, land scarcity, the high price of the crop at purchase, and vice versa, deteriorating social network, lack of animal feed, oxen shortage, lack of wood, labor shortage, and others, specify) ____

____

41) What have you done to cope with the problems of environmental degradation? 1) Reducing consumption in each meal 2) Eating famine period food or less preferred food 3) Borrow grain or money to buy food 4) Selling firewood 5) Selling charcoal 6) Rely on food aid 7) Selling small animals (goat, sheep, chicken) 8) Selling cattle 9) Migrate to nearby urban areas for casual wage labor 10) Migrate to other areas for farmland acquisition 11) others, specify ____
____

Forest Resources

42) What is your perception of vegetation? 1) Source of forest products (e.g., fodder, fuelwood, and shelter for local people) __2) Source of supplementary income__ 3) Source of government revenue __ 4) Obstacles to agricultural expansion ___ 5) Climatic importance__

43) Do you have trees on your farmland? 1) yes 2) no

44) What is the type of fuel used by the household?

Energy Type/Fuel	Cooking	Lighting	Heating
1) Charcoal			
2) Fuel wood			
3) Candles			
4) Kerosene			
5) Animal dung			
6) Electricity			
7) Others, specify_________			

45) If firewood is commonly used, please indicate the source. 1) Own forest /plantation 2) community forest 3) Government Forest 4) Market 5) others__________________________

46) Currently, is there adequate forest cover in your village? 1) Yes 2) No

47) While you compare the present natural forest with the past years: 1) Highly decreased 2) decreased 3) no change 4) increased 5) Highly increased

48) If decreasing to Q47, what are the major causes?
1) Over-cultivation_______ 2) need of cropland______ 3) Cyclic events (e.g. erratic rainfall, drought) __ 4) Illegal cutting of wood_______ 5) Over-grazing_______ 6) Government weak forest law enforcement; 7) land-use change

49) Has the change negatively affected your livelihoods? 1) Yes 2) No

50) If **yes,** what are some of the negative changes? 1) Scarcity of fuelwood and construction materials 2) streamflow decreased or dried up 3) runoff increased 4) yield has declined 5) Gullies and rills occurred

51) In general, are there any environmental management/conservation schemes like afforestation, reforestation, closure, terracing, etc., in your area? 1) Yes 2) no

52) If "yes" please specify the conservation schemes applied in order of importance.
____
____

53) Who is responsible for environmental management/protection? 1) Local Farmers

themselves 2) the community 3) government 4) NGOs 5) all
54) What do you think are the factors influencing farmers' decision-making on resource management options? 1) Educational status of households 2) level of extension service provision 3) wealth of households possessed 4) fragmentations of the farmland 5) lack of awareness of the problem 6) any other ____

____

55) What are the most priority environmental issues in your locality that need intervention? Please forward your suggestion.

____
____
____

Any comments and observations not covered?

APPENDIX II

GUIDING QUESTIONS FOR KEY INFORMANTS AND FGDS

1. What looks the trend of natural vegetation in your locality?
2. What major land use/cover type changes occurred in your locality in the past 40 years?
3. What do you think are the causes for these changes occurred in your locality in the last 40 years?
4. What effects have these land use/cover changes brought on the local environment (forest, soil, wildlife, grazing land, water resources or hydrology, climate) and local livelihoods (resource availability, incomes, and living conditions)?
5. How do you or the local community cope with these changes and the impacts?
6. What natural and human factors affect land resource management?
7. Have you attended any workshops, training, and discussion on land management and conservation program organized by the government, NGOs, and others?
8. Who is responsible for environmental management/protection? (Farmers themselves, the community, government, NGOs)
9. What are the traditional or indigenous methods of resource conservation and management of the local community practice in your area? (Soil, forest, grazing land, water, wildlife)
10. What do you think are the major production constraints of the study area? (Crop, livestock, forest)
11. Is there an effort made (by the government or NGOs) that encourages farmers to rely on natural fertilizer than chemical fertilizer to improve soil fertility largely?
12. Who practices soil conservation and management more, the poor or the rich, and why?
13. How can you improve your resource management practices sustaining your livelihoods and the environment?

Any comments and observations not covered?
Thank you for participating!

APPENDIX III

I. ACCURACY ASSESSMENT OF THE LULC CLASSIFICATION

Once the LULC classification is completed, the final step is to conduct an accuracy assessment to quantitively assess the method's effectiveness in correctly assigning the pixels to the proper land cover classes (Rwanga and Ndambuki 2017). Accuracy assessments are one of the most important steps of classification to validate the output classification product and the data quality. This assessment is done by comparing the pixels of the classified image with ground truth data and is used in both supervised and unsupervised classification algorithms.

In the study, supervised classification was used. Then the complete set of training data collected in the field was divided into two subsamples, one used for algorithm training and the other used for error testing so that the same sample is never used for training and testing (Geiß et al., 2017). An error matrix is generated by comparing the LULC type calculated by the algorithm for a given pixel with the true LULC class identified by the ground truth sample. The error matrix is a simple grid that lists the target classes and their respective number of correct and incorrect pixel classifications. Error as a percent of the total number of pixels of each class is calculated. An overall classification error (kappa coefficient or similar statistic) is usually also calculated (Feng et al. 2018). Error matrices are helpful for organizing and presenting accurate assessment information in a descriptive and effective manner (Stehman 1997).

To estimate the accuracy of image classification, the performance and accuracy were assessed and quantified by comparing the classified map with a reference map. Therefore, a full accuracy assessment that includes the report on Overall accuracy, User Accuracy, and Producer Accuracy was investigated using the Kappa coefficient.

A classified image or change detection map must be compared against reference data assumed to be true, to assess its performance and quantify its accuracy (Foody, 2002). Accordingly, the outcome of the accuracy assessment shows that the overall accuracy for the year 2022 was 86.59%, and the kappa coefficient was 82.69%, which showed a strong agreement (Fleiss et al., 2003). This result indicates that both commission and omission errors are very low, inferring acceptable classification accuracy. The producer’s accuracy shows how well the situation on the ground is mapped, whereas the user’s accuracy implies how reliable the map is. The latter one tells how often the class on the map will be present on the ground.

II. CONFUSION MATRIX

Confusion matrices, like error matrices, show the percentage of correctly classified pixels. In addition, confusion matrices show which pixels may have been misclassified as another class type, also known as the "producer accuracy" (Ahmad and Quegan 2013). Confusion matrices enable the analysis of patterns of misclassification. Using confusion matrices, researchers can better understand how accurate the overall classification is and common errors that may have occurred that can sometimes be corrected by incorporating additional information into the classification analysis.

Results of user's accuracy in this study showed that in 2022 the maximum class accuracy was for bare land (97.50%) and settlement (93.62%), and the minimum accuracy was for shrub (62.50%) and cropland (74%). Conversely, the results of the producer's accuracy showed that cropland, and settlement area were relatively correctly classified: 90.24%, and 91.67%, respectively.

Appendices table 1. Confusion Matrix of LULC assessment - 2022 GC

LULC classes - 2022	Bare land	Crop land	Forest	Grass land	Settleme nt	Shrub	Raw Total	User Accuracy
Bare Land	39	1	0	0	0	0	40	97.50%
Crop Land	8	37	0	1	4	0	50	74.00%
Forest	2	0	26	0	0	1	29	89.66%
Grass Land	0	1	0	4	0	0	5	80.00%
Settlement	0	2	1	0	44	0	47	93.62%
Shrub	1	0	2	0	0	5	8	62.50%
Column Total	50	41	29	5	48	6	179	
Producer Accuracy	78.00%	90.24%	89.66%	80.00%	91.67%	83.33%		

APPENDIX IV

SAMPLE PICTURES FROM THE FGDs

Picture 1. Participants of FGDs in Ademere Kebele

Picture 2: Participants of FGD in Guraricho Kebele

APPENDIX V

SAMPLE PICTURES FROM THE FIELD OBSERVATIONS

Picture 3 & 4. Agricultural lands – with some remnant trees in the target kebeles, June 05, 2022

Picture 5. Agricultural land in mountainous or steep slopes areas, in Guraricho kebeles

Picture 6. Degraded land areas in the target district on the way to Guraricho kebele