



College of Social Science and Humanities

Department of Geography and Environmental Studies

A Research Title on:

**Land use Land, Cover Change Analysis and Land Degradation
using Geospatial tools in the case of Drought Prone Area
Legambo District, Ethiopia.**

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College of Social Science and Humanities

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using Geospatial tools in the case of Drought Prone Area Legambo
District, Ethiopia.**

**Thematic area: Land degradation, LULCC, Rehabilitation and conservation,
Conservation of degraded land**

Summited to Mekdla Amba University Academic, Research and
Technology transfer Vic President

Declaration

We declare Argaw Tesfaye, Minale Melese, Mohammed Ahmed, here by declares that the thesis entitled Land use Land, Cover Change Analysis and Land Degradation using Geospatial tools in the case of Drought Prone Area Legambo District, Ethiopia. submitted to Mekedla Amba University College of social Science and Humanities, is original work and it hasn't been presented for the award of any other Degree, Diploma, Fellowship or other similar titles of any other college or institution.

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Approval of Thesis

We, the undersigned members of the boarded of the examiners of the final open defense by Argaw Tesfaye, Minale Melese, Mohammed Ahmed have read and evaluated thesis entitled, Land use Land, Cover Change Analysis and Land Degradation using Geospatial tools in the case of Drought Prone Area Legambo District, Ethiopia. This is therefore to certify that the thesis has been accepted

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Acronym

ANRS	Amhara National Regional State
ASTER	Advanced Space born Thermal Emission and Reflection Radiometer Radar for Topography Mission
CHIRPS	Climate Hazards Center InfraRed Precipitation with Station data
CSA	Central Statistical Agency
CV	Coefficient of Variation
DA	Development Agent
DADO	District Agricultural Development Office
EMA	Ethiopian Mapping Agency
ERDAS	Earth Resource Data Analysis System
ETM+	Enhanced Thematic Mapper Plus
FAO	Food Agricultural Organization
FDRE	Federal Democratic Republic of Ethiopia
FGD	Focus Group Discussion
GCP	Ground Control Point
GDEM	Global Digital Elevation Model
GPS	Global Positioning System
GTP	Growth and Transformation Plan
IPCC	Inter-governmental climate change
SLM	Integrated Sustainable Land Management
KIs	Key Informants
LULC	Land Use Land Cover change
M asl	Meter above sea level
PCI	Precipitation Concentration Index
SRA	Standardized Rainfall Anomalies
TM	Thematic Mapper
UNDP	United Nation Development Program
USAID	United States Agency for International Development
USGS	United States Geological Survey

Abstract

This study examines the dynamics of land use, land cover change (LULCC), and land degradation in the drought-prone Legambo District, Ethiopia, using geospatial tools and a mixed-methods research approach. Data collection involved both qualitative and quantitative methods to comprehensively address the research objectives. Primary data were gathered from stakeholders, while secondary data were obtained from various sources, including satellite imagery and meteorological data. Landsat data covering a period of 1993-2023 was accessed from United States Geological Survey (USGS). In addition to this, rainfall and temperature data was be collected from the National Metrological Agency of Ethiopia (NMAE) from 1992 to 2022. Pre-processing and post-processing will be done in LULCC analysis. Precipitation Concentration Index (PCI), Standardized Rainfall Anomaly (SRA), Linear Regression (LR), Coefficient of Variation (CV) was used to analyze the climate data. The findings reveal significant change in LULC the last 30 years in the study area. The bare land and vegetation have decreased at -2.3, and -0.9 respectively, settlements +2430.1% waterbody at +1.8%, and agricultural land at 0.4% increase from 1993-2023. Agricultural is dominance economic activities (90.1 %) of respondents, concerns about soil erosion, poor soil fertility, and rainfall variability were identified, affecting agricultural productivity and livelihoods. The study also shows the vulnerability of rural communities to drought, food inadequacy, and other challenges. Annual rainfall in the study area has shown a statistically significant declining trend by 18.80c/ decade over the study period and variability in rainfall across seasons. The Precipitation Concentration Index (PCI) indicates highly concentrated rainfall in a few wet months, with July, August, and September. Mean annual maximum and minimum temperatures have shown an increasing trend (0.04⁰C /decade and 0.09⁰C /decade) statistically significant at $p = 0.05$; 0.01 respectively warming trends observed in the study period. The survey result indicates that land degradation significantly impacts rural livelihoods, with key issues including increased prices for farming commodities, loss of biodiversity, desertification, migration, poverty, unemployment, threats to human and animal life, and decreasing land productivity. Sustainable land management practices are recommended to mitigate soil erosion, improve soil fertility, and promote ecosystem health. The study recommended that integrated approaches that balance socio-economic development with environmental conservation objectives. Community participation, capacity building, and policy intervention are essential for addressing land degradation and promoting resilience to climate-related shocks. By prioritizing collaboration among stakeholders, sustainable land management and conservation efforts can be enhanced to ensure the long-term sustainability of agricultural landscapes in Legambo district, Ethiopia.

Key words: Agriculture, Land use land cover change, Climate, Legambo, Ethiopia

Chapter one

1. Introduction

1.1. Background of the study

Land is the most fundamental natural capital, which provides habitat and livelihood for all living things. Nonetheless, land degradation accelerated the deterioration of the ecosystem services of land, mainly in the 20th and 21st centuries (Hossain et al.,2020). According to Teshome et al., (2018) land degradation affected about 30% of the total global terrestrial land and from 5 to 8 million ha of productive agriculture land has been out of use per year (FAO, 2003). Interactions between land use and land cover change (thereafter LULCC) and land degradation have been found to be complicated, yet at the same time very important for environmental adaptation and management (Liu et al. 2008).

Africa is the most vulnerable to land degradation (UNEP, 2015). In this continent, land quality deterioration is the main challenge in striving for achieving agricultural productivity and food security (Liniger et al., 2011). In the Sub-Saharan African (SSA) countries agriculture sector contributes on average about 30% of GDP, 40% of export items, 40% of the foreign revenue, and created about 70-80% of job opportunities (Commission for Africa, 2016). However, the sector has been affected by abject land degradation in the region (Liniger et al., 2011). Therefore, in the region most of the population is vulnerable to extreme poverty (Teshome et al., 2018).

Agriculture is the backbone of the national economy of Ethiopia it generates about 43% of GDP; bases for over 80% of total employment and 90% of export earnings (Muluye, 2021; Mohammed,2022). However, the sector continues to be hampered by abject land degradation in the form of soil erosion, soil nutrient depletion, lack of soil moisture, and drought (Khan et al., 2021). As a result, the country has persisted as one of the poorest countries of the world and people are remained chronically food insecure (Asrat and Anteneh, 2020; Wudil et al., 2022).) and, has become a major food aid recipient country in Africa. The problem is very pervasive in many parts of the country, but it is the worst in the highland regions, where in most densely populated areas (Eshetu and Guye,2021). Land degradation in Ethiopia is the result of various complex webs of human and natural driving and pressure forces (Gebreselassie et al., 2016; Assefa et al., 2017; Teshome et al.,2018).Key driving forces such as rapid population growth,

low and poor implementation of SLM technologies, institutional dynamics, erosive rainfall, and cultivation of steep slope areas are major factors for the occurrence of direct land degradation drivers (Gebreselassie et al, 2016; Kirui, 2017).

Similarly, major pressures such as destruction of woodland and forest, poor farming technique, and over and free grazing, deforestation, and overexploitation natural resources (soil, water, forest, and rangeland), the use of dung and crop residue for domestic energy, and house construction have been accelerated land degradation in the country (Kirui, 2016). Cultivated land which has a slope greater than 30% should not normally be used for crop production, but it is recommended to use for forestry. Considering the past limitations, the country re-established new SLM strategies, approaches, and technologies designed for farmers by technical experts (Abi et al., 2018; Teshome et al., 2016).

Mainly, since 1995 the government has integrated several SLM technologies into agricultural extension packages through community mass mobilization at the watershed level (Abi et al., 2018; Teshome et al., 2016). For example, Growth and Transformation Program-GTP I and II (FDRE, 2016); Sustainable Land Management Project-SLMP (SLMP-I (2008 – 2013) and SLMP-II (2013 – 2018)); Making Environmental Resource to Enable Transition to More Sustainable Livelihood (MERET) project; Climate Resilient Green Economy Strategy (CRGE) (Awraris et al., 2014); Public Works Program of the Productive Safety net program (PSNP) and many others (World Bank, 2020).

South Wollo is among the drought prone areas in the region, and is among the food insecure areas of the country and farming is practiced in the context of variable rainfall (Hubertus, 2020; Wassie et al., 2022; Mohammed et al., 2022; Tofu et al., 2023) and has frequently suffered from recurrent drought often followed by devastating famine (Teshome and Zhang, 2019). Due to the smaller per-capita land availability and highly fragmented parcel of farmland coupled with erratic nature of rainfall, the south wollo zone is a highly degraded part Amhara region. Therefore, the area is home of fragile lands caused by soil erosion and deforestation (Wassie, 2020).

1.2. Statement of the problem

In Ethiopia, land degradation is a major immediate cause of declining natural resource base productivity and low agricultural productivity, persistent food insecurity, and rural poverty (Awraris et al., 2014; Sani, and Kemaw, 2019; Ayele , 2020). These are the result of a vicious cycle of natural resource degradation and poverty and make the country's food production far behind the growing population and one of the African countries (Wassie, 2020).

Part of the highly elevated escarpments of the country (Yesuph,2020), in the study area there is a drastic land cover clearing (deforestation) for agricultural activity, charcoal and fuel wood; experiencing climate variability (Worku et al., 2018) which resulted in reduced or variable rainfall, warming temperatures, crop and livestock pests and diseases, flooding, shortage of water and soil erosion (Alemayehu et al., 2020). Due to its steepness of the slope (area of high roofing escarpments) coupled with the contemporary changing climate resulted in high degradation of the uplands.

In recent years, some studies assessed landscape dynamics in the upper Blue Nile (Bewket, 2003; Teferi et al., 2013). However, the landscape in Ethiopia in general and in the South Wollo, in particular, has been characterized by significant differences in terms of population distribution, socio-economic condition, agro ecosystem, soil characteristics, climate condition, farming system, and biodiversity distribution (Ademe et al., 2020).

Studies in the past have identified the physical and human factors for the occurrence of land degradation and landscape change in Ethiopia in general (Gebreselassie et al., 2016) and in the Abbay basin in particular (Bewket, 2003; Teferi et al., 2013). However, most of the studies were focused on the type of drivers for LULC change instead of more concerned about the priority of the key driving forces and pressures of change using local land users' knowledge for effective responses against the drivers and pressures of land degradation. Local people are clearing away natural forests either to expand their cultivation land or to get fuel wood and charcoal. In addition to this, in the study area, research attention particularly in assessment of LULCC and land rehabilitation is vital.

Mapping and quantifying land degradation status plays an important role in the cost-effective design of land management policies and strategies. This enables stakeholders to identify the most vulnerable areas and to give priority for the locational intervention (Bewket and Teferi,

2009;Ewunetu et al.,2021). But, these types of studies are scant in the Ethiopian highlands. Most of the GIS-based land degradation assessments in the past were based on a single indicator, for instance, soil erosion (Bewket and Teferi, 2009; Molla and Sisheber, 2016; Haregeweyn et al., 2017). Thus, to fill this gap we used a new approach for the development of a comprehensive land degradation status map using remote sensing, GIS, climate change and variability analysis using standard rainfall anomalies, coefficient of variation and precipitation concentration index) to account for many factors responsible for land degradation in the South wollo Zone, Legambo District.

1.3. Objective of the study

1.3.1. General objective

The main objective of this study is analysis the Impact of Land Use Land Cover Change on Land Degradation Using Geospatial Tools. The Case of Drought Prone Area Legambo districts Amhara Region Ethiopia.

1.3.2. Specific objectives

The specific objectives of this study are:

1. To analyze land use/land cover change (1993-2023).
2. To explore the major driving forces and pressure on LULC change
3. To examine the climate variability trends (rainfall and temperature) in the study area
4. To perceived impacts of land degradation on rural livelihood
5. To identify the conservation measure for land degradation.

1.4. Research Questions

1. What changes observed in the LULCC of the study area in 1993-2023?
2. What are the major driving forces and pressures of LULC change?
3. What are the climate variability trend in rainfall and temperature in the study area?
4. What are the perceived impacts of land degradation on the livelihood?
5. What conservation measures for the land degradation?

1.5. Significance of the Study

Conducting a study on land use/land cover change (LULCC) analysis and land degradation in the drought-prone Legambo District, Ethiopia, using geospatial tools carries significant importance for several reasons: Understanding Vulnerability to Drought Legambo District, like many other regions in Ethiopia, is vulnerable to droughts, which can exacerbate land degradation. By analyzing LULCC and its relationship with land degradation, the study can

provide insights into the district's susceptibility to drought and its impacts on the environment and local communities. Informing Climate Resilience Strategies the findings of the study can inform the development of climate resilience strategies tailored to the specific challenges faced by Legambo District. By identifying areas prone to land degradation and the drivers of change, policymakers and stakeholders can prioritize interventions aimed at mitigating the impacts of drought and promoting sustainable land management practices. supporting sustainable development goals the study aligns with various Sustainable Development Goals (SDGs), including Goal 15 (Life on Land) and Goal 13 (Climate Action).

By addressing land degradation and promoting sustainable land use practices, the study contributes to efforts to combat desertification, halt biodiversity loss, and mitigate climate change impacts. Enhancing environmental conservation Legambo District is endowed with diverse ecosystems and natural resources that require protection from degradation. By assessing the impacts of LULCC on land degradation, the study can guide conservation efforts aimed at preserving biodiversity, maintaining ecosystem services, and safeguarding the district's natural heritage.

Empowering local communities engaging local communities in the study process can empower them with knowledge and tools to participate in decision-making processes related to land management and environmental conservation. By incorporating local knowledge and perspectives, the study can ensure that interventions are contextually relevant and socially inclusive. facilitating evidence-based policy making the study provides evidence-based insights into the drivers and impacts of LULCC and land degradation in Legambo district. Policymakers can use these findings to formulate policies and regulations that promote sustainable land management, conservation, and resilience-building measures in the face of drought and climate variability.

Contributing to scientific knowledg through the use of geospatial tools and remote sensing techniques, the study advances scientific knowledge on the dynamics of LULCC and land degradation in drought-prone areas. The findings can contribute to academic research, peer-reviewed publications, and the broader scientific community's understanding of environmental change processes.

1.6. Scope of the study

The scope of the study encompasses a comprehensive analysis of LULCC and land degradation in Legambo District, Ethiopia, using geospatial tools and remote sensing techniques. The study aims to generate insights into the drivers, impacts, and spatial patterns of land degradation and provide actionable recommendations for sustainable land management and resilience-building efforts in the region.

The study was focus on Legambo District, Ethiopia, as the primary study area. Temporal analysis will cover multiple time periods to capture historical trends and recent changes in land use/land cover and land degradation. Remote sensing imagery covering different seasons and years will be acquired for the study area. Ancillary data sources, including climate data, topographic maps, soil maps, and socio-economic data, will be utilized for contextual analysis and validation. Remote sensing techniques, such as image classification, change detection, and vegetation indices analysis, will be employed to quantify LULCC and assess land degradation. Geospatial tools and software packages, such as GIS (Geographic Information Systems) and RS (Remote Sensing) software, will be used for data processing, analysis, and visualization.

The study was analyzing the drivers of LULCC and land degradation, including deforestation, agricultural expansion, urbanization, climate variability, and human activities. Impacts of land degradation on soil fertility, water resources, biodiversity, ecosystem services, and socio-economic systems was assessed. Spatial patterns of LULCC and land degradation was mapped and analyzed to identify hotspots, trends, and spatial distribution patterns. Vulnerable areas within Legambo District, such as steep slopes, river basins, and degraded lands, was prioritized for further analysis and intervention.

1.7. Limitation of the study

Among the challenges, lack of willingness of the household and the community to participate in the study, lack of documented and published historical data and time constraint were the most serious limiting factors.

Data Limitations availability and quality of remote sensing data may vary, particularly for historical imagery or high-resolution datasets. Limited ground truth data for validation purposes may hinder the accuracy of land cover classification and change detection analyses. Scale and Resolution the spatial and temporal resolution of satellite imagery may not be sufficient to

capture fine-scale changes in land cover or detect subtle forms of land degradation. Analysis at a coarse scale may overlook localized or small-scale land degradation processes and fail to capture their significance.

Complexity of drivers identifying and attributing specific drivers of LULCC and land degradation, such as climate variability, land management practices, population dynamics, and policy interventions, can be challenging due to their interconnected and multifaceted nature. Socioeconomic factors, such as market dynamics, institutional capacities, and community perceptions, play a significant role in shaping land use decisions and land degradation processes but may be challenging to quantify or integrate into the analysis.

Complexity of land degradation, land degradation is a complex and multifaceted process influenced by various biophysical, climatic, and anthropogenic factors, making it difficult to isolate and quantify specific causes or effects. Resource Constraints, including time, budget, and expertise, may limit the extent and depth of the study, affecting the comprehensiveness and robustness of the analysis and results.

Acknowledging these limitations is crucial for ensuring the transparency, reliability, and validity of the study findings and for guiding future research efforts to address knowledge gaps and improve methodologies for assessing LULCC and land degradation in drought-prone areas like Legambo District, Ethiopia.

To address the limitations of a study on land use/land cover change (LULCC) analysis and land degradation in the drought-prone Legambo district, Ethiopia, using geospatial tools, several strategies can be employed: Utilize multiple sources of satellite imagery with varying resolutions and sensors to capture different aspects of land cover dynamics. Incorporate historical aerial photographs, high-resolution satellite data to supplement analysis and improve accuracy. Refine spatial and temporal scales of analysis to capture both broad-scale patterns and fine-scale dynamics of LULCC and land degradation. Integrate multi-temporal datasets to examine long-term trends, seasonal variations, and cyclical patterns of land cover change.

1.8. Organization of the paper

This study was organized in five chapters, the first chapter discusses background of the study, statement of the problem, research objectives, and research questions, significant of the study, scope of the study. The second chapter comprises the literature review; conceptual literature,

empirical and theoretical literature. The third chapter explains brief description of the study area and research methods and materials as physical and socio-economic features, research design, and sample population. The fourth chapter explains data presentation and analysis as well as the results and discussions of the research. Finally, conclusion and recommendations of the study are presented in chapter five.

Chapter two

2. Review related literature

Land use/land cover change (LULCC) and land degradation are significant environmental challenges with far-reaching implications for ecosystems, biodiversity, and human well-being. Understanding the drivers, impacts, and mitigation strategies associated with these phenomena is essential for sustainable land management. The following literature review provides an overview of key studies that contribute to our understanding of LULCC and land degradation, supported by relevant literature

2.1 Theoretical framework

Theoretical perspectives in the literature offer insights into the underlying mechanisms and dynamics of land use/land cover change (LULCC) and land degradation. For instance, Turner et al. (2007) present a comprehensive overview of human-environment interactions within the context of land change science, emphasizing the reciprocal relationships between human activities and environmental processes. They argue that understanding the drivers of LULCC requires a multidisciplinary approach that integrates concepts from geography, ecology, and social sciences.

Building upon this framework, Lambin and Meyfroidt (2011) propose a telecoupling framework to analyze the socio-economic and environmental interactions driving LULCC across distant places. They highlight the interconnectedness of land systems through flows of information, goods, people, and capital, emphasizing the need for Trans disciplinary research approaches to address complex land change dynamics.

Furthermore, political ecology perspectives, as outlined by Robbins (2012), delve into the power relations and political-economic forces shaping land use decisions and land degradation processes. By examining the socio-political contexts within which land use changes occur, political ecology offers critical insights into issues of resource access, land tenure, and environmental justice.

2.1.1. Definition and rationale of Land use/Land cover change

Many books use land use and land cover concepts interchangeably, although they are different. Land cover refers to the physical characteristics of the earth's surface, captured in the distribution of vegetation, water, desert, ice and other physical features of the land, including

those created solely by human activities such as settlement (Billah and Anisur, 2004). And the same authors define land use as the intended employment and management of strategy placed on land cover type by human agents or land managers.

According to UNFAO, Land use is “the total of all arrangements, activities and inputs that people undertake in a certain land cover type”. In contrast, Land cover “is the observed physical and biological cover of the earth’s land as vegetation, rocks, water body or man-made features” (UNFAO, 2000). However, Land use is obviously determined by environmental factors such as soil characteristics, climate, topography, vegetation and water body etc. but also reflect the land’s importance as fundamental factor of production. Land use change is defined to be any physical, biological or chemical change attributable to management, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species, and conversion to non-agricultural uses (Quentin et al., 2006).

Land cover data documents how much of a region is covered by forests, wetlands, impervious surfaces, cropland, and other land and water types. Water types include wetlands or open water. Land use shows how people use the landscape, whether for development, conservation, or mixed uses. But here there are classes like crop land which is both land use and land cover at the same time, therefore land use /land cover is the most preferable term to use (MaD CAT manual, 2011). 2011).

Liang et al. (2002, as cited in Hussein Ali, 2009) stated that land use/land cover classification has recently been a hot research topic for a variety of applications. A great deal of research has been conducted throughout the world in an attempt to understand major shifts in land use and land cover and to relate them to changing environmental conditions.

Hence Land use /land cover pattern of a region is an outcome of natural and socio economic factors and their utilization by man in time and space. Land use/land cover change has become central component in current strategies for managing natural resources. The advancement in the concept of vegetation mapping has greatly increased research on land use /land cover change (Zubair, 2006).

Therefore, Land use/land cover change (LUCC) research needs to deal with the identification, qualitative description and parameterization of factors which drive changes in land use/ land cover, as well as the integration of their consequences and feedbacks. However, one of the major challenges in LUCC analysis is to link behavior of people to biophysical information in the appropriate spatial and temporal scales. But, it is argued that land use and land cover change trends can be easily assessed and linked to population data, if the unit of analysis is the national, regional, district or municipal level (Codjoe, 2007).

In order to use land optimally, it is not only necessary to have the information on existing land use land cover but also the capability to monitor the dynamics of land use/land cover resulting out of both changing demands of increasing population and forces of nature acting to shape the landscape (Zubair, 2006).

2.2. Role of Remote Sensing and GIS in Land-use and Land-cover change

Remote sensing and geographic information system (GIS) techniques have emerged as invaluable tools worldwide for investigating historical changes in land use/land cover (LU/LC) and analyzing land surface temperature (LST) dynamics. Researchers have utilized remote sensing to identify various surface characteristics, including vegetation cover, air pollution, and LST (Zha, 2012; Weng, 2004). Understanding the correlation between LST and LU/LC is crucial for effective land management, as it provides comprehensive data for detailed analysis and change detection, facilitated by airborne and space borne sensors.

With the advent of historical remote sensing data and advancements in satellite technology, the cost of data acquisition has decreased, while spatial resolution has increased, empowering remote sensing technology to play a pivotal role in monitoring land-cover change. Landsat satellites, notably the Landsat Multi Scanner (MSS) and Landsat Thematic Mapper (TM), have been instrumental since 1972 in providing global coverage of high-resolution multispectral imagery (Turner et al., 2003). The launch of Landsat 7 with Enhanced Thematic Mapper Plus sensors in 1999 further augmented the capability to document changes in LU/LC over time.

Macleod and Congation (1998) delineate four key aspects of LU/LC change detection that are integral to monitoring natural resources:

1. Distinguishing the nature of the change.
2. Detecting and identifying changes that have occurred.
3. Measuring the extent of change in area.
4. Assessing and investigating the spatial pattern of change.

These aspects serve as fundamental principles guiding the analysis and interpretation of LU/LC dynamics, facilitating informed decision-making in resource management.

2.2.1. Geographic Information System (GIS) for LULC change

GIS technology serves as a valuable tool for decision-makers, aiding in the identification of alternative scenarios for development and conservation planning, and facilitating the modeling of potential outcomes. As emphasized by Daniel et al. (2002), the process of decision-making begins and ends with the real-world context. Data collection from the real world forms the foundation for analysis, with compiled information guiding decision-makers towards actions and plans implemented in reality.

In their study comparing land use/land cover change detection methods, Daniel et al. (2002) highlight the utilization of various approaches including traditional post-classification cross-tabulation, cross-correlation analysis, neural networks, knowledge-based expert systems, and image segmentation and object-oriented classification. These methods offer diverse perspectives and analytical techniques for comprehensively understanding land use dynamics.

Moreover, the integration of remote sensing (RS) and GIS techniques has revolutionized land use/cover mapping, offering a detailed and efficient approach for selecting areas designated for agricultural, urban, or industrial purposes (Selcuk et al., 2003). Remote sensing data enables the study of land cover changes in a timely, cost-effective, and accurate manner (Kachhwala, 1985), especially when coupled with GIS, which provides a suitable platform for data analysis, updating, and retrieval (Star et al., 1997; Chilar, 2000).

RS, in conjunction with GIS tools, facilitates the gathering, display, storage, analysis, and output of environmental change-related data, empowering researchers and planners with comprehensive datasets for better understanding and management of a given area. This integrated approach enhances decision-making processes by providing valuable insights into spatial patterns and trends. GIS technology plays a crucial role in decision-making and planning processes by offering a systematic framework for analysing spatial data and modelling potential scenarios. Through the integration of RS and GIS techniques, decision-makers gain access to valuable information for addressing complex environmental challenges and guiding sustainable development initiatives.

2.2.2. Application of Remote Sensing for LULC change

Maktav et al. (2005) underscored the limitations of traditional data collection methods such as demographic data, census, and sample maps for urban land use management. Accurate information regarding LULC change is crucial for various stakeholders, necessitating the utilization of remotely sensed data due to its capacity to provide comprehensive land cover information. Remote sensing, as defined by Campbell (2002), involves acquiring information about objects or phenomena on the Earth's surface without physical contact, achieved through sensing and recording reflected or emitted energy. This technology, facilitated by sensors measuring electromagnetic radiation, forms the basis for analyzing LULC change (Lelesand and Kiefer, 1994).

Remote sensing data serves as a vital source for GIS, enabling studies of spatial and temporal changes in land cover. Multi-temporal remote sensing datasets allow for mapping and identification of landscape changes, contributing to sustainable landscape planning and management (Dewan and Yamaguchi, 2009). The key advantage of remote sensing lies in its multi-spectral and temporal resolution, where images are captured across different portions of the electromagnetic spectrum and the same area is imaged at specified time intervals. This characteristic facilitates change detection applications by providing consistent data over time (Billah and Anisur, 2004).

Furthermore, remote sensing plays a pivotal role in documenting actual changes in LULC on regional and global scales since the mid-1970s (Ashenafi Burqa, 2008). Its ability to provide data quickly and accurately enhances its significance in monitoring and analyzing LULC dynamics. This technology contributes substantially to understanding environmental changes and informs decision-making processes aimed at sustainable land management and resource utilization. Remote sensing applications for LULC change offer a powerful toolset for acquiring timely, accurate, and comprehensive data to support sustainable development initiatives and land management strategies.

2.2.3. Image classification and change detection techniques

Image Classification Approaches:

Image classification, a fundamental process in environmental and socioeconomic applications such as land use/land cover (LULC) change detection, demands high accuracy for reliable results. Defined as the extraction of differentiated classes from remotely sensed digital satellite

data, image classification plays a pivotal role in various applications (Weng, 2012). Lu and Weng (2007) emphasize its significance in providing the foundation for environmental, social, and economic analyses. However, achieving accurate classification faces challenges stemming from factors such as study area characteristics, data resolution, availability of ancillary data, suitable classification algorithms, analyst experience, and time constraints.

Supervised classification, as outlined by Lilles and Kiefer (2000), involves the image analyst guiding pixel categorization by providing numerical descriptors of land cover types through training areas. This method, widely used for quantifying remote sensing data (Reichardt, 1999), relies on suitable algorithms to label pixels according to ground cover types.

Accuracy assessment is integral to evaluating classification outcomes, particularly in change detection processes. While standard procedures for one-point-in-time land cover products are well-established, assessing accuracies for multi-temporal change analysis products poses challenges, often limited to recent image references using ground control points (Wegderes, 2014).

Change Detection Analysis Approaches:

Change detection, crucial in monitoring natural resources and urban development, entails identifying differences in objects or phenomena observed at different times using remote sensing techniques. Singh (1989) emphasizes its importance in quantitatively analyzing spatial distribution changes. Land use/land cover changes, as noted by Moshen A (1999), can yield significant environmental, social, and economic impacts, making accurate data crucial for planning and resource management. Macleod and Congation (1998) delineate four aspects vital in monitoring natural resources through change detection: detecting changes, identifying their nature, ensuring their area extent, and assessing their spatial pattern.

Accuracy Assessment:

Assessing accuracy provides insights into the reliability of land cover maps. Awotwi (2009) underscores the imperfections inherent in maps and the need to gauge their accuracy for intended uses. Producers' accuracy and users' accuracy, as defined by Jensen (2003), offer measures of omission and commission errors, respectively, aiding in evaluating classification reliability.

In conclusion, image classification and change detection techniques, coupled with accuracy assessment procedures, form indispensable tools in environmental and socioeconomic analyses, facilitating informed decision-making and resource management.

2.2.4 Land-use and Land-cover Change in Ethiopia

Land-use dynamics pose significant environmental challenges in Ethiopia, necessitating comprehensive research and management strategies (Berhan, 2010). Scholars have extensively studied land-use and land-cover changes across Ethiopia's diverse landscapes, particularly in the highland regions, revealing complex interactions influenced by various factors (Eyayu et al., 2009; Hassen et al., 2015; Mohammed, 2011; Woldeamlak, 2002; Woldeamlak and Sterk, 2005; Yeshaneh et al., 2013).

Driving Forces of Change: Human-induced factors predominantly drive land-use and land-cover changes, resulting in intricate landscapes alterations (Agarwal et al., 2002; Verheye, 2007). These forces, ranging from biophysical attributes to socio-economic drivers, encompass diverse factors such as modification of topography, climate, vegetation, soil characteristics, and cultural practices like deforestation and soil degradation (Veldkamp and Lambin, 2001; Lambin et al., 2003).

Impact on Vegetation Cover and Deforestation: Ethiopia's vegetation cover is dwindling due to the expansion of agricultural land, leading to alarming rates of deforestation (Abate, 2011; Belay, 2002; Gessesse and Kleman, 2007; Gete and Hurni, 2001). Estimates suggest extensive deforestation, primarily driven by the expansion of rain-fed agriculture, with significant declines in forest cover over the past century (EPA, 1997; EFAP, 1993; Badege, 2001; Wubalem, 2012). Remnant natural forests are now confined to restricted areas, such as religious sites, riverbanks, and hill peaks, reflecting the rapid expansion of agricultural and settlement areas (Warra et al., 2013).

Consequences of Land-use and Land-cover Changes: The escalating deforestation rates and unsustainable land-use practices have triggered severe soil erosion and land degradation, particularly in the Ethiopian highlands (Hassen et al., 2015; Hurni et al., 2005; Mohammed et al., 2005). Population pressures, economic factors, and policy issues have exacerbated these challenges, leading to the expansion of settlements, farmland, and degraded lands at the expense of grasslands and forest areas (Alemu et al., 2015; Eleni et al., 2013; Getachew et al., 2011; Tsehaye and Mohammed, 2013; Woldeamlak, 2002). Additionally, urban sprawl has encroached upon forested areas; further exacerbating land-use change patterns (Mohammed, 2011).

Implications for Ecosystem and Human Livelihoods: The repercussions of land-use and land-cover changes extend beyond environmental degradation, impacting soil quality, water supply,

agricultural productivity, and ecological balance (Maitima et al., 2009; Sharma et al., 2011). Consequently, these changes pose significant challenges to human livelihoods, exacerbating soil erosion, biodiversity loss, and land degradation across Ethiopia's highlands (Belay, 2002; Desta et al., 2000; Girma, 2001).

Land-use and land-cover changes in Ethiopia, driven by a complex interplay of socio-economic and environmental factors, pose significant environmental and socio-economic challenges. Addressing these challenges necessitates holistic management strategies to mitigate deforestation, soil erosion, and land degradation while promoting sustainable land-use practices for the well-being of ecosystems and human livelihoods.

2.3. Driving and pressure forces of land degradation

Land-use and land-cover changes (LULCC) in Ethiopia result from a complex interplay of natural and anthropogenic factors, leading to profound environmental transformations. Understanding the driving forces behind these changes is crucial for effective land management and conservation efforts.

Natural and Anthropogenic Drivers: The United States Environmental Protection Agency (EPA) identifies three primary causes of LULCC: natural processes, direct human activities, and indirect human impacts (EPA, 1999). However, anthropogenic factors emerge as the predominant drivers of land degradation in Ethiopia (Brink et al., 2014; Niamir-Fuller et al., 2012). While natural processes contribute, human-induced activities such as deforestation, soil erosion, and urban expansion exert significant pressures on the land (Agarwal et al., 2002).

Impacts of Anthropogenic Activities: Expansion of agricultural land, driven by rapid population growth, leads to the widespread clearing of natural vegetation, resulting in biodiversity loss and land degradation (Bongers and Tennigkeit, 2010; Cotula, 2009; Donato et al., 2016). Soil erosion, exacerbated by exhausted land and unsustainable agricultural practices, further degrades soil quality and reduces agricultural productivity (Sandra et al., 2017; Shukla et al., 1990). Intensification of agriculture encroaches upon natural ecosystems, diminishing plant species diversity and disrupting ecological balance (Lambin and Meyfroidt, 2011).

Urban Expansion and Deforestation: Rapid population growth drives urban expansion, leading to dramatic changes in landscape patterns and land-use types (Fenglei et al., 2009; Jiang and Tian, 2010). This urban sprawl alters the availability of biophysical resources and ecosystem services,

exacerbating environmental degradation (Hussien, 2009). Deforestation, driven by urbanization and population pressure, contributes to climate change, air pollution, and hydrological disruptions (Peter, 1994; William and Turner, 1992).

Consequences on Climate and Environment: Deforestation and changes in land-use patterns significantly impact climate, hydrology, and air quality. Forest destruction increases carbon dioxide levels, exacerbates climate change, and intensifies the risk of wildfires (Yadvinder et al., 2008). Moreover, alterations in land-use and land-cover disrupt hydrological cycles, leading to water pollution, groundwater depletion, and increased flooding events (Shukla et al., 1990; William and Turner, 1992).

Anthropogenic activities, driven by population growth and socio-economic development, are the primary drivers of land degradation in Ethiopia. Expansion of agricultural land and urban areas, coupled with unsustainable land management practices, exacerbates environmental challenges, including deforestation, soil erosion, and biodiversity loss. Addressing these challenges requires concerted efforts to promote sustainable land-use practices, conservation measures, and urban planning strategies to mitigate the adverse impacts on ecosystems and human well-being.

2.4. Climate change and variability

2.4.1. Climate change and variability

Climate change and variability encompass a spectrum of shifts in weather patterns and atmospheric conditions over time, with implications for ecosystems and human societies. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as alterations in climate attributed to both natural variability and human activity, particularly changes in the composition of the global atmosphere (IPCC, 2007; IPCC, 2014; Mimura et al., 2015). This includes observed rises in global temperatures, heightened frequency of extreme weather events, melting ice caps, rising sea levels, and altered precipitation patterns (Adem et al., 2017). Such changes pose significant challenges to sustainable livelihoods, food security, and economic development, especially in developing nations (Goma et al., 2015).

The influence of human activities on climate is evident through the unprecedented emission of greenhouse gases, driven by factors such as population growth, economic activities, and land use changes (Barros et al., 2014; Hijioka et al., 2016). These emissions have contributed

substantially to observed climate shifts since the mid-20th century, amplifying the occurrence and severity of extreme weather events like heat waves, droughts, floods, cyclones, and wildfires (Barros et al., 2014). Such events expose vulnerabilities in both natural and human systems to current climate variability (Barros et al., 2014).

Climate variability, distinct from human-induced changes, refers to fluctuations in atmospheric conditions around mean states, affecting weather patterns on various timescales (Makate and Mango, 2018). In regions like Ethiopia, heavily reliant on rain-fed agriculture, such variability poses significant risks to food security and livelihoods, exacerbating challenges such as malnutrition and famine (Altieri and Nicholls, 2017). Ethiopia's vulnerability to climate risks is further compounded by its low levels of development and high dependence on agriculture (Weldegebriel et al., 2014).

In Ethiopia, climate variability and extreme events, notably droughts and heavy rains, have profound socio-economic impacts, affecting life, property, and natural resources (Work et al., 2018). The agricultural sector, upon which a vast majority of rural households depend, is particularly sensitive to these climate risks (FAO, 2016; WFP, 2015). Decreases in seasonal rainfall exacerbate food insecurity, while the increasing frequency and intensity of droughts threaten biodiversity, water resources, and human health (Ali et al., 2017).

2.4.2. Rainfall and temperature trends

East Africa experiences complex temperature conditions due to the effects of its varying topography. The temperature in the region ranges from very hot ($>40^{\circ}\text{C}$) at the Afar depression, Ethiopia (Awulachew et al., 2010) to very cold at the peak of Mount Kilimanjaro (Omondi et al., 2014). In recent years over the Greater Horn of Africa (GHA) region, particularly in Kenya, Ethiopia and Somali, climate-related extremes have been the dominant trigger of natural disasters. The region has recently witnessed frequent episodes of both excessive (Ouma et al., 2018). Rainfall trends over the past years are less evident than for temperature, and there are large variations in the direction and extent of changes across the region. An increase in rainfall in some locations for some seasons is observed but a decrease in rainfall is observed in other parts of the regions and overall trends are weak and hard to detect (Nakawuka et al., 2018). In Ethiopia, the mean annual temperature varies between less than 10°C over Northwest, Central and Southeast highlands to about 40°C in the lowlands of Afar, eastern and southeastern regions.

For example, the highlands of Ethiopia experienced wetter conditions during the 1970s and drier condition during 1980s and 1990s (Jury and Funk, 2013; Degefa and Bewket, 2015).

Trend analysis of annual rainfall in Ethiopia shows that rainfall remained more or less constant. When averaged over the whole country while a declining trend over the Northern half of the country and Southwestern Ethiopia (Belay et al., 2017). In the Central Rift Valley of Ethiopia, climate change and variability is manifest through frequent droughts and floods, erratic rainfall and fluctuating mean temperature Ethiopia is highly heterogeneous in elevation, climate, agricultural production, cultural practices and other socio-economic factors (Gizachew and Shimelis, 2014).

2.4.3. Rainfall variability and trends

Climate variability is mainly expressed through observed changes in temperature and rainfall trends. The National Metrological Agency (2001) revealed that in Ethiopia climate variability and change in the country is mainly manifested through the variability and a decreasing trend in rainfall and increasing trend in temperature. Besides, rainfall and temperature patterns show large regional differences. Ethiopia has three rainy seasons, namely, June–September (called Kiremt), October–January (Bega), and February–May (Belg). Kiremt rains account for 50–80 percent of the annual rainfall totals over the regions having high agricultural productivity and major water reservoirs (MEF, 2015). McSweeney et al. (2008) as cited in Bewket et al. (2015). Previous studies dealing with annual and seasonal rainfall trends in Ethiopia revealed controversial results. Seleshi and Demaree (1995); Osman and Sauerborn (2002), indicated high rainfall variability and its negative trend during the main rainy season (June-September). Using data in the last half a century NMA (2001), reported a significant reduction in annual rainfall in the north, southwest part of the country while there was an increasing trend of annual rainfall in the central part of Ethiopia. Considering rainfall data of the Amhara Region (North West Ethiopia), Bewket and Conway (2007), reported inconsistent results in the annual, Kiremt and Belg rainfall trends within the stations of the region. The author noted that for the period 1975-2003, Kiremt and annual rainfall shows significantly increasing trend at Dessie and Lalibela while Debre Tabor revealed significantly decreasing rainfall trend during both seasons. On the other hand, Meze-Hausken (2004); Seleshi and Camberlin (2006); Cheung et al., (2008) did not find any significant trend over the northern and northeastern part of the country.

2.2.4. Temperature Variability and trends

Historical climate data analysis of the country shows an increase in mean annual temperature by 1.3°C between 1960 and 2006, which translates into an average rate of 0.28°C per decade. Moreover, the annual minimum temperature increased by about 0.370°C every decade between 1951 and 2006. The year-to-year variation of annual minimum temperatures expressed in terms of temperature differences from the mean and averaged very high. The minimum temperature has increased by 0.37 °C per decade between 1951 and 2006 (NMA, 2007). In the case of Ethiopia, the annual temperature has rapidly increased in the last five decades.

The mean annual temperature rose by 1.3°C or by 0.28 per decade during 1960- 2006. The frequencies of hot days and nights have also shown an increasing trend during these years. While the average number of ‘cold days’ has decreased by 5.8 % between 1960-2003, the average number of ‘cold’ nights per years has decreased by 11.2% (UNDP, 2008). In the coming 100 years, the average temperature in Ethiopia has projected to increase from 23.08 0C during 1961-1990 to 26.920C in 2070-2099 (WB, 2008). However, there is also a significant temperature difference temporally and spatially.

2.5. Impact of Land Degradation on Rural Livelihood

Land degradation poses a significant threat to rural livelihoods worldwide, particularly in agrarian economies like Ethiopia. This section explores the multifaceted impacts of land degradation on agricultural productivity, food security, and economic well-being in rural communities.

Extent of Land Degradation: Land degradation affects a substantial portion of the Earth's land area, with the majority of affected populations residing in developing countries (Gessew, 2017; Walmsley, 2002). In Ethiopia, land degradation has profound implications for both rural livelihoods and the national economy (FAO, 1986; Berry, 2003).

The loss of soil through erosion significantly diminishes agricultural productivity, reducing crop and livestock yields and necessitating increased inputs such as fertilizers (Pimentel and Burgess, 2013). Soil erosion also leads to off-site effects, including the loss of soil nutrients into water bodies, which further exacerbates agricultural challenges downstream (Woodhouse et al., 2000).

A study conducted in the Dry Zone of Myanmar revealed that highly degraded land experiences substantial reductions in crop productivity and increased cultivation costs, adversely affecting farmers' livelihoods (Tun et al., 2015). Similar challenges are faced by rural communities in

Ethiopia, where land degradation undermines agricultural productivity and exacerbates food insecurity (Peprah, 2014).

The economic consequences of land degradation are severe, particularly in sub-Saharan Africa, where a significant portion of the population relies on agriculture for their livelihoods (Peprah, 2014). In Ethiopia, soil erosion, water loss, and biodiversity decline result in substantial economic losses amounting to billions of birrs annually (Dubale, 2001; Gebreselassie et al., 2016). Rural communities in Ethiopia heavily depend on land resources for their livelihoods, with agriculture serving as the primary source of income (Tilahun et al., 2001). Land degradation, therefore, poses a direct threat to rural livelihoods by reducing agricultural productivity, degrading grazing lands, and diminishing access to essential resources like firewood (Meles, 2014).

The relationship between livelihoods and land degradation forms a vicious cycle, wherein degradation exacerbates poverty and food insecurity, leading to further land exploitation (Olsson et al., 2019). To break this cycle and achieve sustainable development, interventions must focus on integrating livelihood improvement strategies with land degradation control measures.

Land degradation jeopardizes rural livelihoods by undermining agricultural productivity, exacerbating poverty, and threatening food security. Addressing this challenge requires holistic approaches that integrate sustainable land management practices with livelihood enhancement strategies to promote resilience and sustainable development in rural communities

2.6. Land Management Practices in Ethiopia

Ethiopia has undertaken various initiatives to foster sustainable land management, although their outcomes have been diverse. This section examines the historical context of land management endeavours in the country and assesses their efficacy.

Since the 1970s, Ethiopia has implemented numerous soil and water conservation measures, but their success has been uneven. A notable challenge has been the destruction of conservation structures by farmers in many areas where soil conservation was introduced (Nurhussen, J, 1995). By 1994, only a fraction of the implemented conservation measures remained intact, indicating significant shortcomings in sustainability. In the early 1970s, initiatives supported by development food aid from organizations like USAID and the World Food Program (WFP) focused on reforestation and soil and water conservation in drought-prone regions (Nurhussen, J,

1995). By the 1980s, the WFP expanded its support to include the rehabilitation of forests, grazing lands, and agricultural areas. Concurrently, the Ethiopian government adopted the watershed or catchment approach as a central strategy for land management.

Various physical structures and conservation practices were employed as part of soil conservation activities, including farmland and hillside terracing, cut-off drains, micro-basins, check dams, water harvesting structures, reforestation, area closure, and gully rehabilitation (Betru et al., 2003). Despite these efforts, evaluations conducted up to the early 2000s revealed significant inadequacies. Only a small portion (7%) of the total land area requiring treatment had been addressed, with projections suggesting that treating the remaining land could take decades (Woldeamlak, 2003). Furthermore, the interventions were deemed ineffective, insufficient, and unsustainable, indicating the need for a reevaluation of land management strategies.

Ethiopia has undertaken considerable efforts to address soil erosion and promote sustainable land management, but the outcomes have been mixed. Challenges such as inadequate coverage, insufficient resources, and the destruction of conservation structures have hindered the effectiveness and sustainability of these initiatives. Moving forward, there is a need for more comprehensive and innovative approaches to land management to ensure long-term sustainability.

2.7. Effects of SLM technology adoption on land degradation

Sustainable Land Management (SLM) technologies play a crucial role in addressing land degradation challenges in Ethiopia. As a country highly vulnerable to soil erosion, deforestation, and desertification, Ethiopia has implemented various SLM interventions to promote soil conservation, enhance agricultural productivity, and safeguard natural resources. This literature review aims to explore the impacts of SLM technology adoption on land degradation in Ethiopia, drawing insights from existing research.

Conservation agriculture techniques, including minimum tillage, cover cropping, and crop rotation, have gained traction in Ethiopia as part of SLM initiatives. Studies such as Bekele et al. (2017) and Adimassu et al. (2017) show the positive effects of CA adoption in reducing soil erosion, improving soil fertility, and mitigating land degradation. By promoting sustainable farming practices that minimize soil disturbance and enhance organic matter content, CA contributes to long-term soil conservation and resilience against erosion risks.

Water scarcity is a critical issue in many parts of Ethiopia, exacerbating land degradation and agricultural vulnerabilities. SLM technologies focused on water harvesting and management offer promising solutions to mitigate these challenges. Research by Tessema et al. (2019) and Haile et al. (2016) assess the impacts of water harvesting techniques such as micro-catchment systems and check dams on land degradation. These studies demonstrate the effectiveness of water harvesting interventions in replenishing groundwater resources, reducing soil erosion, and supporting sustainable agriculture in water-stressed regions.

Integrated watershed management (IWM) strategies encompass a range of SLM practices aimed at holistic land and water conservation. Studies by Birhanu et al. (2020) and Lemma et al. (2018) evaluate the outcomes of IWM interventions on land degradation in Ethiopia. Through coordinated efforts involving terracing, agroforestry, soil conservation measures, and community engagement, IWM initiatives have succeeded in restoring degraded landscapes, enhancing ecosystem services, and improving livelihoods for rural communities.

Effective implementation of SLM technologies relies on supportive policy frameworks and institutional capacities. Government-led initiatives such as the Sustainable Land Management Program (SLMP) and the Climate-Resilient Green Economy (CRGE) strategy prioritize SLM interventions to combat land degradation and promote sustainable development. Research by Assefa et al. (2020) evaluates the policy implications of SLM technology adoption in Ethiopia, emphasizing the importance of stakeholder collaboration, capacity building, and adaptive management approaches.

The adoption of Sustainable Land Management (SLM) technologies has significant implications for mitigating land degradation and promoting sustainable land use practices in Ethiopia. Conservation agriculture, water harvesting, integrated watershed management, and supportive policy interventions play integral roles in enhancing ecosystem resilience, conserving natural resources, and improving livelihoods for rural communities. However, challenges remain in scaling up SLM interventions, addressing socio-economic disparities, and integrating traditional knowledge with modern technologies. Future research should focus on assessing the long-term impacts of SLM technology adoption and identifying innovative strategies to enhance their effectiveness in diverse agroecological contexts.

Chapter Three

Research Methodology

3.1. Description of the study site

This study was conducted in Legambo South Wollo Zone, Amhara Region, Ethiopia. Legambo is bordered on the south by Legahida and Kelala, on the southwest by Wegde, on the west by Borena, on the northwest by Sayint, on the north by Tenta, on the northeast by Dessie Zuria, and on the southeast by Were Ilu. Towns in Legambo include Aqesta and Embacheber. Elevations in this district range from 1500 to 4200 meters; the highest point in this district, as well as the Debub Wollo Zone, is Mount Amba Ferit, which lies on the border with Sayint. The District found between the coordinates (10°30'00" -11°0'00" N and 39°0'00" -39°15'00" E) (Figure 1).

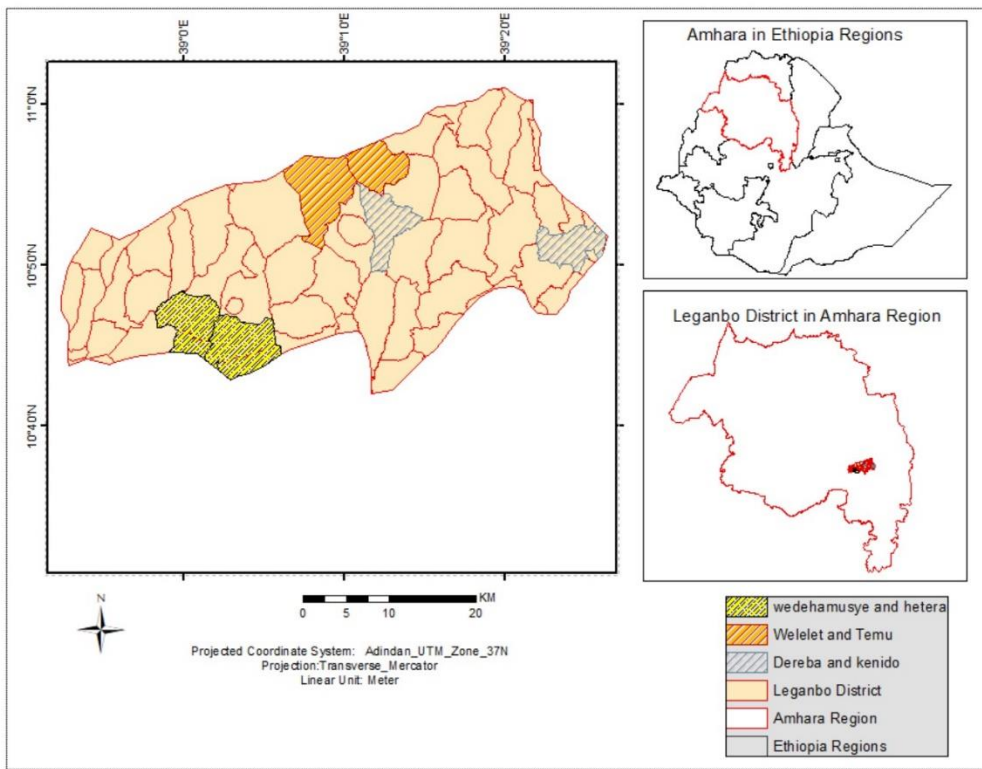


Figure 1 Location map

3.1.1. Topography and Drainage

The altitude of the Legambo 1500 and 4200 m above sea level (masl) and characterized with agro ecology types ranging from (weyna dega), and cold to very cold moist/sub moist sub afroalpine to afroalpine in parts of the highlands (dega and wurch). The major rivers are listed in

figure 1, and other small streams. These and other streams are used for both human domestic purposes and livestock drinking. However, water used for irrigation farming activity in the area is very low compared to the available water potential.

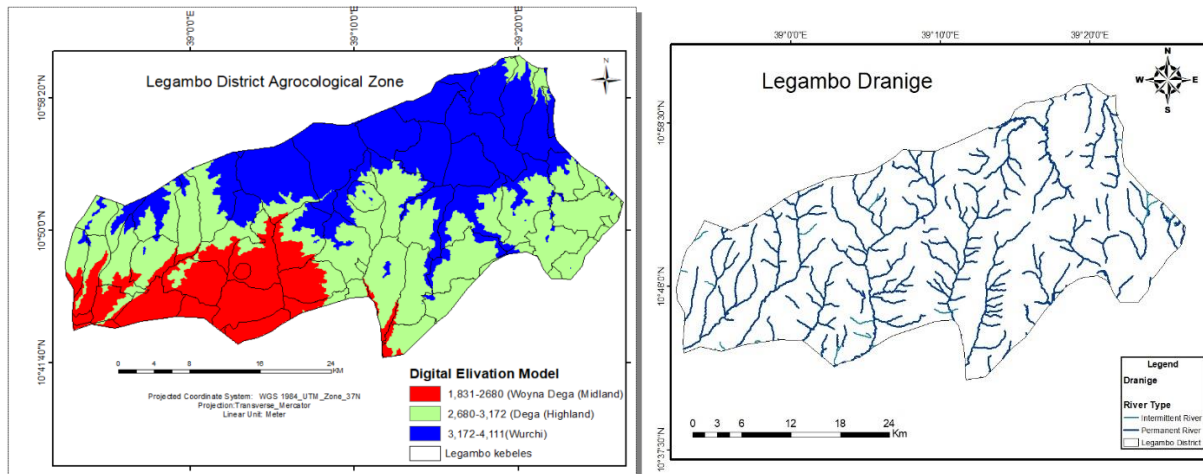


Figure 2 Topography and river maps

3.1.2. Economic activity

Rain-fed crop production supported by livestock rearing is the main economy of smallholder farmers (LWDoFED, 2022) which are both under mercy of nature. Agriculture is constrained by poor soil fertility, small per capita landholding, soil degradation, and erratic rainfall; as a result, most parts of the area are chronically food insecure (Amare et al., 2011).

Population

Base on the 2007 national census conducted by the Central Statistical Agency of Ethiopia (CSA), this district has a total population of 165,026, an increase of 3.93% over the 1994 census, of whom 81,268 are men and 83,758 women; 7,327 or 4.44% are urban inhabitants. With an area of 1,017.35 square kilometres, Legambo has a population density of 162.21, which is greater than the Zone average of 147.58 persons per square kilometre.

A total of 39,078 households were counted in this district, resulting in an average of 4.22 persons to a household, and 37,384 housing units. The 1994 national census reported a total population for this district of 158,785 in 38,182 households, of whom 78,087 were men and 80,698 were women; 4,286 or 2.7% of its population were urban dwellers.

3.2. Research Approach

For this study, a mixed methods research approach was employed. Mixed methods enable the researcher to collect both qualitative and quantitative data simultaneously or sequentially to have

the necessary data concerning the research problem under inquiry. Mixed methods provide a better solution to the problem and the research questions (Creswell, 2009; Shekhar et al., 2018).

3.3. Research design

Research design is defined as the procedure or blueprint for economical collection and analysis of data in a manner that aims to combine relevant things for the research purpose. Indeed, it is an outline of what the researcher was analysis of data to its final operational implications (Kothari, 2004). In this study, descriptive and explanatory research design was utilized. The reason for using descriptive design in this study is to describe the existing phenomenon of the situation in relation to land use land cover change and land degradation (Kothari, 2004). Explanatory type of research was also applied in this study in order to answer why certain phenomenon is happened in relation to the issue of study. Explanatory research is important to explain why a certain phenomenon is happening in a particular situation (Kothari, 2004).

3.4. Types and Sources of Data

Primary data sources: household heads, elders, community leaders, development agents, and expertise in the Legambo District is the main primary data sources for this study.

Secondary data sources: secondary data related to the study objectives was obtained from published and unpublished materials. These include information on the agroecologist of the study area, crop and livestock, demographic, meteorological, topographic maps, and vector overlays such as rivers and town's data were obtained from government offices. International rainfall data for the period 1991-2021 was obtained from the website. Likewise, Landsat images and ASTER-GDEM are downloaded from the US Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS).

3.4.1. LULC Data

The data source for the LULCC was United States Geological Survey (USGS) with <https://earthexplorer.usgs.gov/>. Four LANDSAT imagery covering: 1991 (Landsat-5 TM); 2001 (Landsat-7 ETM+), 2011 (Landsat-7 ETM+), and 2021 (Sentinel 2B) was used. The images acquired from the period January and February (mostly a clear sky season in the region) for reducing atmospheric, radiometric and phenology effects. For the study of LULC, GCPs was collected before we analyze satellite images.

3.4.2. Climate Data

Climate forcing from the baseline (1992–2022) was used to assess climate change of the study area from meteorological agency of Ethiopia. The reason to use the baseline is 1992 to analysis the climate change and variability at minimum take 30 year in a given place we can say in that area climate change is happen. The other reason there is drought season in South Wollo zone 1984 is famine year in northern part of Ethiopia so after this year to assess is there change in rainfall and temperature. In addition to the above the Environmental degradation take a long period of time for instance deforestation, land degradation (soil erosion) it recommends take for long period of satellite data.

3.5. Sampling Technique and Sample Size

To acquire data for this study was followed multistage sampling techniques and both probability and non-probability sampling techniques. In the first stage, Legambo district selected from 20 district from south wollo zone purposively, the study area is vulnerable to ecosystem services change and land degradation problem was less researched and the thematic area of the Mekedla Amba University.

Secondly, six kebeles was select from three different agro ecological zones. Accordingly, Temu and Welelet, from Wurchi, Derba and Kendio is from Dega, Wed Humusiye and Hetetera are from Weyna Dega Agro ecological zones respectively (Figure 2). In the third stage, sample household will be selected using simple random sampling technique, which gives equal chance to be selected at household level (Table 1). With the intention to select the households fill the questionnaire survey, Kothari (2004) sample size determination employ as shown below.

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq}$$

Where, n = Sample Size

Z= Standard Variation at 95 % confidence interval (1.96)

p= Sample Proportion in the target population estimated to have the characteristics being measured (0.5)

q=1-p

N= Size of the target population (2032)

e= the estimated should be within 5 % of the true value (0.05)

$$n = \frac{(1.96)^2 0.5(1-0.5)(3630)}{(0.05)^2 (3630-1) + (1.96)^2 (0.5)(1-0.5)}$$

$$\frac{227.158}{1.938} = 117.212$$

$$n = \frac{3,486.25}{10.0329}$$

$$n = 347.5 \approx 348$$

A total of 348 household heads will be sample for a questionnaire survey from the three rural *kebeles* using simple random sampling technique based on the sampling frames obtained from the rural *kebele* offices (Table.1). From these total samples, to select the desired proportional household sample from respective *kebeles*, the researcher will be employed another Kothari (2004) formula.

$$n_j = \frac{N_1 x n}{N}$$

Where, n_j = Number of samples to be selected from J stratum

N_1 = total population in strata one

N = total population of the studied area

n = selected total population

Table 1 Sample Households

Rural kebeles	Agro-ecological zones	Household head	Sample size
Temu and Welelte	Wurchi	1,289	124
Derba & Kenido	Dega	970	93
Wed Humsiye & Hetetrea	Weyna Dega	1371	131
Total		3,630	348

Note: * Obtained Depending on the above Sampling Technique

** Obtained from Basic data of *Legambo* district Agriculture Office (LWARDO, 2022).

Sampling producer

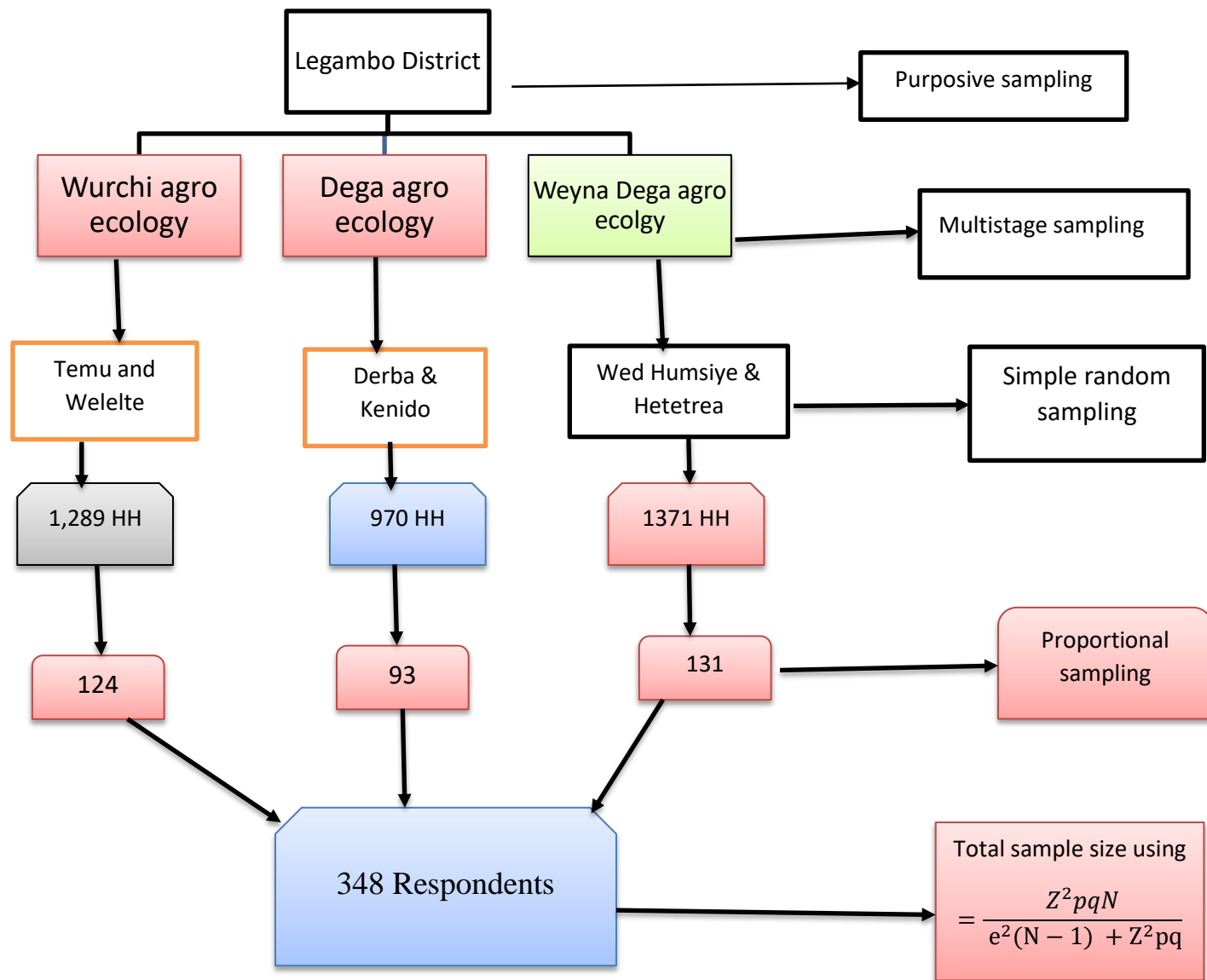


Figure 3 .Sampling producers

3.6. Data Gathering Instruments

To strength the robustness of each data gathering instrument and collect comprehensive data, we will used diverse instruments for this study.

Household Survey questionnaire

All relevant primary data about the study objectives will be collect from 348 rural households using open and close-ended questionnaires. The questionnaire has different demographic, socioeconomic, topographic, plot, infrastructure, and institutional characteristics.

Focus Group Discussion (FGD)

In this study, to triangulating quantitative data, 6 FGDs (6 in each selected kebele) was conduct with different local communities. To catch various information, FGD participants was select from different social classes based on their age, gender, and local knowledge of the study area. There is no conclusive design for the number of participants in one FGD meeting. But, the most recommended in one FGD meeting is ranged from 6 to 10 participants. Because, if the participant number is lower than 6 it may be restricting the diversity of the opinions to be offered while if it is more than 10 participants may be difficult for everyone to express their opinions broadly (Marczyk, 2005). Therefore, group members was limit from 6-10 people in this study. Translated into the local language (Amharic).

Key Informant Interview (KII)

Key informant interview was used to gather qualitative information. Using this instrument in-depth information about the processes of LULC change and drivers of change, soil erosion, soil compaction, soil drainage, soil depth reduction, and soil nutrient depletion and impact of land degradation on the rural livelihood, and land management measures, as well as its effectiveness on households' food security collected. The key informants of this study was the elderly people who lived for long years in the study area and expertise of natural resources management, crop, and livestock productivity in each selected site. For these purposes, a total of 12 key informant interviews will be conduct.

Field Observation

Field observation was applied to document some of the observable evidence of the study. This enables to observe the actual situation and current biophysical status of the land resource bases. Likewise, it enables the identification of various SLM technologies and their effectiveness across different landscape and land use types. The observation data was recorded in the form of photos and text to supplement results from other data sources.

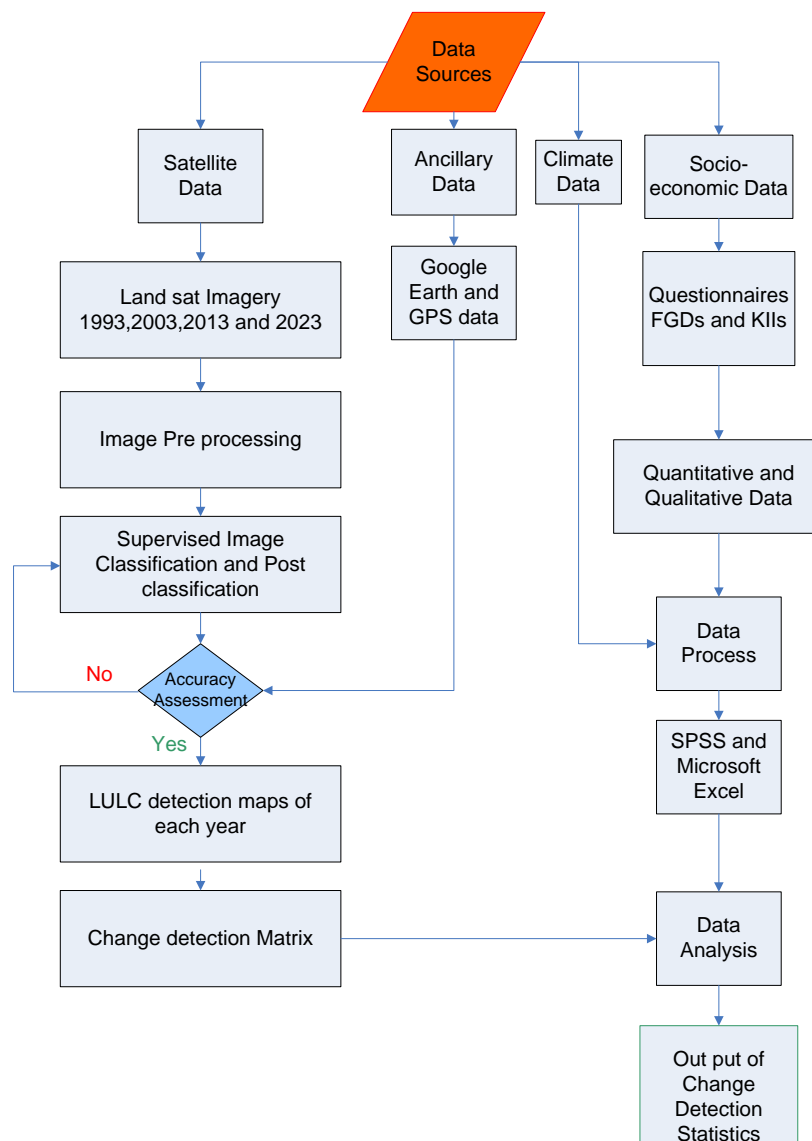
GPS Survey: A reconnaissance field survey was held using 1:50,000 topographic maps, local knowledgeable persons, and observing google earth pro map to identify major LULC types. Using the stratified random sampling technique, GCP (100 points from 30 kebele) was collect for accuracy assessment and classification purposes using a handholding GPS instrument.

3.7. Methods of Data Analysis

Qualitative data gathered from key informants, FGDs participants, and observation was used to triangulate, substitute and complement quantitative data. Also, the qualitative data was used to describe the study area composed of information gained from the secondary data sources.

Besides, Landsat imagers were analyzing using ERDAS IMGINE14, and ArcGIS10.8 software. On the other hand, quantitative data was analyzed with both basic descriptive statistics and econometric model regression techniques via SPSS 23 (Statistical Package for Social Sciences).

Descriptive statistical methods that use in this study was frequency, mean, standard devotion, and percentage. These methods were used to reveal the farm households’ key socioeconomic, demographic, institutional, and plot characteristics that determine household heads. Moreover, descriptive statistical tools were applying to compare variables of interest that include: households’ perceptions on land degradation and drivers of landscape change, and its impact on rural livelihood, the response against land degradation in the Legambo district the method of data analysis below flow chart.



3.7.1. Land use/Land cover analysis

For LULCC analysis, the two types of image processing stages (pre-processing and post processing) was employed before the actual derivation of LULC maps of the study area. In the pre-processing stage image mosaic and tinning, geometric and radiometric correction, image sub setting (masking) and unsupervised classification and collection of ground control points (thereafter GCPs) was carried out over the original Landsat images of the study area acquired in four periods of (1993, 2003, 2013 and 2023).

On the other hand, the post processing stages of image processing includes: reclassification (supervised classification), accuracy assessment, change matrix calculation and change detection. At each GCP location, GPS measurements was taken during a field work so as to verify and confirm the information gathered through remote sensing. The classified images were compared over three decades i.e. 1993-2003, 2003-2013, and 2013-2023. Change statistics was computed by comparing values of area of one data set with the corresponding value of the second data set in each period.

The values were presented in terms of hector and percentage. Quantification of the rate of change was applied to generate information about the LULC dynamics of the study area. The rate of change of each LULC can be calculated using the following formula:

Of each land use class were computed to validate the magnitude of the variations experienced between the periods using the following equations:

$$\text{Area change of land use land cover} = x_2 - x_1$$

$$\text{Percent change} = \left(\frac{x_2 - x_1}{x_1} \right) * 100$$

$$\text{Annual rate of change} = \left(\frac{\text{percent change observed}}{Y} \right)$$

Where X2= Area of final year land use land cover change.

X1= Area of initial year land use land cover change.

Y= time interval between the final and initial years

Table 2 Data sources and description

Data	Data type	Resolution(m)	Sources
Landsat image	Land use and land cover	30	USGS
Climate data	Rainfall		NMA
DEM (Digital elevation model)	Drainage, Elevation	30	USGS
Sentinel 2 Data	Land use and land cover	10	Copernicus

3.7.2. Land sat Thematic Mapper (TM) data1993

The TM sensor has a wavelength range of visible to thermal infrared in the electromagnetic spectrum and a spatial resolution of thirty meters (Raja Shekar and Mathew, 2023). Following the consideration of six TM bands (not including the thermal band) for layer stacking, TM bands 4, 3, and 2 were combined to create a conventional false-color composite image.

3.7.3. Land sat ETM+ of image 2003

Landsat 7 carried with it the introduction of the Landsat Enhanced Thematic Mapper (ETM+). ETM data span the electromagnetic spectrum's visible, near-infrared, shortwave, and thermal infrared spectral bands. The U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA) collaborated on the Landsat Project. Establishing and implementing a data acquisition approach that guarantees the repetitive acquisition of observations over the Earth's land mass, coastal limits, and coral reefs is the goal of Landsat's Global Survey Mission. enhanced Thematic Mapper (ETM), an upgraded TM sensor version. (ETC) The TM's 120 m spatial resolution is not as good as the thermal band's 60 m spatial resolution. A 15m panchromatic band is also present in the ETM. Following six bands of the (ETM+) were taken into consideration for layer composite, omitting the thermal band. (ETM+) Conventional false-color composite images were created by combining bands 4, 3, and 2. (Abebe et al., 2022)

3.7.4. Land sat 8 Data for 2013 Images

On February 11, 2013, NASA successfully launched the Landsat Data Continuity Mission. The USGS now oversees the satellite's operations, which were renamed Landsat 8. You can

download the data that Landsat 8's Thermal Infrared Sensor (TIRS) and Operational Land Imager (OLI) have been collecting since April 11, 2013. Only the very shortest wavelengths (bands 1–4 and 8) of its 11 bands can detect visible light; the remaining bands are in regions of the spectrum that are invisible to humans. Less than half of what Landsat observes is visible in real color. The images must therefore be extended and contrast-enhanced. Histogram equalization was applied to improve the image by this suggestion, and positive results were obtained. Following the consideration of seven Landsat 8 bands (except the thermal band) for layer stacking, Landsat 8 bands 5, 4, and 3 were merged to create conventional false-color composite pictures with a spatial resolution of 30 meters. (Anthony et al.,2024) .

3.7.5. Sentinel 2 Data for 2023 Images

SENTINEL-2 is a multispectral, wide-swath, high-resolution imaging mission operated by Europe. The twin satellites' entire mission specification, which calls for them to fly in the same orbit but phased at 180 degrees, is intended to provide a high revisit frequency of five days at the Equator. 13 spectral bands are sampled by the optical instrument payload carried by SENTINEL-2: four bands at 10 m, six bands at 20 m, and three bands at 60 m spatial resolution. The 290 km orbital sweep width. By continuing to supply comparable kinds of image data and contribute to continuous multispectral observations, the SENTINEL-2 twin spacecraft continue the legacy of SPOT and LANDSAT. Land management, agriculture, forestry, disaster relief, risk mapping, humanitarian aid operations, and security issues are just a few of the services and applications that Copernicus provides with the help of these satellites.(Verstraeten et al., 2024)

3.7.6. Accuracy Assessment of the Classification

The accuracy can be thought of as a measurement of the number of ground truth pixels that were successfully classified. Maps are not perfect; we must consider their accuracy and whether it is enough for the purposes for which we intend to use the data they depict (Nichol et al., 2023). The mistakes must be measured and assessed in terms of classification accuracy to use the resulting land use/cover map for additional change analysis. This makes it easier for users and readers to understand the degree of imprecision and inaccuracy involved in image classification. As a result, an accuracy evaluation was done to rate the land cover maps' quality. By constructing an error (confusion) matrix using various accuracy measurements, including the producer's accuracy, user's accuracy, and overall accuracy, the image classification results were verified. Kappa statistics were then calculated from the error matrixes. A table with columns labeling the reference (observed) classes and the row-classified (mapped) classes is the confusion matrix

3.7.7. Climate change analysis

Examining the spatiotemporal dynamics of meteorological variables in the context of changing climate is vital to assess climate-induced changes. To that end, Precipitation Concentration Index, Standardized Rainfall Anomaly, Linear Regression and Coefficient of variation will be used to analyze the climate data.

Standardized Rainfall Anomaly (SRA) values and the corresponding drought severity classes will be computed as follows:

$$SRA = (P_t - P_m) / \sigma$$

Where SRA = standardized rainfall anomaly, P_t = annual rainfall in year t , P_m = is long-term mean annual rainfall over a period of observation and σ = standard deviation of annual rainfall over the period of observation. The drought severity classes based on SRA are extreme drought ($SRA < -1.65$), severe drought ($-1.28 > SRA > -1.65$), moderate drought ($-0.84 > SRA > -1.28$), and no drought ($SRA > -0.84$).

The precipitation concentration index (PCI) will also use be as showed in De Luis *et al.* (2000):

$$PCI = 100 \times [\sum P_i^2 / (\sum P_i)^2]$$

Where: P_i = the rainfall amount of the i^{th} month; and $\sum P_i^2$ = summation over the 12 months. PCI values of less than 10 indicate uniform monthly distribution of rainfall, values between 11 and 20 indicate high concentration, and values above 21 indicate very high concentration.

Similarly, coefficient of variation (CV) was calculated to evaluate the variability of rainfall both in time and space. It is given as:

$$CV = (S / \mu)$$

Where CV= is the coefficient of variation; S= is the standard deviation, and μ = is the mean rainfall.

The Time series of mean annual maximum and minimum temperature anomalies of the study area will be analyzed based on the following equation:

$$STA = (T_t - T_m) / \sigma$$

Where: STA is standardized temperature anomaly, T_t is annual maximum/minimum temperature in year t; T_m is long-term mean annual maximum/minimum temperature over a period of observation; and σ is standard deviation of maximum/minimum annual temperature over the period of observation. Linear regression will be used to each of the grid points to detect changes or trends in rainfall and minimum and maximum temperatures. It is given as:

$$Y = mx + b$$

Where y= is dependent variable, m =is the slope, x= is independent variable and b= is the intercept.

3.8. Validity and Reliability test

Reliability and validity are ensured by pre-testing the research instrument in a pilot study.

3.8.1. Validity test

Refers to the extent to which the concept one wishes to measure is actually being measured by a particular scale or index. According to Kothari (2004), validity aims at establishing the results which are linked with the condition. It is concerned with the extent to which the scale accurately represents the construct of interest. the validity of questions prepared for primary data collection for this research objective will be checked.

3.8.2. Reliability Test

According to Kothari (2004), reliability is the consistency with which a measuring instrument yields a certain result when the entity being measured has not changed. The reliability of research instrument was tested using cronbach alpha method. Cronbach's coefficient alpha is the most common measure of internal consistency of research instrument. Zikmund et al., (2013) noted that the research instruments with coefficient alpha between 0.60 and 0.699; 0.70 and 0.799, and above 0.80 are respectively considered to have fair, good, and very good reliability. The SPSS output was summarized in Table 2 below. The reliability measure shows that the coefficient alpha result (.879) was between .818 and .907. This suggested that the reliability of the instrument of this study was signified to be good so that the items of the questionnaires were accepted.

Table 3 **Reliability Statistics**

Variable	Scale Mean if Item Deleted	Cronbach's Alpha if Item Deleted	Total Reliability Statistics
Land Productivity status	19.6722	.907	.879
Cause of decline productivity	17.2663	.825	
Driving force for LULCC	17.0451	.828	
Impact of land degradation on livelihood	17.0624	.823	
Sustainable land management constraints	17.1856	.868	
Livelihood Vulnerable	19.4883	.897	
Conservation of land degradation	17.0500	.818	

Source: survey result, 2023

3.9 Ethical Consideration

In research, ethical consideration is one of the most important points that deserve attention. This is mainly due to:

- ✎ The necessity to strictly respect the consent of the participant whether they are willing to participate in the research or not. Likewise, it is to assure to the subjects of the study that they are free to withdraw from participating in the study whenever they found it necessary;
- ✎ The necessity to protect subjects of the study from possible dangers that might be encountered;
- ✎ Confidentiality, the actual names of participants in the study are kept secret while the sex or age of respondents might be used where it seems appropriate.

Therefore, those are the researcher going to assure the respondents in which the research is strictly governed by the above ethical principles during data collection.

CHAPTER FOUR

4. Result and Discussion

The main objective of this study was assessing Land use Land, Cover Change Analysis and Land Degradation using Geospatial tools in the case of drought prone area Legambo District, Ethiopia. The collected data from respondents was analyzed and interpreted in order to achieve the ultimate objective of the study using both quantitative and qualitative analysis, which also involves descriptive analysis employed to investigate the Land use Land, Cover Change Analysis and Land Degradation using Geospatial tools in the case of drought prone area Legambo district, Ethiopia. To analyze the collected data in line with the overall objective of the research, statistical procedures were carried out using SPSS version 23. The Satellite image data analysis using ERDIS14 and ARC GIS 10.8.

Response Rate

Response rate refers to the number of questionnaires completed and returned from the respondents divided by the number distributed to respondents and multiplied by 100 in doing so 90.22% collected from respondents, 348 questionnaires were distributed to household out of which 314 were completed and returned. 34 questionnaires rejected due to incomplete and inconsistency.

4.1. Socio demographic of characteristics Respondents

4.1.1. Gender of respondents

Regarding the gender category, among 314 of the total respondents, 59.9% respondents were male and the remaining respondents of 40.1% were female. This shows that the majority of Male respondents were higher than the female respondents figure 4.

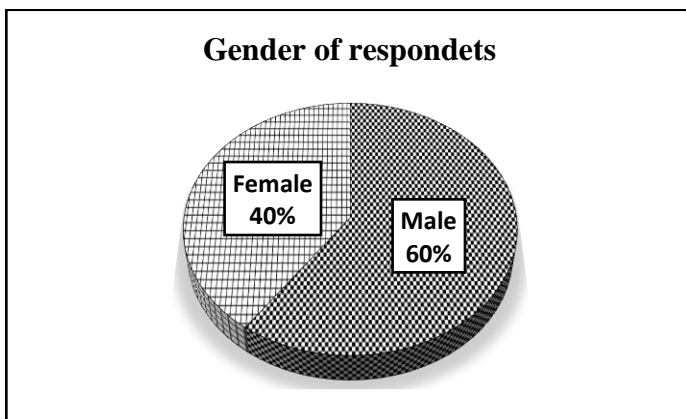


Figure 4. Gender of respondents

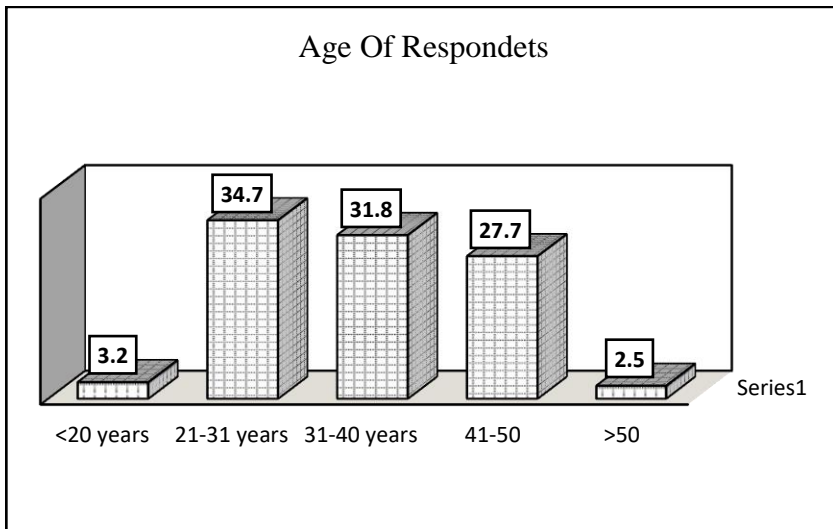
Source: Survey result, 2023

4.1.2. Age of respondents

According to the figure 5 age category, respondents, 34.7 % were found to have an age interval between 31 and 40 years, 31.8 % respondents were found to have an age interval between 21 and 30 years, 27.7% respondents were found to age interval between 41 and 50 years and 3.2 % respondents were found age interval between < 20 year and >50 years 2.5 % of the respondents were found age above 50 years old. According to Santrock (2011), age group categorization from 20-40 young, 41-65 adult and >65 are elders.

The categorization of age groups into young, adult, and elder categories suggests that different age may have varying perspectives, priorities, and approaches to land management. For instance, older farmers may rely more on traditional farming practices passed down through generations, while younger farmers may be more open to adopting modern agricultural technologies and practices (Wubneh and Beshir, 2018). Understanding these differences in perspectives is essential for designing targeted interventions and policies to address land degradation and promote sustainable land management practices.

The significant proportion of respondents in the age range of 21-40 years suggests that a large portion of the agricultural workforce consists of young individuals. This aligns with findings from studies in Ethiopia, such as Abera et al. (2017), which indicate that youth participation in agriculture is increasing due to factors such as limited off-farm employment opportunities and the need for livelihood diversification. However, the involvement of young farmers may also indicate a lack of experience and traditional knowledge, potentially influencing land management practices in ways that contribute to land degradation (Mekuria and Aynekulu, 2013).



Source: Survey result, 2023

Figure 5 Age of respondents

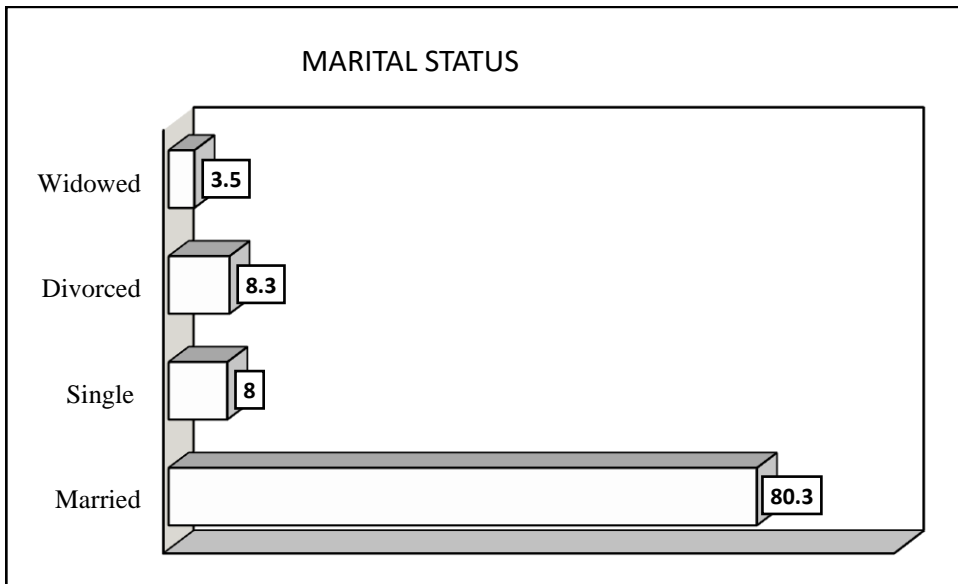
The majority of respondents (66.5%) age interval between 20 and 40 young and reproductive age and the second respondent's age interval between 41-50 years 30.2 % of respondents were adult This shows that all respondents were mature enough to give relevant information and understand land use land, cover change analysis and land degradation in the case of drought prone area Legambo district, Ethiopia.

4.1.3. Marital status

Regarding to the marital status of the respondents, as indicated in the figure 6 below 80.3% of respondents were married. Married individuals often form households that engage in various land use activities such as agriculture, grazing, and settlement. Study by Bekele and Drake (2003) in Ethiopia found that stable marriages contribute to cohesive household units, which are more likely to adopt sustainable land management practices and mitigate land degradation.

8 % of respondents were unmarried, 8.3 % of respondents were divorced 3.5 % respondents were windowed because of different socio economic and cultural factors. Study by EDHS (2012), showed an 11% divorce or widow situation at national level. Figure 6 showed that there is a stable marriage situation in the study area.

Marital status influences household economic stability, which in turn affects investments in land improvement and conservation measures. A study by Alemu et al. (2017) in Ethiopia found that stable marriages are associated with better economic outcomes, enabling households to invest in sustainable land management practices and cope with environmental challenges.



Source: Survey result, 2023

Figure 6 Marital Status

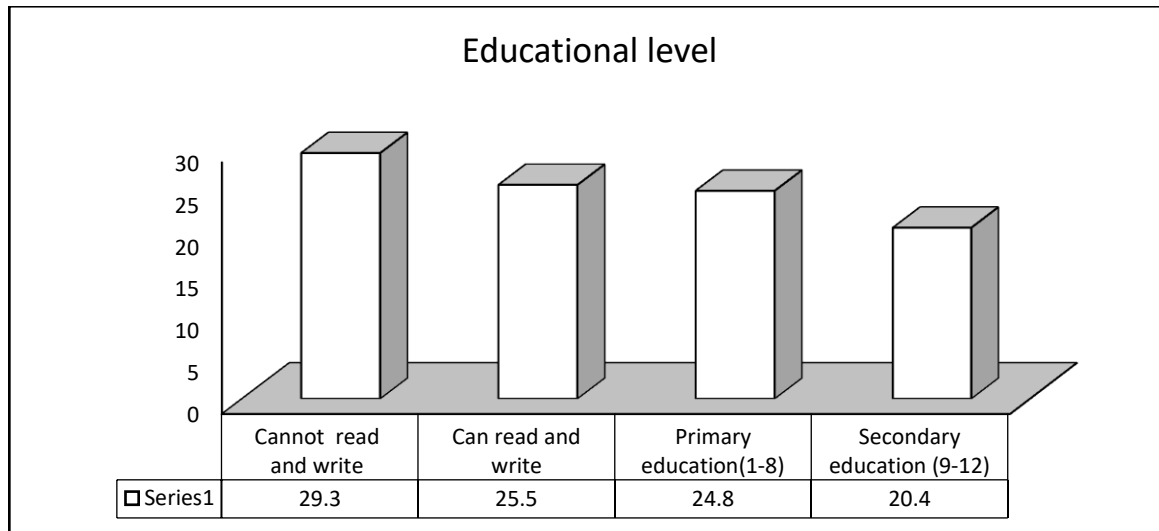
4.1.4. Educational Level of Respondents

Respondents were given answers to the question of education level they have to establish the level of understanding the land use land, cover change analysis and land degradation in the study area. Figure 7 shows that respondents 29.3 % were cannot read and write, 25.5 % were read and write 24.8 % were primary school (1-8 grade), and the remaining 20.4 % of respondents were secondary education (9-12 grade). The majority (70.7 %) of respondents were able to read and write therefore, it is reasonable to suggest that more of the educated respondents could justify the causes land degradation, impact of land degradation, conservation mechanism to prevent land degradation in the study area and better understanding the problems.

A study by Mekonnen and Kassa (2019) assessed the impact of education on land management practices in the highlands of Ethiopia. The study found that respondents with higher levels of education were more likely to adopt sustainable land management practices, such as soil conservation and agroforestry, compared to those with lower levels of education. This suggests that education can enhance the understanding of land use dynamics and promote more sustainable land management practices.

Similarly, a study by Abate et al. (2018) investigated the relationship between education and awareness of environmental issues among rural communities in Ethiopia. The study found that respondents with higher levels of education were more aware of the impacts of land degradation and were more likely to engage in conservation activities. Education was identified as a key factor in shaping attitudes and behaviors towards the environment.

Furthermore, a study by Tesfaye et al. (2017) examined the role of education in mitigating land degradation in the Ethiopian highlands. The study found that education not only increased awareness of environmental issues but also empowered communities to implement sustainable land management practices. Education was identified as a critical factor in building the capacity of communities to address land degradation and adapt to environmental changes.



Source: Survey result, 2023

Figure 7 Educational level

4.1.5. Family size of respondents

According to the respondent responses about 46.8 % in the study area had a family size between 3-5 family size, followed by 6-8 family size. 37.3 % of respondents, 12.4 % of respondents having greater than eight family sizes. The remaining 3.5 % of respondents having less than 3 family size. The majority (84.1 %) of respondents in the study area having the family size between 3-8 families this indicate that in the area lack of use family planning and the perception of respondents were having more children has source of wealth (figure 8).

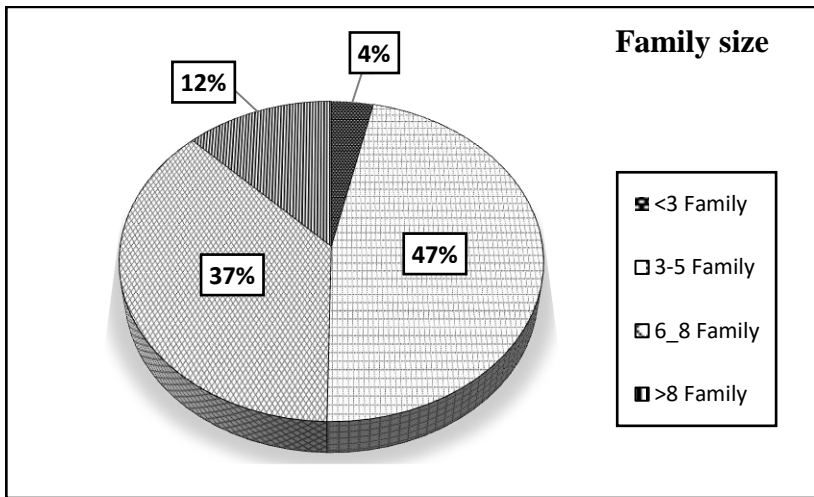
The lack of family planning, as indicated by the majority of respondents having larger family sizes, suggests a need for interventions to promote sustainable land management practices and population control measures. Encouraging smaller family sizes through education, access to contraception, and awareness campaigns can help alleviate the pressure on land resources and mitigate the adverse impacts of population growth on the environment.

Increased pressure on land resources due to larger family sizes can contribute to land degradation. Overgrazing, intensive agricultural practices, and deforestation are common consequences of population pressure on land. This can lead to soil erosion, loss of soil fertility, desertification, and ultimately, reduced productivity of land for agriculture and other purposes.

Study conducted by Teshome et al. (2018) examined the impact of population growth on land use change and land degradation in the Lake Tana Basin of Ethiopia. The study found that rapid population growth, driven by larger family sizes, has led to increased demand for agricultural land, resulting in deforestation, soil erosion, and loss of soil fertility. Overgrazing and intensive agricultural practices were identified as major drivers of land degradation in the region.

Similarly, another study by Assefa et al. (2017) investigated the relationship between population dynamics and land degradation in the Ethiopian highlands. The study highlighted the role of larger family sizes in exacerbating land degradation through unsustainable land use practices such as deforestation, overgrazing, and soil erosion. The authors emphasized the importance of promoting family planning and sustainable land management practices to address the issue.

Furthermore, a study by Hassen et al. (2016) focused on the impact of population pressure on land resources and land degradation in the Bale Mountains Eco-region of Ethiopia. The study identified rapid population growth, characterized by larger family sizes, as a significant driver of land degradation, leading to soil erosion, loss of soil fertility, and desertification. The authors underscored the need for integrated approaches that combine family planning initiatives with sustainable land management strategies to mitigate the adverse impacts of population growth on the environment.



Source: Survey result, 2023

Figure 8 Family size

4.2. Economics characteristics of respondents

Mixed agricultural farming practice is the major livelihood sources undertaken in the study areas. However, this sector is vulnerable with rapid reduction of grazing land, land fragmentation, high input price, rainfall variability and drought. Major of the (90.1 % of respondents) in study area were as elsewhere in Ethiopia depends on rain fed agriculture. In Ethiopia, rain-fed agriculture is vulnerable to climate variability and drought, leading to soil degradation and reduced crop yields (Ayalneh et al., 2017). Soil erosion and nutrient depletion are common challenges associated with rain-fed farming practices, contributing to land degradation (Mengistu et al., 2019). (9.9 % of respondents) practice both rain feed and irrigated agriculture table 3. Irrigation can enhance agricultural productivity and mitigate the impact of climate variability on crop production, thereby reducing land degradation (Legesse et al., 2019). However, improper irrigation practices, such as waterlogging and salinization, can exacerbate soil degradation and ecosystem disruption (Abegaz et al., 2020).

4.2.1. Land holding size and land use

Landholding size under subsistence agriculture plays a significant role in the household food security situation. According to FAO (2009), the size of the land in agriculture influences household livelihood. According to Degefa (1996), those who have land size of <2-hectare, 2-4 hectare and >4 hectare was categorized under small, medium and high land holding size

respectively. As shown below in table 3. Over half (53.5%) of respondents have land holdings smaller than 1 hectare. Small landholdings often result in intensive cultivation practices, leading to soil erosion, nutrient depletion, and land degradation (Gebrehiwot et al., 2019). Limited access to land and resources exacerbates poverty and food insecurity among smallholder farmers, driving further land degradation (Nyssen et al., 2019).

Nearly 40% of respondents have land holdings ranging from 1.1 to 3 hectares. Moderate-sized farms may adopt more sustainable land management practices compared to small-scale farms, but still face challenges related to soil erosion and degradation (Alemayehu et al., 2018). A small proportion (7.1%) of respondents' own land holdings larger than 3.1 hectares. Large-scale farms may implement mechanized farming practices, which can contribute to soil compaction and degradation if not managed properly (Gebremichael et al., 2020). However, larger farms may also have the resources to invest in conservation measures and sustainable land management practices.

4.2.2. Land productivity and fertility

The respondents were asked to identify the general fertility status of their farm plots. Fertility status of farm plot is determining factor for agricultural productivity and livelihood of households. 42.4% of respondents indicate that their farmland has low fertility. Low soil fertility limits agricultural productivity and exacerbates land degradation, especially in areas with intensive farming practices (Adugna et al., 2016). Soil fertility decline is often associated with nutrient depletion, erosion, and inadequate soil management practices (Beshir et al., 2017). The majority (53.8%) of respondents report medium fertility status of their farmland. Medium fertility soils require sustainable management practices to maintain productivity and prevent degradation, such as organic matter addition and crop rotation (Hagos et al., 2020). Only 3.8% of respondents perceive their farmland to have high fertility. High fertility soils are crucial for sustaining agricultural productivity and reducing pressure on marginal lands prone to degradation (Yitaferu et al., 2017). Conservation agriculture practices can help preserve soil fertility and enhance the resilience of high fertility soils to degradation (Taddese et al., 2018) table 3.

Table 4 economic activities of respondents

Type of agricultural activities		Frequency	Percent
1.	Rain fed agricultural	283	90.1
2.	Both agriculture rain fed and irrigation	31	9.9
	Total	314	100
Land holding size			
1.	<1 hectars	168	53.5
2.	1.1 -3 hectars	124	39.4
3.	>3.1 hectars	22	7.1
	Total	314	100.0
The Fertility status of farm land			
1.	Low	133	42.4
2.	Medium	169	53.8
3.	High	12	3.8
	Total	314	100
Productivity of farm land			
1.	Increasing	87	27.7
2.	Decreasing	148	47.1
3.	Constant	79	25.2
	Total	314	100.0

Source: Survey result, 2023

According to the respondents, show in Table 3 about 27.7% of respondents observe increasing productivity of their farmland. Increasing productivity indicates successful implementation of sustainable land management practices, which improve soil health, water management, and crop yields (Birhanu et al., 2020). Nearly half (47.1%) of respondent's report decreasing productivity of their farmland. Declining productivity suggests the prevalence of land degradation processes such as soil erosion, nutrient depletion, and waterlogging, which hinder agricultural development (Kassahun et al., 2019). 25.2% of respondents perceive their farmland productivity to be constant. Maintaining constant productivity requires continuous investment in sustainable land management practices and adaptation to changing environmental conditions (Getachew et al., 2021).

The data shown in table 3 suggests that dominance of rain-fed agriculture, coupled with small landholdings and varying fertility levels, poses significant challenges for land degradation in Ethiopia. Soil erosion, nutrient depletion, and declining productivity threaten food security and

livelihoods, particularly among smallholder farmers. Sustainable land management practices, including soil conservation, water harvesting, and agroforestry, are essential for mitigating land degradation and promoting resilient agricultural systems in Ethiopia. Policy interventions and targeted support programs are needed to address the underlying drivers of land degradation and enhance the sustainability of agricultural production systems across different agro-ecological zones in Ethiopia.

4.2.3. Cause of decline productivity of farmland

There are many reasons that the declining of land productivity those categories in to two that is manmade and natural cause. According to the survey result, (table 4)100 % of total sample respondents land productivity decrease due to soil erosion. Soil erosion leads to the loss of topsoil, reducing soil fertility, and compromising soil structure and water retention capacity. This can result in reduced agricultural productivity, increased sedimentation in water bodies, and ecosystem degradation. In Ethiopia, soil erosion is widespread due to factors such as deforestation, overgrazing, and unsustainable farming practices (Hassen et al., 2014). Soil erosion leads to loss of topsoil, reduced soil fertility, and land degradation, affecting agricultural productivity and food security (Megersa et al., 2020). rainfall variably (94.9% respondents) are the major problem in decline land productivity the study area. Climate change exacerbates rainfall variability, leading to droughts or floods, which impact crop yields and livelihoods (Tekle et al., 2017). Farmers struggle to adapt to unpredictable weather patterns, resulting in crop failures and reduced agricultural productivity (Mekuria et al., 2018). Like in most rural parts of Ethiopia, the source of livelihood in the study area (Legambo Districts), is agriculture. Erratic rainfall results soil erosion and nutrients depilation, which have also long terms agricultural impact.

Inadequate soil fertility limits crop growth and yields, leading to reduced agricultural productivity. This can result from nutrient depletion, soil acidification, and soil compaction, among other factors, contributing to land degradation (Alemu et al., 2018). Decrease soil fertility through soil erosion and this eventually leads to decrease in crop yield and vulnerable their livelihood.

Table 5 cause of declining productivity

No	Cause of decline productivity	Response	Yes	No	Total	Rank
1.	Soil erosion	Frq.	314	-	314	1 st
		%	100	-	100	
2.	Rainfall variability	Frq.	298	16	314	3 rd
		%	94.9	5.1	100	
3.	Poor soil fertility	Frq.	303	11	314	2 nd
		%	96.5	3.5	100	
4	Water logging	Frq.	242	72	314	5 th
		%	77.1	22.9	100	
5	High concentration of stones	Frq.	266	48	314	4 th
		%	84.7	15.3	100	
6	Wildlife attack	Frq.	222	92	314	6 th
		%	70.7	29.3	100	

Source: Survey result, 2023

The other reason when the respondents were asking for decrease of land productivity is High concentration of stones (84.7%) of respondents. water logging and wildlife attack were the cause of land productivity declining 77.1 % and 70.7 % of respondents were agree respectively. Waterlogging restricts oxygen availability to plant roots, leading to reduced crop growth and yield. It can also exacerbate soil erosion and nutrient leaching, contributing to land degradation (Beyene et al., 2016)).

The identified causes of declining productivity in Ethiopia are closely linked to land degradation processes, including soil erosion, soil fertility depletion, and waterlogging. Land degradation reduces the capacity of ecosystems to support agriculture, exacerbating food insecurity and poverty in rural communities (Tekle et al., 2017). Sustainable land management practices, such as agroforestry, soil conservation, and water management, are essential for mitigating land degradation and improving agricultural productivity in Ethiopia (Megersa et al., 2020). Addressing these causes requires integrated approaches that consider socio-economic factors, environmental conservation, and climate resilience strategies to promote sustainable land use and enhance rural livelihoods in Ethiopia

4.2.4. Livelihood vulnerability

Livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. This livelihood is vulnerable by differ factors like drought; flood; Food inadequacy; Shortage of farm land in the study area .Drought affects 96.5% of livelihoods, ranking first among vulnerability factors (table 5). Drought-induced soil moisture deficits reduce vegetation cover and biomass production, increasing susceptibility to erosion and land degradation (Taddese et al., 2019). Land degradation aggravates the impacts of drought by reducing soil water retention capacity and exacerbating water scarcity for agricultural activities (Temesgen et al., 2018). In Ethiopia studies conducted following the 1984 “Ethiopian famine” that affected almost all part of the country particularly in the study area.

Food inadequacy affects 91.7% of livelihoods, ranking second among vulnerability factors. Insufficient food availability and access can drive unsustainable land use practices, such as deforestation and overgrazing, as households seek alternative sources of income and food (Tesfaye et al., 2019). Land degradation exacerbates food insecurity by reducing agricultural productivity and compromising the resilience of rural communities to climate shocks (Kassie et al., 2017). The majority of respondents were participating in to productive safe tent program.

Shortage of animal feed affects 83.4% of livelihoods, ranking third among vulnerability factors. Overgrazing and unsustainable livestock management practices worsen land degradation by compacting soils, accelerating erosion, and depleting vegetation cover (Gebremedhin et al., 2019). Integrated crop-livestock systems and sustainable pasture management are essential for mitigating land degradation and ensuring food security (Mulugeta et al., 2020).

Shortage of farm land affects 82.5% of livelihoods, ranking fourth among vulnerability factors. Land scarcity forces farmers to intensify cultivation on limited land, leading to soil erosion, nutrient depletion, and degradation of marginal lands (Birhanu et al., 2018). Land fragmentation due to population pressure further exacerbates land degradation by reducing the effectiveness of soil and water conservation measures (Tefera et al., 2020).

Table 6 Livelihood vulnerable

No	Livelihood vulnerable by		Yes	No	total	Rank
1	Flood	Frq.	214	100	314	5 th
		%	68.2	31.8	100	
2	Food inadequacy	Frq.	288	26	314	2 nd
		%	91.7	8.3	100	
3	Shortage of farm land	Frq.	259	55	314	4 th
		%	82.5	17.5	100	
4	Drought	Frq.	303	11	314	1 st
		%	96.5	3.5	100	
5	Shortage of animal's feed	Frq.	262	52	314	3 rd
		%	83.4	16.6	100	
6	Price fluctuations for agricultural products	Frq.	198	116	314	6 th
		%	63.1	36.9	100	

Source: Survey result, 2023

Flooding in Ethiopia is mainly occurred by heavy rains and the topography of the highlands and lowlands, which are connected by natural drainage systems created by the major river basins. Floods can lead to soil erosion, sediment deposition, and waterlogging, resulting in crop damage and loss of agricultural productivity. Floods affect 68.2% of livelihoods, ranking fifth among vulnerability factors. In Ethiopia, floods can cause soil erosion, sedimentation, and land degradation, particularly in low-lying areas and river basins (Mengistu et al., 2020). Soil erosion caused by floods leads to loss of fertile topsoil, decreased agricultural productivity, and increased sedimentation in water bodies (Gebremedhin et al., 2018).

Price fluctuations for agricultural products are identified as a cause of declining productivity by 63.1% of respondents. Price fluctuations can affect farmers' income and profitability, influencing their land use decisions. For example, farmers may switch to more profitable crops or adopt agroforestry practices to diversify income sources and mitigate economic risks (Mulugeta et al., 2020)

One of FGDs members in Kola agro ecological zone stated “our land is fertile, during good season farmers produce different crops like wheat, tiff, sorghum and others crops. In such seasons, in the area market became full of various food crops, traders from town and other place used to come and purchased our products. However, what always surprises me is that during drought seasons/years when intense crop failure occurred, no enough crops available in local market and no trends of bringing food crops from other market to our market. Because of this, we have been forced travel to 4 -6 hours town to buy food crops which exposed us for high costs”

4.3. Land Use/Land Cover Change

Legambo District 's land use and land cover changes were studied through the analysis of satellite images taken in 1993, 2003, 2013, and 2023. To analyze the changes in land use and land cover in the study area, 1993 was used as the base year. Settlement (S), Vegetation(V), Agricultural Land (AL), Bare Land (BL), and Waterbodies (WB) are the main land use land cover classification (LULC) classifications for the study periods, as shown in the classification scheme. The classified images were taken during the dry season, to reduce atmospheric and radiometric effects.(Raja Shekar and Mathew, 2023).

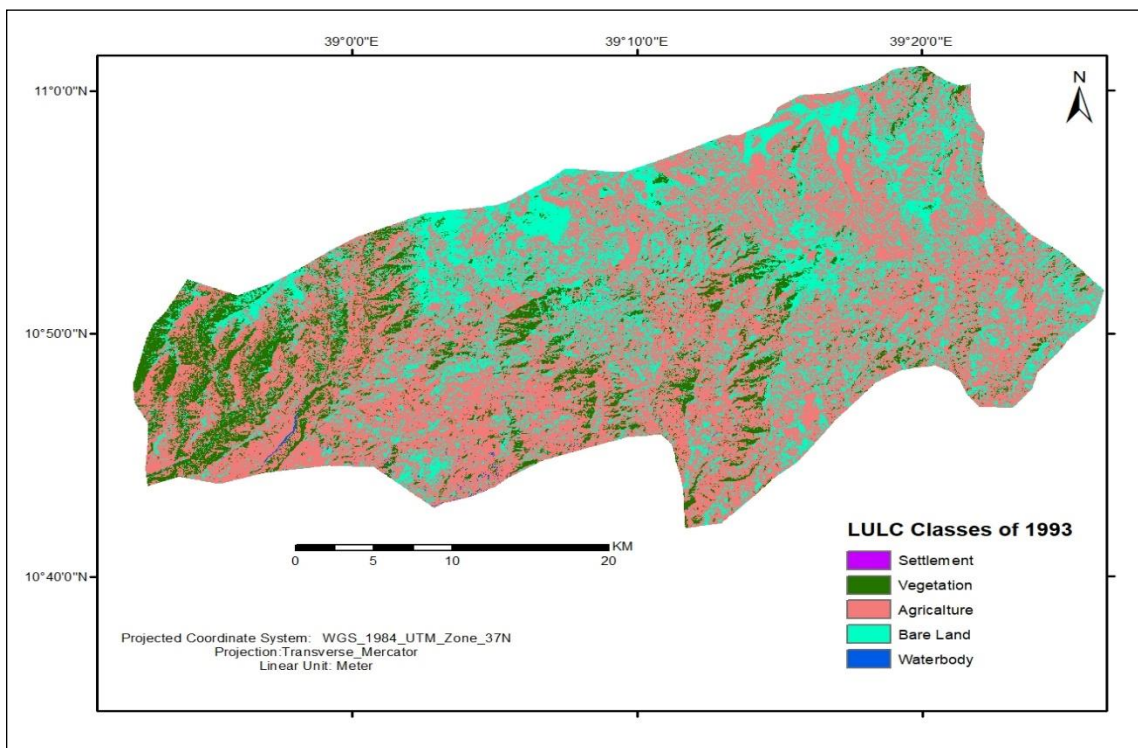


Figure 9 Land use land cover Map of Legambo district in 1993

The land use and land cover (LULC) classes distribution of Legambo district in 1993 provides valuable insight into the spatial patterns of land use and how it has changed over time (Figure 9)

Table 6 presents the classification result of the land sat 1993 image. It indicates that the majority of the land in the districts is agricultural land, 59.98 % share of total area. Agriculture dominates the land of Legambo district, covering almost 60 % of the total area. This indicates a heavy reliance on agriculture for livelihoods in the area. However, extensive agricultural practices, such as slash-and-burn cultivation or monocropping, can degrade soil fertility and contribute to land degradation. Tesfaye et al. (2018) conducted a study on sustainable land management practices in Ethiopia, emphasizing the importance of soil conservation and agroforestry to mitigate land degradation.

Bare land follows with 28.22 % share of total area, the high percentage of bare land suggests that a significant portion of the land may be experiencing land degradation or desertification processes. A study by Bewket and Teferi (2009) investigated the drivers of land degradation in Ethiopia's highlands, highlighting the role of population pressure, agricultural expansion, and deforestation.

Table 7 Land use land cover Classes Distribution of Legambo district in 1993

No.	LULC Type	1993	
		Area (ha)	Area (%)
1	Settlement	23.65	0.02
2	Vegetation	13904.29	11.62
3	Agriculture	71797.09	59.98
4	Bare Land	33780.26	28.22
5	Waterbody	188.1	0.16
	Total	119693.4	100

Source: from satellite imageries, 1993 analysis

Vegetation includes forests, woodlands, and natural vegetation cover land 11.62 % share of total area, the relatively low percentage of vegetation cover indicates potential deforestation, land degradation, or conversion of natural habitats for agricultural purposes. Deforestation can lead to biodiversity loss, soil erosion, and decreased ecosystem services. Study by Alemayehu et al. (2018) emphasized the need for conservation efforts and sustainable land management practices to mitigate deforestation in Ethiopia.

Waterbodies 0.16 % share of total area it represents natural water bodies such as rivers, lakes, or wetlands. The small percentage indicates limited water resources within Legambo district. Sustainable water management is crucial for agricultural productivity, ecosystem health, and human well-being. A study by Mekonnen et al. (2020) assessed the impacts of climate change on water resources in Ethiopia, emphasizing the need for adaptive water management strategies. Settlement 0.02% share from total area. The represents urban and built-up areas. The small percentage suggests that urbanization was limited in Legambo district in 1993. However, it's essential to monitor urban expansion over time, as rapid urbanization can lead to land degradation and loss of agricultural land. A study by Ayele et al. (2019) on urban expansion in Ethiopia found that rapid urban growth has led to land use changes and environmental challenges.

The LULC data for Legambo district in 1993 reflects the dynamic interactions between human activities and the environment, highlighting the importance of sustainable land management practices, conservation efforts, and policy interventions to promote environmental sustainability and enhance resilience to environmental change in the region.

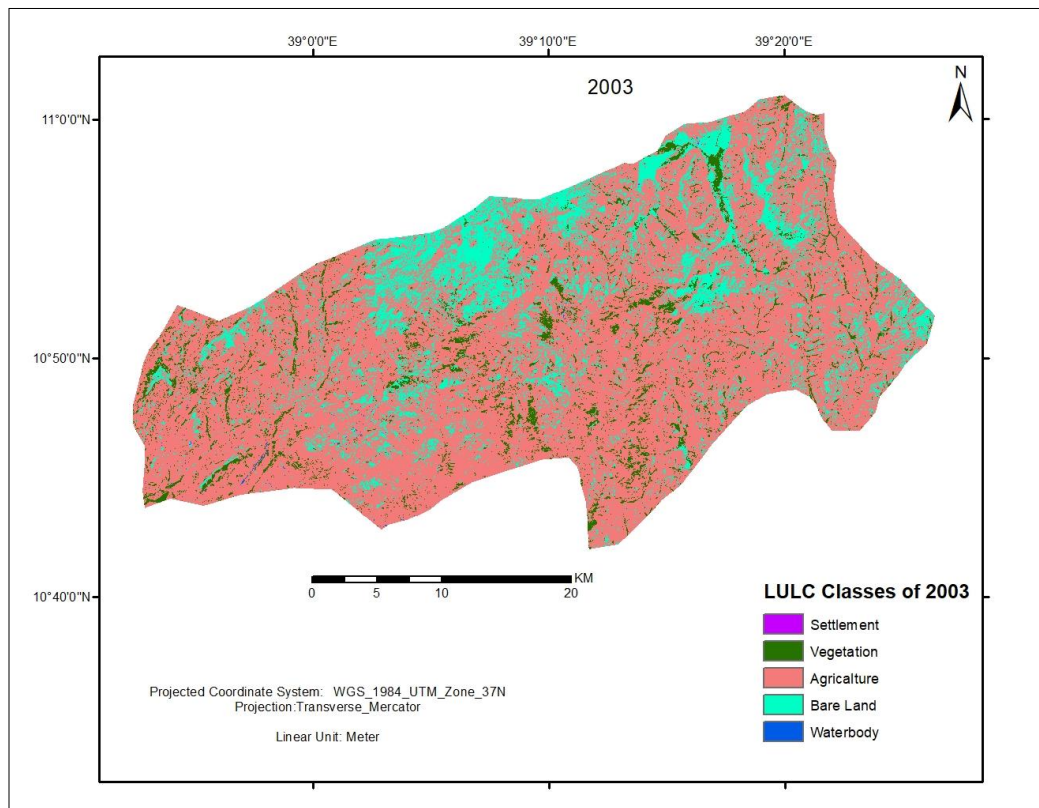


Figure 10 Land use land cover Map of Legambo district in 2003

The land use and land cover (LULC) distribution data for Legambo district in 2003 reveals significant changes in the landscape compared to the distribution in 1993.

As shows in Table 7 above for the land sat ETM+ 2003 image, 76.27 % of the total land area was set up for agriculture. Agriculture continues to dominate the landscape, occupying the majority of the total area. The increase in agricultural land reflects the expansion of farming activities to meet growing food demands. However, intensive agricultural practices can lead to soil erosion, loss of soil fertility, and water pollution. A study by Tilahun et al. (2019) assessed the impacts of land use changes on soil erosion in Ethiopia, highlighting the need for soil conservation measures and agroecological practices to sustain agricultural productivity.

Table 8. Land use land cover Classes Distribution in 2003

No.	LULC Type	2003	
		Area (ha)	Area (%)
1	Settlement	52.12	0.04
2	Vegetation	7870.46	6.58
3	Agriculture	91289.81	76.27
4	Bare Land	20433.32	17.07
5	Water body	49.14	0.04
	Total	119694.9	100

Source: from satellite imageries, 2003 analysis

There is a decrease in the amount of bare land 17.07 % of total area. The significant proportion of bare land suggests ongoing land degradation processes, such as soil erosion, desertification, or overexploitation of natural resources. Land degradation poses threats to food security, livelihoods, and ecosystem resilience. Study by Mulugeta et al. (2017) investigated the drivers and impacts of land degradation in Ethiopia's drylands, emphasizing the importance of integrated land management approaches and community participation in land restoration efforts.

The vegetation covering 6.58 % share of total area there is a decreasing trend to compare 1993. The decrease in vegetation cover indicated deforestation, land degradation, or conversion of natural habitats for agricultural purposes. Deforestation is a significant concern in Ethiopia due

to its impacts on biodiversity, carbon sequestration, and ecosystem services. Study by Tadesse et al. (2016) examined the drivers of deforestation in Ethiopia and underscored the importance of conservation measures and sustainable land management practices to protect remaining forest ecosystems.

The waterbodies area has cover 0.04 % of the total area. The small percentage of water bodies shows the limited availability of surface water resources in the study area. Access to clean and reliable water sources is crucial for agriculture, human health, and ecosystem functioning. A study by Alemayehu et al. (2020) examined water resource management challenges in Ethiopia and shows the need for integrated water management strategies to address water scarcity and ensure sustainable water use.

Settlement's area covers 0.04 % of the total area. The slight increase in settlement area indicates urban expansion or infrastructure development. Urbanization can lead to land fragmentation, loss of natural habitats, and changes in hydrological patterns. A study by Gebrehiwot et al. (2018) investigated the impacts of urban expansion on land use and land cover changes in Ethiopia, emphasizing the need for sustainable urban planning to mitigate environmental degradation.

The analysis of LULC distribution in Legambo district in 2003 reveals significant changes in land cover types and this indicate the complex interactions between human activities and the environment. Sustainable land management practices, conservation efforts, and policy interventions are essential to address land degradation, promote biodiversity conservation, and ensure the long-term sustainability of natural resources in Ethiopia.

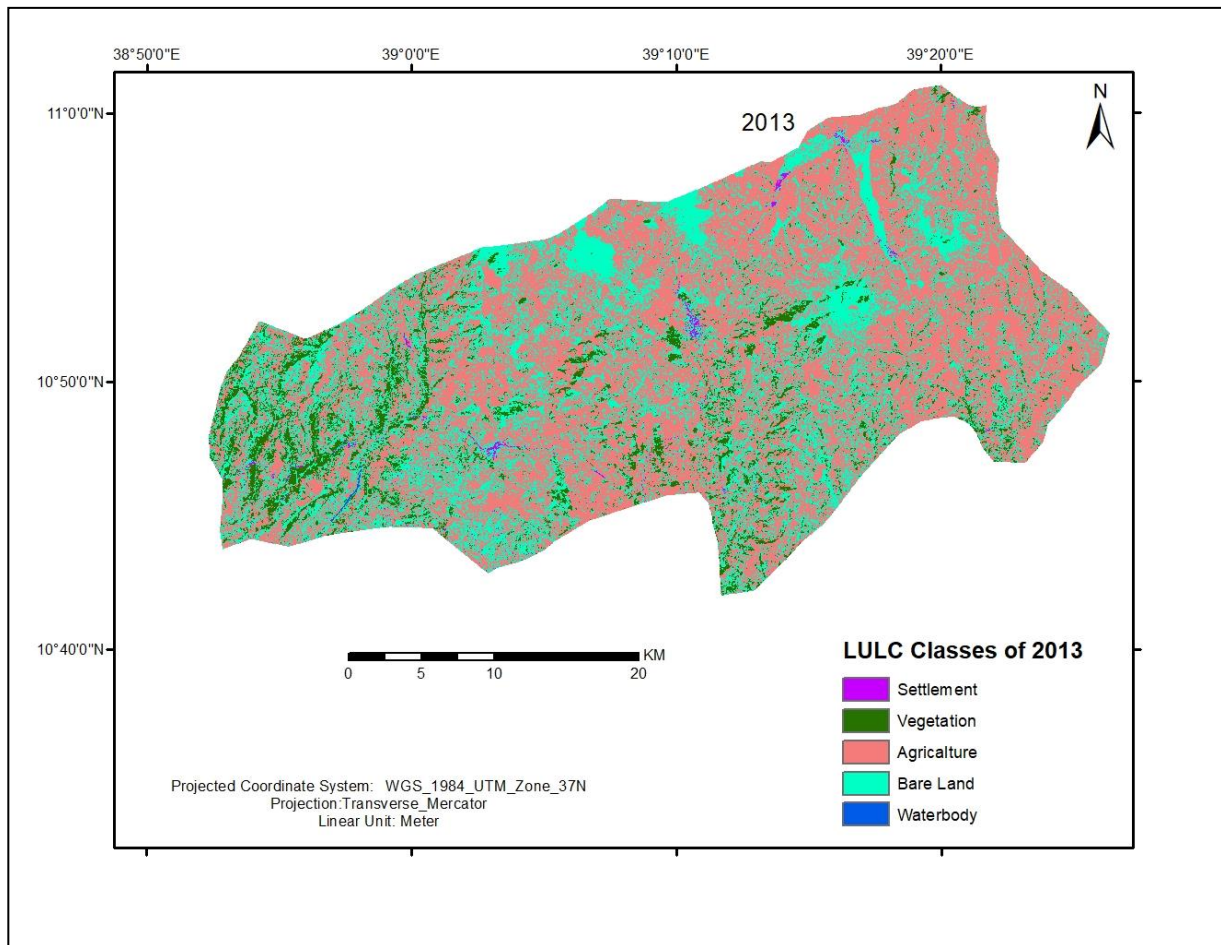


Figure 11 Land use land cover Map of Legambo district in 2013

The land use and land cover (LULC) distribution data for Legambo districts in 2013 reveals changes in the landscape compared to previous years,2003.

The land use and land cover map in 2013 image as shown in Table 8 increases the amount of land covered by vegetation and settlement areas, making up around 8.11% and 0.4%) of the total land area of the district, respectively. The increase in settlement area indicates ongoing urbanization and infrastructure development. Urban expansion can lead to land fragmentation, habitat loss, and environmental degradation. A study by Alemu et al. (2019) examined urban expansion dynamics in Ethiopia and emphasized the need for sustainable urban planning to mitigate environmental impacts and promote inclusive development.

Table 9 Land use land cover Classes Distribution of Legambo district in 2013

No.	LULC Type	2013	
		Area	Percentage
1	Settlement	494.46	0.41
2	Vegetation	9708.08	8.11
3	Agriculture	70452.45	58.86
4	Bare Land	38984.37	32.57
5	Waterbody	55.2	0.05
	Total	119694.6	100

Source: from satellite imageries, 20013 analysis

Agriculture land 58.86% of total area it remains the dominant land use, covering a significant portion of the land. The stability of agricultural land indicates the continued importance of farming activities for livelihoods in the area. However, intensive agricultural practices can lead to soil degradation, water pollution, and biodiversity loss. A study by Wondimagegn et al. (2020) investigated the impacts of agricultural intensification on soil health in Ethiopia and underscored the importance of sustainable agricultural practices to maintain soil fertility and productivity.

Bare Land 32.57 % of total area the significant proportion of bare land suggests ongoing land degradation processes, such as soil erosion, desertification, or overexploitation of natural resources. Land degradation poses threats to ecosystem resilience, food security, and rural livelihoods. Study by Mengistu et al. (2018) examined the drivers and impacts of land degradation in Ethiopia's highlands and highlighted the need for integrated land management approaches and community-based initiatives to restore degraded lands and improve land productivity.

Waterbody 0.05% of total area the small percentage of water bodies indicates limited availability of surface water resources in the region. Access to clean and reliable water sources is essential for agriculture, human health, and ecosystem functioning. A study by Ayalew et al. (2017) assessed water resource management challenges in Ethiopia and recommended integrated water management strategies to address water scarcity and ensure sustainable water use.

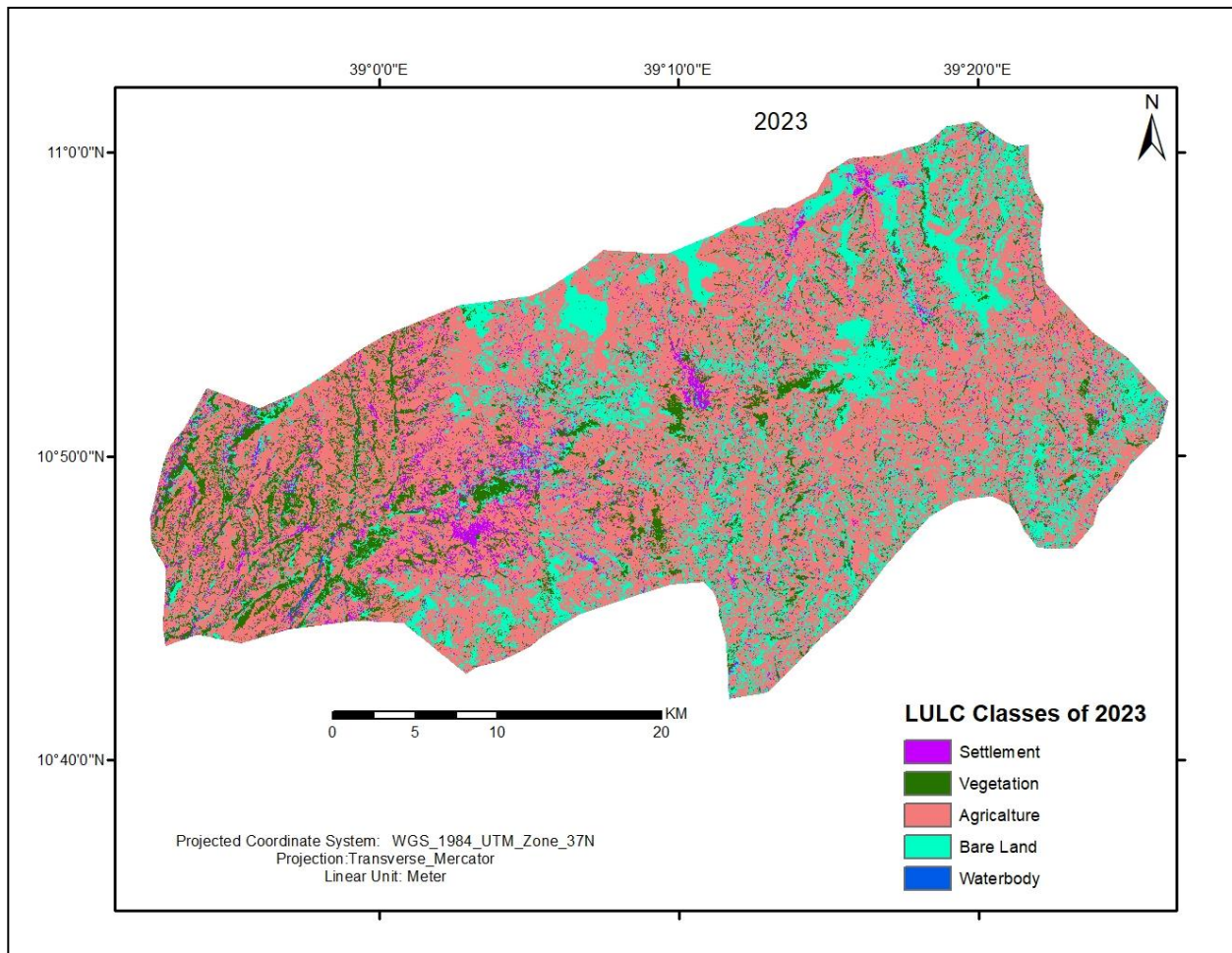


Figure 12 Land use land cover Map of Legambo District in 2023

The land use and land cover (LULC) distribution data for Legambo District in 2023 demonstrates further changes in the landscape compared to previous years.

The result revealed in the Table above 9 2023's land use and land cover map show dramatic expansions of settlement areas and waterbodies, which make up roughly 4.82% and 0.19% of the districts total land area, respectively. The significant increase in settlement area indicates rapid urbanization and population growth. Urban expansion can lead to land fragmentation, habitat loss, and environmental degradation. A study by Lemma et al. (2021) examined urbanization trends in Ethiopia and emphasized the need for sustainable urban planning to address the challenges of informal settlements, infrastructure development, and environmental degradation.

Table 10 Land use land cover Classes Distribution of Legambo District in 2023

No.	LULC Type	2023	
		Area	percentage
1	Settlement	5771.88	4.82
2	Vegetation	12679.09	10.59
3	Agriculture	75063.38	62.71
4	Bare Land	25964.63	21.69
5	Waterbody	222.02	0.19
	Total	119701.0	100

Source: from satellite imageries, 2023 analysis

Agriculture 62.71% of total area in 2023 it is continuing to dominate the landscape, covering the majority of the total area. The stability of agricultural land indicates the continued importance of farming activities for livelihoods and food security in the region. However, intensive agricultural practices can lead to soil degradation, water pollution, and biodiversity loss. A study by Tilahun et al. (2020) investigated the impacts of agricultural intensification on soil fertility in Ethiopia and recommended sustainable land management practices to maintain soil health and productivity.

The dimensioning bare land and vegetation 21.69 % of total area. Research by Mengistu et al. (2018) examined the drivers and impacts of land degradation in Ethiopia's highlands and emphasized the importance of integrated land management approaches and community-based initiatives to restore degraded lands and improve land productivity.

Vegetation 10.59 % of total area the slight increase in vegetation cover suggests efforts to conserve natural habitats or restore degraded landscapes. Vegetation cover is vital for biodiversity conservation, soil stabilization, and climate regulation. Study by Tadesse et al. (2019) assessed the impacts of reforestation and afforestation initiatives in Ethiopia and highlighted their contributions to ecosystem restoration, carbon sequestration, and community livelihoods.

4.3.2. Accuracy assessment of 1993 to 2023 images

The Land sat TM image of 1993 supervised classification results shows that overall accuracy is 90.2% and kappa coefficient 83 %. The user's accuracy of individual classes ranged from a

lower accuracy of 60% for Waterbody to a higher accuracy of 100% (settlement) and the producer's accuracy for each class ranged from a lower accuracy (83%, bare land) to a higher accuracy of 100% (settlement) and other classes a have a good user's and producer's accuracy. Higher producer accuracy means more pixels on the original image were correctly classified for a given class in reference plots. Higher user accuracy means more pixels on the map were classified as shown in (Table 10)

Table 11 Error matrix for land use land cover map of 1993

Class Value	Settlement	Vegetation	Agriculture	Bare Land	Waterbody	Total	U_Accuracy	Kappa
Settlement	10	0	0	0	0	10	1	0
Vegetation	0	9	0	1	0	10	0.9	0
Agriculture	0	2	71	2	0	75	0.946667	0
Bare Land	0	0	3	15	0	18	0.833333	0
Waterbody	0	1	3	0	6	10	0.6	0
Total	10	12	77	18	6	123	0	0
P_Accuracy	1	0.75	0.922078	0.833333	1	0	0.902439	0
Kappa	0	0	0	0	0	0	0	0.83131

Source: from satellite imageries, 1993 analysis

P=producer; U= user; Green color = correctly classified pixels

Table 12 Error matrix for land use land cover map of 2003

Class Value	Settlement	Vegetation	Agriculture	Bare Land	Waterbody	Total	U_Accuracy	Kappa
Settlement	9	0	0	1	0	10	0.9	0
Vegetation	0	12	0	0	0	12	1	0
Agriculture	1	2	54	2	0	59	0.915254	0
Bare Land	0	0	3	26	0	29	0.896552	0
Waterbody	0	0	0	0	10	10	1	0
Total	10	14	57	29	10	120	0	0
Accuracy	0.9	0.857143	0.947368	0.896552	1	0	0.925	0
Kappa	0	0	0	0	0	0	0	0.89

Source: from satellite imageries, 2003 analysis

P=producer; U= user; Green color = correctly classified pixels

In 2003 land sat image, supervised classification with an overall accuracy of 92.5 % was achieved, and a kappa coefficient of 89% was examined. the maximum user's accuracy was vegetation and waterbody which was 100%, whereas the minimum user's accuracy was bare land which was 89.6%. Similarly, the maximum producer was also waterbody (100%), whereas the minimum producer's accuracy was vegetation which was 85.7% as shown in (Table 11).

The accuracy assessment of LULC classification provides valuable information on the distribution of land cover types and their implications for land degradation in Ethiopia. Sustainable land management practices are crucial to mitigate land degradation and promote ecosystem resilience in the region.

Table 13 Error matrix for land use land cover map of 2013

Class Value	Settlement	Vegetation	Agriculture	Bare Land	Waterbody	Total	U_Accuracy	Kappa
Settlement	10	0	0	0	0	10	1	0
Vegetation	0	10	0	0	0	10	1	0
Agriculture	0	0	58	0	0	58	1	0
Bare Land	0	3	4	26	0	33	0.787879	0
Waterbody	0	0	0	1	9	10	0.9	0
Total	10	13	62	27	9	121	0	0
P_Accuracy	1	0.769231	0.935484	0.962963	1	0	0.933884	0
Kappa	0	0	0	0	0	0	0	0.9015

Source: from satellite imageries, 2013 analysis

P=producer; U= user; Green color = correctly classified pixels

The Land sat 8 2013 supervised classified image overall accuracy of 93.3 % was achieved with a Kappa coefficient of 0.90.1%. classification results of user accuracy in this study showed that maximum class accuracy was 100 %, which settlement, vegetation, and agriculture were correctly classified. The minimum was bare land with an accuracy of 78.7 %. Maximum producers were also settlement and waterbody (100%), whereas the minimum producer's accuracy was vegetation which was 76.9% as presented in (Table 12).

Table 14 Error matrix for land use land cover map of 2023

Class Value	Settlement	Vegetation	Agriculture	Bare Land	Waterbody	Total	U_Accuracy	Kappa
Settlement	10	0	0	0	0	10	1	0
Vegetation	0	10	0	1	0	11	0.909091	0
Agriculture	1	1	58	2	0	62	0.935484	0
Bare Land	0	0	2	20	0	22	0.909091	0
Waterbody	0	0	0	0	10	10	1	0
Total	11	11	60	23	10	115	0	0
P_Accuracy	0.909091	0.909091	0.966667	0.869565	1	0	0.93913	0
Kappa	0	0	0	0	0	0	0	0.907

Source: from satellite imageries, 2023 analysis

P=producer; U= user; Green color = correctly classified pixels

The 2023 Sentinel 2 image supervised classified image overall accuracy of 93.9% was achieved with a Kappa coefficient of 90.7%. The user's accuracy in maximum class accuracy was 100%, in which the settlement and the waterbody were correctly classified, and the minimum was bare land and vegetation with an accuracy of 90.9%, and the maximum producer was also the waterbody (100%). In contrast, the minimum producer's accuracy was vegetation and settlement, which was 90.9%, as shown in Table 13. Generally, the overall accuracy of the above (Tables 10 to 13). It is calculated by dividing the total number of correctly classified pixels (i.e., the sum of the elements along the major diagonal) by the total number of reference pixels. It shows the overall result of the tabular error matrix.

In the study period, 1993 was 90.2% (Table 10), 2003 was 92.5% (Table 11), and 2013 was 93.3% (Table 12). and during 2023 it was 93.9% (Table 13). According to van Vliet et al., (2011), Kappa is used to measure the accuracy or agreement between the classification map derived from remote sensing and the reference data, as indicated by the major diagonals and the row and column totals, respectively. This allows for a reliable land cover classification. The percentage of agreement left over after deducting the percentage of agreement that could have happened by chance is known as the Kappa coefficient. This implies that the Kappa value of 0.8454 represents a probable 84.54% better accuracy (Liu et al., 2007). According to Brovelli et al., (2000). when the kappa coefficient approaches 1 indicates that the classification is better and if it approaches to negative value indicates that the classification is poor performance. Based on this in this research analysis, the kappa coefficients are approaches to 1 therefore the classification was a good performance.

4.3.3. Change detection analysis

Since remotely sensed images give both geographical and temporal information about the land use and land cover conditions of the area, they are essential for detecting changes in land use and land cover. Within the 30-year time duration of this research, four change detection periods have been identified: the first from 1993 to 2003, the second from 2003 to 2013, the third from 2013 to 2023, and the fourth from 1993 to 2023 (from initial to final years changes). This serves to determine a lengthy history of land use and land cover. These intervals were selected by the districts access to satellite imagery and other data. Using the post-classification cross-tabulation approach in ArcGIS software, the land use land cover change detection was evaluated.

In this research, multi-date composite image change detection and post-classification comparison were working as methods for detecting changes in land use and land cover. This approach is popular and simple to understand. One benefit of this approach is the ability to extract detailed information (Kuma et al., 2022). For the years 1993–2003, 2003–2013, 2013–2023, and the fourth, change detection was performed.

To get from-to information on land use and cover changes between 1993 and 2023, with a focus on observing the rate of change, the amount of land used for agriculture, vegetation, bare land, waterbody, and the amount of settlement in the study area. The four time periods for which the categorized images were compared were 1993–2003, 2003–20013, 2013–2023, and 1993–2023. By comparing the area values of one data set with the matching values of the second data set for each period, change statistics were calculated, and hectares and percentages were used to display the values. The rate of change in hectares per year (Ochuka et al., 2019) and percentage share (Bufebo & Elias, 2021) .

Table 15 Land use land cover Conversion matrix for the years 1993 - 2003

LULC Types	1993	2003	LULC 1993-2003	
	Area in (ha)	Area in (ha)	Area in (ha)	Area in (%)
Settlement	23.65	52.12	28.466812	120.346463
Vegetation	13904.29	7870.46	-6,033.83	-43.395441
Agriculture	71797.09	91289.8	19492.723	27.14974
Bare Land	33780.26	20433.32	-13346.940	-39.511066
Waterbody	188.1	49.14	-138.9651	-73.877866

Source: Area statistics of the land use and land cover change from 1993-2003 satellite image

(-) the sign indicates the decrement of the LULC classes

Table 14 shows that there was a significant change in various land use land cover categories between 1993 and 2003, including agriculture (19492.7 ha) and settlement (28.47 ha). The settlement made up the largest portion of the land use and cover change in the study area between 1993 and 2003, accounting for more than 120 % of the total change. reflects rapid

urbanization and infrastructure development. Urban expansion often leads to land degradation through soil sealing, habitat fragmentation, and loss of vegetative cover (Lemma et al., 2021).

The significance decreasing trend in vegetation by 43.39 % of the area. The substantial decrease in vegetation cover indicates deforestation or conversion of natural habitats for other land uses. Deforestation contributes to land degradation by increasing soil erosion, reducing biodiversity, and altering ecosystem functions (Tadesse et al., 2019).

The significance increases of agricultural land by 27.15% The expansion of agricultural land suggests intensified agricultural practices or conversion of other land cover types for farming. Intensive agriculture can lead to soil degradation, water pollution, and loss of biodiversity, contributing to land degradation (Tilahun et al., 2020).

The significant decrease by 39.5 % in bare land area suggests reclamation or conversion of barren areas for other land uses. However, bare land is susceptible to degradation processes such as soil erosion and desertification, highlighting the importance of sustainable land management practices (Mengistu et al., 2018). The decrease in waterbody by 73.88 % area indicates waterbody loss or degradation. Water resources are vital for ecosystem functioning, and their depletion or degradation can lead to adverse environmental impacts, including land degradation (Ayalew et al., 2017).

Table 16 Post-classification Transition Matrix of Study Area between 1993-2003

The year		2003											
1993	Classes	AL		BL		S		V		WB		Total area (ha)	Total area %
		Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%		
	AL	59403.5	49.6	8590.1	7.18	23.4	0.02	3740.5	3.1	19.4	0.02	71777.0	60
	BL	20831.8	17.4	11533.8	9.6	25.9	0.02	1375.3	1.1	1.5	0.0	33768.3	28.2
	S	4.7	0.00	17.4	0.01	1.5	0.0	0.0	0.0	0.0	0.0	23.7	0.02
	V	10858.1	9.1	286.5	0.24	1.3	0.0	2749.1	2.3	3.5	0.0	13898.5	11.6
	WB	160.4	0.13	0.14	0.0	0.0	0.0	2.7	0.0	24.6	0.02	187.7	0.17
	Grand Total	91258.5	76.3	20427.9	17.07	52.1	0.04	7867.6	6.5	49.1	0.04	119655.2	100

The conversion matrix for land use and land cover for the years 1993–2003 is shown in Table 15 above, the proportion of each matrix's land use and land cover classes that remained constant from 1993 to 2003 is indicated on the diagonal of each matrix. In decreasing order of area coverage, agriculture, bare land, vegetation, and waterbodies were the main land use areas throughout this time. Over 60 % of the land in the research area was agriculture, according to the transition matrix, 49.65 % of the land was used for agriculture in 1993 and remained so in 2003. By 2003, the remaining over 10% had been converted and modified to various land use land cover types, which included bare land uses (7.18%), vegetation (3.1%), settlement (0.02%), and waterbodies (0.02%). On the other hand, 26.6% of other land cover types were converted to agricultural use. Furthermore, bare land makes up 28.2 % of the research area; in 1993, 9.6% constant or unchanged by 2003, however, almost over 18% of the bare land had transformed into other land use land cover.

Table 17 Land use land cover Conversion matrix for the years 2003-2013

LULC Types	2003	2013	LULC 2003-2013	
	Area in (ha)	Area in (ha)	Area in (ha)	Area in (%)
Settlement	52.12	494.5	442.3	848.7
Vegetation	7870.5	9708.1	1837.6	23.3
Agriculture	91289.8	70452.4	-20837.4	-22.8
Bare Land	20433.3	38984.4	18551.0	90.8
Water body	49.14	55.2	6.0	12.3

Source: Area statistics of the land use and land cover change from 2003-2013 satellite imageries

(-) the sign indicates the decrement of the LULC classes

Table 16 illustrates the rise in bare land, which increased from 20433.3 (ha) of the study area in 2003 to 38984.4 (ha) in 2013. The difference between these two figures is 18551.05 (ha). However, as Table 4.3.3 makes abundantly evident, there has been a decline in agricultural lands. A drop in agricultural lands from 91289.8 (ha) in 2003 to 70452.4 (ha) in 2013 suggests that a decrease of -20837.4 (ha) was observed between 2003 and 2013. The research area's most common land cover class, agricultural land, was shown to be continuously declining from

91289.8 (ha) in 2003 to 70452.4 (ha) in 2013, as indicated by table 4.3.3 above. The study periods about rapid population growth and the shortage of farmlands in rural areas have seen a dynamic increase in settlement areas due to the successive decrease of agricultural areas; however, vegetation cover has dramatically increased by over 1837 (ha).

Table 17 Post-classification Transition Matrix of Study Area between 2003-2013

The year 2013													
2003	LU/LC Classes	AL		BL		S		V		WB		Total area (ha)	Total area (%)
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%		
	AL	59243.3	49.5	25597.1	21.4	321.8	0.3	6066.1	5.1	31.4	0.0	91259.7	76.3
	BL	10651.7	8.9	9422.4	7.9	142.2	0.1	211.0	0.2	0.2	0.0	20427.6	17.1
	S	6.9	0.0	30.3	0.0	13.1	0.0	1.8	0.0	0.0	0.0	52.1	0.0
	V	522.3	0.4	3908.1	3.3	15.4	0.0	3421.9	2.9	0.3	0.0	7868.0	6.6
	WB	8.6	0.0	12.5	0.0	1.9	0.0	2.8	0.0	23.3	0.0	49.1	0.0
Grand Total		70432.8	58.8	38970.4	32.6	494.4	0.4	9703.7	8.2	55.2	0	119656.4	100

Source: from analysis of satellite imageries, 2003-2013

The diagonal values (shaded in yellow) from cross-tabulation matrix Table 17 show land use land cover that was unchanged in the given years. In the study period of 2003 and 2013 out of 91259.7 (ha) of land under agriculture in 2003, 59243.3 (ha) remained unchanged while 321.81 and 25597.1 (ha) were converted to settlement and bare land respectively, for settlement 30.3 (ha) out of 52.1 ha to converted bare land while 6.9 ha converted to agriculture. In the area

under vegetation cover, 15.4 (ha) was converted to settlement out of the total 7868.0 (ha) while 522.3 (ha) was converted to agriculture. From the above Table 4.3.3, 6066.1 (ha), out of 91259.7(ha) occupied by agriculture in 2003 converted to vegetation cover, 321.8 (ha) converted to settlement and 25597.1 (ha) to bare land, to waterbodies 31.4 (ha).

Table 18 Land use land cover Conversion matrix for the year 2013-2023

LULC Types	2013	2023	LULC 2013-2023	
	Area in (ha)	Area in (ha)	Area in (ha)	Area in (%)
Settlement	494.5	5771.9	5277.419437	1067.318351
Vegetation	9708.08	12679.09	2971.009357	30.603473
Agriculture	70452.45	75063.38	4610.933265	6.544745
Bare Land	38984.37	25964.63	-13019.742267	-33.397337
Waterbody	55.2	222.02	166.826354	302.236844

Source: Area statistics of the land use and land cover change from 20013-2023 satellite imageries

(-) the sign indicates the decrement of the LULC classes

Through the period 2013-2023, there was a substantial change in several land use land cover categories including settlements (5277.419437 ha), agricultural land (4610.933265 ha), vegetation (2971.009357 ha), and waterbody (166.826354 ha) area increased. According to Table 18 tendency towards more land brought under settlements, agriculture, vegetation, and water body. These data expressly stated that an increase in settlements, agriculture, Vegetation, and water body resulted in population pressure on land and good government policies, and a decrease in bare land which was converted to other land use land cover.

Table 19 Post-classification Transition Matrix of Study Area between 2013-2023

Year		2023											
2013	Classes LULC	AL		BL		S		V		WB		Total	Total
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	area (ha)	Area (%)
	AL	54850.2	45.8	11260.0	9.4	2369.4	2.1	1888.5	1.6	64.9	0.0	70433.0	58.9
	BL	16887.3	14.1	13061.1	10.9	2646.0	2.2	6302.1	5.3	71.3	0.1	38967.8	32.6
	S	124.3	0.1	35.5	0.0	319.3	0.3	7.3	0.0	7.8	0.0	494.3	0.4
	V	3159.1	2.6	1595.9	1.3	434.0	0.4	4474.0	3.7	39.2	0.0	9702.2	8.1
	WB	12.8	0.0	1.1	0.0	0.9	0.0	1.9	0.0	38.5	0.0	55.2	0.0
Grand Total		75033.7	62.6	25953.7	21.6	5769.5	5.0	12673.8	10.6	221.8	0.1	119652.5	100

Source: from analysis of satellite imageries, 2013-2023

The yellow color = indicates unchanged

The increase in land use land cover in the research area was attributable to the growth of agriculture covering (58.9%), bare land (32.6%), and vegetation (8.1%), as per year the above Table 19 conversion matrix for the years 2013–2023. Compared to the research period of 2003–2013, there has been generally a substantial decline in bare land and agricultural land, suggesting that agricultural land is the area most impacted by changes in land use cover.

Table 20 Land use land cover Conversion matrix for the years 1993-2023

LULC Types	1993	2023	LULC 1993-2023	
	Area in (ha)	Area in (ha)	Area in (ha)	Area in (%)
Settlement	23.65	5771.9	5748.22137	24301.214547
Vegetation	13904.3	12679.1	-1225.206282	-8.811711
Agriculture	71797.1	75063.4	3266.294529	4.549341
Bare Land	33780.3	25964.6	-7815.629751	-23.136677
Water body	188.1	222.02	33.922397	18.034122

(-) the sign indicates the decrement in the LULC classes

Source: Area statistics of the land use and land cover change from 1993-2023 satellite imageries

Though the period of 1993 to 2023 there is a dramatic expansion of several land use land cover categories including settlements (5748.22137 ha) or (24301.2145 %), agriculture (3266.2945 ha) or (4.5493%), water body (33.9223 ha.) or (18.0341%) are increased and bare land decreased to (-7815.6297ha) or (-23.1367.3%). According to the above Table 20 tendency towards more land brought under settlement and agriculture and water body. These data expressly stated that an increase in settlement resulted in population pressure.

Table 21 Post-classification Transition Matrix of Study Area between 1993-2023

Year		2023											
1993	LULC Classes	AL		BL		S		V		WB		Total area (ha)	Total area (%)
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%		
	AL	50244.9	42.0	11883.6	10.0	3342.3	2.8	6178.6	5.2	126.7	0.1	71776.0	60.1
	BL	17880.5	15.0	11728.6	9.8	1419.8	1.2	2724.4	2.3	14.6	0.0	33768.0	28.2
	S	5.7	0.0	15.2	0.0	1.5	0.0	1.3	0.0	0.0	0.0	23.7	0.0
	V	6796.3	5.7	2303.7	2.0	1002.6	0.8	3759.3	3.1	35.9	0.0	13897.9	11.6
	WB	105.9	0.0	22.8	0.0	3.5	0.0	10.9	0.0	44.6	0.0	187.7	0.1
	Grand Total	75033.4	62.7	25953.9	21.8	5769.7	4.8	12674.4	10.6	221.8	0.1	119653.2	100

Source: from analysis of satellite imageries, 1993-2023

For the entire period covered by the study area, it is clear that the area covered by agriculture is slowly being edged out by other land uses, mainly by settlement out of 71777.0 (h)a of land under agriculture in 1993, 3342.3 (ha)were converted to settlement and 11883.6 ha converted to bare land, for bare land 1419.8 (ha) out of 33768.3 (ha) covered by bare land were converted to settlement while 17880.5 (ha) were converted to agriculture; 1002.6 (ha) of a total of 13898.5 (ha) of vegetation have changed to settlement land as shown in Table 21. The change detection result indicates that agricultural land is being edge out slowly by other land uses, especially by settlement. The implication of these rapid changes in land use is a decline in area under agricultural land.

4.3.4. Gain and losses of land use/ land cover change (1993- 2023)

In general, there has been a continuous land use/land cover change taking place for the majority of parts of the Legambo district in the last 30 years. The land cover changes from 1993 to 2023 has been discussed in four periods. Each period has ten years of gap i.e. the first period from 1993 to 2003, the second period from 2003 to 2013, the third period from 2013 to 2023 and the last period has 30 years gap from 1993-2023 the covers dynamics. the rate of land cover change from 1993 to 2003, 2003 to 2013, 2013 to 2023, and collective land cover change from 1993 to 2023. Table 22 clearly shows the land cover change rate for the past 30 years.

Table 22 Rate of change in land use and covers classes

Land use land cover Classes	Periods							
	1993	2003	2013	2023	Annual Rate of Change %	Annual Rate of Change %	Annual Rate of Change %	Aggregated Rate of change % (1993- 2023)
	(ha)	(ha)	(ha)	(ha)	(1993- 2003)	(2003- 2013)	(2013- 2023)	
Settlement	23.65	52.1	494.5	5771.9	+12.1	+84.9	+106.7	+2430.1
Vegetation	13904.3	7870.5	9708.1	12679.1	-4.3	+2.3	+3.1	-0.9
Agriculture	71797.1	91289.8	70452. 4	75063.4	+2.7	-2.3	+0.6	+0.4
Bare Land	33780.3	20433.3	38984. 4	25964.6	-3.9	+9.1	-3.3	-2.3
Waterbody	188.1	49.14	55.2	222.0	-7.3	+1.2	+30.2	+1.8

From analysis of satellite imageries, 1993-2023

(-) the sign indicates the decrement of the land use land cover classes

Waterbodies show the highest annual rate of change for 1993, to 2003, with -7.3 % decrease and the same situation for vegetation by -4.3% and bare land by -3.9 while settlement and agricultural shows +12.1% and +2.7 increment for the same period respectively. Possibly due to the destruction of vegetation and bare land for Fuel wood, Expansion of agricultural land, timber production, Construction purposes, and urban expansion.

In the second period between 2003 to 2013 the rate of change shows a significant increment both in increment and decrease 1993-2003, that is, the maximum decrease is in Agricultural land class with -2.3% and the maximum increment is settlement +84.9 % for the class of bare land followed by vegetation and waterbody with +9.1 %, +2.3 and +1.2% respectively. Agricultural land possibly decreased due to expansions of settlement.

Table 23 Summary of land use land cover change in percentage from 1993 to 2023

Years	Settlement	Vegetation	Agriculture	Bare land	Waterbody	Total
1993	0.02	11.62	59.98	28.22	0.16	100%
2003	0.04	6.58	76.27	17.07	0.04	100%
2013	0.41	8.11	58.86	32.57	0.05	100%
2023	4.82	10.59	62.71	21.69	0.19	100%

From analysis of satellite imageries, 1993-2023

The third period was between 2013 to 2023 the rate of change also shows significant decrease and increase both in increment and decrease from 2003-2013, that is, the maximum decrease is in Bare land class with -3.3% and the maximum increment is settlement +106.7 % for class followed by waterbody with +30.2 %, vegetation +3.1 and agriculture +0.6. Possibly bare land decreases due to areas left under construction, residence and settlement increased due to expansion of built-up areas and vegetation increased due to government policy encouraging vegetation. When we see the general situation concerning the aggregate rate of change indicates that bare land and vegetation have decreased at -2.3, and -0.9 respectively, while the rest classes namely settlements at +2430.1%, water body at +1.8%, and agricultural at 0.4% increase. Possibly increment due expansion of settlement, increment of water body seasonal climate modification increases the amount of rainfall. and decrease bare land due to areas left under construction, residence and urban expansion, and reduction of vegetation possibly due to the expansion of agricultural land, timber production, construction purposes, and urban expansion.

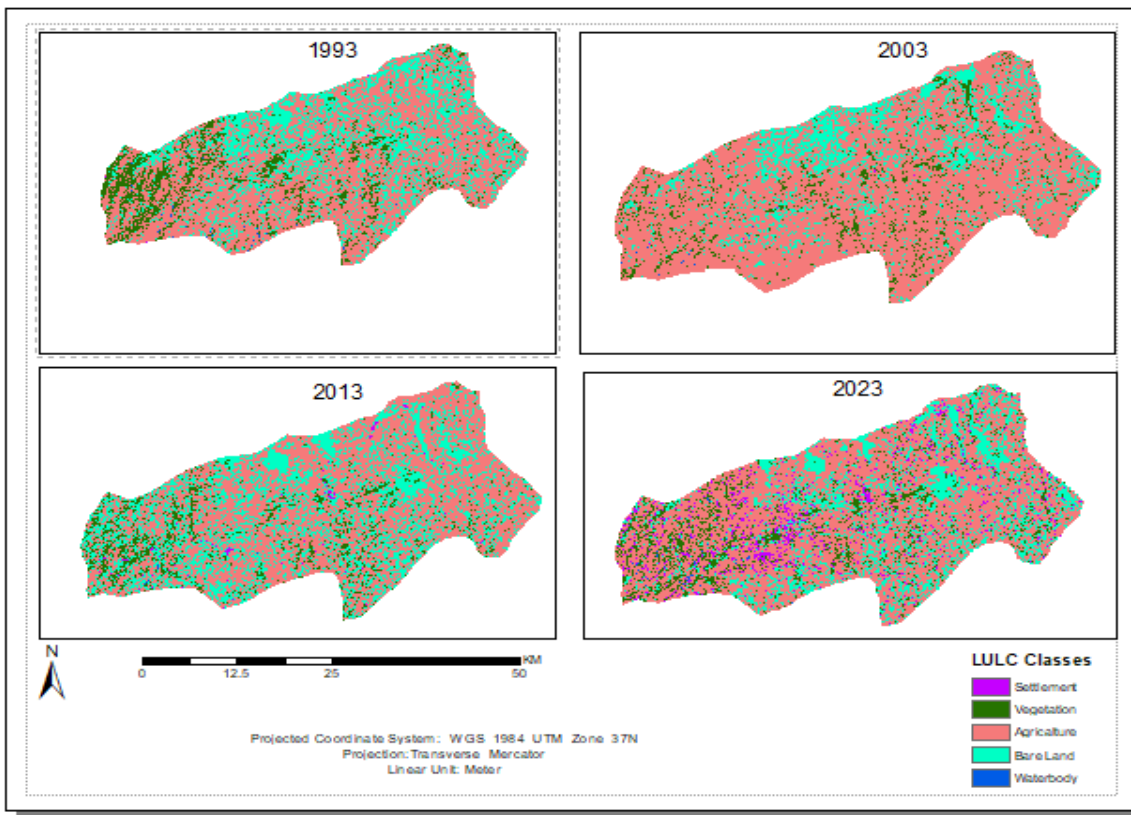


Figure 13 Land use land cover change from 1993-2023

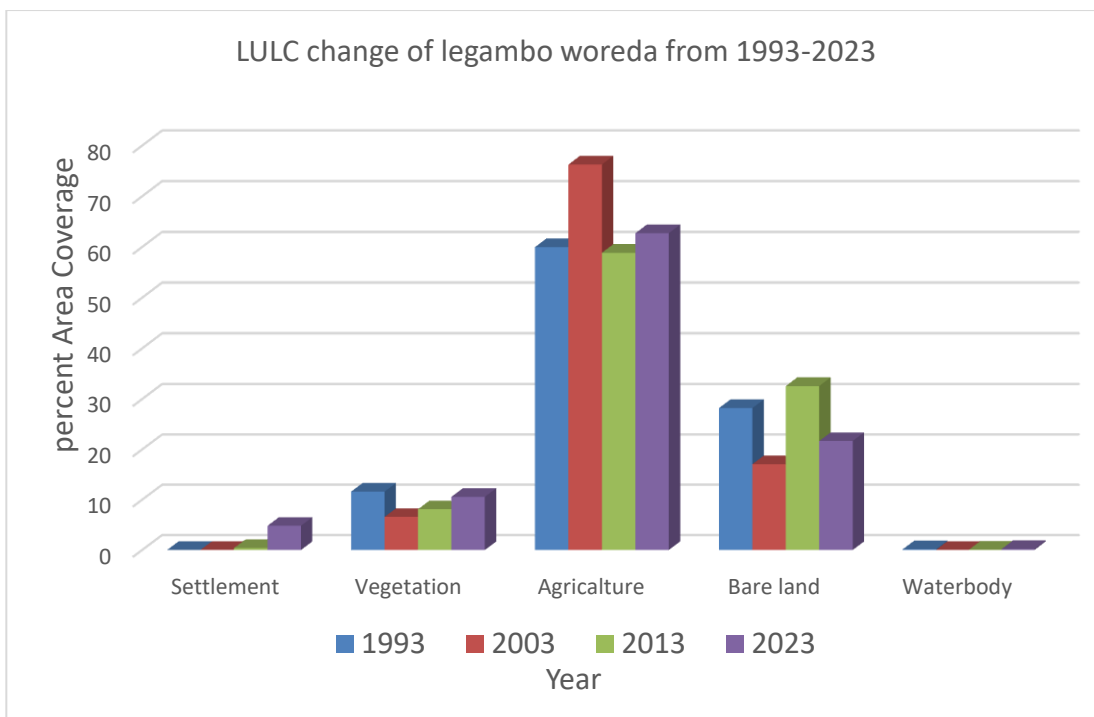


Figure 14 Graph of Land use land cover change from 1993-2023

Change detection statistics showed in Figure 13 and Figure 14 that from 1993 to 2023 there was a dynamic change in numerous land use land cover categories including settlement in 1993 it was 0.02% coverage in the study area then it increased by 4.82%, which implies that greater changes occurred in 30 years. In contrast bare land in 1993, it was (28.2%) which decreased to (21.69%) in 2023. Vegetation covered 11.62% in 1993 and decreased to 10.59% in 2023 in the middle period that was in 2003 it was 6.58% and in 2013 it increased (to 8.1%). Agriculture in the period of 1993 was 59.98% and it increased to 62.71% in the period of 2023, this increment was population pressure in the study area and bare land and vegetation went to agricultural land due to the demand for agricultural land for farming, overall, through the periods of from 1993 to 2023 presented in the above Figure 13 and 14.

Change detection statics are shown in Figure 13 and Figure 14 over the years 1993, 2003, 2013, and 2023, broken down into settlement, vegetation, agriculture, bare land, and waterbody categories. Here's a brief analysis of the trends Settlement shows a stable increase from 1993 to 2023, indicating urban or infrastructure development over time. Vegetation decreased significantly from 1993 to 2003, then varied with a slight increase by 2013 and a further increase by 2023. This could imply deforestation or natural vegetation loss followed by potential conservation efforts or reforestation. Agriculture declined initially from 1993 to 2003, then gradually increased by 2013 and 2023. This pattern might suggest shifts in agricultural practices, possibly influenced by economic factors or land management policies. Bare Land experienced fluctuations but generally decreased over time, indicating potential conversion to settlement, vegetation, or agriculture. Water body remained relatively stable across the years, with minor variations. This suggests consistency in water body distribution. Overall, the data suggests a dynamic interaction between urbanization, agricultural activities, environmental conservation, and land management practices over the observed years. Further analysis could investigate into the drivers behind these changes and their implications for sustainability and resource management.

4.5. Driving force for land use land cover change

The respondents were asked to indicate their level of agreement to the sort of statements about the cause of land degradation the study area. The mean value of 3.80 suggests that high rainfall amounts are considered a significant driving force for LULC change. High rainfall amounts can lead to increased soil erosion, flooding, and changes in vegetation cover, influencing land use patterns and agricultural practices. This may result in the conversion of natural habitats to

agricultural lands or changes in cropping patterns to adapt to wetter conditions (Foley et al., 2005). Regions with abundant rainfall often experience changes in land use patterns due to increased agricultural productivity and vegetation growth. However, the relatively low standard deviation (SD) of 0.752 indicates a relatively consistent perception of the impact of rainfall on LULC change among respondents. With a mean value of 3.78, overgrazing is also perceived as a notable driver of LULC change. Overgrazing leads to vegetation degradation and soil erosion, particularly in arid and semi-arid regions. The higher standard deviation (0.873) suggests greater variability in perceptions regarding the extent of overgrazing's impact among respondents.

Deforestation, indicated by a mean value of 3.79, is widely recognized as a significant driver of LULC change globally table 24. Deforestation can lead to habitat loss, soil erosion, and changes in microclimate, affecting land productivity and ecosystem services. This may result in the conversion of forests to agricultural lands, urban expansion, or infrastructure development, exacerbating biodiversity loss and carbon emissions (Hansen et al., 2013). The conversion of forested land for agriculture, logging, and urbanization alters ecosystems, biodiversity, and carbon storage. The relatively low standard deviation (0.738) indicates a relatively consistent perception among respondents regarding the impact of deforestation.

Table 24. Driving force for land use land cover change

No	Driving force for LULC	Mean	S.D
1.	High of rain fall amount	3.80	.752
2.	Overgrazing	3.78	.873
3.	Deforestation	3.79	.738
4.	Population pressure	3.57	.836
5.	High poverty	3.81	.725
6.	Expansion of farmland	3.81	.742
7.	Urban land expansion	3.80	.962
8.	Traditional farm practices	3.58	.816
9.	Land fragmentation	3.88	.973
10.	Poor soil fertility	3.79	.738
11.	Excessive tillage	3.92	.784
12.	Bad cultivation practices	3.61	.771
	Average mean and SD	3.74	0.82

Source: Survey result, 2023

Despite having a mean value of 3.57, indicating a relatively lower perception compared to other factors, population pressure remains a significant driver of LULC change. Rapid population growth leads to increased demand for land, resulting in deforestation, urban expansion, and agricultural intensification. The higher standard deviation (0.836) suggests varied perceptions among respondents regarding the influence of population pressure.

Poverty, with a mean value of 3.81, is perceived as a significant driver of LULC change. Poverty can drive unsustainable land use practices as individuals exploit natural resources for immediate economic needs. The relatively low standard deviation (0.725) indicates a consistent perception among respondents regarding the impact of poverty on LULC change. High poverty levels can drive unsustainable land use practices, such as overexploitation of natural resources, land degradation, and deforestation, as communities prioritize short-term livelihood needs over long-term environmental conservation (Geist & Lambin, 2002).

The mean value of 3.81 indicates that the expansion of farmland is considered a significant driver of LULC change. Agricultural expansion alters landscapes, leading to habitat loss and fragmentation. The standard deviation (0.742) suggests relatively consistent perceptions among respondents regarding the impact of farmland expansion. Expansion of farmland can lead to deforestation, habitat loss, and biodiversity decline, as natural ecosystems are converted to agricultural lands. This may result in soil degradation, water pollution, and loss of ecosystem services, impacting both local livelihoods and global environmental sustainability (Foley et al., 2005).

Urbanization, reflected by a mean value of 3.80, is a major driver of LULC change globally. Urban expansion leads to land conversion, habitat loss, and changes in ecosystem services. The higher standard deviation (0.962) suggests varied perceptions among respondents regarding the influence of urban land expansion.

Traditional farming practices, indicated by a mean value of 3.58, are perceived as contributing to LULC change. While traditional practices may promote sustainability in some contexts, they can also lead to soil degradation and biodiversity loss. The standard deviation (0.816) suggests varied perceptions among respondents regarding the impact of traditional farm practices.

With a mean value of 3.88, land fragmentation is perceived as a significant driver of LULC change. Fragmentation alters landscape connectivity and ecological processes, impacting biodiversity and ecosystem resilience. The relatively high standard deviation (0.973) suggests varied perceptions among respondents regarding the influence of land fragmentation.

Poor soil fertility, indicated by a mean value of 3.79, is perceived as a driver of LULC change. Regions with poor soil fertility may experience land degradation and conversion to other land uses. The relatively low standard deviation (0.738) indicates a consistent perception among respondents regarding the impact of poor soil fertility.

Excessive tillage, with a mean value of 3.92, is perceived as a significant driver of LULC change. Intensive tillage practices can degrade soil quality and increase erosion rates, influencing land use decisions and cropping systems. The standard deviation (0.784) suggests relatively consistent perceptions among respondents regarding the impact of excessive tillage.

Bad cultivation practices, reflected by a mean value of 3.61, are perceived as contributing to LULC change. Improper irrigation, agrochemical use, and monoculture cropping can degrade soil quality and reduce agricultural productivity. The standard deviation (0.771) suggests varied perceptions among respondents regarding the impact of bad cultivation practices. Mean value score ranging from 3.57 to 3.88 out of 5, the results indicate that Perceptions of respondents about the cause of land degradation mostly moderate to solely a highest extent. All the standard deviations of the variables were below 1.00 ranging from 0.725 to 0.973, which indicates that the perception among respondents were not contrary each other. The average scored mean and standard deviations of cause of land degradation 3.77 and 0.82 respectively.

The analysis of the provided data suggests that multiple driving forces, including high rainfall amounts, deforestation, overgrazing, population pressure, and others, contribute to LULC change. While some factors may have relatively consistent perceptions among respondents, others exhibit greater variability in perceptions. Understanding these driving forces and their impacts is crucial for implementing effective land management and conservation strategies.

These driving forces show the complex interactions between human activities and environmental changes, highlighting the need for integrated land use planning, sustainable resource management, and policy interventions to mitigate land degradation, biodiversity loss, and other adverse impacts of land use and land cover change.

4.6. Climate variability trends (rainfall and temperature)

4.6.1. Trends and variability in rainfall and temperature

Rainfall and temperature are important meteorological variables that determine water availability, production of crops and livestock rearing or food production processes in countries where agriculture is more dependent on rainfall, (Abebe, 2013). Recently changes in the extreme's events at various regions of the world are common. Drought and flooding are the dominate ones (IPCC, 2014). Report by NMA (2020), indicates that annual rainfall is significantly changed across Ethiopia and suggesting high inter-annual variability with a slight but statistically significant negative trend. This is in line with previous analyses, which highlight the importance of integrand intra-seasonal rainfall variability over total annual rainfall in determining livelihood and food security outcomes (Hadgu et al., 2014).

4.6.1.1. Inter-annual and seasonal variability of rainfall

Table 25, has shown that the rainfall has high annual and seasonal variation trend in the study period (1992-2022). As shown Table 25 the average annual rainfall of the area for the study period was 934.3 mm and this has been varying from lowest amount of 411.3 mm (in 2005) to highest amount 1,466mm (in 2020). In addition, stander deviation SD 313 and CV 33.5 is observed. Over the period of observation, annual rainfall shows declining trend (1.88 mm/decade) statically significant at $p=0.05$ level. This will be having adverse impact on the rainfall dependent smallholder farming in the area. High mean annual rainfall generally supports lush vegetation growth and agricultural productivity in regions where water availability is a limiting factor (FAO, 2008). However, excessive rainfall can lead to waterlogging, erosion, and nutrient leaching, contributing to land degradation (Lal, 2001). In contrast, regions experiencing lower mean annual rainfall may face challenges related to water scarcity, reduced crop yields, and increased vulnerability to drought (FAO, 2017).

Table 25 . Mean annual and seasonal rainfall

	Mean	LR/mm 10 year	Wettest year	Amount rainfall(mm)	Driest year	Amount rain fall(mm)	SD	CV	%
Annual	934.3	-18.8***	2020	1466	2005	411.3	313	33.5	
Kirmet	683	0.64**	2022	1057	2005	226	224	32	73
Belg	171.3	-0.28***	2016	432	2003	42	96	56	18
Bega	78.5	0.84	1999	184.6	2011	10.54	52	66	9

*** = Significant at 0.01 level; **= Significant at 0.05 level; LT = linear trend ($^{\circ}\text{C} / 10\text{yr}$)

Source: Computed based on row data obtained from, NMA,2023

The mean rainfall during the Kirmet season (June to September) is 683 mm. Kirmet is the main rainy season in Ethiopia, coinciding with the summer months. It plays a crucial role in agriculture, as it is vital for the cultivation of crops such as maize, sorghum, and teff. The Kiremt season typically corresponds to the main growing season in many regions, supporting crop cultivation and pasture growth (Dile et al., 2013). Adequate Kiremt rainfall is essential for replenishing soil moisture, sustaining surface water resources, and promoting agricultural production (Abebe et al., 2017). However, irregularities in Kiremt rainfall patterns, such as prolonged dry spells or intense precipitation events, can adversely affect crop yields and exacerbate soil erosion (Gebrehiwot et al., 2014).

The mean rainfall during the Belg season (February to May) is 171.3 mm table 25 . Belg is a shorter rainy season occurring in the spring, characterized by light to moderate rainfall. While it contributes less to total annual precipitation compared to Kirmet, Belg rainfall is important for early-season planting and the growth of certain crops. The Belg season provides supplementary moisture for crop growth, particularly in areas with bimodal rainfall patterns (Deressa et al., 2009). Belg rains are crucial for early planting, germination, and establishment of short-cycle crops, contributing to agricultural diversification and food security (Bizuayehu et al., 2017). However, variations in Belg rainfall intensity and timing can influence crop performance, affecting farm productivity and livelihoods (Funk et al., 2012).

Coefficient of variation

Coefficient of variation (CV) and standardized rainfall anomaly (SRA) were used to analyze and understand the degree of rainfall variability in the study area. The rainfall coefficient of variation is categorized as less ($\text{CV} < 20\%$), moderate ($20\% < \text{CV} < 30\%$), and high ($\text{CV} > 30\%$).

The coefficient of variation (%CV) for Kirmet is 32%, indicating moderate variability in rainfall during this season. Belg season shows the highest variability with a %CV of 56%, suggesting significant fluctuations in rainfall from year to year. Bega season has a %CV of 66%, indicating relatively high variability compared to the other seasons. These values indicate varying degrees of variability across the seasons, with Belg and Bega seasons experiencing higher fluctuations in rainfall compared to Kirmet table 25. In line with other studies in Ethiopia, Baley (2014) who reported that inter-annual rainfall coefficient variation (18 to 40%), *Kirimet* (CV 17 to 39%) and *Belg* (CV 27 to 57%) for rift valley of Ethiopia.

Small change in amount and distribution of main season (June to September) rainfall could negatively influence crop production and livestock, which is already impacted by the current climate variability, which May likely cause further challenges in the future climate change. Main rain season (June to September) rainfall contributed the highest Percentages (73%) of rainfall to annual rainfall. The secondary rain season Belg rainfall contributed 18 %. Study in the Amhara regional state of Ethiopia, Kiremt and Belg rainfall had contributed 55-85% and 8-24%, respectively to the annual rainfall totals (Bewket and Conway, 2007; Ayalew et al., 2012).

Precipitation Concentration Index (PCI)

The calculated precipitation concentration index (PCI) for the study districts was about 19.6 %. Bewket and Conway (2007) showed that the PCI less than 10 indicates uniform distribution, between 11% and 20% shows high concentration and greater than 20% indicates very high concentration. This showed that the rainfall distribution in the study area was highly concentrated in the few wet months (July, August and September) average rainfall 294.6 mm, 287.5mm and 81mm respectively. The minimum amount rainfall contribution month November (11mm) December (11.4mm) and January (15.9mm). The percentage share for the total rainfall July 30%, August 29 % and September 8% (Figure 15).

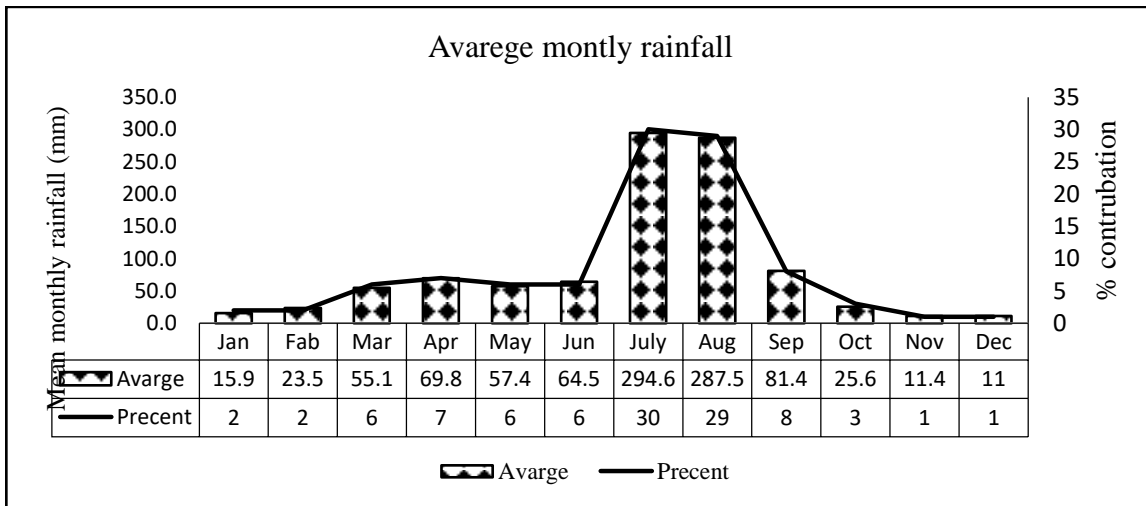


Figure 15 Monthly rainfall contribution

Source: Computed based on row data obtained from NMA,2023

Standardized Rainfall Anomalies (SRA)

Analysis of the standard rainfall anomaly is presented in Figure 16 This study used SRA to demonstrate the intensity and frequency of drought and inter-annual variation at various time scales and area. The negative anomalies of 47 % during the period of 1992 to 2022. Extreme drought (<-1.65) was observed in 1992, 2000,2001, 2004, 2007 and 2011 in all stations. Severity drought (-1.28 - -1.65) was observed the year 2005,2011 and 2015 (Figures 16). In line with this, Quinn and Neal (1987) and Webb and Braun (1994) cited in NMA (2007) reported that Ethiopia experienced drought years in 1983 to 1984, 1987 to 1988, 1990 to 1992, 2000, and 2002 to 2003. This is in harmony with the findings of (NMA, 2007) who reported that there was increase in the dry year frequency in Ethiopia. The rainfall pattern in the studied stations showed the characteristics that a dry year is followed by another two or three dry years and vis-à-vis for the wet years. Inter-annual variability problems in rainfall would negatively affect the ability of farmers to cope with climate change and variability (Ayalew et al., 2012).

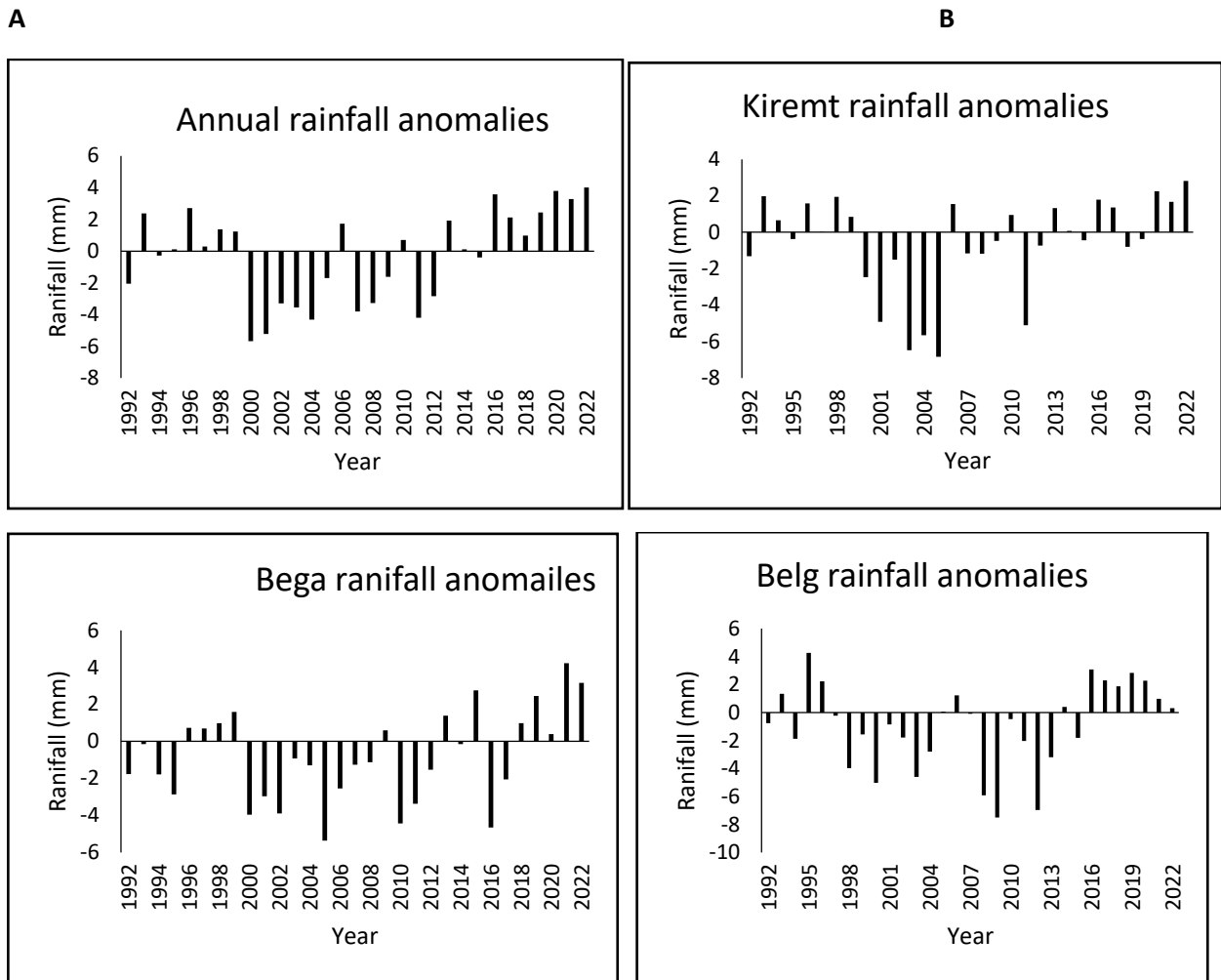


Figure 16 Rainfall anomalies (A), Annual (B), kiremt, (C), Bega and (D) Belg

Source: Computed based on row data obtained from NMA,2023

As shown in Figure 16, seasonal rainfall anomalies for the Kiremt season are 53% negative and 47% positive for the period 1992–2022. In Figure 16, negative and positive Belg rainfall anomalies account for 57% and 43% of observations for the period 1992–2022, respectively in districts. This finding coincides with the earlier works of Bewket and Conway (2007) and Ayalew et al., (2012) in the same region. Rosell (2011) also reported a similar finding for the central highlands of Ethiopia.

4.6.1.2. Rainfall and temperature trends analysis

The results of trend analysis of annual and seasonal rainfall are presented in (Figure 17). It shows declining trends by 18.8 mm/decade, a statistically significant decreasing trend at $p = 0.01$. The average rainfall of Belg was 171 mm and with a standard deviation of 96 mm. Declining trends of 0.28 mm/decade in the study period from 1992 to 2022. Belg rainfall shows significant

decreasing trend at $p = 0.05$ level. The result is line with Williams et al., (2012) and Kebede (2013) reported declining trends in Belg rainfall. In the area, kiremt has shown statistically significant increasing with annual trend of 0.64 mm/decade in the study period (Figure 17). This season is very important for the main cropping season locally known as Meher.

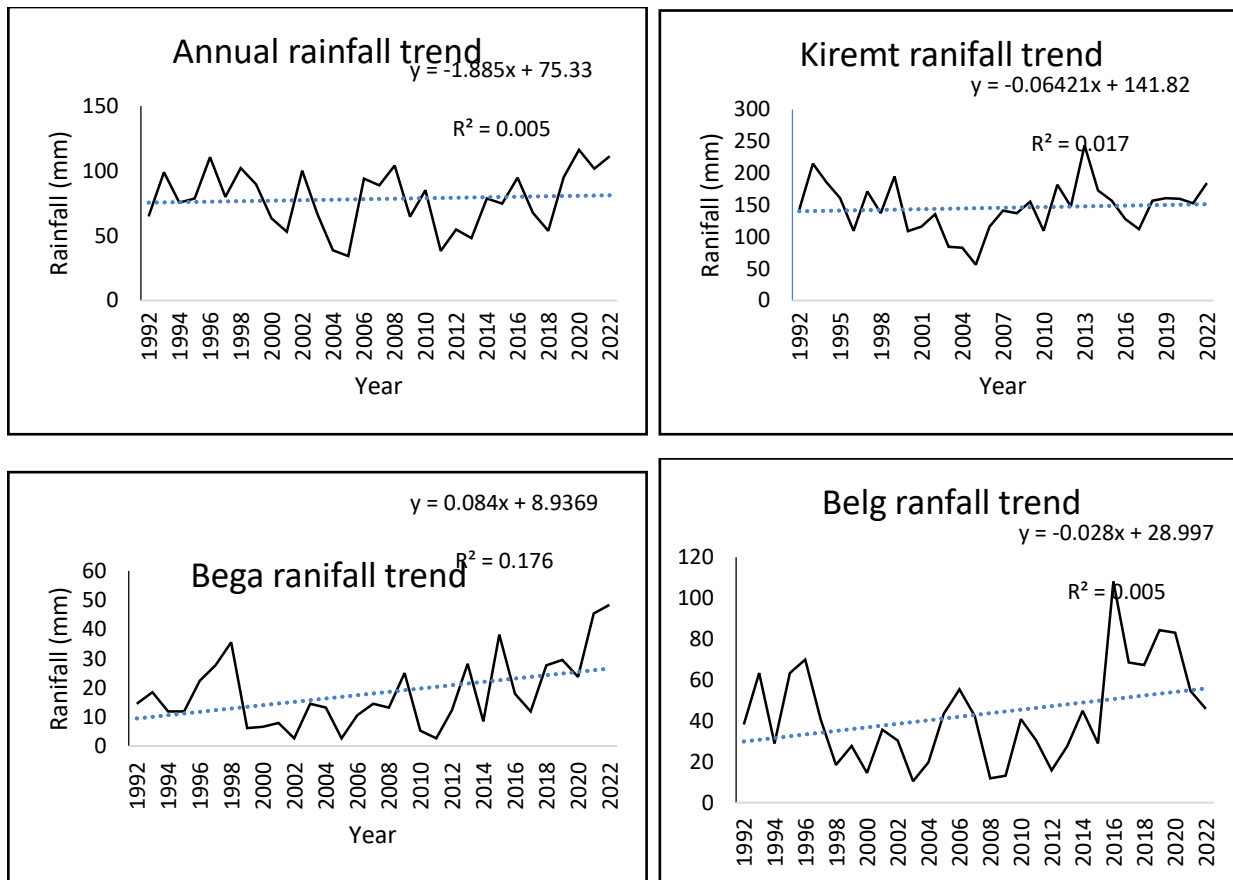


Figure 17 Rainfall trends (A), Annual (B), kiremt,(C),Bega and (D) Belg

Source: Computed based on row data obtained from NMA,2023

As indicate Figure 17 the trends of Bega rainfall increasing of 0.84 mm/decade the average rainfall Bega 78.5 mm with standard deviation 66 and coefficient of variation 56. The maximum rainfall 184.6 (1999) and the minimum rainfall 10.5 (2011) it is the dry year. These results corroborate the findings of Bewket and Conway (2007) and Ayalew *et al.*, (2012) which reported moderate inter-annual variability of rainfall for most parts of the Amhara region.

A previous study has shown that climate variability has a significant negative effect on crop production in this area (Alemayehu and Bewket 2016). Asfaw et al., 2018 Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka

sub-basin most widespread and potentially devastating impact of the north central highlands of Ethiopia would be change in the frequency, intensity and predictability of rainfall.

KIIs state that

“Belg rain fall is as vital as that of kiremt due to different reasons. Availability of water and pasture becomes scarce after the long dry season (which extends from November–February). It is the belg rainfall which saves our livestock. Land preparation for kiremt planting should be undertaken ahead of time during winter and it is the belg rain which makes the task easy. Irrigation carried out using river diversion, springs and night storage modalities is also supplemented by belg rainfall whenever the availability of water during bega becomes less. Besides, we are using the belg rainfall to plant crops (like maize and sorghum) which need longer gestation period for harvesting. In short, belg rainfall is crucial for smallholder farmers. But, we lost all these opportunities due to failure or/and inadequate belg rain for the successive years”.

Temperature trends analysis

The mean annual maximum and minimum temperature is 13.97 and 6.3 °C respectively table 26. Rising mean annual maximum and minimum temperatures can have significant implications for ecosystems, agriculture, and water resources (IPCC, 2014). Higher temperatures may lead to increased evaporation rates, water stress, and reduced crop yields, particularly in regions already prone to heat stress (Wheeler and von Braun, 2013). Changes in temperature regimes can also affect the distribution of plant and animal species, alter phenological patterns, and influence ecosystem dynamics, contributing to shifts in land cover and biodiversity (Parmesan and Yohe, 2003). The maximum temperature recorded during the Belg season in May 2009 was 34.67°C. This indicates the occurrence of extreme heat events during specific months, which may have implications for human health, agriculture, and ecosystems. The minimum temperature recorded during the Belg season in February 1997 was 1.83°C. This indicates the occurrence of extreme cold events during specific months, which may have implications for human health, agriculture, and ecosystems.

Due to climate change/variability, the overall temperature in Ethiopia is showing an increasing trend. At a country level, both the annual minimum and maximum temperature have shown a considerable increase Temperature Variability. According to NMA (2007), the average annual minimum temperature over the country has increased by about 0.37°C, whereas, average annual maximum temperature has increased by about 0.1°C every decade (NMA, 2001).The mean

annual temperature for Ethiopia had increased by about 1.3⁰C between 1960 and 2006. Halonen *et al.*, (2009) indicated that for the period between 2040 and 2069, temperatures are projected to increase between 1⁰C and 3⁰C for Ethiopia. Keller (2009), also indicated that the patterns of temperature in Ethiopia showed an increasing trend but the increase is more pronounced since 2000; and this result is quite similar to that of the present study.

Maximum temperature

The mean annual maximum temperature shows warming trend the district for the period 1992-2022. The warming trends in the maximum temperature for Legambo(0.04⁰C /decade) the standard deviation 0.29. Statistically significant at p = 0.05 level table26 .Studies have documented the increasing trend in maximum temperatures in Ethiopia and its implications for agricultural productivity, water resources, and livelihoods (Deressa *et al.*, 2011; Funk *et al.*, 2019).

Table 4.16. Annual and seasonal maximum temperature

Table 26 Mean annual and seasonal maximum temperature

	Maximum temperature					
	Mean	LR / Decade	Temperature (°C)	Month	Year	SD
Annual	13.97	0.04***	16.99	Jun	2017	0.29
<i>Bega</i>	12.2	0.01***	14.6	January	1998	0.52
<i>Kirmet</i>	14.57	0.112**	16.99	Jun	2017	0.44
<i>Belg</i>	15.15	0.02	34.67	May	2009	0.37

*** = Significant at 0.01 level; **= Significant at 0.05 level; LT = linear trend (⁰C /10yr)

Source: Computed based on row data obtained from NMA,2023

The mean maximum temperature during the Kirmet season is 14.57⁰C. Kirmet coincides with the summer months in Ethiopia and typically experiences warmer temperatures. Increasing maximum temperatures during the Kiremt season can influence precipitation patterns, cloud dynamics, and atmospheric circulation, affecting regional climate variability and hydrological cycles (Hagos *et al.*, 2014). Warmer temperatures may intensify convective processes, enhance rainfall variability, and contribute to extreme weather events, such as heavy rainfall and flooding, with implications for land erosion and land use planning (Trenberth *et al.*, 2014). Changes in temperature regimes can also interact with other climatic factors, such as humidity,

wind patterns, and atmospheric pressure systems, influencing ecological processes and ecosystem services (Diffenbaugh et al., 2013).

The mean maximum temperature during the Belg season is 15.15°C. Belg is the shorter rainy season occurring in the spring, and temperatures during this period may vary depending on precipitation patterns and atmospheric conditions. Rising maximum temperatures during the Belg season can affect the timing, intensity, and duration of precipitation events, impacting agricultural activities, water availability, and soil moisture conditions (Dinku et al., 2007). Increased temperatures may shorten the Belg season, reduce water infiltration rates, and exacerbate runoff and soil erosion, leading to land degradation and loss of soil fertility (Hurni et al., 2015). Changes in maximum temperatures during the Belg season can influence crop phenology, flowering, and fruiting stages, affecting crop yields, quality, and market dynamics (Lobell et al., 2011).

The mean maximum temperature during the Bega season is 12.2°C. Bega is the dry season in Ethiopia, characterized by relatively cooler temperatures compared to the rainy seasons. Table 26 . High maximum temperatures during the Bega season exacerbate water stress and heat-related impacts on agricultural productivity and natural ecosystems (Ciais et al., 2005). Raised temperatures can accelerate evapotranspiration rates, soil moisture depletion, and vegetation stress, leading to reduced biomass production and increased vulnerability to drought (Seneviratne et al., 2012). Extreme heat events during the Bega season can also pose health risks, particularly for vulnerable populations, and further strain water resources and energy demand (IPCC, 2012).

Maximum temperature Trends

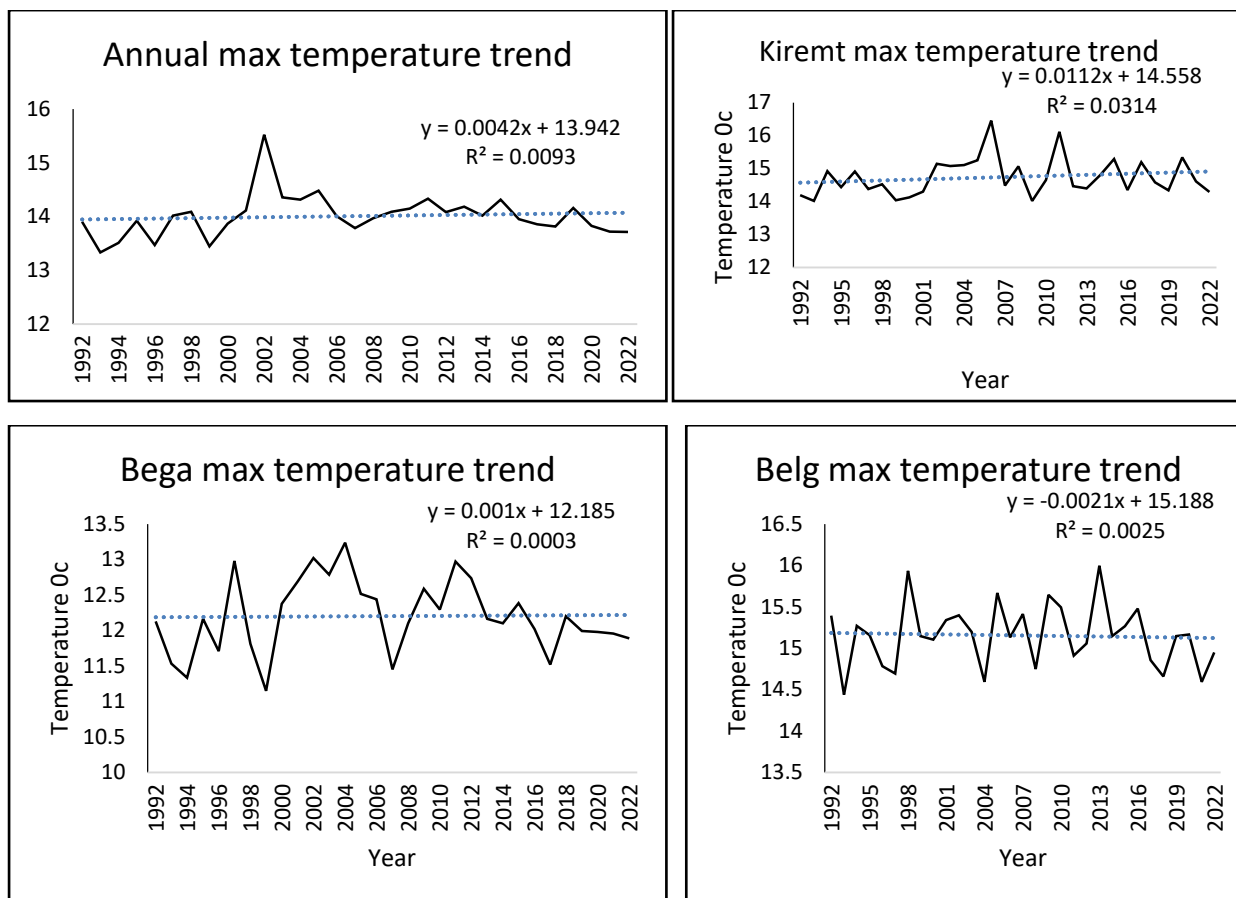


Figure 18 Maximum temperature trends(A); Annual (B); kiremt (C);Bega (D); Belg

Source: Computed based on row data obtained from NMA,2023

The mean annual maximum temperature shows warming trend 1992-2022. The warming trends in the maximum temperature for Legambo districts (0.04°C /decade) statistically significant at $p = 0.01$ (Figure 18). These results are consistent with earlier studies by Alemayehu and Bewkte,2016 Asfaw et al.,2018; Jury and Funk (2019), in the country that found a warming trend in the annual maximum temperature.

Seasonal trends in the maximum temperature are examined, Bega and Kiremt season experienced statistically significant increasing trends in in the Legambo district at $p = 0.01$ and 0.05 level respectively. Statistically non-significant but increasing trends in Belg season by 0.02mm/decade (Figure 18).

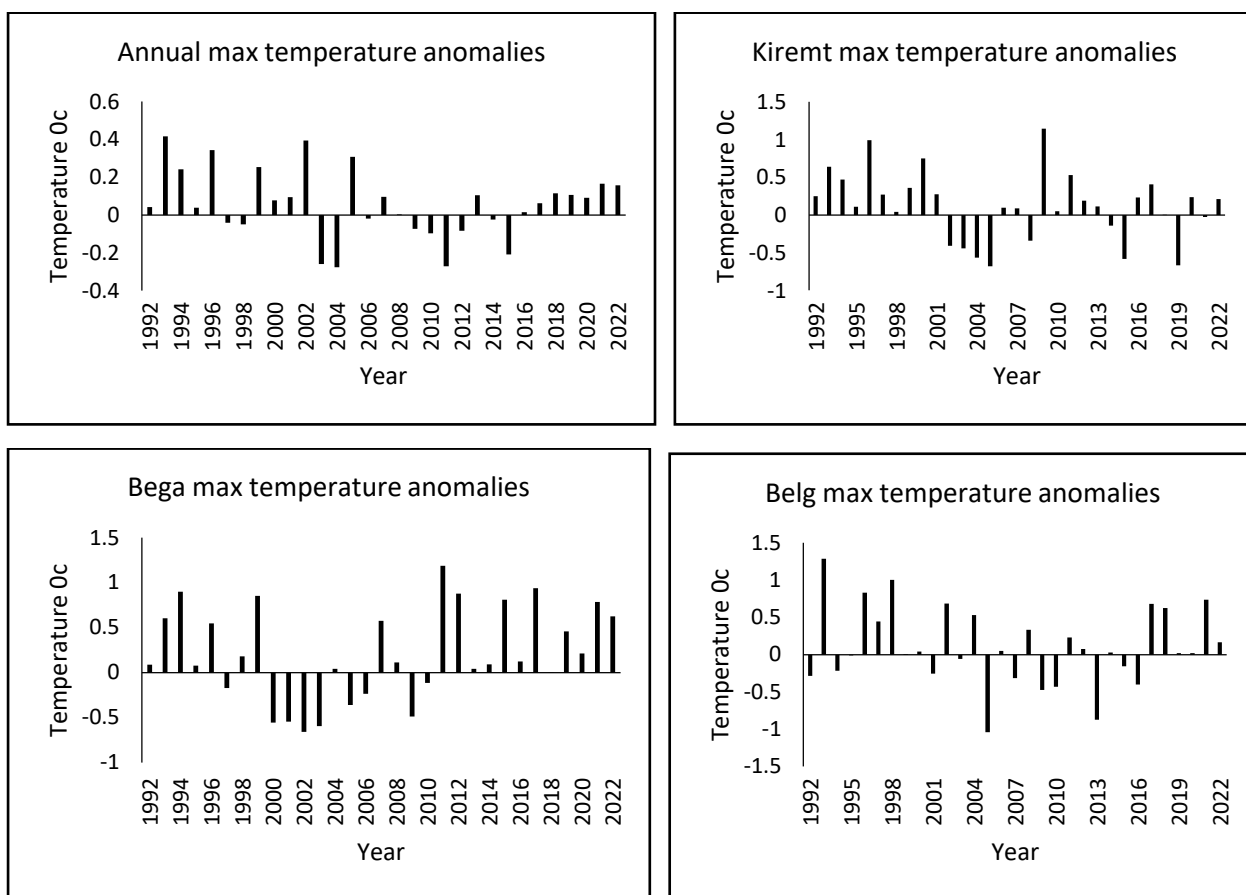


Figure 19 Maximum temperature trend (A); annual (B);Kiremt (C) Bega ;(D);Belg

Source: Computed based on row data obtained from NMA,2023

Figure 19 shows standardized annual and seasonal maximum temperature anomalies in the district for the period 1992-2022. The proportion of annual maximum temperature positive and negative anomalies 60% and 40% respectively of the total number of observations. Seasonal maximum temperature anomalies also show similar patterns as shown in (Figure 19). In kiremt season anomalies from 1992-2001 and 2009- 2002 positive anomalies. From 200-2010 are negative anomalies in Bega season. The year from 1993 -2003 except the year 1994 and 2003 are positive anomalies in Belg season.

Minimum temperature

The mean annual minimum temperature is 6.3°C from 1992-2022. The mean minimum temperature during the Kiremt season is 8.98°C. Kiremt is the main rainy season in Ethiopia, coinciding with the summer months. Typically, minimum temperatures during this season are higher due to increased cloud cover and humidity. Belg Season (February): The mean minimum

temperature during the Belg season is 7.74°C. Belg is a shorter rainy season occurring in the spring, characterized by cooler temperatures compared to the Kiremt season. Bega Season (November): The mean minimum temperature during the Bega season is 3.5°C. Bega is the dry season in Ethiopia, characterized by relatively cooler temperatures compared to the rainy seasons table 27 .

Table 27 Minimum temperature

	Minimum temperature					
	Mean	LT/10 years	Temperature (°C)	Month	Year	SD
Annual	6.3	0.09**	-0.05	November	2008	0.42
Kiremt	8.98	-0.01	4.67	September	1994	0.43
Belg	7.74	0.08***	1.83	February	1997	0.90
Bega	3.5	0.01***	-0.05	November	2008	0.54

Source: Computed based on row data obtained from NMA,2023

The annual minimum temperature shows positive trends districts has experienced statistically significant increasing trend (0.09⁰C /decade) at p = 0.05 level. With the standard deviation 0.8. Rising mean annual minimum temperatures can influence frost occurrence, growing season length impacting agricultural productivity and land management practices (Hänninen & Tanino, 2011). Changes in minimum temperatures can also influence pest and disease dynamics, affecting crop health, food security, and agroecosystem resilience (Bebber et al., 2013). Kiremt mean minimum temperature declining trend (-0.1/decade) *Bega* and Belg has statistically significant increassating trend (0.01 and 0.08 °C/decade) at p=0.01 level and standard deviation 0.54 and 0.90 respectively (Table 27). Rising minimum temperatures during the Belg season can affect precipitation regimes, cloud cover dynamics, and moisture availability, influencing crop water requirements and irrigation demands (Easterling et al., 2000). Warmer minimum temperatures affect water availability for agriculture, hydropower generation, and ecosystem services (Mote et al., 2018).

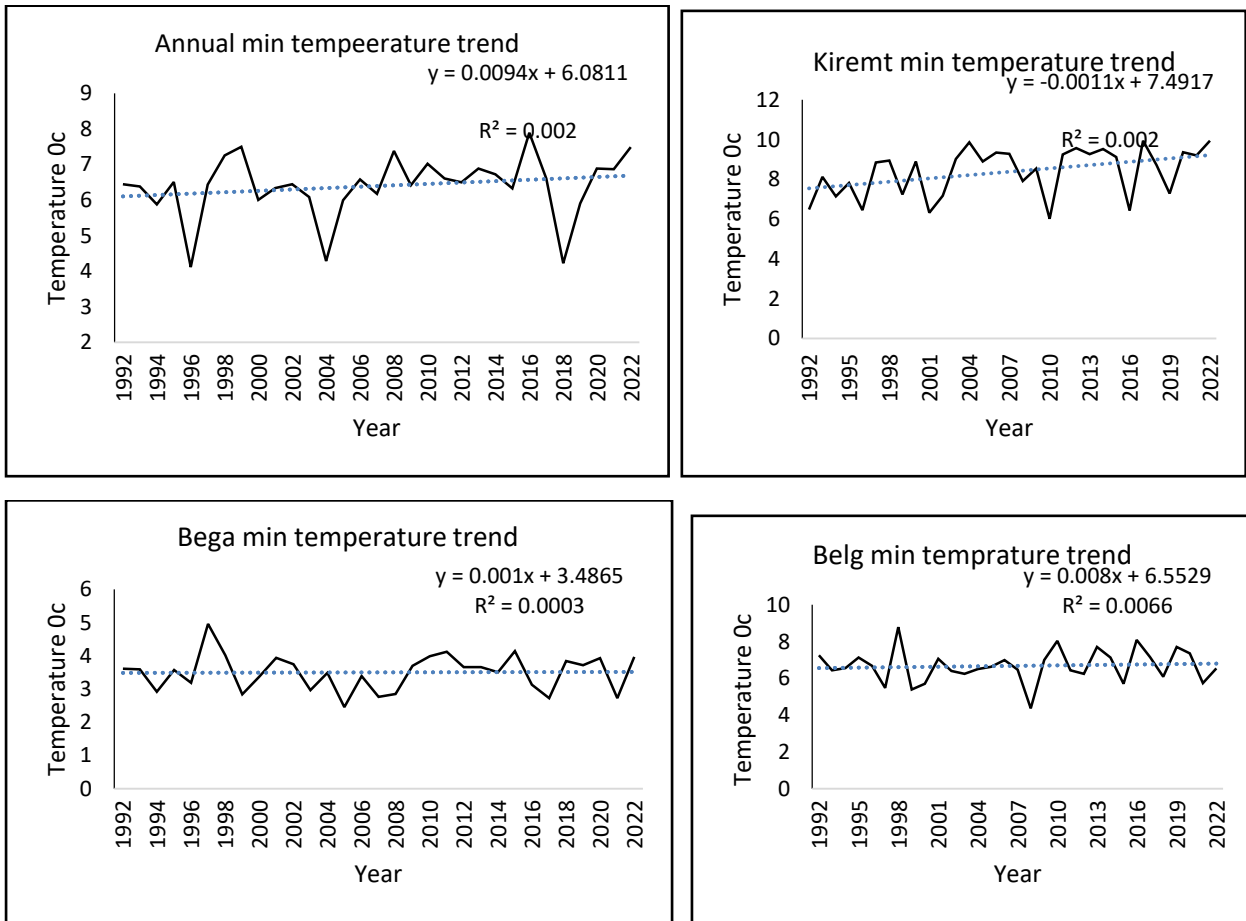


Figure 20 Minimum temperature trend (A); annual (B);Kiremt (C) Bega ;(D);Belg

Source: Computed based on row data obtained from NMA,2023

Figure 20 shows standardized annual and seasonal minimum temperature anomalies in the district for the period 1992-2022. Negative and positive anomalies account for 36 % and 64 % of the total observations, respectively. The 1994, 1999 and 2004-year highest negative 1998; the highest positive anomalies. to show from three-season Kiremt has 50 % positive anomalies whereas Bega 76 % and Belg 57% positive anomalies respectively.

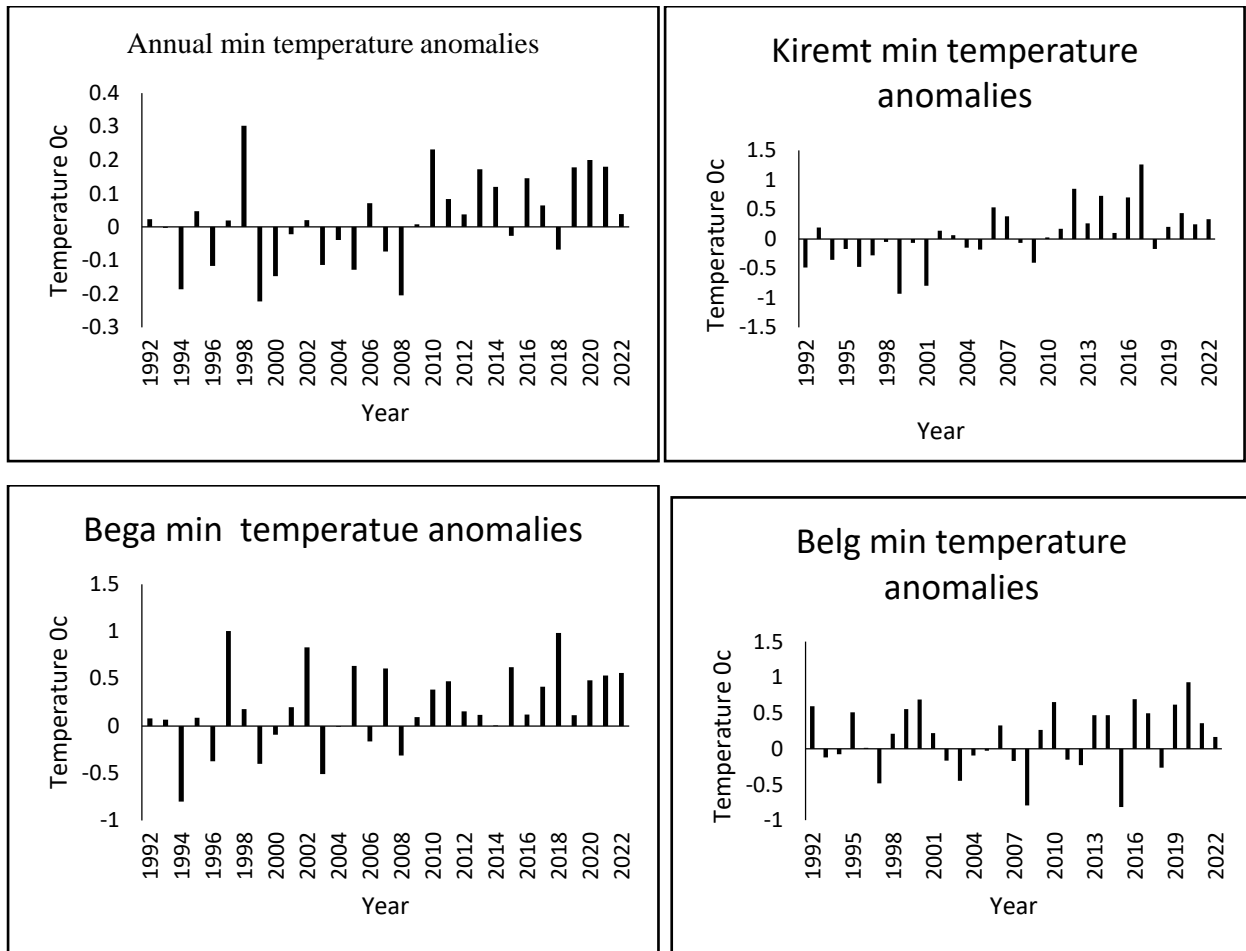


Figure 21 Minimum temperature Anomalies (A); annual (B); Kiremt (C) Bega ;(D); Belg

Source: Computed based on row data obtained from NMA

4.7. Impact of land degradation on rural livelihood

The impact of land degradation both on human beings (increased prices for farming commodities; Poverty and unemployment and increased threat to human and animal life) and Environment (Loss of biodiversity and decreasing land productivity Table 28).

The mean value of 3.84 suggests that increased prices for farming commodities are perceived as a significant impact of land degradation on rural livelihoods. This perception aligns with the understanding that land degradation can reduce agricultural productivity, leading to decreased supply and increased prices for farming commodities (Lal, 2015 Gashu and Muchie, 2018). The relatively low standard deviation (0.667) indicates a relatively consistent perception among respondents regarding this impact. Land degradation can reduce agricultural productivity, leading to decreased crop yields and increased production costs. This may result in higher prices

for farming commodities, impacting the income and food security of rural communities dependent on agriculture (Lal, 2015).

With a mean value of 3.56, the loss of biodiversity is perceived as a significant impact of land degradation on rural livelihoods. Land degradation, such as deforestation and habitat destruction, can lead to the loss of biodiversity, affecting ecosystem services and livelihood opportunities dependent on natural resources (Millennium Ecosystem Assessment, 2005). The relatively high standard deviation (0.844) suggests varied perceptions among respondents regarding the extent of biodiversity loss. Land degradation can lead to habitat destruction, fragmentation, and loss of biodiversity, affecting ecosystem services, such as pollination, pest control, and soil fertility. This may impact rural livelihoods reliant on natural resources for food, medicine, and cultural practices (MEA, 2005).

The mean value of 3.79 indicates that desertification and soil degradation, including topsoil erosion, are perceived as significant impacts of land degradation on rural livelihoods. Soil erosion and desertification reduce land productivity and agricultural resilience, posing challenges for rural communities dependent on agriculture (UNCCD, 2019). The relatively low standard deviation (0.751) suggests a relatively consistent perception among respondents regarding this impact. Land degradation, such as desertification and soil erosion, can degrade soil fertility, water retention capacity, and crop productivity. This may lead to reduced agricultural yields, food insecurity, and poverty among rural populations dependent on agriculture (UNCCD, 2019).

With a mean value of 3.87, migration, resettlement, and conflict are perceived as significant impacts of land degradation on rural livelihoods. Land degradation can lead to resource scarcity and competition, resulting in population displacement, resettlement, and conflicts over land and natural resources (UNCCD, 2019). The relatively high standard deviation (0.972) suggests varied perceptions among respondents regarding the extent of these social impacts. Land degradation can trigger rural outmigration, resettlement, and conflicts over land and natural resources, as communities compete for dwindling resources. This may lead to social unrest, displacement, and loss of traditional livelihoods, exacerbating poverty and vulnerability (Daum and Birner 2020).

Table 28 Impact of land degradation on rural livelihood

No	Impact of land degradation on rural livelihood	Mean	S.D
1.	Increased prices for farming commodities	3.84	.667
2.	Loss of Biodiversity	3.56	.844
3.	Desertification and soil degradation (top soil erosion)	3.79	.751
4.	Migration, resettlement, conflict	3.87	.972
5.	Poverty and unemployment	3.78	.738
6.	Increased threat to human and animal life	3.57	.836
7.	Decreasing land productivity	3.80	.725
	Grand mean	3.74	0.79

Source: Survey result, 2023

The mean value of 3.78 indicates that poverty and unemployment are perceived as significant impacts of land degradation on rural livelihoods. Land degradation can reduce agricultural productivity and livelihood opportunities, exacerbating poverty and unemployment in rural communities (World Bank, 2020). The relatively low standard deviation (0.738) suggests a relatively consistent perception among respondents regarding this impact.

Land degradation can perpetuate poverty and unemployment in rural areas by reducing agricultural productivity, income opportunities, and access to natural resources. This may lead to socio-economic disparities and marginalization among rural communities (UNDP, 2015).

With a mean value of 3.57, the increased threat to human and animal life is perceived as a significant impact of land degradation. Land degradation can lead to environmental hazards such as soil pollution, water contamination, and exposure to hazardous chemicals, posing health risks to humans and animals (UNEP, 2020). The relatively high standard deviation (0.836) suggests varied perceptions among respondents regarding the extent of this impact.

Land degradation can pose health risks to human and animal populations through exposure to contaminated water, air pollution, and vector-borne diseases. This may impact rural livelihoods by affecting livestock health, agricultural productivity, and human well-being (WHO, 2021).

The mean value of 3.80 suggests that decreasing land productivity is perceived as a significant impact of land degradation on rural livelihoods. Land degradation reduces soil fertility and water availability, leading to decreased agricultural yields and land productivity (UNEP, 2020). The relatively low standard deviation (0.725) indicates a relatively consistent perception among respondents regarding this impact. Land degradation can decrease land productivity, leading to reduced agricultural output, income losses, and food insecurity. This may undermine the resilience and sustainability of rural livelihoods, particularly in vulnerable regions prone to environmental degradation (FAO, 2015).

Land degradation has multifaceted impacts on rural livelihoods, affecting agricultural productivity, income generation, food security, and human well-being. Addressing these challenges requires integrated approaches that promote sustainable land management, ecosystem conservation, and socio-economic development to enhance resilience and livelihood opportunities in rural areas.

Mean value score ranging from 3.57 to 3.87 out of 5, the results indicate that respondents about the impact of land degradation mostly moderate to solely a highest extent. All the standard deviations of the variables were below 1.00 ranging from 0.667 to 0.972, which indicates that the perception among respondents were not contrary each other. The average scored mean and standard deviations of cause of land degradation 3.74 and 0.79 respectively.

KIIs from the Legambo district Agricultural and development office head "sate that *Changes in land use, such as deforestation, urbanization, and agricultural expansion, can increase soil erosion rates. Removal of vegetation cover exposes the soil to erosion by wind and water, leading to loss of fertile topsoil, decreased soil moisture retention, and increased sedimentation in water bodies. In addition to this in the district Intensive agricultural practices excessive use of agrochemicals, can degrade soil fertility over time. Loss of organic matter, nutrients, and soil structure impairs soil health and productivity, reducing agricultural yields and increasing the reliance on external input*

4.8. Conservation Measure for land degradation

Cultivating along the contour, with a mean value of 3.74, is perceived as an effective conservation measure for addressing land degradation. Contour cultivation helps reduce soil

erosion by minimizing water runoff and promoting water infiltration, thus preserving soil fertility and structure (Fenta et al., 2022). The standard deviation (0.777) suggests relatively consistent perceptions among respondents regarding this measure. Cultivating along the contour helps to reduce soil erosion by minimizing water runoff and promoting soil moisture retention. This technique can improve soil fertility, water infiltration, and crop yields, while also conserving soil and water resources (Abiye, 2022).

Terracing, indicated by a mean value of 3.80, is perceived as an effective measure for mitigating land degradation. Terraces help control soil erosion on sloping terrain by reducing the speed of water runoff and promoting soil moisture retention (Fenta et al., 2022). The standard deviation (0.742) suggests relatively consistent perceptions among respondents regarding this conservation measure.

Terracing involves constructing level or graded platforms on sloping terrain to control soil erosion and manage water runoff. This technique helps to retain soil moisture, reduce surface runoff, and prevent soil loss, thereby enhancing agricultural productivity and soil conservation (Bekele and Mebrate, 2023).

Strip-cropping along the contour, with a mean value of 3.80, is perceived as an effective measure for conserving land. This practice involves planting crops in alternating strips along the contour to reduce soil erosion and enhance water infiltration (Dabney et al., 2010). The relatively high standard deviation (0.962) suggests varied perceptions among respondents regarding the effectiveness of strip-cropping. Strip-cropping along the contour involves planting different crops in alternating strips along the contour lines to reduce soil erosion and improve soil fertility. This technique helps to trap sediment, minimize water runoff, and enhance biodiversity, while also providing multiple ecosystem services (Lal, 2016; Misebo, 2018).

Afforestation, with a mean value of 3.57, is perceived as an effective conservation measure for addressing land degradation. Planting trees helps stabilize soil, prevent erosion, and enhance biodiversity, thus restoring degraded land (Meragiaw, 2017). The standard deviation (0.816) suggests varied perceptions among respondents regarding the effectiveness of afforestation. Afforestation involves planting trees on degraded or deforested lands to restore ecosystem services, such as carbon sequestration, soil stabilization, and water regulation. This technique helps to mitigate climate change, reduce soil erosion, and enhance biodiversity, while also providing economic and social benefits (Meragiaw, 2017).

Table 29 Conservation Measure for land degradation

No	Conservation Measure for land degradation	Mean	SD
1.	Cultivation along the contour	3.74	.777
2.	Terracing	3.80	.742
3.	Strip-cropping along the contour	3.80	.962
4.	Afforestation	3.57	.816
5.	Vegetative and crop cover	3.57	.836
6.	Grassed waterways	3.81	.708
7.	Tree planting	3.80	.970
8.	Check dams	3.82	.686
9.	Agroforestry	3.84	.952
10.	Reforestation	3.58	.835
11.	Use of inorganic fertilizer	3.82	.723
	Average mean and SD	3.74	0.82

Source: Survey result, 2023

Vegetative and crop cover, indicated by a mean value of 3.57, is perceived as an effective measure for land conservation. Cover crops and vegetation help protect soil from erosion, improve soil structure, and enhance soil fertility (Giller, et al.,2021). The future of farming: Who will produce our food?. *Food Security*, 13(5), 1073-1099. et al., 2021). The standard deviation (0.836) suggests varied perceptions among respondents regarding the effectiveness of vegetative and crop cover. Maintaining vegetative and crop cover helps to protect soil from erosion, improve soil structure, and enhance water retention capacity. This technique also promotes biodiversity, nutrient cycling, and pest control, contributing to sustainable land use and agricultural productivity (Montgomery, 2007).

Grassed waterways, with a mean value of 3.81, are perceived as an effective measure for managing water runoff and erosion. Grassed waterways help stabilize soil, filter sediment, and reduce nutrient runoff, thus protecting downstream water quality (Abiye,2022). The standard deviation (0.708) suggests relatively consistent perceptions among respondents regarding this conservation measure.

Tree planting, with a mean value of 3.80, is perceived as an effective measure for land conservation. Trees provide numerous ecosystem services, including soil stabilization, carbon sequestration, and habitat provision, thus contributing to land restoration efforts (Santiago-García

et al., 2019). The relatively high standard deviation (0.970) suggests varied perceptions among respondents regarding the effectiveness of tree planting. Tree planting involves establishing tree cover on degraded or deforested lands to restore ecosystem functions, such as carbon sequestration, biodiversity conservation, and soil protection. This technique helps to mitigate climate change, reduce soil erosion, and enhance landscape resilience (FAO, 2020).

Check dams, indicated by a mean value of 3.82, are perceived as an effective measure for managing water runoff and erosion in hilly terrain. Check dams help slow down water flow, trap sediment, and promote infiltration, thus reducing erosion and downstream flooding (Abbasi et al., 2021). The standard deviation (0.686) suggests relatively consistent perceptions among respondents regarding this conservation measure. Check dams are small structures built across gullies or ephemeral streams to control erosion, slow down water flow, and retain sediment. This technique helps to stabilize slopes, recharge groundwater, and reduce downstream flooding, while also providing habitat for aquatic species (Addisie and Wassie, 2021).

Agroforestry, with a mean value of 3.84, is perceived as an effective measure for integrating trees into agricultural landscapes to enhance sustainability. Agroforestry systems improve soil fertility, provide additional income streams, and enhance biodiversity, thus contributing to land restoration and livelihood improvement (Gupta et al., 2020). The relatively high standard deviation (0.952) suggests varied perceptions among respondents regarding the effectiveness of agroforestry. Agroforestry integrates trees with crops or livestock on agricultural lands to enhance ecosystem services, such as soil fertility, water conservation, and biodiversity conservation. This technique helps to diversify income sources, improve land productivity, and promote environmental sustainability (Lelamo;2021).

Reforestation, indicated by a mean value of 3.58, is perceived as an effective measure for restoring degraded land and enhancing ecosystem services. Reforestation helps sequester carbon, stabilize soil, and restore biodiversity, thus mitigating the impacts of land degradation (Chazdon et al., 2016). The standard deviation (0.835) suggests varied perceptions among respondents regarding the effectiveness of reforestation. Reforestation involves replanting trees in areas that were previously deforested or degraded to restore forest ecosystems and ecosystem services. This technique helps to sequester carbon, conserve biodiversity, and protect watersheds, while also

providing socio-economic benefits to local communities (Chazdon et al., 2016; Ethis-Eriakha and Akemu 2023).

The use of inorganic fertilizer, with a mean value of 3.82, is perceived as a measure for enhancing soil fertility but may have mixed implications for land conservation. While fertilizers can improve crop yields, their improper use can lead to soil degradation, nutrient runoff, and water pollution (Abebe et al., 2022). The standard deviation (0.723) suggests relatively consistent perceptions among respondents regarding this practice. The use of inorganic fertilizer can increase soil fertility and crop yields in degraded or nutrient-poor soils. However, excessive or improper use of fertilizers can lead to soil and water pollution, nutrient runoff, and ecosystem degradation, posing environmental and health risks (Alemineu and Alemayehu ,2020).

Mean of the result, it scores from 3.57 to 3.84 out of 5; the results indicate that the practices had been performed in moderate extent. All the standard deviations of the variables ranging from .686 to 970.

The analysis of the provided data suggests that various conservation measures are perceived differently in terms of their effectiveness in addressing land degradation. Implementing a combination of these measures tailored to specific contexts can help effectively mitigate land degradation and promote sustainable land management practices.

Implementing conservation measures for land degradation is crucial for promoting sustainable land management, enhancing ecosystem resilience, and supporting rural livelihoods. These measures offer multiple benefits, including soil conservation, water management, biodiversity conservation, and climate change mitigation, contributing to the overall well-being of communities and ecosystems.

4.8.1. The effect of Sustainable land managements on land degradation

As shown in table 30, SLM practices are perceived to lead to increased crop yield, as indicated by the mean value of 3.67. Sustainable practices such as conservation tillage, crop rotation, and agroforestry can improve soil health, nutrient availability, and water retention, leading to enhanced crop productivity (Pretty et al., 2006). The relatively high standard deviation (0.916) suggests varied perceptions among respondents regarding the extent of yield improvement.

SLM practices play a crucial role in preventing soil erosion, as highlighted by the mean value of 3.69. Erosion-control measures such as contour plowing, terracing, and cover cropping help stabilize soil, reduce water runoff, and minimize soil loss, thus preserving soil fertility and

agricultural productivity (Montgomery, 2007). The relatively high standard deviation (1.123) suggests varied perceptions among respondents regarding the effectiveness of erosion prevention measures.

SLM practices contribute to improved soil-water retention, as indicated by the mean value of 3.49. Practices such as mulching, agroforestry, and soil conservation techniques enhance soil structure, organic matter content, and infiltration capacity, leading to better water retention and availability for crops (Abiye ,2022;) Lenga et al.,2024. The relatively high standard deviation (0.915) suggests varied perceptions among respondents regarding the effectiveness of soil-water retention measures.

Table 30 the effect of Sustainable land managements on land degradation

No	Effects of Sustainable Land Management	Mean	SD
1.	Increased crop yield	3.67	.916
2.	Prevent soil erosion	3.69	1.123
3.	Improved soil-water retention	3.49	.915
4.	Assuring long term productivity of land	3.57	.816
	Average mean and SD	3.61	0.94

Source: Survey result, 2023

SLM practices are perceived to assure the long-term productivity of land, as reflected by the mean value of 3.57. Sustainable practices such as crop diversification, soil conservation, and agro ecological approaches help maintain soil fertility, biodiversity, and ecosystem services, ensuring sustained productivity over time (Temegne et al., 2021). The relatively low standard deviation (0.816) suggests relatively consistent perceptions among respondents regarding the long-term benefits of SLM practices.

The analysis of the provided data indicates that Sustainable Land Management practices have positive effects on various aspects of land and agricultural productivity, including increased crop yield, soil erosion prevention, improved soil-water retention, and long-term land productivity. However, there are varied perceptions among respondents regarding the effectiveness of these practices, highlighting the importance of context-specific approaches and stakeholder engagement in implementing SLM interventions.

Chapter five

5. Major findings Conclusion and Recommendation

5.1. Major findings

The study aimed to assess land use land cover change (LULCC) and land degradation in the drought-prone Legambo District, Ethiopia, utilizing geospatial tools and analyzing both quantitative and qualitative data. The findings are summarized as follows: mixed methods research approach was employed, combining both qualitative and quantitative data collection methods to comprehensively address the research problem. The study utilized a descriptive and explanatory research design. Descriptive design was used to portray the existing phenomenon of land use land cover change (LULCC) and land degradation, while explanatory research aimed to provide insights into why certain phenomena occurred.

Primary data were gathered from various stakeholders in the Legambo Woreda, including household heads, elders, community leaders, and development agents. Secondary data were obtained from published and unpublished materials, government offices, and international sources such as meteorological agencies and satellite imagery. LULC Data: LULCC data were sourced from the United States Geological Survey (USGS), utilizing four LANDSAT imagery spanning from 1992 to 2022. Ground Control Points (GCPs) were collected before satellite image analysis to enhance accuracy. Climate data spanning from 1992 to 2022 were obtained from the meteorological agency of Ethiopia to assess climate change and variability in the study area. A multistage sampling technique was employed to select the study area and sample households. The total sample size of 348 household heads was determined using a formula based on standard variation, sample proportion, target population size, and desired precision.

The response rate was high, with 90.22% of questionnaires returned out of 348 distributed. This indicates strong engagement from respondents in the study area.

Socio-demographic Characteristics of Respondents: Gender 59.9% of respondents were male, indicating a higher representation of males in the study. Majority of respondents (66.5%) were between 20 and 40 years old, considered the young and reproductive age group. Marital Status: 80.3% of respondents were married, suggesting a stable marital situation in the area.

Educational Level 70.7% of respondents were able to read and write, indicating a reasonable level of education. Educated respondents may contribute to a better understanding of land degradation issues. Family Size: Most respondents (84.1%) had family sizes between 3-8, indicating larger families, possibly due to cultural or socio-economic factors.

Majority of respondents (90.1%) depend on rain-fed agriculture, which is vulnerable to factors like land fragmentation, high input prices, and rainfall variability.

Landholding sizes are mostly small, with 53.5% having less than 1 hectare, influencing land use practices and potentially contributing to land degradation. Soil fertility is predominantly medium (53.8%), but a significant portion (42.4%) is low, affecting agricultural productivity and livelihoods. Land productivity is decreasing for 47.1% of respondents, indicating potential land degradation issues

Main reasons for declining land productivity include soil erosion, poor soil fertility, and rainfall variability, affecting agricultural productivity and livelihoods.

High concentrations of stones, waterlogging, and wildlife attacks also contribute to land productivity decline. Livelihoods are vulnerable to various factors, with drought affecting 96.5% of respondents, followed by food inadequacy (91.7%) and shortage of farm land (82.5%).

Flooding, shortage of animals' feed, and price fluctuations for agricultural products also pose challenges to livelihoods and agricultural productivity. The study analysed land use and land cover changes in Legambo district using satellite images from 1993, 2003, 2013, and 2023. The key findings indicate significant transformations in the landscape over the study period. In 1993, agriculture dominated the land cover, covering nearly 60% of the total area. Bare land, indicating potential land degradation, accounted for over 28%.

By 2003, agricultural land expanded further to cover approximately 76% of the area, reflecting increasing farming activities. However, the percentage of bare land decreased, suggesting changes in land use practices. In 2013, while agriculture remained dominant, there was a slight decrease in its share compared to 2003. Vegetation cover also decreased, indicating potential deforestation or habitat conversion. Settlement areas increased gradually over the study period, indicating ongoing urbanization and infrastructure development.

The analysis of LULC in Legambo district for 2023 reveals significant changes compared to previous years, notably expansions in settlement areas, indicating rapid urbanization, and population growth. The observed land use changes have several implications for the

environment, economy, and society in Legambo district. Expansion of agricultural land may enhance food production but could lead to soil erosion, loss of soil fertility, and water pollution. Decreases in vegetation cover raise concerns about deforestation, loss of biodiversity, and ecosystem degradation. Increasing settlement areas reflect urbanization trends, which can fragment habitats, exacerbate environmental degradation, and strain resources.

Annual rainfall in the study area has shown a statistically significant declining trend over the period of observation. Variability in rainfall across seasons is shown, with the Belg season exhibiting the highest coefficient of variation (CV) at 56%, indicating significant fluctuations in rainfall from year to year. The Precipitation Concentration Index (PCI) indicates highly concentrated rainfall in a few wet months, with July, August, and September contributing the most to total rainfall. Standardized Rainfall Anomalies (SRA) analysis shows negative anomalies, indicating drought conditions during specific years, with implications for agriculture and livelihoods.

Mean annual maximum and minimum temperatures have shown an increasing trend, with statistically significant warming trends observed. Rising maximum temperatures during the Kiremt and Belg seasons may influence precipitation patterns and agricultural activities, exacerbating water stress and impacting crop yields. Increasing minimum temperatures during the Belg season can affect precipitation regimes and soil moisture availability, influencing agricultural productivity and land management practices.

The survey indicates that land degradation significantly impacts rural livelihoods, with key issues including increased prices for farming commodities, loss of biodiversity, desertification, migration, poverty, unemployment, threats to human and animal life, and decreasing land productivity. Respondents perceive these impacts moderately to highly, with relatively consistent perceptions among them. Conservation Measures for Land Degradation Various conservation measures are perceived as effective in addressing land degradation. Cultivating along the contour, terracing, strip-cropping along the contour, afforestation, grassed waterways, tree planting, check dams, agroforestry, reforestation, and judicious use of inorganic fertilizers are among the recognized measures. These practices vary in perceived effectiveness, with relatively consistent perceptions among respondents for some measures.

Effect of Sustainable Land Management (SLM) Practices SLM practices is perceived to have positive effects on land degradation. They contribute to increased crop yield, prevention of soil

erosion, improved soil-water retention, and assurance of long-term land productivity. However, there are varied perceptions among respondents regarding the extent of these effects, indicating the need for context-specific approaches in implementing SLM interventions.

5.2. Conclusion

The data illustrates the dynamic nature of LULCC in Legambo district, influenced by various natural and anthropogenic factors. Understanding these dynamics is essential for sustainable land management and conservation efforts. Impact of human activities such as urban expansion, agricultural intensification, deforestation, and overgrazing significantly contribute to changes in land use and land cover. Addressing these activities requires holistic approaches that consider socio-economic factors, environmental sustainability, and community livelihoods.

Environmental Implications Changes in land use and land cover have environmental implications, including habitat loss, biodiversity decline, soil erosion, and altered ecosystem services. Sustainable land management practices are necessary to mitigate these impacts and promote ecosystem resilience.

The study result revealed that the complex interactions between climate variability, rainfall patterns, temperature trends, and their impacts on agricultural productivity and rural livelihoods. Declining trends in annual rainfall, coupled with increasing temperatures, pose significant challenges to food security, water availability, and ecosystem resilience in the study area. Addressing these challenges requires integrated approaches that prioritize sustainable land management, adaptation strategies, and community resilience-building efforts.

SLM practices were perceived to have positive effects on various aspects of land and agricultural productivity, including increased crop yield, prevention of soil erosion, improved soil-water retention, and assurance of long-term land productivity. However, there were varied perceptions among respondents regarding the effectiveness of these practices, suggesting the need for context-specific approaches and stakeholder engagement in implementing SLM intervention

5.3. Recommendation

Sustainable Land Management Practices: Implement sustainable land management practices to mitigate soil erosion, improve soil fertility, and promote ecosystem health. This includes measures such as agroforestry, soil conservation, and integrated land management approaches. Implement integrated land use planning and management approaches that balance socio-

economic development with environmental conservation objectives. This includes zoning regulations, land use policies, and community engagement initiatives.

Conservation Efforts: Prioritize conservation efforts to protect remaining vegetation cover, forests, and natural habitats. Encourage community participation in conservation initiatives and establish protected areas to safeguard biodiversity.

Community Participation: Engage local communities in decision-making processes related to land use and land cover management. Empowering communities to participate in conservation activities fosters ownership and ensures the long-term success of initiatives.

Capacity Building: Invest in capacity building programs to enhance knowledge and skills related to sustainable land management practices, including agroforestry, soil conservation, water management, and climate-smart agriculture. Provide training and extension services to farmers on climate-smart agriculture practices and adaptive water management strategies. Enhance local capacity for early warning systems and disaster preparedness to mitigate the impacts of extreme weather events..

Monitoring and Assessment: Establish strong monitoring and assessment mechanisms to track changes in land use and land cover over time. Regular assessments help identify emerging trends, evaluate the effectiveness of interventions, and inform adaptive management strategies.

Adaptation Strategies: Implement climate-resilient agricultural practices, such as drought-resistant crop varieties, water-saving irrigation techniques, and soil conservation measures. Promote diversified livelihood options, including non-farm income sources, to enhance community resilience to climate-related shocks.

Research and Monitoring:

Conduct further research to assess the vulnerability of specific crops and ecosystems to climate variability and develop targeted adaptation strategies. Establish long-term monitoring programs to track changes in rainfall patterns, temperature trends, and their impacts on agriculture and livelihoods.

Policy Intervention: Formulate and enforce policies that promote sustainable land use practices, conservation of natural habitats, and responsible urban development to achieve long-term environmental sustainability. Develop and enforce policies that promote sustainable land use practices, conservation, and climate resilience. Support initiatives that empower local communities, strengthen land tenure systems, and foster partnerships between government agencies, NGOs, and stakeholders.

By prioritizing these recommendations and fostering collaboration among stakeholders, it is possible to mitigate land degradation, protect rural livelihoods, and ensure the long-term sustainability of agricultural landscapes.

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College of Social Science and Humanities

Department of Geography and Environmental Studies

Appendix I Questionnaire

Dear respondents,

This questionnaire is designed to obtain or gather data to develop research for academic purpose and so, that are intended to investigate the **Land use Land, Cover Change Analysis and Land Degradation using Geospatial tools In the case of Drought Prone Area Legambo District, Ethiopia**. The success of this academic research depends on your honest response and, thus you are kindly requested to respond clearly and genuinely. you may not respond if you are not comfortable with the questionnaires. Your response will have kept confidently

Thank you in advance!

Part one: socio demographic characteristics of respondents

No	Questions	Category	Please Put “√ or ×” mark for choice questions
1.	Sex of household head	Male	
		Female	
2.	Age of the respondent	<30 years	
		31—45 years	
		46—64 years	
		>65 years	
3.	Marital Status of the household head	Married	
		Not married	
		Divorced	
		Widowed	
4.	Education level of the HHs head	cannot read and write	
		can read and write	
		primary school(1-8)	
		secondary and Above	
5.	What are the main economic activates for the household?	Farmers	
		Merchant	
		Daily labor/wages/	
	Family size including the household head:	< 3 family	
		3-8 family	
		>8 family	
6.	How long have you lived in this area	Less than one years	
		2-5 years	
		6-10 years	
		11-20 years	
		>21 years	

Part Two: Economic Characteristics of the households

7. What kind of agriculture are you practicing?

- 1 Rain fed agriculture 2. Irrigated agricultures 3. Both rain fed and irrigated agriculture

Land:

8. Do you have your own land? 1 yes 2 no

9. If yes, how many teamed do you have? _____

10. How did you get the land you have currently?

1. through renting 2. Through share cropping 3. Inherited from parents 4. Allocated by Kebele

11. What are the total sizes of the following land types that you use?

no	Land type Others	Unit in local measure (timed)	Hectare
1	Cultivated land		
2	Grazing land		
3	Tree land		

12. How do you perceive the productivity of your land?

1. Increasing 2. Decreasing 3. Constant 4. Do not know

13. If the yield from your farmland is decreasing, what are the main constraints to your farmlands?

No	the level constraints of farmland	1. Yes	2. No
1	Erosion		
2	Water logging		
3	Poor soil fertility		
5	Rainfall variability		
7	High concentration of stones on the topsoil		
8	Inaccessibility to water or drought		
9	Wildlife attack		

14. Would you please tell us the number of livestock you own at present?

no	Type of animals	Number		Current Equivalent cash
		Before 10 years	Current	
1	Cows			
2	Oxen			

3	Sheep			
4	Goats			
5	Mules			
6	Horses			
7	Donkeys			
8	Calves			
9	other			

15. Are your livelihood vulnerable?

1. Yes 2. No

No	the level of effects in your life	Yes	no
1	Drought		
2	Food inadequacy		
3	Shortage of farm land		
4	Flood		
5	Shortage of animal's feed		
7	Price fluctuations for agricultural products		
8	Shortage of water supply		
9	Poor health		
10	Migration		

16. If yes, which of the following affects your life?

Part three. Based on your experience, what are the cause of Land degradation in your area?

Please rate your level of agreement to the following statements:

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

No	Cause of land degradation	1	2	3	4	5
1.	High of rain fall amount					
2.	Overgrazing					
3.	Deforestation					
4.	Human population pressure					
5.	High poverty					
6.	Improper settlement					
7.	Expansion of farmland					

8.	Urban land expansion					
9.	Traditional farm practices					
10.	Poor access to Gov,t/NGO services					
11.	Poor access to modern farm input					
12.	Low non-farm income					
13.	Poor soil fertility					
14.	Land fragmentation					
15.	Poor soil cover					
16.	Excessive tillage					
17.	Bad cultivation practices					

Part four: Impact of Land degradation on livelihood

Based on your experience, what are the impact of Land degradation in your area?

Please rate your level of agreement to the following statements:

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

No Impact of land degradation **1 2 3 4 5**

1. Increased prices for farming commodities
2. Loss of Biodiversity
3. Desertification and soil degradation (top soil erosion)
4. Migration, resettlement, conflict
5. Poverty and unemployment
6. Increased threat to human and animal life
7. Decreasing land productivity

Part five: Conservation Measure for land degradation

Based on your experience, what are the conservation measure for land degradation in your area?

Please rate your level of agreement to the following statements:

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

No	Conservation Measure for land degradation	1	2	3	4	5
1.	Cultivation along the contour					
2.	Terracing					
3.	Strip-cropping along the contour					
4.	afforestation					
5.	Vegetative and crop cover					
6.	Grassed waterways					
7.	Tree planting					
8.	Check dams					
9.	Agroforestry					
10.	Reforestation					
11.	Use of inorganic fertilizer					

Part six: What are the effects of Sustainable land measures?

Based on your experience, what are the conservation measure for land degradation in your area?

Please rate your level of agreement to the following statements:

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

no	SLM	1	2	3	4	5
1.	Increased crop yield					
2.	Prevent soil erosion					
3.	Improved soil-water retention					
4.	Assuring long term productivity of land					

Part seven: Sustainable Land Management Adoption constraints

Based on your experience, what are Sustainable Land Management Adoption constraints for land degradation in your area?

Please rate your level of agreement to the following statements:

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

no	Sustainable Land management's constraints	1	2	3	4	5
1.	Technology attributes					
2.	Small farm size					
3.	Property rights					
4.	Lack of tillage tools					
5.	Lack of money/capital					
6.	Lack of labor					
7.	Tenure security					

Thank you a lot

