Thesis in Geo-informatics

MEKELLE UNVERSITY

Institute of Geo-information and Earth Observation Sciences (IGEOS)
Department Of Geo-informatics

Evaluation of land use/cover change and implication for land management of mountainous landscape in Laygaint, North Ethiopia

A thesis submitted in partial fulfillment of the requirements of Mekelle University, Institute of Geo-information and Earth Observation Sciences for the degree of Master of Science in Geo-information and Earth Observation Sciences, Specialization Geo-informatics**.**

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January, 2024

Mekelle, Ethiopia

Abstract

Land Use Land Cover Change (LULCC) is one of the major human induced global changes. Information on LULCC, the forces and processes behind such changes are essential for proper understanding of how land was being used in the past, what type of changes have occurred and is expected in the future. This study was carried out to examine land use land cover changes and driving forces behind the changes in Laygaint district, north Ethiopia. The main objective of this thesis is to evaluate the land use/cover with its implication of land management and predictable in the future on mountain landscape. It was conducted using satellite image of Landsat5 TM 1990 and 2000, Landsat7 ETM+ 2010 and Landsat8 OIL/TIROS 2023. In addition, field observations, Key informant interview (KII) and Focus Group Discussion (FGD) were also conducted. ArcGIS 10.5 and QGIS (MOLUSCE 3.0.1), soft wares were used for satellite image processing, map preparation and LULCC prediction respectively. The main finding of this study revealed an expansion of agriculture/crop land as well as bare land and reduction of grass land and dense forest over the last 33 years between 1990 and 2023. Crop land/agriculture and bare land increased by 23700ha and 19800ha, with a corresponding 24000ha and 19600ha decline in the area of grass land and dense forest respectively. If the current rate of LULCC continues, bare land is predicted by 23.9% in 2033. In contrast agriculture/crop land, dense forest and grass land are predicted to shrink 60.81%, 0.61% and 2.88% respectively. LULCC in Laygaint is a result of several proximate and underlying drivers. The major proximate driving forces of LULCC in the study area are agricultural expansion, illegal logging and fuel wood extraction, overgrazing and expansion of illegal and unplanned settlements. Demographic, economic, technological, institution and policy, socio-cultural and biophysical factors constitute the major underlying drivers of LULCC in the study area. Hence, the right policy packages are required to control the expansion of agriculture and bare land at the shrink of grass land and dense forest resources in the study area.

Key words: Drivers, land use land cover, Change prediction, underlying and proximate drivers

Declaration

I, the undersigned, declare that this thesis entitled “Evaluation of land use/cover change and implication for land management of mountainous landscape in Laygaint, North Ethiopia” is my original work and has not been presented for any other award, and that all source of materials used in this thesis are duly acknowledged. This thesis was carried out under the supervision of my principal advisor Dr. Gebrerufael Hailu, institute of Geo information and earth observation science, Mekelle University.

Name of student _Walelign Zewdie

Signature with date________________________

Approval sheet I

This is to certify that the thesis entitled "Evaluation of land use/cover change and implication for land management of mountainous landscape in Laygaint, North Ethiopia" submitted partial fulfillment of the requirements of Mekelle University, Institute of Geo-information and Earth Observation Sciences for the degree of Master of Science in Geo information and Earth Observation Sciences, specialization in Geo-informatics by Walelign Zewdie, under my supervision.

Therefore, I recommend that the student has fulfilled the requirements and hence here by can submit the thesis to the department.

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Approval sheet II

We the undersigned members of the Board of Examiners of the final open defense by Walelign Zewdie have read and evaluated his thesis entitled "Evaluation of land use/cover change and implication for land management of mountainous landscape in Laygaint, North Ethiopia" and examined the candidate. Accordingly this is to certify that the thesis has been accepted in partial fulfillment of the requirement for the degree of Master of Science.

Name of the Chairperson Signature with date

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Acknowledgement

First of all my everlasting thanks go for the Almighty God to his eternal love and kindness. This thesis has been possible with the help of many peoples. My special thanks go to my first advisor Dr. Gebrerufael Hailu and Co advisor Mr. Halemariam Gebrewahid for their indispensable support in all stage of my thesis. I deeply thanks to them for devoting their precious time in reading, commenting and correcting my thesis; without whom this paper would not be in its present form. I am also thankful to South Gondar Zone agriculture bureau, Woreda offices in laygaint, farmers and field guides for their immeasurable cooperation and participation during the course of data collection. And I am thankful to my wife W/or Yekaba Alelign, my mother w/or Alemnesh Asefa and my brother Abebe Zewdie for their endless support and encouragement. At last but not the least I thank all my classmates in Mekelle University, Institute of Geo-information and Earth Observation Sciences Department of Geo-informatics and for their support and suggestions.

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List the Acronyms

Aster = advanced space borne thermal emission and reflection radiometer

ANN = artificial neural networks

DEM = Digital Elevation Model

DSS= Decision Support System

CA = Cellular automata

^{0}C = degree centigrade

ERDAS = earth resources data analysis system

ETM+ = Enhanced Thematic Mapper plus

ENVI = Environmental for Visualization of Image

ESA= Ethiopia statics agency

EFDR= Ethiopia federal democratic republic

FA= Farmer Association

FAO = Food and Agriculture Organization

FGD= focus group discussion

GPS = global positioning system

GIS = geographic information system

GCP = ground control points

Ha = hectare

Km = kilo meter

KII= key informant interviews

LULC= land use land cover

LULCC= land use land cover change

M = meter

MCM = Markov chain model

MLP = Multi-Layer Perceptron

MOLUSCE = Modules of Land Use Change Evaluation

NTFP = Non-Timber Forest Products

OLI = Operational Land sat Imager

PFM = participatory forest management

PRM = participatory rangeland management

QGIS = Quantum Geographical Information System

RGB = Red, Green and Blue

RS = remote sensing

SSE = Supervised spatial encoder

TM = Thematic Mapper

T.A = total area

USGS-EROS = United State Geological- Earth Resource Observation and Science

UTM = universal Transverse Mercator

WGS = World Geodetic System

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

Land use land cover systems have complex dynamics that consists of natural, social and economic spatial factors (Yan, 2015). Both natural and human activities are responsible for LULCC (Burka, 2008), while the latter is increasingly recognized as dominant force in LULCC (Lamichane, 2008). Human activities are responsible for the conversion and transformation of the natural land (Hamza and Iyela, 2012). Land use land cover change have become a central and important component in current strategies of humans for managing natural resources and monitoring environmental changes (Rawat, 2013).

In Ethiopia, change in land use, mainly through the conversion of natural forests to agricultural land and settlement, is the most widely distributed activity. Based on WBISPP, the land use and land cover statistics in Ethiopia indicates that woody vegetation, high forests covers over 50% of the land (WBISPP., 2005). The presence of old remnant forests around old churches and protected areas are indicators of the types of forest that covered the country in the past. However, in 21st century (now a day), forest coverage has reached a low level of 3.56% (WBISPP, 2004). Available evidence indicates that major deforestation in the northern highlands of Ethiopia took place at least 2000 years ago (Eshetu, 2002). The cause of LULC changes in deforestation are particularly related to population increment, who demand more crop land, grazing land and forest resource consumption for different purposes (Verburg P. V., 1999). These human factors are advancing at a faster rate in Ethiopia and play an important role in the conversion of endemic forests into crop and grazing lands. Land use land cover dynamics are wide - spread, accelerating and significant process driven by human actions, while also producing changes that impact humans (Agarwal, 2002). These dynamics alter the availability of different biophysical resource, including soil, vegetation, water, animal feed and others. Not only from the above, but also LULC changes could be decreased by the availability of different products and service of human and livestock, agricultural production. These damage the environment.

Mountain ecosystems are sensitive to land use land cover (Eshetu, 2002). It is because these areas were characterized by high population pressure and cultivated for a long period of time (Kindu., 2013). Mountain regions have thus high socio-economic value but they are less developed due to various physical barriers caused by human activity. A challenge that has to be resolved when evaluating and modeling land-use change in mountainous regions is the topographic complexity. These regions has a large impact on land-use decisions (Gellrich, 2008). Mountain ecosystems are also very sensitive to change and subtle shifts in the environment. They can have a large impact on land-use dynamics (Houet et al., 2010). Not only the above, Topographic complexity also affects agricultural land-use directly, as it has a strong influence on soil characteristics.

Land management affects agriculture that can consequence of intensive use or destructive land management (Reyers, 2009). Land use is the purpose for which humans exploit the land cover (e.g. grazing, hay production on grasslands). This purpose is achieved by land management practices (verburg, 2009) . Management practices or activities are characterize land use (includes irrigation, pesticide use, livestock management and nature conservation measures (Bennett, 2009). These management activities define the type and intensity of land use. Land use intensity is characterized by the amount of human input and extraction. Land use intensity ranges from light or extensive with minimal human intervention to intensive and very intensive management with many human interventions (De Groot, 2010). Different land management practices such as agricultural intensity(Temme, 2011), vegetation or ecological degradation (Reyers, 2009) or restoration measures (Chazdon, 2008) affect ecosystem services. The production and use of information on the effects of LUCC management practices on ecosystem functioning are decisive for the design of policies (Nelson, 2009). However, this requires taking into account interactions between multiple human uses, they are a source of complexity for planning managers(Naeem, 2009). Regional planning at the federal level and at Land level is aimed at integrating the economic, social and environmental goals of sustainability for the purposes of sustainable land-use management, conserving resources and safeguarding development potential.

To determine the condition of the LULC in the next two or more years, it can be done with modeling of LULC predictions. The modeling can be done by cellular automata model (Guan etal.2011). Models of land degradation indicate whether the land use and land cover changes were sustainable or unsustainable. Such analyses were essential for planning and decision-making focusing on actions related to environmental degradation.

Therefore, this study maps out the status of land use land cover of Laygaint from 1990 to 2023 with a view to detecting the land consumption rate and to predict possible changes. This study also aims to assess the effectiveness of land management measures being practiced based on mountain landscape user association in the study areas.

1.2. Statement of the Problem

Land use land cover change and degradation of natural resource particularly vegetation and soils are increasing at alarming rate in the highlands of Ethiopia (Zeleke, 2001). These changes were primarily due to human activities with the population growth. The LULC change is critical in the highlands of Ethiopia (Garedew et al., 2012) because its adverse effects are environmental degradation in the form of soil erosion, soil quality reduction, loss of biodiversity, habitat distraction, and diminishing availability of water (Wubie et al., 2016; Miheretu and Assefa, 2017).

A study area is characterize by mountain land scape. For instance famous mountain mount Guna is found in study area. In study area land degradation and expansion of arable lands are a major problem because rapid population growth has forced farming families to expand their fields onto the sleeper slopes (LakewDesta, 2000). As a result of this, large areas which covered by forest and grass land are now expose to heavy soil erosion resulted in land degradation environment. Besides to this, the loss of the vegetative cover has resulted in flash floods and information of big gullies.

There is also continue expansion of cultivated and settlement over years in the study area. As human and cattle populations have demographically expanded, their demand for space and resources has increased. The consequences of an ever-increasing pressure of human development are resulted in changes of land and vegetation cover in the area. It also a result of depletion, degradation and fragmentation of habitats, loss of corridors and an increased human–animal conflict. The fact that activities such as grazing, cutting and fire have contributed to processes of land use land cover change in the area.

The need for land use and land cover change information has become a focus in current strategies for managing natural resources and monitoring environmental change. The understanding of the environmental conditions and factors involve in the deterioration of the eco-systems found inside the study areas are fundamental for appropriate management.

Some studies clearly demonstrated the potential of integrating remote sensing, GIS and field information for landscape assessment but not showed evaluation of land management in the study area.

Recent studies conducted in the study area such as: (Tesfa Gebrie, 2018), (Heliyon, 2022) have pointed out the impacts of LULC change on ecosystem. These researchers not mentioned to analyze the LULCC, evaluation and cause of driving forces in the study area. They also did not study the prediction of LULC change in the future. Detail research investigations were required in order to understand the problems and take correction policy and other measures on the above mentioned problems. Thus, the above problems are motivated me to conduct this research study.

Therefore, in view of the literature gaps above, the researcher can be analyzed the LULCC, evaluation and cause of driving forces of change from 1990 to 2023. The research also predicts future LULCC in study area as well.

1.3. Objective the study

1.3.1. General objective

The main objective is to evaluate the land use/cover and its drivers with its implication of land management and predictable in the future on mountain landscape between 1990 -2023.

1.3.2. Specific objective

I. To study the land use land cover changes detection as well as causes of driving force of mountain landscape between 1990 -2023 in study area.
II. To evaluate the implication of land use land cover change on land management.
III. To predict the Land use land cover pattern of 2033 in the future using cellular automata model.

1.4. Research Question

1. What is the trend, nature and rate of LULC in mountain landscape in the study area?
2. What is the cause of driving force of mountain land scape from 1990 to 2023?
3. What will be the future trends in LULC dynamics and associated result?
4. Are there dynamics of LULC in study area?
5. What is the evaluation of LULC change on land management in the study area from 1990-2023?

1.5. Significant of the study

The LULC change has significantly impacts on natural resources, socioeconomic and environmental systems. Understanding the types and the effects of LULC change are essential indicators for resource base analysis, development effect and appropriate response strategies for sustainable management of natural resources in the country and at the study area. Modeling output can help actors and decisions makers to set up land-use planning for a sustainable development. Such data were value to resource managers that plan and assess land use land cover patterns by giving tangible information about the land use land cover changes in Laygaint woreda the last 33 years. This also enables to see the futurity of this woreda. By analyzing the LULCC trend and driving forces behind the changes, it helps to understand how land was being used in the past?, what type of changes have occurred and what changes will be expected in the future?

1.6. The scope of the study

Geographically the study delimited in Laygaint woreda south Gondar zone Amhara region in North east of Ethiopia. The study was focused on the assessment and modeling of LULC change mountain landscape between 1990 -2023.

1.7. Limitation of the Study

This study was made an effort in acquiring all the necessary data collection and processing, interpretation and analysis. However, the thesis has encountered some restrictions. Firstly Google Earth image resolutions in 1990 and 2023 were one of the challenges in image classification of the study. Secondly, Taking ground control points and observing the type of LULC around the secured place were also tedious limitation. Not only the above limitation but also tedious process to get data from governmental organizations.

1.8. Organization of the Thesis

This thesis is organized into six chapters. The first chapter presents the introduction part of the study including the background of the study, statement of the problem, objectives of the study, significance of the study, scope, and limitation of the study.

The second chapter describe literature review which give emphasis on concepts about LULC change and their impacts, drivers of land use/land covers, types of classification and types of model.

Chapter three explains the data needed for the research and methods followed to obtain results from the input data.

The fourth chapter explains about the major LULC types, their change, the relationship between LULC, drivers of the LULCC, the main analysis and discuss of the thesis.

The fifth and the last chapter is conclusions and recommendations of the study area.

CHAPTER TWO

REVIEW RELATED LATRATURE

2.1. Land use and land cover

2.1.1. Land

Land is defined as, “the terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system” (United Nations, 1994). A more definition of land is provided in the Food and Agriculture Organization (FAO), where land is described as “a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)” (Sims, 1997).

2.1.2. Land Use

The terms land use and land cover are often used interchangeably, though they have different meanings. Land use is the purpose for which land is used. A formal description by FAO states that land use is “the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it”. Spatial Planning and Land Use Management in 2013 (SPLUMA) defines land use as “the purpose for which land is used law fully in terms of a land use scheme, existing scheme or in terms of any other authorization, permit or consent issued by a competent authority, and includes and conditions related to such land use purpose.” This definition is however not entirely correct as people can take de facto control of land and use it for various purposes which may not align with any land use scheme or authorization. The use of land is therefore uncertain, does not end at political boundaries and can be both legal and illegal (Cooper, 2014). Land use systems exist when different land uses are systematically linked through temporal interactions e.g. Crop rotation or spatial relations.

2.1.3. Land Cover

According to (Turner, 1994), “Land cover is the biophysical state of the earth’s surface and immediate subsurface.” Land cover therefore includes quantity and types of all features over the earth such as vegetation, water, soil, artificial surfaces, etc.

Land use and land cover are obviously linked; however, it should be noted that a single land cover can support multiple land uses and vice versa. For instance, a land cover e.g. grassland can support many land uses such as grazing and recreation and a single land use may also take place on various land covers. Land cover can be determined by analyzing remotely sensed images such as satellite images or aerial photos, while land use and land use change require additional socio-economic data and methods to determine the activities occurring on the landscape (Ellis and Pontius, 2007). According to (Verburg P. V., 1999), Land use is not directly observable though it can be inferred from activities such as grazing or structural landscape elements e.g. logging roads.

2.2. Land use and land cover definition and concept

LULC can be characterized as the conversion and modification land from land category to other land category. For instance change of farmland to urban land is example of conversion of land whereas degradation of forest land is land modification of land within a land cover category (Meyer and Turner, 1994).Consequently, LULCC became prominent as a research topic on the global environmental change several decades ago with the idea of processes in the earth's surface influence climate (Bireda Alemayehu, 2015).

The land use/cover change assessment is an important step in planning sustainable land management that can help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopia (Hadgue, 2008).

Why to study land use/cover change?

The need for optimal use of the land resources and for balance of Land-Cover capability with anthropogenic stress are one of the mega-scale issues of mankind. People use the land has become a source of wide spread concern for the future of the world. The inability of many countries to balance environmental and production needs, as well as Land Cover capability and anthropogenic stress, emphasize mega-scale issues. Precise and credible data on land use/land cover change and their trends are necessary for understanding global, regional and local environmental problems (Milanova et al., 2007). Land use datam are also needed in the analysis of environmental processes and problems that must be understood, if living conditions and standards are improved or maintained at current levels. Information on land use/cover in the form of maps and statically data is very vital for spatial planning, management and utilization of land for agriculture, forestry, pasture, urban industrial, environmental studies, economic, production. Today, with the growing population pressure, low man-land ratio and increasing land degradation, the need for optimum utilization of land assumes much greater relevance (Royet at, 2008). Land cover change play a vital role in regional, social and economic development and global environmental changes. It contributes significantly to earth atmosphere interactions. Biodiversity loss is a major factor in sustainable development and human response to global change, important in integrated modeling and assessment of environmental issues in general.

Documentation of the land use/cover change provides information for the better understanding of historical land use practices, current, land use patterns and future land use trajectory. LUCC contributes significantly to earth atmosphere interactions, forest fragmentation, and biodiversity loss. It is the major issues for environmental change monitoring and natural resource management. Identifying, delineating and mapping of the types of land use and land cover are important activities in support of sustainable natural resource management (Zhang et al, 2004). Generally, determining the effects of land-use and land-cover change on the earth system depends on an understanding of past land-use practices, current land-use and land- cover patterns, projections of future land use and cover, as affected by human institutions, population size and distribution, economic development, technology, and other factors. LULC assessment is an improvement step in planning sustainable land management that can help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopia (Kiros, 2008).

2.3. Land Use and Land Cover Change Studies in Ethiopia

In Ethiopia, the land is used to grow crops, trees, animals for food, as building sites for houses and roads, or for recreational purposes. Most of the land in the country is being used by stakeholders who farm for subsistence. The rapid population growth and in the absence of agricultural intensification, stockholders require more land to grow crops. It results in deforestation and land use conversions from other types of land cover to cropland. The researches that have been conducted in different parts of Ethiopia have shown, there were considerable land use and land cover changes in the country. Most of these studies indicated that croplands have expanded at the expanse of natural vegetation including forests and shrub lands.

The changes of land use and land cover that occurred from 1990 to 2020 in Guna Mountain and its surrounding results an expansion of cultivated land at the expense of the grasslands identified that decrease of natural vegetation and expansion of agricultural land over a period of 33 years in Gaint, northern part of Ethiopia. This concluded that population pressure was an important deriver for expansion and intensification of agricultural land in recent periods.

2.4. Drivers of land use/land cover

The world's land surface are estimated to cover about 13,340 million hectare (Verheye, 2011),which 54% of this land surface disturbed by both human activities and natural factors(Briassoulis, 2011).The change in LULC at all level is associated with several natural and human induced factors(Rahdary *et al.*, 2008). The natural or biophysical causes of LULCC include slop, climate change, soil type, wildfire, pest infestation, flood and drought (Garedew,2010; Shiferaw, 2011). Human driving force LULC grouped as the direct effects of human activity (EPA, 1999reportcited in Morie, 2007).

According to Briassoulis (2011), one-third to one-half of the global land surface change by human activities such as logging, agricultural expansion, over grazing, fire management, forest harvesting and urban and suburban construction and development.

2.5. Image Classification

In order to examine and assess environmental and socioeconomic applications such as LULC change detection, socioeconomic variables and image classification results with better accuracy are mandatory. Image classification refers to the extraction of differentiate classes or themes, usually land cover and land use categories, from raw remotely sensed digital satellite data(Weng, 2012).

Classifications are the backbone of environmental, social and economic applications (Lu and Weng, 2007). Digital image classification is divided into supervised and unsupervised classification.

2.5.1. Unsupervised classification

Unsupervised classification uses statistical clustering techniques to combines pixels into groups (classes) according to the degree of similarity of their brightness value in each spectral band. The analyst combines and reliable spectral classes into real land cover type as unambiguously as possible using maps and field based knowledge. Unsupervised image classification algorithms are based on categorizing each pixel to unknown cluster centers and then moving from one cluster center to another (Qian, 2007).

2.5.2. Supervised classification

Supervised image classification analyst has previous knowledge about pixels to generate representative parameters for each land cover class. The classified process of supervised classification involved with the human cognition and experience. This process is more flexible than the unsupervised classification due to the selection of pixels, which can be identified directly or based on other sources like Google Earth. It is available for user to search the same position and observe the type of land use land cover of this position up to users. Using this method, there is a step called “training”, which is used to generate representative parameters for every land cover class based on samples of image elements called “training areas”. They are digitized by user. The software decided that sub class each pixel belongs to. Thus, each pixel in this step in the image is classified into different class it most closely resembles. The pixel which is unlike any training area categorized into “unknown” class (Lillesand, 2004, pp. 554). The Maximum Likelihood classification, under the category of supervised classification, which is the most widely, used per-pixel method by taking in to account spectral information of land cover classes (Qian, 2007).

2.6. Post-classification approach

Post classification is among the most widely applied techniques for change detection purpose. The pixel-based classification process brings out small noisy appears in isolated pixel or small group of pixels, which classification process is different from its neighboring pixels (Huang, et al., 2004). The representation of classified map is usually a salt-and-pepper appearance (Lillesand, 2004, pp. 584), for instance, there are some very small spots existing. They are not suitable for analyzing. The post-classification processing can generate a smoother image. In Erdas, the common ways of post-classification is to clump, sieve, eliminate and recode.

To be more specific, clumping is a way to produce an output image through calculating the areas of every sorted spots and recording the classified value of the largest adjacent pattern. Sieving is a way of dissolve the isolated small spots after clumping and assigning new values to the small spots. Eliminating is used to dissolve the isolated small spots in classified image or clumped image, and these small spots merged into the largest adjacent class (Zhu, 2009). Recoding is also a way to reassign the class code of each category.

2.7. Land use land cover change detection

Change detection can be defined as the process of identifying differences in the state of object or phenomena by observing them at different times by using remote sensing techniques, which provide vital information of area change and rate of changes, spatial distribution of changed types, change trajectories (trends) of land cover types and accuracy assessment of change detection results (Bireda Alemayehu, 2015). Change detection is the measure of the different data framework and thematic change information that can guide to more tangible understandings in to underlying process involving land cover and land use changes than the information obtained from continuous change (Ramachandra and Kumar, 2004). Change detection process is to recognize LULC on digital images that change features of interest between two or more dates which involve the procedures of data acquired by the same sensor and be recorded using the same spatial resolution, viewing geometry, spectral bands, radiometric resolution, and time of day (Duguma Erasu, 2017).

2.9 Modeling

Bellinger (2004, p.1) refers to a model as being a “simplified representation of a system at some particular point in time or space intended to promote understanding of the real system. Models can be classified as continuous or discrete state models based on the values of the state variables. A model is a continuous state model if the variable can assume any value at any instant in time and a discrete state model when it assumes a single value at a point in time. A discrete state model could further be classified as continuous or discrete time model. A continuous time model is when the state variable can change at any time and it is discrete time if the state variable can change their values at a discrete time instant. Most discrete time even driven simulations really on underlying equations to manage the event in time but automata models (including agent based cellular automata models) do not manage time. In automata models, the automata cell or agent (trees, humans, land use cover) in the model are directly represented and process an internal state and set of rules which determine low the agent state is update from one step to the next (Bellinger, 2004; Guizani et al, 2010).

Deterministic and probabilistic models are repeating the same input starting conditions or initial state always produces the same output then the model is deterministic, while it is probabilistic or stochastic the output keeps changing due to the randomness of variables. A deterministic model and probabilistic model has no random variables whilst probabilistic model have at least one random variable as input (Gibb, st-jacques Nourry and Johnson, 2002). A transition probabilities matrix determines the likelihood that a cell or pixel move from a land-use category or class to every other category from date 1 to date 2. This matrix is the result of cross tabulation of the two images adjusted by the proportional error and translated in a set of probability images for each land-use class. A transition area matrix which records the number of cells or pixels that are expected to change from each land-use class to each other land use class over the next time period. This matrix is produced by multiplication of each column in the transition probability matrix by the number of cells of corresponding land use in the later image. A model is said to be open it is able into take one or more external inputs, called closed model if it has no eternal inputs (Guizani et al, 2010 p,5). LULC simulation models are mainly event driven therefore dynamic (change over time) in nature.

Models are used in a variety of fields including in LULCC studies (Brown et al., 2004). In LULCC studies models have been developed to address the questions when, where and why LULCC occurs. They usually involve empirically fitting the models to some historical pattern of change, then extending those patterns into the future for prediction. Modeling LULCC plays a significant role for understanding the factors that cause LULCC and the impacts of the changes (Araya, 2009; Adedeji et al., 2015). Models are useful for sorting out the complex groups of socio-economic and biophysical forces that influence the rate, spatial pattern of LULCC and for estimating the impacts of changes in LULCC (verburg, 2009).

Models also enable the projection into the future of the expected effects of governmental programs aiming at the conservation and utilization of resources. Assessing and predicting LULCC would help for effective environmental management and sustainable resources use. Additionally it helps to better understand the functioning of the LULC system and to support land use planning and policy as well as development plans and decision making (Araya, 2009).

2.9.1 Markov chain model

Markov chain model (MCM) has been used extensively for urban and rural LULCC modeling (Brown, Modeling the Relationships Between Land Use and Land Cover on Private Lands in the Upper Midwest, USA., 2000). It is a discrete-time stochastic model, describing the probabilistic movement of one state (LULC type) to another state (LULC type) (Iacono, 2015). MCM consider LULCC as a stochastic process and different LULC categories are the states of a chain (Weng, 273-284). The model specifies both time and a finite set of states as discrete values (Iacono, 2015). The applicability of MCM in LULCC modeling is promising because of its ability: (i) to represent all of the possible directions of LULCC among all of the land use categories, (ii) to quantify the states of conversion between LULC types and (iii) to quantify the rate of conversion among the LULC types (Sang, 2011).

For LULCC prediction MCM utilizes two historic LULC images as input and produces a transition probability matrix, a transition areas matrix and a set of conditional probability images (Sayemuzzaman, 2014). The former represents the probability that each land use/land cover category change to every other category over the specified number of time units, while the later represents the amount of pixels that are anticipated to change from each land use/land cover type to each other land use land cover type over the specified number of time units (Sang, 2011). The conditional probability images report the probability that each land cover type would be found at each pixel after the specified number of time units (IDRISI Selva help system).

According to different authors from the above MCM have several assumptions. One basic assumption is that a future state of LULC at a time (t+1) can be determined only as a function of its current state (t). Mathematically this can be expressed as $X_{t+1}= f (X_t)$. Path of past states X_{t-1}, X_{t-2}, $Xt_{-3}…X_0$ that the process passed through in arriving at X_t does not determine the future state at X_{t+1}. It also assume that the observed trends of LULCC will remain the same (stationary process), thus allowing their projection to the future.

The current state of LULC distributions (X_t) and the future state of LULC distributions at (X_{t+1}) time period, as well as a transition probability matrix (P_{ij}) representing, m × m matrix which expresses the probability that a site in state i at time t will transfer to state j at time t+1, are used to construct the Markov model (Brown, 2000) which is expressed as follows:

$$X_{t+1} = P_{ij} \times X_t$$

Where X_{t+1} and X_t Represent the states of land use at given point t + 1 and t, respectively. The matrix P is row-standardized, such that the sum of transition probabilities from a given state is always equal to one.

2.9.2 Cellular Automata (CA) modeling

The Cellular automata concept was developed by Von Neumann and Ulam and developed in 1940s in the field of computer science for the development of robots. it is being widely applied to various other disciplines such as Physics, Mathematics, Natural Sciences, and GIS had advantage of the construction of model is simple and easy (Singh, 2003), can incorporate spatial component (Baker, 1989). Cellular automata models is provide a formal framework by simulating the present from the past using the image time-series, whereas validating by comparing reference data with simulated output data (Rocha, 2007). Cellular automata provides a powerful tool for the dynamic modeling of LULCC which estimates the taken time in transition that can generate complex spatial patterns from the simple set of rules and predicts LULCC in the future (Singh, 2003).Cellular automata models used for prediction of time (t_2) from historical LULCC process of time (t_0) and time(t_1) and predicted /simulated result is compared with the reference classified map of time (t_2),since reference map(t_2) is usually considered more accurate (Rita and Sevivas, 2018).

2.10 Mountain landscape

Mountains are prominent lands forms that have significant heights above sea level and the surrounding land. They are steeper than hills. A mountain range usually has a peak, which is the pointed top. Mountain have different climates than land at sea level and nearby that land. The climate of mountains tends to include colder and wetter weather and thinner air. Thin air refers to the fact that at the higher altitudes of mountain there is less oxygen to breathe. Also mountains generally have less hospitable condition for plants and animals. This leads to quite different evolutionary adaptations for those plants and animals that make higher elevation their home.

2.11 Land management

Land management influences biodiversity, ecosystem functioning and the composition of ecosystem services (Balvanera, 2006) (Mace, 2012). Land management refers to human activities that affect land cover directly or indirectly and aim to provide specific services (Kremen, 2007) (Verburg P. v., 2009). It defines land use and the intensity of use driven by human activities, such as plough and irrigate (van Oudenhoven, 2012) (Verburg P. v., 2009). Land management is probably the most important factor influencing the provision of ecosystem services at the landscape level (Ceschia, 2010)(Fürst, 2011). For example, activities leading to restoration of vegetation alter ecosystem services by decreasing erosion, stabilizing the water supply, increasing carbon sequestration and providing shelter for wildlife.

CHAPTER THREE

METHODS AND MATERIALS

3.1. Description of the study area

3.1.1. Location

The study area, Laygaint is one of the district in the Amhra region of Ethiopia. Laygaint is bordered on the south by Tachgaint and Muja, on the south west by Misraq Esitie, on the west by Guna Begiemidir, on the north by Ebinat and on the east by north wollo zone. The administrative center is Nefasmewucha town and it contains 31 wide kebelles. The geographical coordination of the area is 11°40' 0" – 12°0'0" N and 38°20'0"-38^{0}40' 0" E.

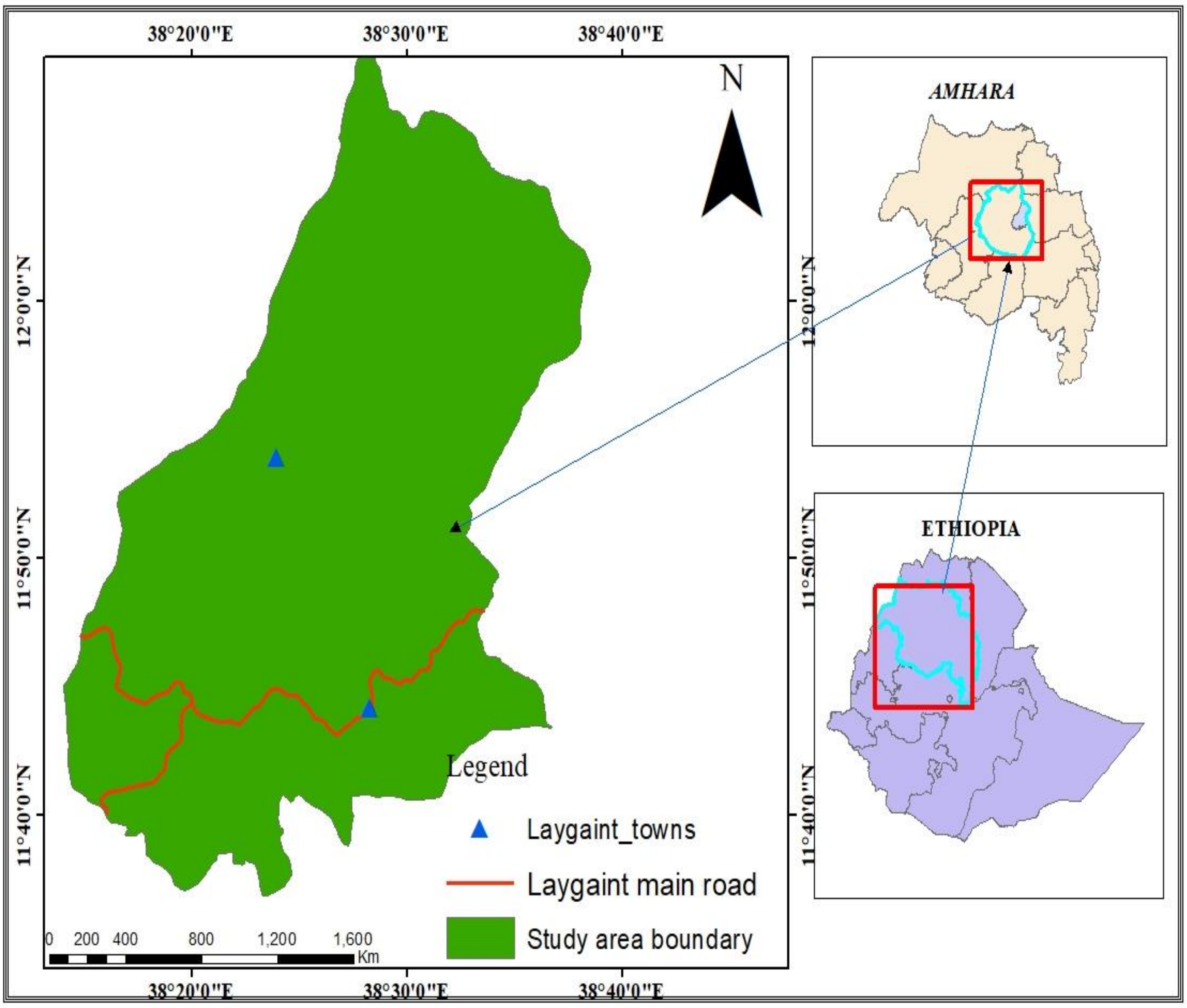
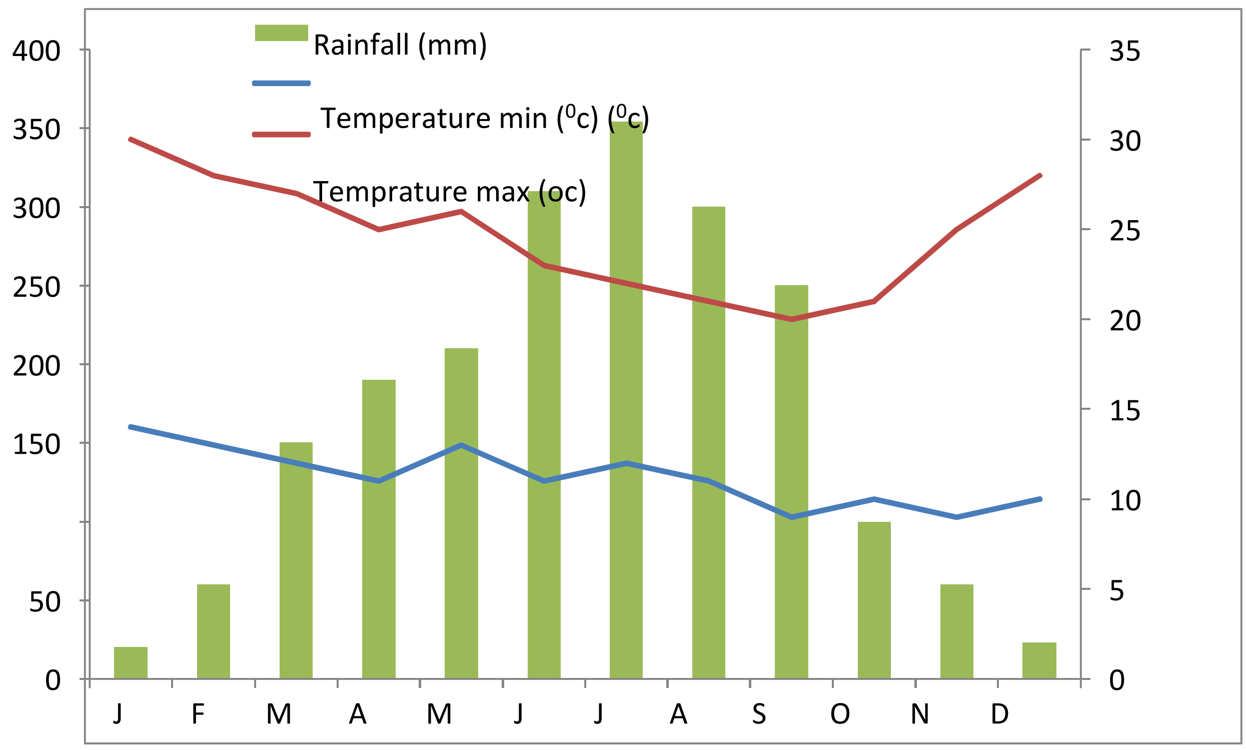


Figure 1 : Location of the study area

3.1.2. Climate

The mountain landscape in Laygaint are marked by moist agro-climatic zones that are locally known as moist “Dega” and “Woyna Dega”. The mean annual rainfall being around 1068.45mm. This data is taken from Debre Tabor and NefasMewcha meteorological stations. The lower rainfall occurs from March to May and the highest rainfall occurs in the summer season from June to September while the dry season ranges from October to February. The average annual temperature for Debretabor is 15.6^{0}C where as it is 13^{0}C for Nifasmewucha station (Adise Mekonnen, 2006).



Graph 1 : Average monthly rainfall and temperature in the study area

3.1.3. Demography of the Study Area

As per the Central Statistical Agency (CSA, 2022) projected figure for 2022, Laygaint has a total population of 271644 of 136922(50.4%) are male and 134722(49.6%) are females. About 8.13% and 91.69% of this population live in urban and rural areas respectively. Small-scale subsistence agriculture using traditional technologies is the major sector that supports the livelihood of households and communities in the area (World Bank, 2007; Rosell, 2011). It contributes about 85% to household’s economy.

Agriculture in the study area involves two major activities are Farming and Livestock husbandry. Farmers in the region grow cereal crops (e.g. been, pea, Barley and Wheat) and horticultural crops particularly vegetables (e.g. onion, potato and cabbage). Cattle, Goats, Sheep, Horses, Mule and Donkeys are important livestock species reared by farmers in Laygaint for destructive (skins, selling and meat), and non-destructive (transport, plough, reproduction and milk) purposes. Rural households also generate significant portions of their income from forest products including firewood, charcoal and non-timber forest products (NTFPs).

This implies that farming and livestock husbandry are the two main livelihood sources of local communities in study area.

3.1.4. Biophysical Characteristics

Laygaint is a high land area with a vertical expansion ranging from 1373 to 4078 meter above sea level and the majority areas are steep area. Not only this, but also the contour shows a steep land with many chains. Therefore, this study area is prone to change LULC type (Figure 2). The central afro-alpine plateau of the eco-region reaches more than 4000 meters above sea level.

Laygaint has a largest mountain with an Afro-alpine area left in Ethiopia and characterized by forest areas, afro-alpine plateau, mountains, valleys, grasslands and agricultural land (WPISPP, 2008). The Afro-alpine plateau and forests in Laygaint especially in mount Guna are home of globally unique diverse fauna and flora, including a significant number of rare and endemic species (FARM Africa, 2008). Guna is named as a 'water tower' of north Ethiopia. The ecosystem also provides several goods and services for thousands of peoples living in the highland and lowland part of the region.

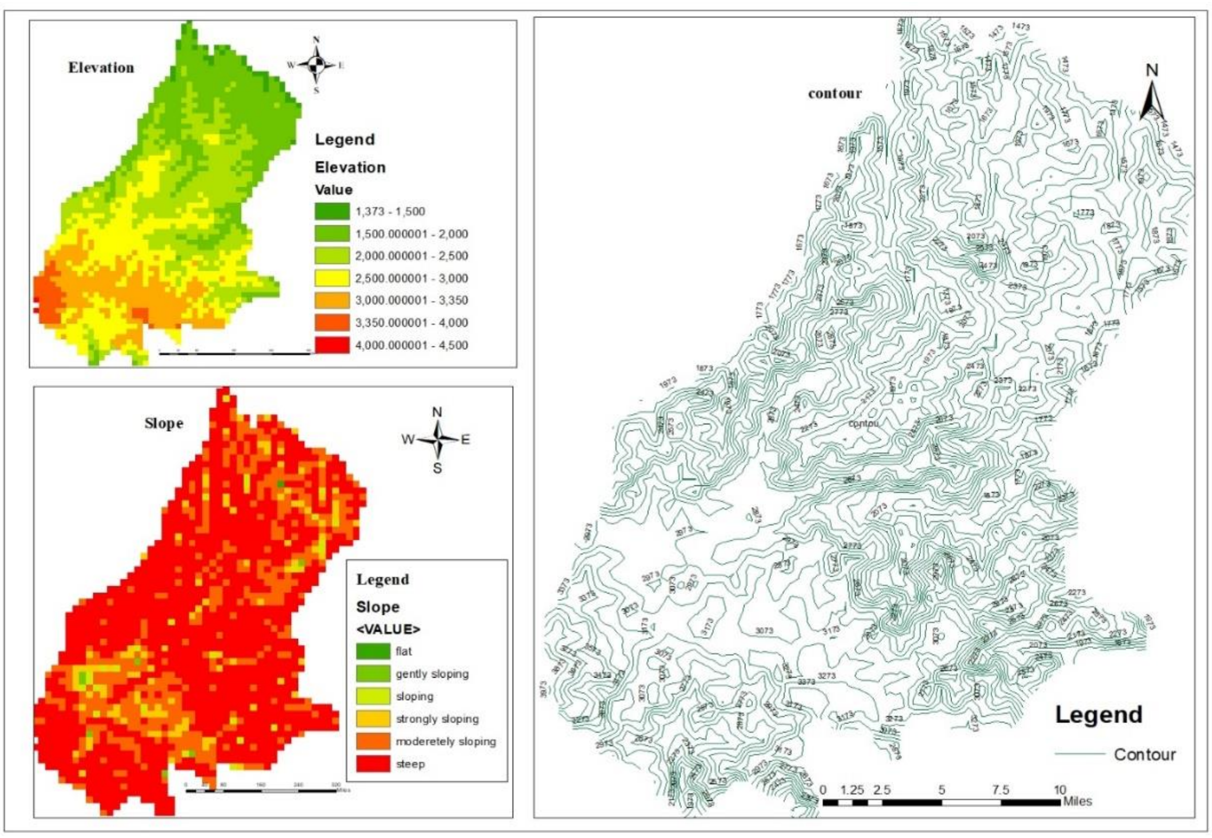


Figure 2: Elevation, slope and contour of the study area

3.2. Materials

3.2.1. Data source and Type

To meet the objectives of this research, the study used various methods to collect important data both primary and secondary data source. Data from primary sources included satellite imagery and field data. Secondary data such as unpublished official documents, land and environmental conservation office from district documents, rule and regulation of land management documents and different reports in different years concerning to land management document. Additionally, past research works were used as supportive secondary data sources.

3.2.2. Data Acquisition

3.2.2.1. Satellite Image

Time series land sat images of 1990, 2000, 2010 and 2023 were used to analyze LULC of entire in study area. The reason why images of these years were selected in order to match the RS data with major events undertaken during these years. All data were collected from U.S. Geological Survey Center for Earth Resources Observation and Science (USGS-EROS) (http://geography.usgs.gov), which comprised of the Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS). All images used in this study had 30 m spatial resolution and below 10% cloud cover. Characteristics of the sources of data used for the study are shown in (Table 1). To reduce the effect of cloud cover and seasonal variation on the classification result, the researcher tried to consider Landsat images of the same season (December to February). Four months, from November to February, are dry season in study area and have relatively cloud free sky. Therefore, images acquired during this season have relatively low cloud cover. Landsat image data were preferred in LULCC analysis over other multispectral data for example spot images (Bakker et al., 2001). This is because of its free availability and inclusion of middle infrared bands, a legal sharing of data among government department and donor agencies for having the longest record of global scale data for earth observation (Bakker et al., 2001; Gilani et al., 2014). The acquisition dates, sensor, path/row, resolution and the producers of the satellite images use in this study are summarize in the Table below.

Table 1 : The path/raw, acquisition, resolution and productions of satellite image

Path/Row	Acquisition Date	Sensor	Resolution (m)	Producer
170/053	Jan 04, 1990	TM	30	USGS
170/053	Feb 14, 2000	ETM+	30	USGS
170/053	Jan 01, 2010	ETM^{+}	30	USGS
170/053	Feb 02, 2023	OLI	30	USGS

3.2.2.2. Field survey data collection

GPS was used in the collection location of points for training samples of image classification and accuracy assessment of the classification. The field data used to classify image and collected the necessary land cover data for training area delineation and accuracy assessment. 300 ground control points were collected using Garmin Global Position System (GPS) for the sake of land use references.

The required field data concerning the existing LULC types, historical trends in prevailing LULCC and possible drivers of LULCC in the study area were collected by using different data collection tools such as Focus Group Discussion (FGD), Field Observation (FO) and Key Informant

Interview (KII). The field survey was conducted in two phases. The first phase was a reconnaissance survey and it was conducted between March 29, 2023 and April 3, 2023 on 5 Kebele in the study area. The overall aim of this survey was to get a broad picture of the study area and pretest FGD and KII checklists. The information obtained from the reconnaissance survey was used to select sample Kebeles and redesign FGD and KII checklists. The second phase of the field survey was conducted starting from April 10, 2023 until end of May, 2023. It also the ultimate purpose of the field survey conducted collect qualitative and quantitative information to help to better understand, explain, and interpret the land use and land cover change by different tools of data collection of this study.

3.2.2.2.1 Focus Group discussion

As suggested by many authors like Single (1996) cited in Bhawana (2015) and Jayasekara (2012) based on them of study and researchers interest, the number of participants in FGD can range from 4 to 10. One female group and two male groups totally 3 group were formed each sample Kebele. The reason for forming to separate male and female groups, traditionally females were not allow to sit and speak out full in front of males in the study area. The participants of FGDs were selected purposively from both sexes. Two purposive criteria were used to select participants in FGD. The first was age of participants. Elder people who have lived long time in the study area had detail information about the past and present situations of the study sites. The second criterion is capability to understand the topics and express their feelings and opinions. The selection is performed with the help of Development Agents (DAs) and peasant associations (PA) councils.

The FGDs were guided by a list of questions as a checklist. The aim of FGD was to assess and analyze the extent and trend of changes. The participants were perceived the driving force behind such changes on their lands and their surroundings in the past 33 years between 1990 and 2023. This can help to compare participants' perception with GIS and remote sensing analysis.

3.2.2.2.2 Key informant interview

With the intention of obtaining in-depth information and cross-checking the data collect from focus group discussions, few key informant interviews was conducted. In this interview, 30 key informants were selected and involved such as one elder person from each sample Kebeles, one Woreda Natural Resource Conservation and Management Expert, Woreda Environmental, Land Administration Office Coordinator and Kebele Administrator from each sample Kebeles. The selection of elder key informants were executed using snowball sampling method with the help of FGD participants.

3.2.3. Characteristics of land use land cover units

Five major LULC types were identified by using the field data and satellite images of Landsat TM, 1990 and 2000, ETM^+ 2010 and OIL/TIROS 2023. These were dense forest, bare land, scrub or bush land, grassland or rangeland and agriculture or crop land (Table 3).

In the classification, bare land was included from the LULC type in the Landsat images of TM 1990 and 2000, ETM+ 2010 and OIL/TIROS 2023 owing to the presence of ex posed rocks, eroded lands and no vegetation cover in these images. Little vegetation were included in the classification class type of bare land. This was due to resolution problem of the image (30m), the very low likelihood of identifying springs and rivers from little vegetation.

Similarly, forests were human made plantation forest, riverine forests, dry ever green forest and moist mountain forest. Because they had the same spectral nature on the images, they were difficult to differentiate one from the other. This classification was in line with Tesfaye et al. (2014), who grouped both natural forest and plantation forests, were under forest category.

On the other hand, they were difficult to identify settlements especially rural settlements from agricultural land on 30m spatial resolution image and in most cases they were spatially integrated. Therefore, settlements were grouped under agricultural land covers. This classification was in agreement with Desalegn et al. (2014), who grouped agriculture and settlement, were under one class for the same reason. They are listed below.

Based on field observation and general historical information gained from participants during the survey, it was decided to focus on the following major land use and land cover classes summarized below and in Table 2

Table 2: Description of LULC classes in the study area

Land use/cover	Description
Forest	Areas that are covered with dense growth of trees with closed canopies. It includes a virgin forest dominated by indigenous tree species and plantation forest dominated by exotic tree species.
Crop land or agriculture	Areas used for rain fed crop cultivation and scattered rural settlements usually associated with cultivated lands.
Bare land	Areas that have little or no vegetation cover, erosion lands mainly with gullies and ex posed rocks. (Barren eroded lands mostly on top of mountains, open areas near homesteads).
Shrub(bush) land	Covered by bushes and shrubs and sometimes with scattered small trees mixed with grasses.
Grassland	Areas dominated by permanent grass cover mixed with scattered trees along ridges steep slopes and plain areas used for grazing; usually individual as well as communal.

3.2.4. Material and software

The software and materials used to analysis this thesis were list as follows.

Table 3: Software and materials

No.	Software tools and materials	Purpose
1	QGIS2.18.3(MOLUSCE_3.0.13)	To predict land use land cover change in future.
2	ArcGIS10.5	Analyzing, displaying, viewing and classify satellite images spatial data
3	Microsoft office Excel 2013	Meteorological data analysis, data analysis into table and change graph data into table.
	Materials	
4	Compass	Identify direction and location on field survey
5	Garmin GPS 60	To take GCPs for LULC classification
6	Digital camera	To capture ground photo

3.3. Methods of data analysis

3.3.1. Satellite image analysis

3.3.1.1. The land use/cover image pre-processing data analysis

In this study, time series data of LULC produced from Land sat imagery (Land sat TM, ETM^+ and OLI) which were acquired on four separate years: 1990, 2000, 2010 and 2023 in the above table (1). Therefore, firstly, the three scenes downloaded from USGS-EROS using the path and rows indicated in the above table (1). Secondly, the panchromatic bands in each scene stacked together so as to produce a multispectral image for each scene. Thirdly, a mosaic of three scenes covering the study area was created by merging the stacked image via mosaic operation. Subsequently, geometric and radiometric corrections and image enhancement were conducted. All the above mention pre-process were performed on ARC GIS 10.5 software prior to the image classification. Geometric correction was involved conversion of data to ground coordinates e.g. UTM by removal of distortions from sensor geometry. Radiometric correction on the other hand was involved by correcting unwanted sensor or atmospheric noise and correcting the data for sensor irregularities (Seyoum, 2012). Image enhancement is to improve the appearance of the imagery to assists in image analysis, classification and visual interpretation (Bakker et al., 2001). In order to have all the data in the same coordinate system and ensure consistency between data sets during analysis, all maps and satellite images used in this study. It was projected to Universal Transverse Mercator (UTM) projection system Zone 37N and datum of World Geodetic System 84 (WGS84). Radiometric corrections such as haze reduction and cutting dark areas were executed as well. To increase the total distinction between various features in the image and to enhance specific spatial patterns in an image, two enhancement function namely contrast stretching and spatial filtering are executed. Finally, after passing the aforementioned processes, each image clipped using the boundary of the study area.

3.3.1.2. The classification process for Land use land cover mapping

This study used both unsupervised and supervised image classification techniques. First unsupervised classification carried out before field work understood the general LULC classes of the study area and selected sample training sites for data collection during field work. This because unsupervised classification was automatic and required little knowledge of the study area. Then after the field work maximum likelihood supervised classification carried out, it was categorized the images using training sites. Training sites were defined by using original images, the results of unsupervised classification, field study knowledge and ancillary data (Google Earth). Image classification was performed by using ARC GIS 10.5 software. Ground Truth Points and ancillary data (Google Earth) were used to define training sites for the recent image (OLI/TIRS) classification. Training sites for classification of older images (TM and ETM+) were defined based on the result of unsupervised classification, spectral values of recent image and information from elder peoples.

3.3.1.3. Accuracy Assessment

The produced classification is compatible with what actually exists on the ground. It is important to evaluate the accuracy of classification results. Error matrix was produced for all images in this study. An error matrix is a square array of rows and columns and presents the relationship between the classes in the classified and reference data. The reference data used for accuracy assessment were obtained from GPS points during field work and original mosaic image. The GPS points were used in classification accuracy assessment. They were independent of the ground truths in the classification. Based on the error matrix overall accuracy, kappa statistics were used to illustrate the classification accuracy.

3.3.1.4. Land cover Conversion Matrix

The land cover conversion matrix was analyzed the source and destination of each cover type. The land cover conversion matrix analysis was conducted in Arc GIS and conversion comparison map. Each land cover change values were analyzed in excel sheet to clearly show the source, destination of cover types in table and graphs of cover change dynamics.

3.3.1.5. Land cover Change detection analysis

The land cover map for the three period series of images were analyzed based on land cover types area comparison, land cover changes using graphs and charts. The changes over 33 years were analyzed and rate of change for each land cover type was calculated. The land cover of change detection was calculated by the three periods from 1990 -2000, 2001-2010 and 2011 -2023 using the following simple formula below.

1. Rate of land cover changes (ha/year) = (A-B)/C

   Where A-Recent land cover area size

   B- Previous land covers area size

   C-Number of years between A and B

2. Percent LULCC calculated using the following equation:

$$\text{Percent of LULCC} = \frac{A}{B} \times 100$$

   Where A = LULCC area in 10 year B = total area of LULCC in a study area

3. U.A = 100% - C.E (U.A= T.C/ T.R)

   Where U.A= user's accuracy C.E = commission error T.C = total number of correct classifications T.R = total number of row

4. P.A = 100% - O.E (P.A = R.S / T.R)

   Where P.A = producer accuracy O.E = omission error R.S = reference sites T.R = total number of reference sites

5. O.A = T.C.C / T.N.R

   Where O.A = overall accuracy T.C.C = total number of correct classified site T.N.R = total number of all reference site

3.3.2. Modeling and prediction (2033) of the dynamic land use/land cover change

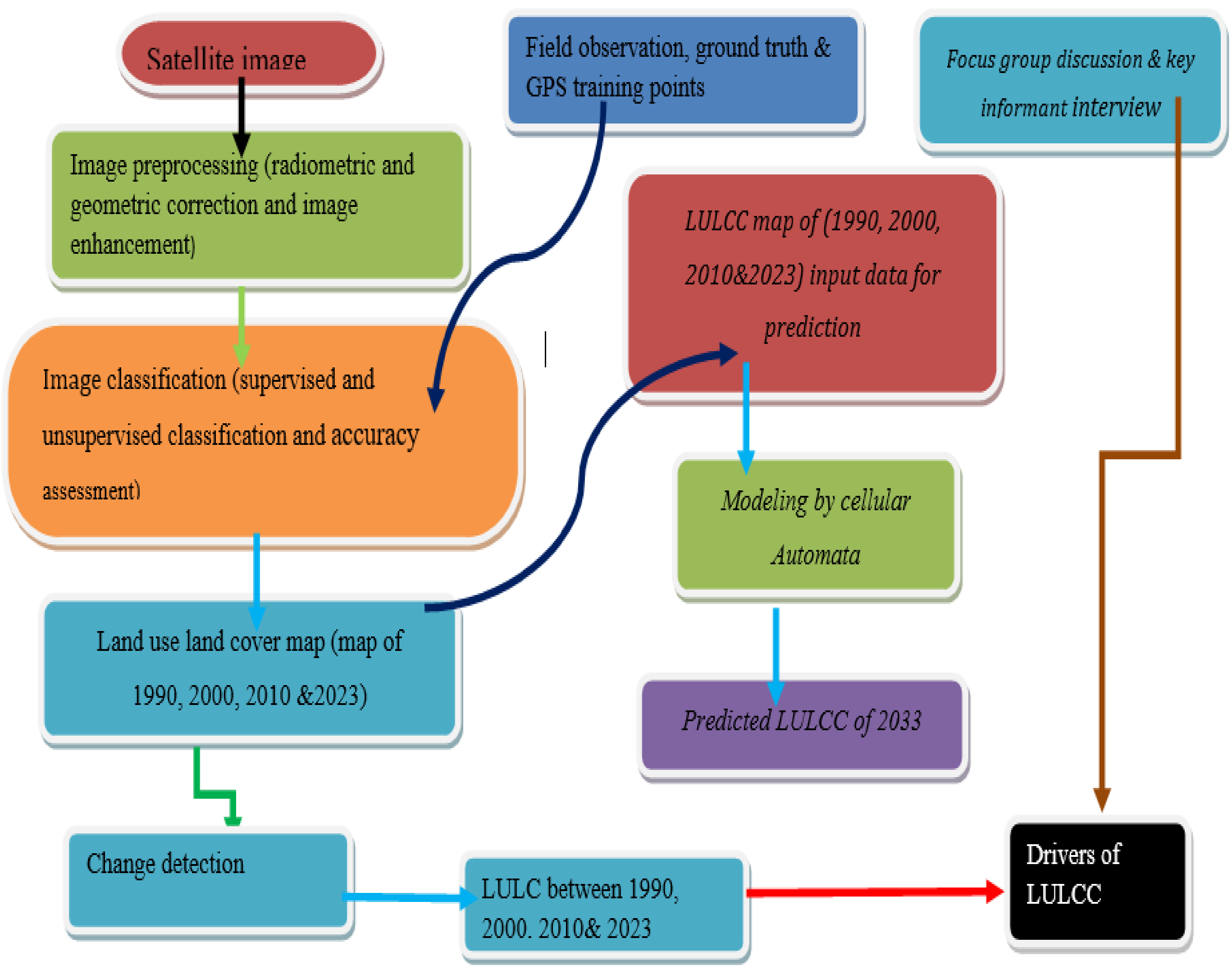
In this research, modeling and prediction of the dynamic LULC change were carried out by using a Markov-CA. LULC maps in 1990, 2000, 2010 and 2023, which were the results of multi-temporal classification of Land sat imagery, were being used as input data for the modeling and prediction LULC in the year 2033 years. Meanwhile, LULC map in 2023 was the classification result of Land sat imagery in 2023. It was being used as a reference map to describe the condition LULC today. The reference of LULC map was being used to perform the calculation of the accuracy assessment LULC in 2023 with cellular automata model approach. Cellular automata model could be used to predict and simulate LULC change in several next year.

It is important to estimate the predictive ability and reliable of the model. Therefore, simulated LULC in 2023 was conducted from the transitional potential of LULC map for time t1 (1990) and for time t2 (2000) to predict LULC for time t3 (2010) and t4 (2023). Then the result was validated between the simulated LULC in 2023 and the reference map in 2023 (classified LULC map of 2023). Therefore, the validated result was achieved an acceptable accuracy, and then 2033 LULCC would be simulated and conducted. The simulated LULCC of 2023 and 2033 were carried out in QGIS MOLUSCE extension plug-in.

3.4. Data presentation

The result from both field work and image analysis were presented in the form of figures, i.e. maps, graphs and tables. Graphs were prepared using Microsoft excel 2013 and Microsoft word 2013.

3.5. Methodology flow chart



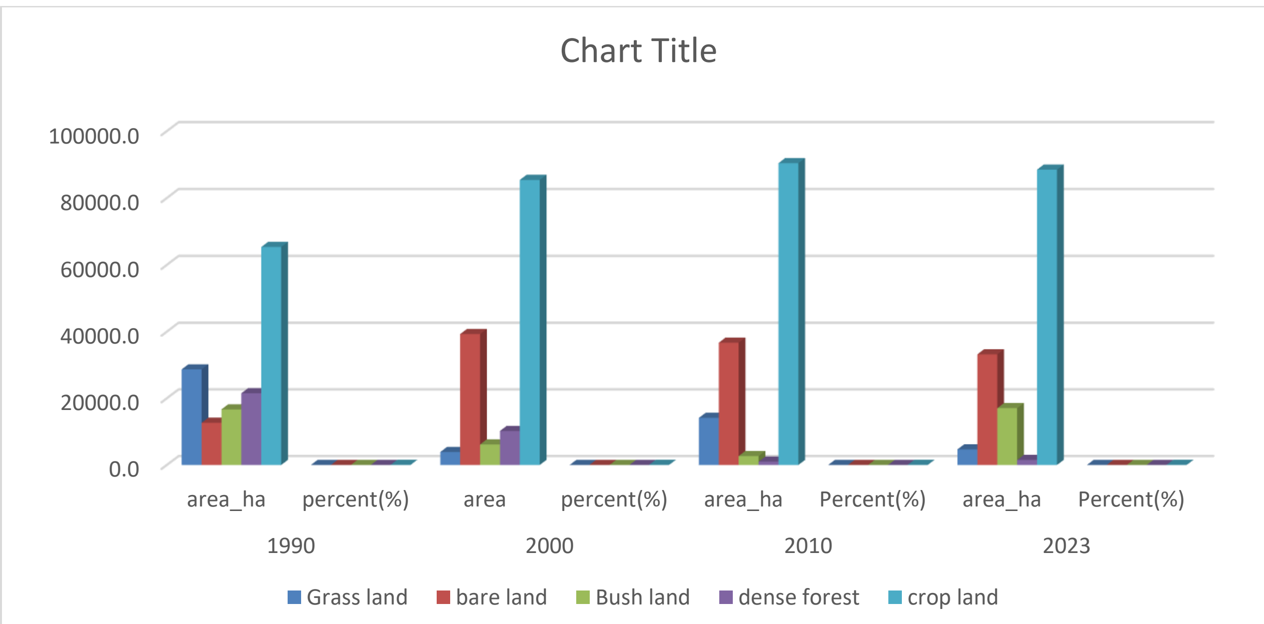
Graph 2 : Flow charts of the work structure

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Land use/Land Covers of the Study Area in 1990, 2000, 2010 and 2023

Four LULC maps were produced for the years 1990, 2000, 2010 and 2023 and five LULCC class type were identified and classified such as dense forest (forest land), grassland (dense vegetation), Crop land (agricultural land), bush (scrub) land, bare land. They are shown below in figure, graph and table.



Graph 3 : area of LULC units at different periods from 1990 -2023

Table 4 : LULCC classification with their area in hectare and percent (%)

Class type	1990		2000		2010		2023	
	Area _ha	Percent (%)	Area _ ha	Percent (%)	Area _ha	Percent (%)	Area _ha	Percent (%)
Grass land	28688.4	19.9	3897.5	2.7	14145.6	9.8	4700.0	3.2
bare land	12678.6	8.7	39285.5	27.1	36712.4	25.1	33205.2	22.9
Bush land	16692.3	11.5	6159.1	4.2	2688.2	1.9	17063.3	11.8
Forest	21543.3	14.9	10207.9	7.0	1003.1	0.7	1516.4	1.0
crop land	65362.9	45.1	85415.4	58.9	90416.1	62.4	88480.5	61.0

LULC analysis from the Landsat imagery of TM and ETM+ showed that starting from mid 1990s to mid-2023s grass land and dense forest were the dominant LULC types in the study area. These two LULC types (grass land and dense forest) in 2023 were accounted for 4700 ha (3.2%), 1516.4 ha (1.04%) respectively and bush land 17063 ha (11%) of the total area from the study area (table_4). However, LULC analysis from the Landsat OLI/TIRS imagery of 2023 indicated that the area coverage of these two LULC types were taken by agriculture/crop land and bare land. Crop land was covered about 88480.5 ha (61%) of the study area (table_4). During the same period, bare land was covered only 33205.2 ha (22.9 %) of the study area. On the other hand, during the entire study periods starting from 1990 to 2023, the smallest portion of the land in the study area was covered by dense forest (Figure 3). Dense forest was accounted for 21543.3 ha (14.9%), 10207.9 ha (7.0%), 1003.1 ha (0.7%) and 1516.4 ha (1%) of the total area in the study area in the years 1990, 2000, 2010 and 2023 respectively.

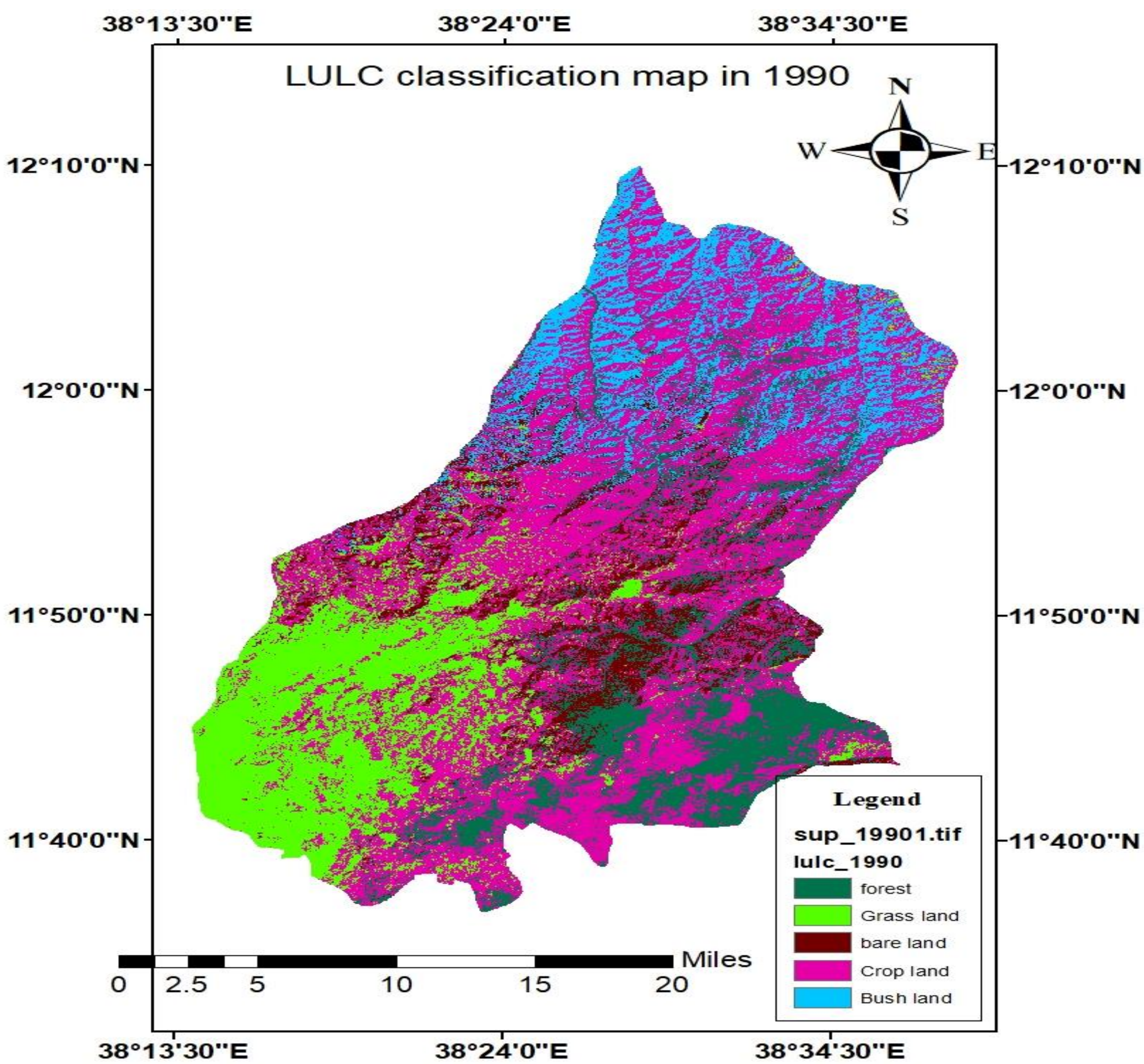


Figure 3(a) LULC **map of Laygaint district in 1990**

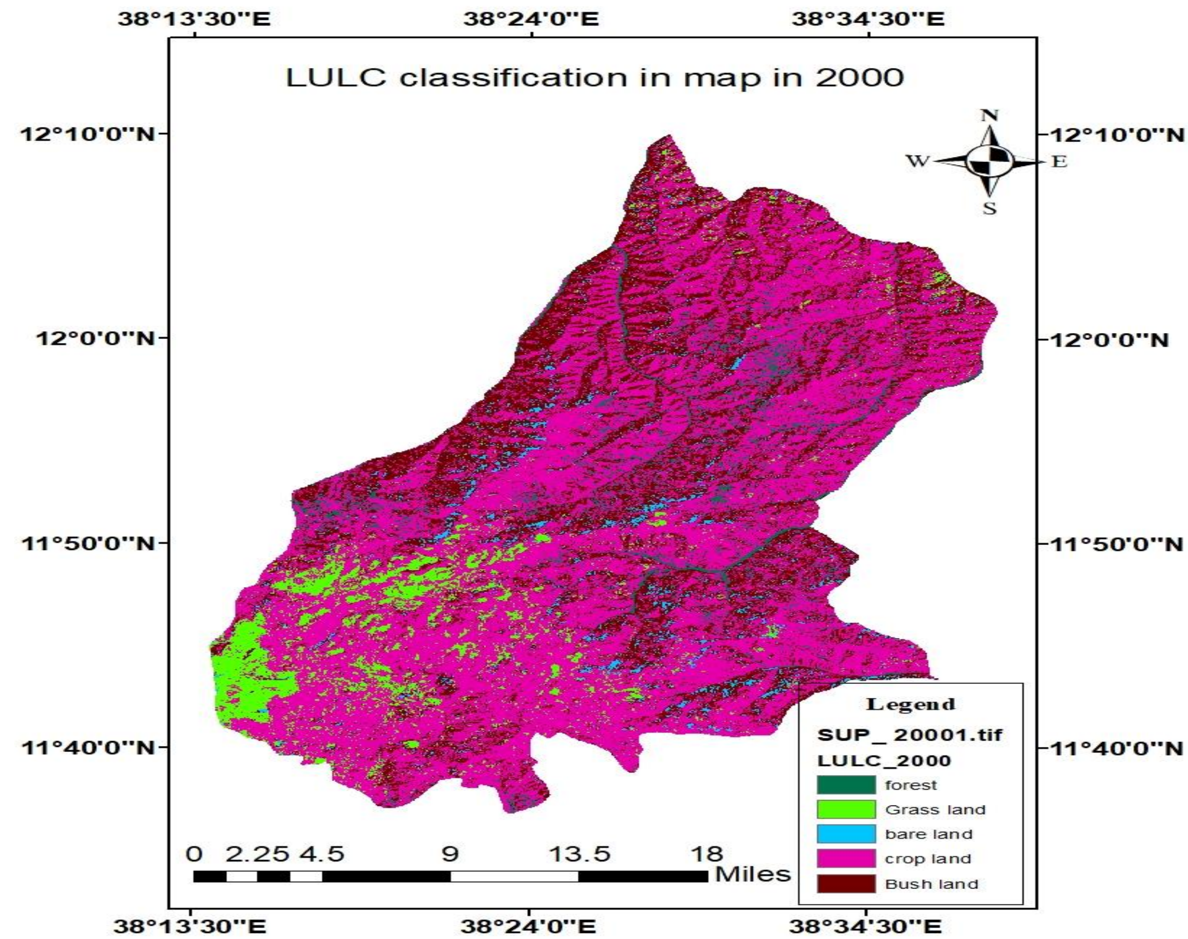


Figure 3(b): LULC map of Laygaint district in 2000

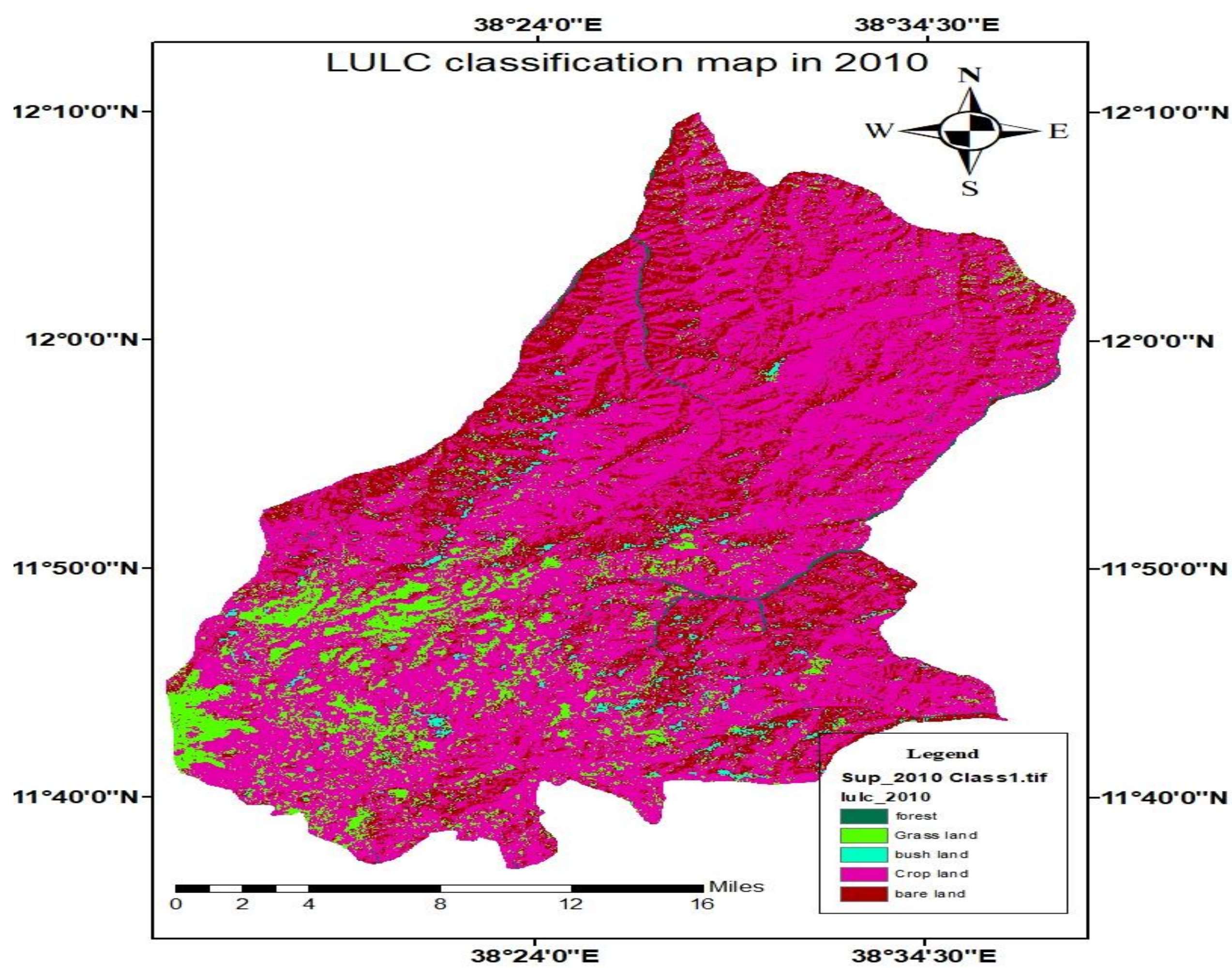


Figure 3(C): LULC map of Laygaint district in 2010

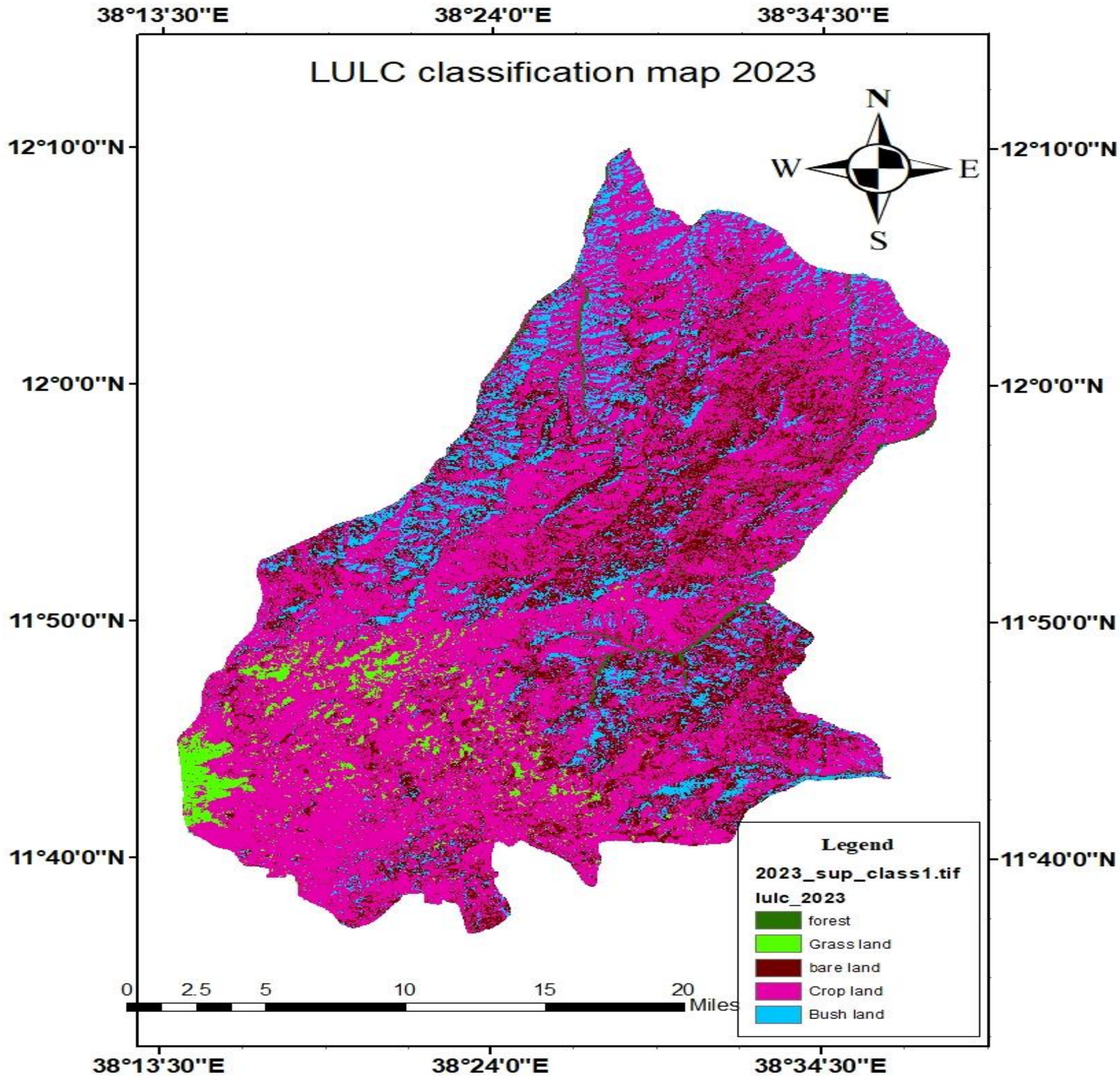


Figure 3(d): LULC **map of Laygaint in 2023**

As it has been shown on the maps in 1990, 2000, 2010 and 2023, the greatest loss of the land was covered by grass land and dense forest. These LULC categories occupied the southern part along the middle parts from the study area. However, in 2023 share of the land was covered by crop land and bare land. In 1990 most of the crop land cover was found on the eastern, middle and western parts of the study area along Negela, Zagoch and Mekuabia. However, starting from 2000 to 2023, this LULC type was greatly expanded to the southern part throughout the high land areas. It is also expected to expand for the year 2033 as well. In all maps, the majority of bush land occupied the northern and south eastern part. In contrast, the majority of grassland/rangeland located at southern parts in the high land area spatially in around Guna mountain areas. There were a great expansion of agriculture/crop land and bare land along the southern and northern part of the study area throughout the whole years.

Generally, over thirty three years (1990-2023), the gross changes in hectares (loss and gain) and percentage change in the study area varied from one LULC class to another whereas transition matrix also varied from period to period.

The accuracy assessment were accommodated during the classification. Therefore, an overall accuracy of 95%, 96%, 97% and 96% was achieved for the Landsat TM of 1990 and 2000, Landsat ETM+ of 2010 and Landsat OLI/TIRS of 2023 respectively (Appendix II). These imply excellent classifications of Landsat images.

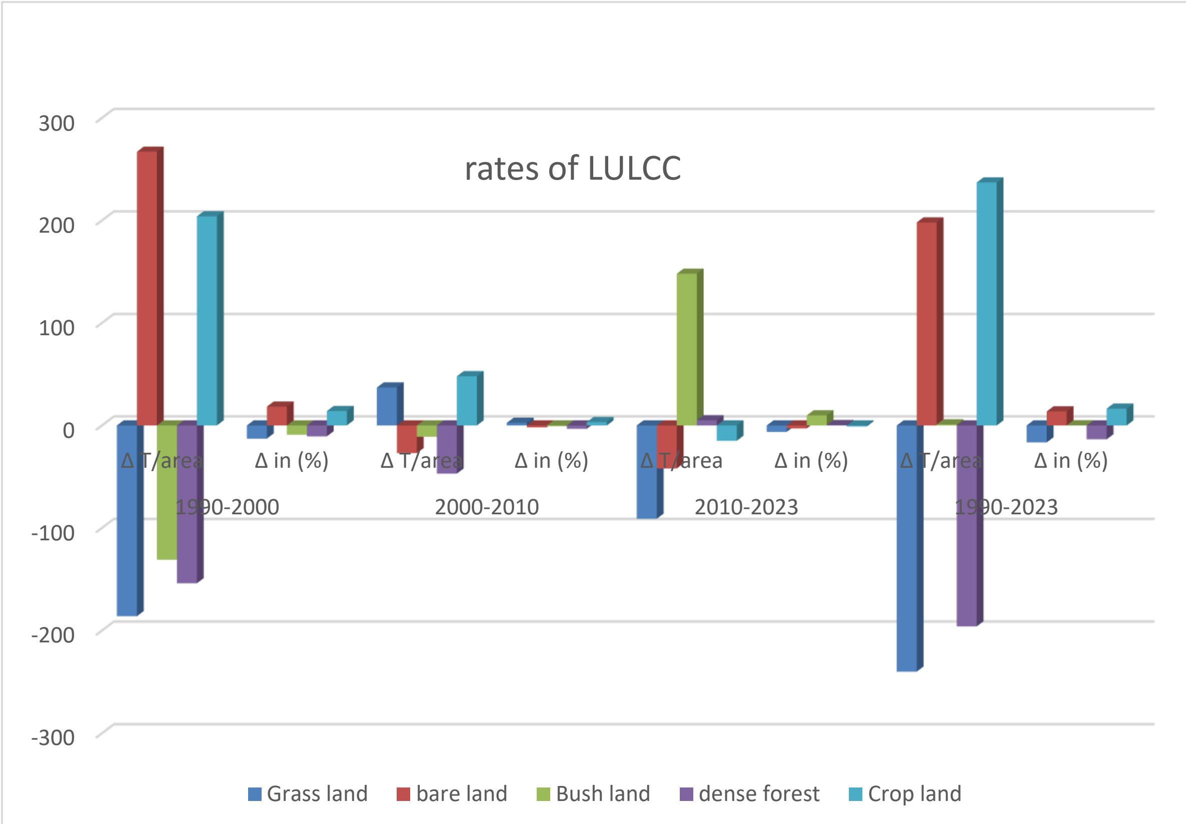
4.2. Land Use Land Cover Change Detection

4.3.1 Trend and Rate of LULCC in study area

Laygaint district has an experience in different LULCC between 1990 and 2023. The land under grass land and dense forest decreased continuously between the above years. In contrast the area of bush land showed a fluctuating trend between the study periods (table -5).

Table 5 : Rate in Km^2 and percent of change of LULC in district of laygaint

LULC class type	1990-2000		2000-2010		2010-2023		1990-2023	
	Δ T/area	Δ In (%)	Δ T/area	Δ In (%)	Δ T/area	Δ In (%)	Δ T/area	Δ In (%)
Grass land	-186	-12.84	37	2.55	-91	-6.28	-240	-16.56
bare land	267	18.42	-27	-1.86	-42	-2.9	198	13.66
Bush land	-131	-9.05	-11	-0.75	148	9.83	1	0.06
Forest	-154	-10.63	-47	-3.24	5	0.35	-196	-13.52
Crop land	204	14.08	48	3.31	-15	-1.04	237	16.35



Graph 4 : Trends of LULC in district of Laygaint

Grass land showed that it declined with a rate of 730 ha/year. This was followed by forest which was losing an estimated 594 ha/year. Agriculture showed the highest increment about 718 ha/year in the period from 1990 to 2023 (Table 5&6).

Table 6 : Rate in Km^2 and percentage in a year of LULC in district of Laygaint rate

LULC class type	1990-2000		2000-2010		2010-2023		1990-2023	
	Δ rate/year	Rate (%)	Δ rate/year	Rate (%)	Δ rate/year	Rate (%)	Δ rate/year	Rate (%)
Grass land	-18.6	-1.28	3.7	0.26	-9.1	-0.48	-7.3	-0.50
bare land	26.7	1.84	-2.7	-0.19	-4.2	-0.22	6	0.41
Bush land	-13.1	-91.00	-1.1	-0.08	14.8	0.75	0.03	0.00
Forest	-15.4	-1.06	-4.7	-0.32	0.5	0.04	-5.94	-0.41
Crop land	20.4	1.41	4.8	0.33	-1.5	-0.10	7.18	0.49

4.3.2 Evaluation of land use land cover change management from 1990-2023

In the period between 1990 and 2000 the land under grass land and dense forest decreased by 18600 ha (12.8%) and 15400 ha (15.6%) respectively, while crop land and bare land increased by 20400 ha (14.1 %) and 26700ha (18.42%) respectively (Graph - 4 and Table - 6). This implies that grass land and dense forest were declining at the rate of 1860 ha and 1540 ha per annual respectively, while land under crop land and bare land increased at the rate of 2040 ha and 2670ha per year over the ten year period (Table_6).

As reported from discussion and interview with focus groups and key informants, the rise crop land between 1990 and 2000 linked with village establishment during the "EFDR" regime which was made effective around the 1991 resettlement and land distribution program. The efforts to improve agricultural systems by the "EFDR" government also played a great role for the expansion of agriculture. According to FGD participants, the massive reduction of grass (vegetation) in between 1990 and 2000 decreased the transitional period (1990/1991). Because during this transitional period, the new government was not capable to manage the country and no one was in charge of protecting the natural resources of the country. Following the end of the war, local people participating in the war were returned to their environment and subsequently they deforested the forest to fulfill their livelihood requirements. A landless youth was also found encroaching on land in areas designated as public space. Therefore, lack of administration coupled with lack of awareness among the local communities about the consequences of forest conversion. The reasons behind this historic deforestation resulted high erosion for lands.

The result for the second period (2000-2010) indicated that the land under forest cover decreased by 4700 ha (3.2%) as compared to the first period (1990 - 2000) (graph 4 and Table 4). On the other hand, grass land and crop land continued to increase in the second period. Grass land increased by 3700 ha (2.55%) and crop land/settlement expanded by 4800 ha (3.31%). Grassland/range land increased at the expense of other LULC categories mainly agriculture (Table 6). Shifting cultivation practices contributed for conversion of dense forest to range (grass) lands in the highland parts of the study area. Creating huge openings in forest land cultivation is abandoned. On the other hand, farmland management practices in the study area implied that the fallow farmlands used as a grazing land for cattle. In some cases, cultivated lands also permanently left for grazing. In agreement to the finding of this study, Alemayehu (2015) also reported expansion of grassland at the expense of agricultural land in Fagita Lekoma Woreda, Awi Zone, and North Western Ethiopia between 1973 and 2015. Shiferaw (2011) also reported expansion of grassland at the expense of forest and shrub land in Borena Woreda of South Wollo Highlands, between 1985 and 2003.

The third period (2010-2023) result shows that forest and shrub land increased (i.e. 50 ha/year (0.04%) and 1480ha/year (0.8)) respectively with a corresponding decreased in crop land and bare land (150 ha/year (0.1%) and 420ha/year (0.2%)) respectively (Table 4). According to FGD, increasing in forest and shrub resource during this period linked with different factors such as the integrated and participatory forest management project and afforestation program during the summer season. In line to the finding of this study, Tesfaye et al. (2014) reported increment in forest cover between 1986 and 2008 in Gilgel Tekeze catchment, Northern Ethiopia. The researcher has claimed that increment in forest cover was due to tree plantation campaign and construction of terraces in the hill slopes. Desalegn et al. (2014) also reported the rise in forest cover between 1975 and 1986 due to implementation of huge afforestation campaign by the Derge government in the northern and central highlands of Ethiopia.

During the 33 year period between 1990 and 2023, the proportion of area covered by grass land was continually decreasing as it was 24000 ha (16.56%) (Table 5). In contrast crop land was continuously increasing as it was 23700 ha (16.35%) (Table 5).

Generally, the major finding from the analysis of Landsat images revealed a great reduction in the area of grass land and dense forest as corresponding increase in the area of agriculture and bare land over the 33 year period. Focus group discussions and interviews were conducted in study area also supported this trend.

In 1990 crop land and bare land were not dominant LULC types in the study area. Because during this time, the areas were characterized by relatively low population pressure, small agricultural activities and to some extent undisturbed environmental condition. However, the largest part of lands that were covered by grass land, bush land and forest before 33 years (Desalegn et al. (2014) now replaced by agriculture and bare land.

In agreement to the finding of this research, studies were conducted in dry and semi-dry land parts of Ethiopia such as Garedew (2010), Alemu et al. (2015) reduction of area under dense forest and increment in area under agricultural land. Rapid reduction in grass land and forest and increment in agriculture and settlement were also reported by Zeleke and Hurni (2001) in Dembecha area of Gojjam, Molla et al. (2010) in the mountain landscape of Tera Gedam and adjacent agro ecosystem, Northwest Ethiopia and Kindu et al. (2013) in Munessa Shashemene landscape of the Ethiopian highlands. However, it was contrary to the work of Alemayehu (2015) who reported expansion of grass land between 1973 and 2015 with corresponding reduction of cultivated land in Fagita Lekoma Woreda, Awi Zone, and Northwestern Ethiopia.

The information was obtained from FGD participants and key informants confirmed that the major reasons for the continual expansion of agriculture between 1990 and 2023 in the study area were rapid population growth, gradual change in the economic activities of communities in the area agro-pastoralist, loss of soil fertility, vilagization and resettlement policies and poverty and food insecurity.

4.3.3 Land Use/Land Cover Change Matrix

Conversion matrixes were analyzed for each period to clearly show the source and destination of the major LULCC. Analysis of conversion matrixes were computed by overlaying classified images of two study year on ArcGIS 10.5. Results of the analysis were presented under Appendix I and figure 4. In all change matrixes the row of the table stand for the initial year and the column of the table symbolize the final year of the change. In all change matrixes show gross gain and loss of each land cover category during the study periods. The diagonal numbers in bold show the unchanged pixels.

During the study period between 1990 and 2000 about 67339 ha (46.5%) of the study area landscape remained unchanged. This implies around 53.5% of the total landscape of the study area was converted from one LULC type to the other (Appendix I, Table 10). The level of conversion varies amidst the LULC types. The grass land in the landscape was mainly convert agriculture (Appendix I, Table 10). Dense forest also was mainly converted to agriculture and bare land. Agriculture replaced about 23627ha of the land that used to be covered by other LULC types. The major conversion were from grass land (22101 ha), dense forest (9404 ha) and bush land (5036 ha) (Appendix I, Table 13 and figure 4(a-d)). All LULC types grass land experienced the lowest persistence, whereas bush land was the most persistent cover type (Appendix I, Table 10). Out of 28461 ha of grass land in 1990 about 24424 ha (85.8 %) were converted to other.

LULC in 2023, while it is only 7945 ha (62.9%) of forest land converted to other LULC types between the indicated period. The net persistence for agriculture, bush land and grassland were large (relatively far from zero in both direction), whereas it is closer to zero for the remaining LULC types (Appendix I, Table 13 and figure 4(a-d)). The net persistence closer to zero indicates the higher tendency of LULC types to persist rather than decline or increase.

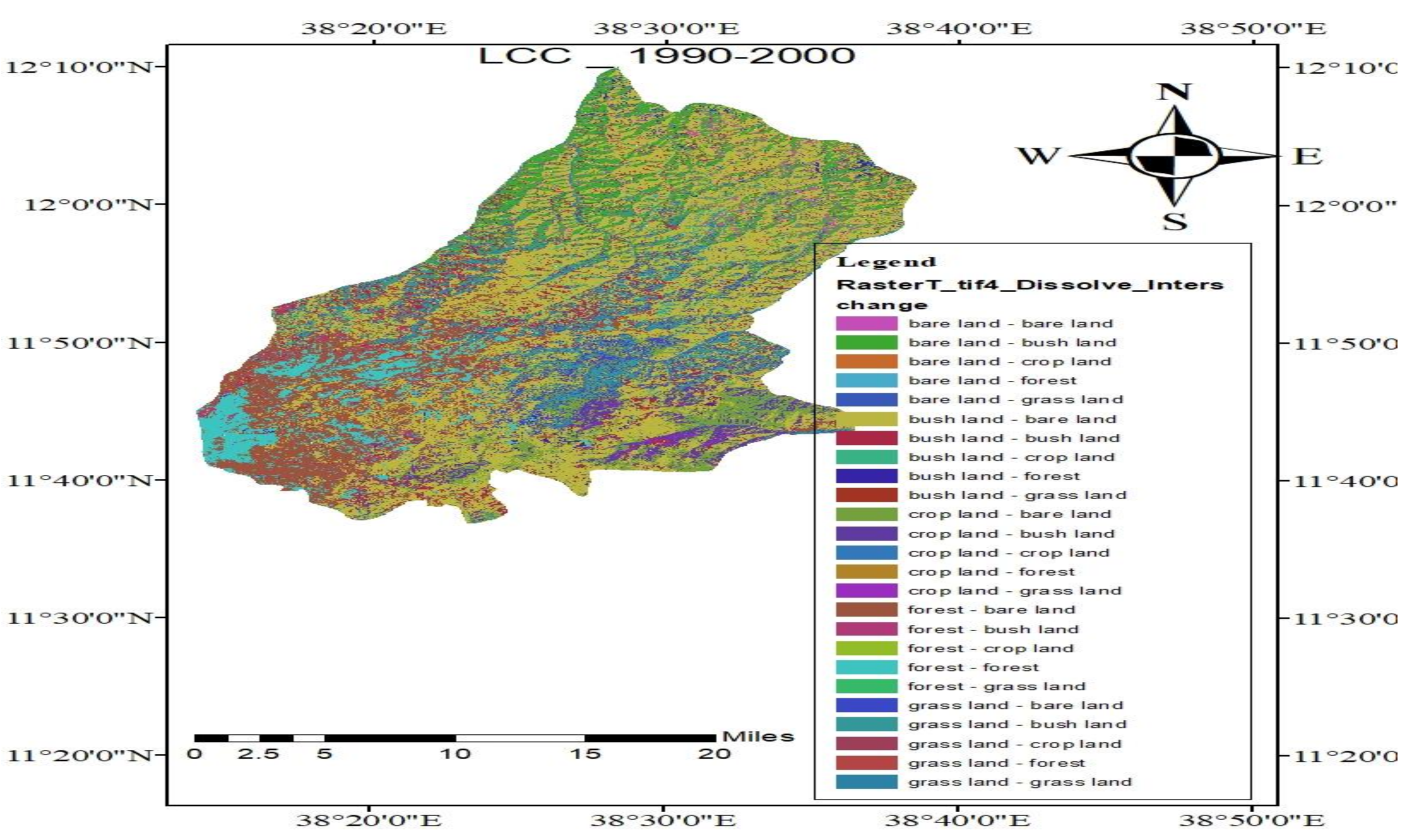


Figure 4(a): Land cover change map in 1990-2000

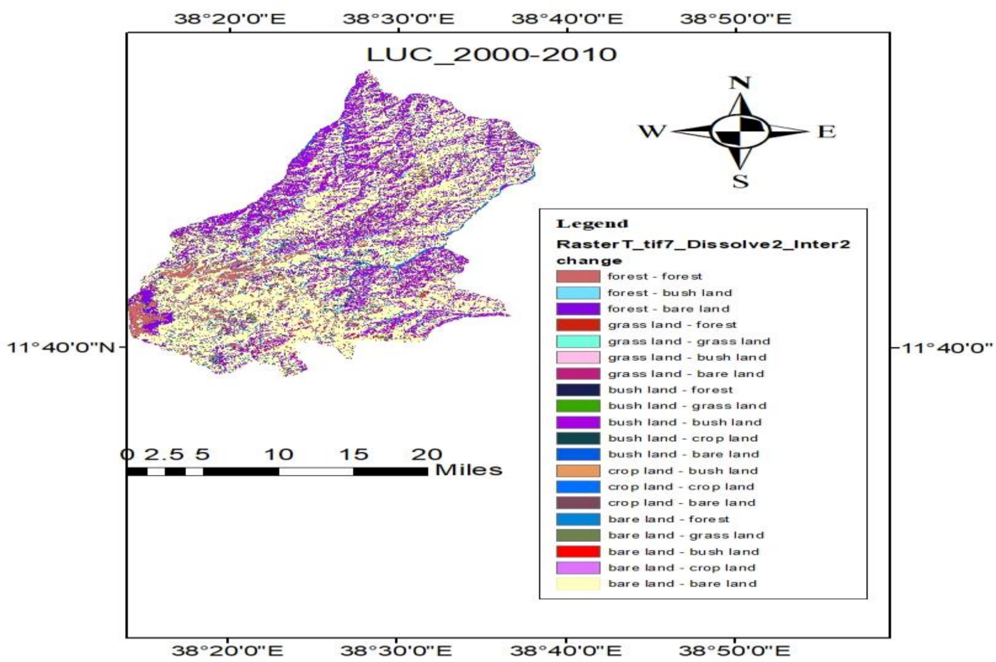


Figure 4(b): land use cover change map in 2000-2010

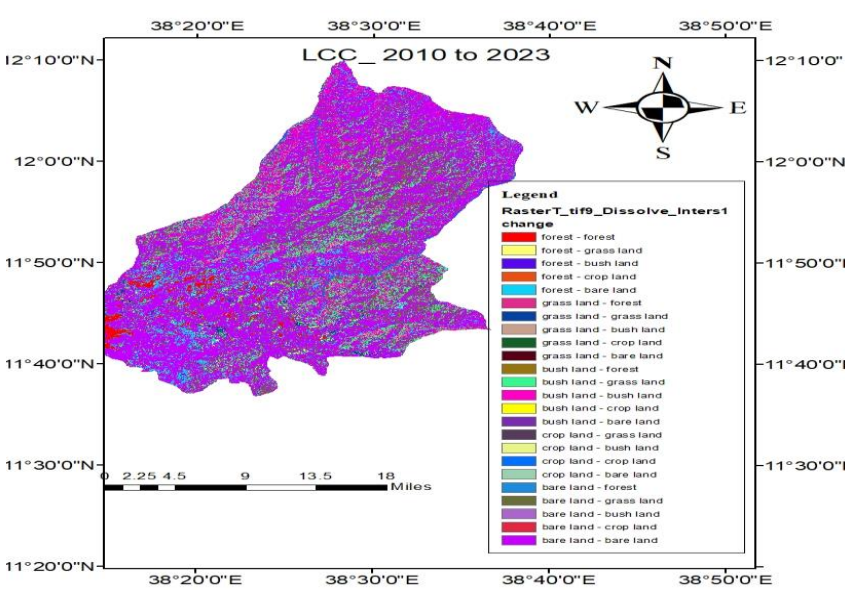


Figure 4(c): land cover change map in 2010-2023

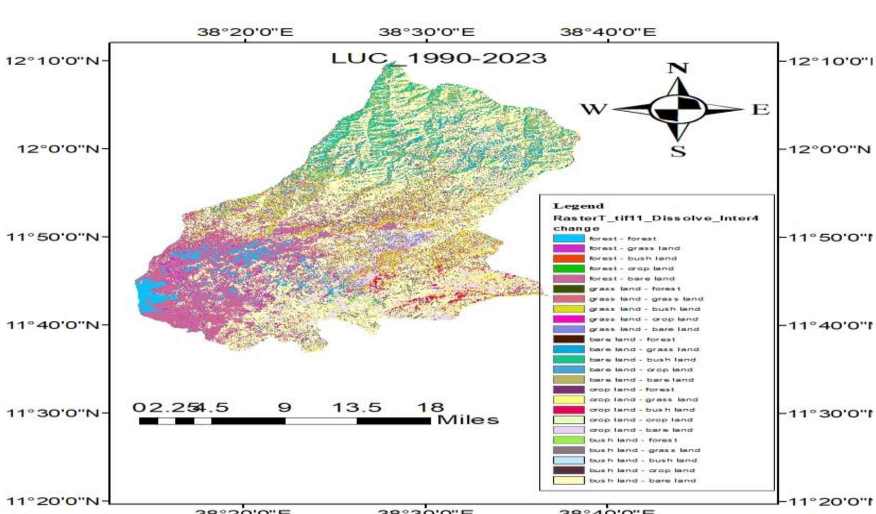


Figure 4(b): Land cover change map in 1990-2023

4.4 Causes of LULCCs

In study area, LULCC is a result of several proximate and underlying causes.

4.4.1 Proximate (Direct) Causes

The series of discussions and interviews were conducted with the FGD participants and key informants. Major proximate (direct) driving forces appear to explain a large part of LULCC in the study area. These are expansion of agriculture, illegal logging, fuel wood extraction, overgrazing and unplanned illegal settlements.

As reported from discussion and interview with focus groups and key informants, expansion of agriculture were the major drivers of LULCC in study area. Agriculture was expanding in all parts at the expanse of grassland/rangeland, forest and bush land. Subsistence crop farming was the major driving forces for forest, grassland and scrub/bush land cover change in highland kebeles especially in kebelle_10 (Guna-Gedba). A number of hills which were previously covered by small grass, bush and forest have been converted to small scale crop farms. Moreover, Laygaint Woreda investment office in 2015, about 10 ha of grassland was given to agricultural/crop land in Guna kebele (This is in agreement with Teshome (2010) who reported that between 1986 and 2006).

Participants in the FGD also identified settlement as one of the major proximate causes of LULCC next to agricultural expansion in the study area. The participants stated that most of the forest and bush land areas were destroyed by cutting and fire. They were converted to agriculture and settlement areas. Farmers also cut the afro-alpine scrub lands to initiate fresh grass for their cattle.

Illegal logging, fuel wood extraction in the form of charcoal and fire wood were also a major driver for the diversion of forest and bush lands in study area.
On the other hand, discussants of this study also confirmed that rural population ploughed farm land and fulfilled the livelihood requirements of their family.

Overgrazing was another major proximate cause of LULCC. This was identified by FGD participants and key informants. They stated that increase a number of livestock from time to time and conversion of grasslands created livestock pressure. This further forced the local communities to send their livestock inside the forest and shrub land resources for grazing by exerting severe pressure on the forest and shrub land through browsing and trampling.

Results from survey interview and group discussion also indicated that expansion of illegal and unplanned settlements inside the dense forests and shrub land were the other major proximate driver of forest and shrub land cover fragmentation in study area. They stated that such settlement was the major problem in Guna grass land. Because a number of illegal farms from the people settled inside the grassland and cleared the grass for the purpose of settlement and crop farm. According to the discussants, most of illegal settlers of grassland and forest land came from landless youth and illegal farmers from the community. They were the victims of this activity. On the other hand, illegal and unplanned settlements expanded for crop land and settlement. They also contributed for fragmentation of forest and shrub lands of lowland area.

Expansion of urban areas and construction of infrastructures like school and roads also contributed for the conversion of grassland, forest and bush land. As it was stated by discussants of this study, the current schools in their locality replaced the land that was covered by grassland and bush land.

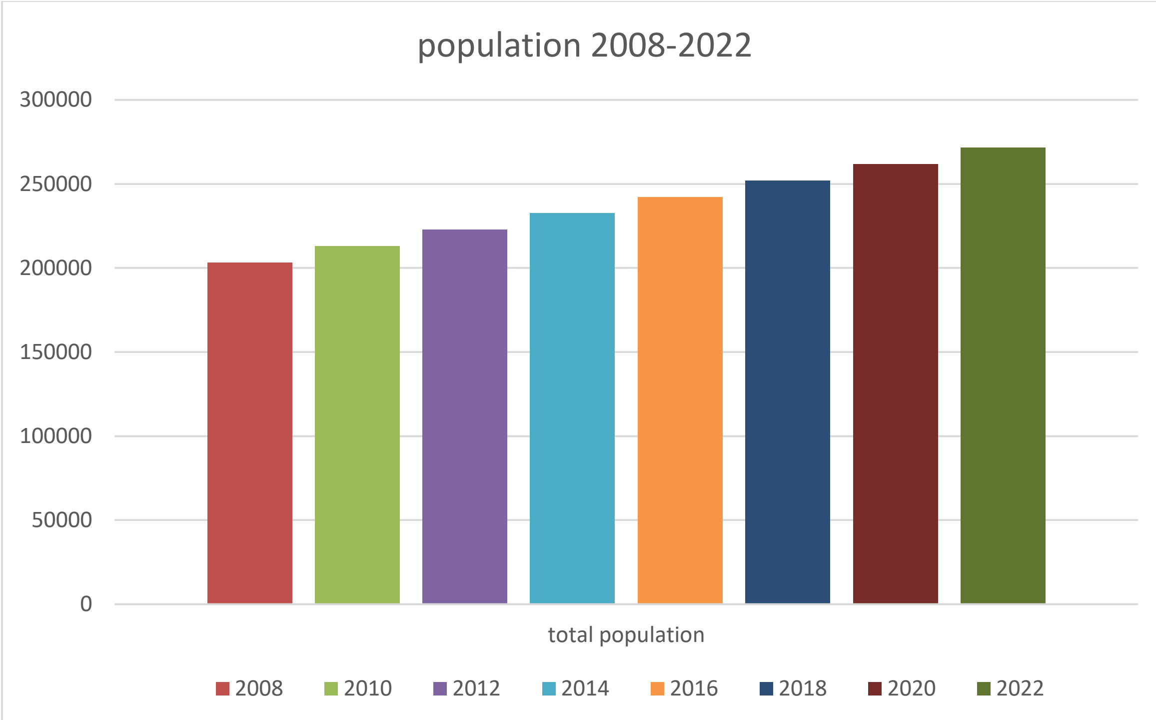
4.4.2 Underlying Causes

The above mentioned proximate causes were triggered by different underlying causes of LULCC. From a range of demographic, economic, technological, institution and policy, socio-cultural and biophysical factors, underlying drivers of LULCC were identified by the FGD participants and key informants in the study area.

4.4.2.1 Demographic Factors

Focus group discussants and key informants of this study confirmed that population growth was the first of all underlying drivers of LULCC identified in the study area. In line to these studies like Oumer (2009), Tefera (2011) and Alemu et al. (2015), population pressure was one of the major underlying drivers of LULCC in different parts of Ethiopia. Key informants and FGD participant perceived that population in study area has been increasing from time to time. They identified major reasons such as high fertility rates, owing to early marriages and polygamy.

According to the knowledge of FGD participant, population growth increased the demand for agriculture, settlement and fuel wood and construction materials. This in turn resulted forest and woodland encroachment for settlement, new agricultural land and fuel wood extraction. The evidence obtained from local informants confirmed that the current resettlement sites and areas were found illegal settler. They were covered by forests, grassland and shrub land plants in the previous three decades. The perception of discussants and key informants was in agreement with CSA reports that rose the total population of in the study area. The total population in the study area was 203191 (CSA, 2008). In (2022), it increased to 271644 with population density of 178.4 person/ km2 (CSA, 2022). Between these two years, the number of population in study area increased from 203191 with annual rate of about 4890 persons / year. As shown in the figure between 2008 and 2022 total population of the study area was increased.



Graph 5 : population growth in study area (2008 - 2022) derived from CSA (Projected from 2022 census by 1.8% rate)

4.4.2.2 Economic Factors

The economic causes of LULCC in study area include poverty and food insecurity, unemployment owing to lack of off-farm jobs (especially for landless and educated youth), change in rural economic activity and opportunity to derive high economic benefits from the sale of cash crops such as old irrigation potatoes and garden vegetables. Key informants and focus group discussants stated that these were the major underlying economic factors behind the expansion of agriculture especially crops farming inside the forest and illegal logging. Due to lack of off-farm, employment opportunities for adults in study area remain unemployed. This resulted in land fragmentation due to sharing of lands from their families, encroachment of forest, grassland and shrub land in search of new agricultural land and fuel wood.

To show the role of poverty on environmental change, the World Commission on Environment and Development (WCED) pointed out that people who are poor and hungry always destroy their immediate environment in order to survive (Belay, 1995). Change in the rural economy from agro-pastoralism to cultivator and establishment of economic linkage between rural and urban centers also played a greatest role for the expansion of agriculture in the study area. Economic linkage between rural and urban areas was facilitated by infrastructural developments such as road and markets.

4.4.2.3 Technological Factors

According to discussants and key informants, the technological factors affected LULCC in study area. Thus, they were improved by access road, markets, schools and agricultural inputs such as inorganic fertilizers, improved seed and herbicides. These were the share of agricultural land; on the other hand, it increases the share of forest, shrub and grasslands (Girma and Hassan, 2014). This implies that access market and improvement of road network promote the conversion of forest, shrub land and grassland into agricultural land.

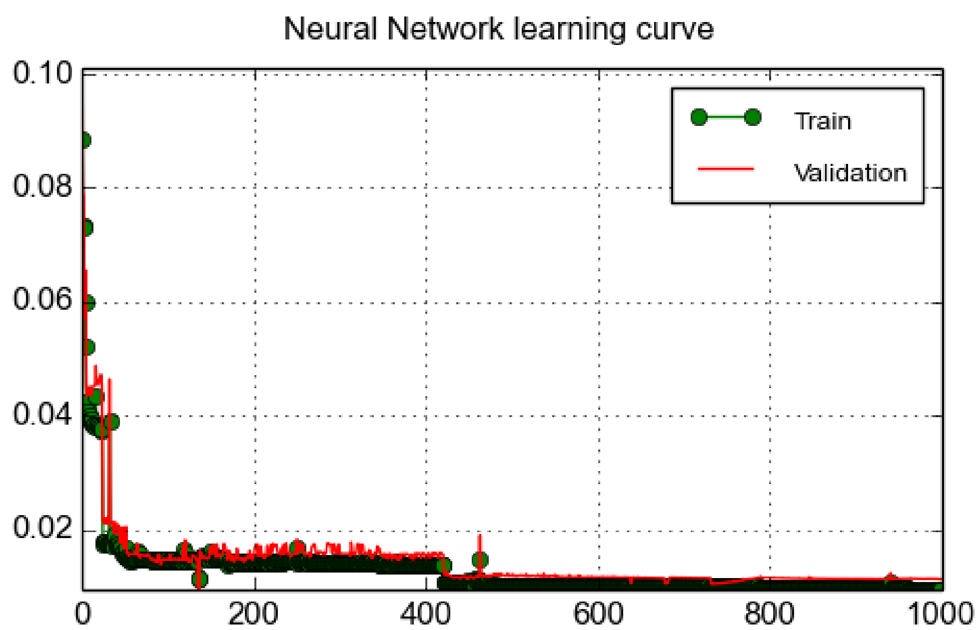
4.4.2.4 Policy & Institutional Factors

As the information obtained from key informant following the arrival of the EFDR government, the division of land and the formation of villages contributed to expansion of settlements and agriculture. The other most important policy contributed for agricultural expansion in the study area was “Land to Tiller” during the DERGE regime where privatization of communal lands were carried out. National and regional policies on land use and economic development such as infrastructural expansion (e.g. roads, schools, markets etc.), attaining food self-sufficiency through investment on agriculture were the other factors contributing to LULCC. These lead to expansion of small and large scale agriculture, construction of several infrastructures at the expanse of forest, shrub land and grassland. Lack of proper land use plans were another policy related to driver of forest and shrub land cover change. It was characterized by encroachment of vegetated lands especially forest, grass land and national park for settlement, pasture and agriculture, cultivation of steep slope and opening of very dense forest areas through road construction. Weak law enforcement was also significant driver of LULCC. As the information obtained from FGD and KII, manifestations of weak law enforcements in the study area were corruption, lack of benefit sharing and delay in decision making by the courts. These all were the major reasons for inability of local institution and community based organizations to discourage illegal settlements in vegetated areas and to control livestock grazing inside the grassland and expansion of both small holder and commercial agriculture. Lack of benefit sharing between local communities and government and non-government organizations were raised as problem especially for those Kebeles.

The other policy and institutional related drivers of LULCC was change in institutional power on land use from shared and customary systems to privatization and formal institutional system. Change in land tenure system was another policy related driver of forest and bush land cover change. Participants of the FGD informed that during the DERGE regime huge size of forest, grassland and bush land in the study area had been converted to other land use types due to change in the land policy of the previous government. Distribution of land and resource among scale farmers following the 1975 “land to tiller” policy and launch of state farms resulted in conversion of vegetated lands to agricultural land. However, in EFDR government land is a public property and administered by government (Tefera, 2011). Rural people have the right to use land indefinitely and to lease/rent, and transfer the land; correspondingly, the land policy of the EFDR government looks better as compared to the DERGE regime (Tefera, 2011). However, in the study area participants of the FGD agreed that farmers are still lacking confidence and feel as they have no right over their land. This coupled with a very low land holding per household motivated local farmers to encroach in to vegetated lands for cropping, grazing and settlement. For the conversion of forest and grass land to agriculture, these people are overriding future resources of their children.

4.5 LULCC prediction using Cellular automata

Cellular automata is simple way of modeling type which allow detailed mathematical analysis to estimates the taken time in transition that can generate complex spatial patterns from the simple set of rules and predicts LULCC in the future (Singh, 2003). (Graph _6) shows modeling of land use cover of the study area by using Cellular Automata modeling which were used 2010 and 2023 input data. Then training artificial neural networks (ANN) with the help of Multi-Layer Perceptron (MLP) were used in which using neighborhood feature was preferred 1 pixel size, learning rate 0.100, the iteration number is 1000 and the maximum moment is 0.080 which is powerful than linear regression (Jogun 2016). At the end of the training artificial neural networks process, the minimum validation overall error was calculated as 0.00947 and the validation kappa value was 0.94036 and also change overall error was -0.00177(graph-6).



Graph 6 : Neural network learning curve

4.3.1 Prediction of 2023 LULCC

Table (7) shows the 2023 LULCC, which was simulated from the initial year (2010) and final year (2023) for calculation of accuracy and kappa statics. It was used for prediction of LULCC for the year of 2033 by using MOLUSCE (3.0.13) plug-in extension (Figueiredo T, 2018). Then simulated and classified map 2023 was used as reference for validation and prediction of 2033.

Table 7: Changed area in hectare and in percent between references map 2023 and simulated map 2033

class type	reference year(2023) in ha	prediction year (2033) in ha	Δ	2023%	2033%	Δ
grass land	4999.98	4176.09	-523.89	3.24	2.88	-0.36
Forest	33205.23	34645.86	1440.63	22.91	23.9	0.99
bush land	17063.28	17096.67	33.39	11.77	11.79	0.02
water body	1516.41	881.82	-634.59	1.05	0.61	-0.44
crop land	88480.53	88164.99	-315.54	61.04	60.81	-0.21

4.3.2 Validation of Model

For the validation of the model overall kappa and multiple resolution budget were used to check, compare and validate simulated image of 2023 from1990, 2000 and 2010 by using actual land use classified image 2023 as reference map and simulated map of 2023 (Landis and Koch 1997). Image correlation coefficient (r) between two images was also calculated by MOLUSCE extension plug-in to determine the similarities between the two images. According to Evans (1996), suggests for the absolute value of correlation 0.00-0.19 very weak, 0.20-0.39 weak, 0.40-0.59 moderate, 0.60-0.79 strong and 0.80-1.0 very strong. Therefore, the results of the correlation coefficient gave a value of 0.95 which indicate very strong. Correlation of classified and simulated map of 2023 were indicated a good positive relationship between the two images and acceptable for the prediction of 2033 maps as shown in (Table.9.).The multiple resolution was the accuracy in location, quantity of the reference and simulated map that correspond to the agreement and disagreement component between two maps (Pontius and Suedmeyer, 2004).

Table 8 : Image correlation matrix

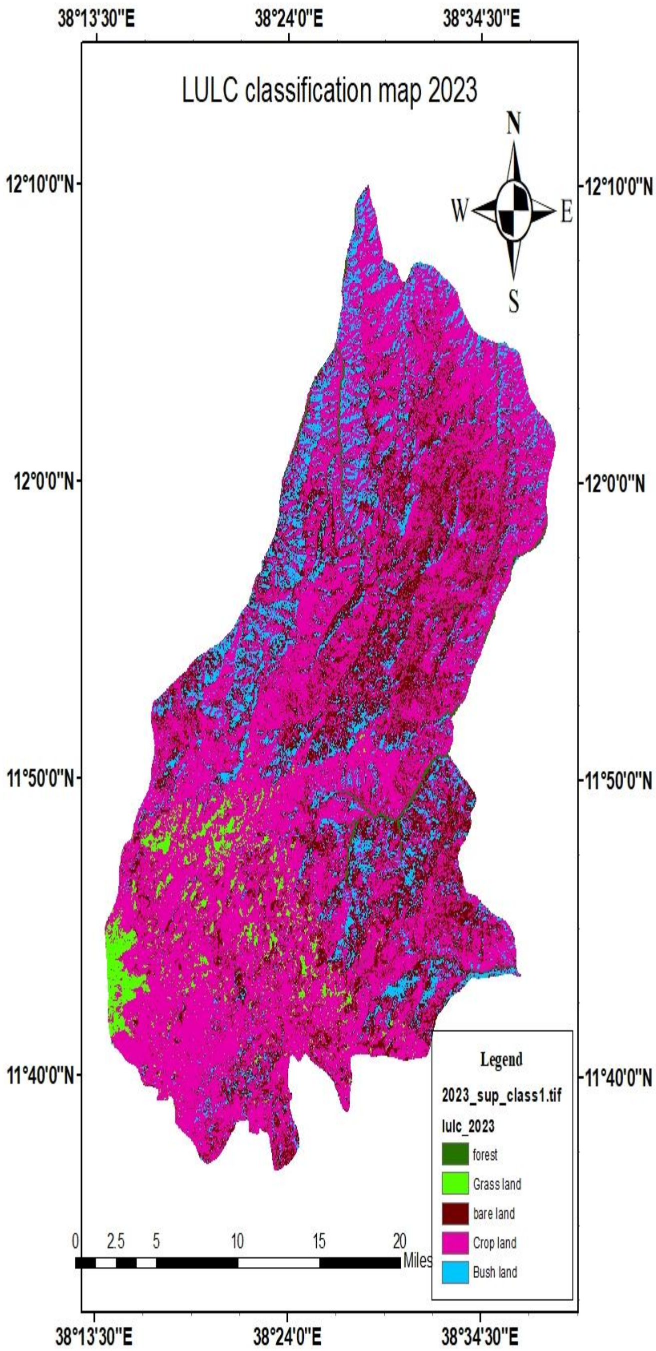
	prediction map of 2033	reference map of _2023
prediction map of _2033	1	0.99087165
reference map of 2023	0.99087165	1

Table 9 : Kappa and correctness of the simulated LULC map in 2033

% of correctness	97.60071
kappa(overal)	0.95709
kappa (histo)	0.98182
kappa(loc)	0.97482

4.3.3 Prediction of future LULC for the year 2033

After the change detection of LULC classes and validation were checked by overall correctness, correlation of the image checked (2023 classified and simulated) and Multiple resolution budget. overall correctness and Multiple resolution budget were aimed for prediction of the next ten future land use land cover changes for the year of 2033 from the initial year of 2023.Then future predicted land use classification map of 2033 was compared with actual classification map of the year 2023 (Figure 4 and Table 7).



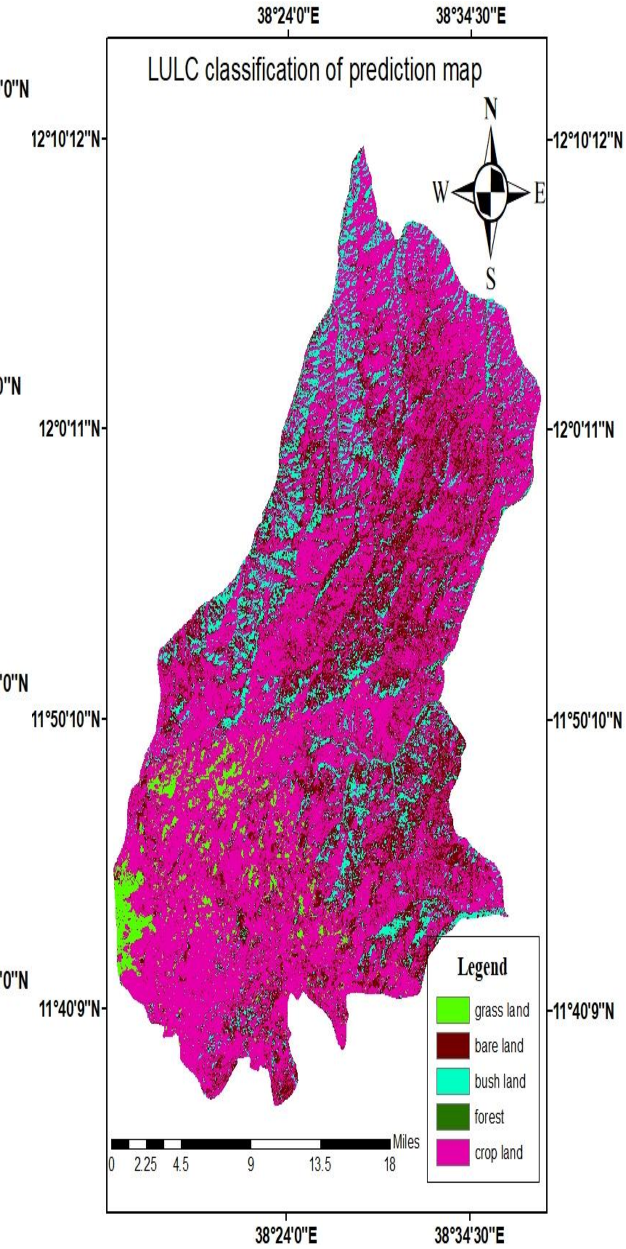


Figure 5(a): LULC **map on Laygaint district in 2023(reference map of the prediction)**

Figure 5(b): LULC **map of Laygaint district in 2023(map of prediction)**

From the Table (7) the result of simulated LULCC of 2033 shows there were decreasing crop land, grass land, and dense forest from 88480.53 ha (61.04%) to 88164.99 ha (60.81%), from 4999.98ha (3.24%) to 4176.09ha(2.88%), from 1516.41ha (1.05%) to 881.82ha (0.61%) respectively, whereas bare land and bush land were increased from 33205 ha (22.91%), 34645.86ha (23.9%), from 17063.28 ha (11.77%) to 17096.67 ha (11.79%) respectively.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In study area especially in Guna mountain has been experiencing different LULC changes. The main finding of this study was revealed a continual increment in agriculture at the expense of grass land and dense forest between 1990 and 2023. During 33 years period agriculture was increased by 88480.5 ha (61%) with a corresponding 4700 ha (3.2%) and 1516.4 ha (1%) declined in the area of grass land and dense forest respectively. The rate of agriculture expansion was high in high land Kebele as well as low in low land kebele under Woreda. On the other hand, rate of grass land and dense forest was high in parts of study area that are managed by Woreda and zone land administration with 2400 ha/year and 1960 ha/year respectively.

LULCC in the study area was a result of different interactions between proximate and underlying causes. The major proximate driving forces of LULCC in the study area were expansion of agriculture, illegal logging, overgrazing and illegal and unplanned settlement. On the other hand, from a range of demographic, economic, technological, policy institution, socio-cultural and biophysical factors underlying drivers of LULCC were identified by key informant and focus group discussants of this study. However, population growth, poverty and food insecurity gradually changed in the economic activities of communities in the area from agro-pastoralist to cultivator, weak law enforcement and drought were the effect of underlying cause. They were appeared to explain a large part of underlying causes.

From the finding, the prediction of 2033 LULCC were carried out by using MOLUSCE extension plug-in with integrating of QGIS in which grassland, crop land and dense forest. They will be decreased to 4176.09 ha (2.88%), 88164 ha (60.81%) and 881ha (0.61%), respectively compared to LULCC classified map of 2023 whereas bare land and bush land will be increased to 34645.86ha (23.9%) and 17096.67(11.79%) respectively. Therefore, robustness of the model and its validation and to use if for effective prediction of LULCC.

5.2 Recommendation

The study emphasized on evaluating land use land cover change and implication for land management of mountainous landscape in Laygaint, North Ethiopia. This study revealed that LULC transformation was one of the major factors that contributed the nature from time to time and place to place. Thus, the following recommendations have been forwarded based on the results obtained from this study.

- Government should be collaborating and integrated to identify the problem, plan and give solutions to collaborate that use the society for sustainable land use management.
- Proper and integrated approach in implementing policies and strategies related to land resources management should be considered. Enhancing productivity using proper technologies needs to be induced to minimize expansion of agriculture into forest lands and it is better to teach, work with and create awareness of the communities rather than working alone.
- Expansion of agriculture especially small scale agriculture by small holder farmers is the major proximate or direct causes of LULCC in study area causing loss of several hectares of grass land and forest land. Therefore, controlling the expansion of agriculture at the expense of grass land and forest land requires the right policy packages by national and regional governments such as livelihood diversification and improving the productivity of existing farm lands through the provision of improved production inputs.
- Population growth is the major root cause for LULCC in the study area. Therefore, controlling the population growth and its associated impacts on the natural environment require the right policy packages by national and regional governments. In addition, the governments should create awareness, provide family planning services, increase productivity, and control illegal settlements.
- Poverty and food insecurity were the other most important root cause for land use land cover change in the study area. Thus, both national and regional governments should design policies and strategies by creating and strengthening environmental friendly non-farm or off-farm income generating activities and provision of safety net programs.

- Even though there are some positive benefits especially on forest resources under the jurisdiction of PFM/PRM, still there is resource degradation. The finding of this study also revealed high loss of resources such as grass land, forest land and scrub lands under the jurisdiction of Woreda administrations as compared to areas under PFM/PRM. In this regard, two major recommendations are forwarded by the researcher. First, currently ongoing efforts under PFM/PRM should be strengthened more. Secondly, the successes achieved in PFM/PRM should be extended to other institutional arrangements in study area.

- Conservation activities have to be taken on rural areas of the study area and recommended to plant trees and delineated bare land areas.

- This study addressed only the change in LULC and driving forces behind the change. Therefore, further study is required to assess impacts of LULC on the climatic change.

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Appendix 1 : Land use land cover change matrixes

Table10: LULCC matrix from 1990 - 2000

		2000					
	LULC class	Grass land	bare land	Bush land	Forest	Crop land	Total
1990	Grass land	17.57	3.38	0.52	81.58	23.10	126.16
	bare land	5.28	2.44	0.91	131.25	27.12	167.00
	Bush Land	6.40	23.06	0.56	65.36	115.60	210.99
	forest	2.30	0.65	83.21	23.02	175.42	284.59
	Crop land	4.10	27.79	13.82	91.81	522.80	660.32
	Total	35.66	57.31	99.03	393.03	864.04	1449.06

Table 11 : LULCC matrix from 2000 - 2010

LULC class		2010					
		Bush land	Crop Land	bare land	Grass land	forest	Total
2000	Bush land	320.1	51.8	6.1	15.0	0.1	393.1
	Crop land	27.6	792.0	2.1	42.2	0.3	864.1
	bare land	16.5	0.2	17.1	2.0	0.0	35.7
	grass land	0.2	21.5	0.0	77.3		99.0
	forest	1.5	46.5		0.0	9.3	57.3
	Total	365.9	911.9	25.3	136.4	9.7	1449.2

Table 12 : LULCC matrix from 2010 - 2023

LULC class		2023					
		Bush land	Crop land	bare land	Grass land	forest	Total
2010	Bush land	141.13	79.27	143.94	0.80	0.74	365.88
	Crop land	7.02	731.03	162.22	5.67	5.93	911.87
	bare land	16.00	1.13	8.13	0.04	0.01	25.31
	Grass land	4.02	84.23	9.31	38.80	0.04	136.38
	forest	0.02	0.98	0.78	0.00	7.92	9.70
	Total	168.19	896.64	324.37	45.32	14.63	1449.14

Table13 : LULCC matrix from 1990 - 2023

LULC_ class		2023					
		Bush land	Crop land	bare land	Grass land	forest	Total
1990	Bush land	68.82	50.36	47.34	0.02	0.43	166.97
	Crop land	19.15	508.07	125.33	4.22	3.57	660.34
	bare land	55.06	23.13	46.72	0.20	1.06	126.17
	Grass land	5.17	221.01	17.93	40.37	0.13	284.61
	forest	19.99	94.04	87.06	0.50	9.41	211.00
	Total	168.19	896.61	324.39	45.31	14.60	1449.10

Appendix 2 : Error matrix of LULC in (1990-2023)

Table 14 : Error Matrix of LULCC in 1990

LULC Class Type	error matrix of LULC in 1990							
	Grass land	bare land	Bush land	forest	Crop land	Total	User Accuracy	Kapp a
Grass land	183	0	1	0	4	189	0.968	0
bare land	3	100	4	0	0	110	0.909	0
Bush land	0	0	90	1	4	95	0.947	0
Forest	5	1	1	142	1	150	0.947	0
Crop land	15	0	1	0	444	461	0.963	0
Total	206	101	97	143	453	1005	0	0
Producer Accuracy	0.888	0.990	0.928	0.993	0.980	0	0.954	0
Kappa	0	0	0	0	0	0	0	0.936

Table 15 : Error matrix of LULCC in 2000

LULC Class Type	error matrix in 2000							
	Grass land	bare land	Bush land	forest	crop land	Total	User Accuracy	Kappa
Grass land	23	0	0	0	1	24	0.958	0
bare land	0	11	1	0	0	12	0.917	0
Bush land	0	0	96	0	3	101	0.950	0
Forest	0	0	1	19	2	22	0.864	0
Crop land	1	0	0	0	219	222	0.986	0
Total	24	11	98	19	225	381	0.000	0
Producer Accuracy	0.958	1	0.980	1	0.973	0	0.966	0
Kappa	0	0	0	0	0	0	0	0.941

Table 16 : Error matrix of LULCC in 2010

LULC class type	error matrix in 2010							
	Grass land	bare land	Bush land	Forest	Crop land	Total	U_ Accuracy	Kappa
Grass land	29	1	0	0	2	32	0.906	0
bare land	0	11	0	0	0	11	1	0
Bush land	0	1	95	0	3	100	0.950	0
Forest	0	0	0	6	0	6	1	0
crop land	2	0	0	0	247	251	0.984	0
Total	31	13	95	6	252	400	0	0
P_ Accuracy	0.935	0.846	1	1	0.980	0	0.970	0
Kappa	0	0	0	0	0	0	0	0.944

Table 17 : Error matrix of LULCC in 2023

LULC Class type	error matrix in s2023							
	Grass Land	bare land	Bush land	Forest	Crop land	Total	U_ Accuracy	Kappa
Grass land	10	0	0	0	0	10	1	0
bare land	1	75	6	0	6	88	0.852	0
Bush Land	0	0	36	0	1	37	0.973	0
Forest	0	0	0	6	0	6	1	0
Crop Land	0	0	0	0	257	258	0.996	0
Total	11	75	42	6	264	399	0	0
P_ Accuracy	0.909	1	0.857	1	0.973	0	0.962	0
Kappa	0	0	0	0	0	0	0	0.928

Appendix 3 : sheets of field observation

Table 18 : field observation sheet

Filled observation sheet					
General Data					
Observers Name			Date and Time		
Sample ID	Location	Position	Altitude (m)	Photo taken	LU/LC type
	Region____________	Lat. (X)___________	Alt. (Z)________	__________jpeg	
	Zone_____________	Long. (y)____________			
	Woreda ____________				
	Kebele _____________				

Appendix 4 : checklist for FDG and KII

1. Checklist for Focus Group Discussion (FDG)

Administrative Unit: Region: _______, Zone: ______, Wereda: _________

Name of Rural Kebele _________________________

Village Name _____________________

No. of participants____________________

Date ___________________________________

1. What are currently existing land use/land cover types in your locality?
2. What does the land use/land cover type of your locality looks like before 30 years, 20 years and 13 years?
3. Which land use/land cover type is increasing and which is decreasing starting from 1990 to this time, why?
4. On which period do you observed a rapid land use/land cover change, why?
5. What kind of land use/land cover change do you expect in the future? And why?
6. What are the direct/proximate drivers of land use/land cover change over the last 33 years, between 1990 & 2000, 2010 & 2023? (Options provided: infrastructure development and urban expansion, forest encroachment for illegal and legal settlement, overgrazing, agricultural expansion, occurrence of fire and unsustainable harvest of forest products (like firewood, charcoal, logging)
7. Which land cover is highly affected by each proximate (direct) drivers of LU/LCC?
8. What are the underlining causes along each proximate driver?

2. Checklist for Key Informant Interview (KII)

1. Have you noted any change in the land use/land cover in your area over the past 33 Years? A) Yes B) No
2. If your answer to question number 1 is yes, what changes did you observed? Increase/decrease in:

   A) Agricultural land
   B) Forest cover
   C) Woodland
   D) Scrub land
   E) Bush/shrub lands
   F) Grassland
   G) Rangeland
   H) Settlement and infrastructure

3. What are the causes behind their increase/decrease?
   I. Direct causes
   II. Indirect (root) causes
4. Participation of the local communities, government and non-government organizations in resource conservation and management activities and how they are participating?
5. How do you evaluate the livestock and human population size in your area in the last 33 years? What do you think the cause for population dynamics in your area?
6. What major technological change occurred in the area of infrastructural development and farming activities in the last 33 years?
7. Do you think national policies and institution implemented until today have responsibility for land use/land cover change? If yes how?
8. What major natural calamities occurred in your area in the last 33 years?
9. Means of land acquisition (tenure) in your PA before 30 years, 20 years and 13 years?
10. What are the main economic activities for the local communities in your area before 30 years, 20 years and 13 years?