ASSESSMENT OF THE EFFECTS OF LAND USE CHANGE ON FOREST COVER ALONG THE SLOPES OF MT ELGON: A CASE STUDY OF MBALE DISTRICT

BY

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DECLARATION

I declare that the information provided in this dissertation is my own work and has not been previously submitted to any higher education institution leading to any degree award and that all the information sources consulted have been acknowledged by means of references.

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APPROVAL

This dissertation has been compiled under my supervision and is now ready for submission.

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DEDICATION

I dedicate this piece of work to my mother, Mrs. Ruth Minjo for the foundation she laid for me very many years ago. This strong foundation formed the basis of this work.

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ACCESS	African Collaborative Centre for Earth System Science
CBO	Community Based Organization
CI	Conservation International
DEAP	District Environmental Action Plan
ECOTRUST	Environmental Conservation Trust of Uganda
EIA	Environmental Impact Assessment
ETOA	Environmental Threats and Opportunities Analysis
FAO	Food and Agriculture Organization
GIS	Geographical Information Systems
GOU	Government of Uganda
GPS	Global Positioning Systems
MDHRVP	Mbale District Hazard, Risk and Vulnerability Profile
MEFR	Mount Elgon Forest Reserve
MWLE	Ministry of Water, Lands and Environment
NAADS	National Agricultural Advisory Services
NARO	National Agricultural Research Organization
NEMA	National Environment Management Authority
NFA	National Forestry Authority
NGO	Non-Governmental Organization
NPHC	National population and housing census
NRM	Natural Resources Management

PA	Protected Areas
UBOS	Uganda Bureau of Statistics
UNEP	United Nations Environment Programme
UWA	Uganda Wildlife Authority

ABSTRACT

Forests are of great importance due to their ecological diversity thus providing a multiplicity of ecosystem goods and services. These valuable ecosystems are however facing increasing threats from anthropogenic activities. This study therefore, analyses the state of forest cover due to land use change between 2009 and 2019 on Mount Elgon slopes in Mbale District in Eastern Uganda. A cross-sectional survey design was adopted following both qualitative and quantitative approaches. Analysis of Landsat images (Landsat 7TM & 8ETM) of the study area for 2009 and 2019 was conducted using semi-automatic classification plugin in QGIS software 3.12. Social economic data on drivers of land use/cover change were collected from a sample of 191 respondents selected from households, local council leaders, district personnel using structured questionnaires and interview guides. To map and characterize the size of forest cover, and assess the effect of land use types on diversity and distribution of forests in the area, maximum likelihood classification of Landsat 7ETM and 8ETH+ images was conducted in QGIS software version 3.12. A land-use/cover conversion matrix was used to explore land use changes over the study area for the two study periods (2009 and 2019). To establish the main drivers of land use change, descriptive statistical analyses were conducted on social-economic data. The study revealed that: i) conversion to farming and built-up infrastructure at the expense of forest cover and other natural vegetation were the main changes in land use/cover. Forest cover in Mbale declined by 0.09% between 2009 and 2019, whilst the area under farming and built-up increased by 8.49% and 5.47%, respectively. ii) Land use change negatively affected forest diversity by increasing the level of fragmentation as shown by reduced forest class area vis-à-vis increased number of forest cover patches. iii) Population pressure was the main driver of land use change and forest cover loss. iv) It is predicted that by 2029, forest cover in Mbale district will have declined by 0.17%. Therefore, land use change, which is largely a human phenomenon negatively affects forest cover. It is recommended that; excess population near forest zone should be relocated to the lower slopes and; farmers should adopt modern farming methods and technologies to maximize output on small farmlands and save the natural vegetation cover.

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Land is one of the most important natural resources, on which life and various development activities depend (George et al., 2016). Land use refers to a series of activities undertaken on land to generate one or more products and or services such as settlement, agriculture, transport and communication, lumbering among others (FAO/UNEP, 2009). Trimble et al. (2011) states that land use has a significant impact on biodiversity worldwide, that is, on global and local climate, biogeochemical cycles, soil quality, hydrology, food safety and human wellbeing. Land uses affect the ability of biological systems to meet the increasing demand for natural resources (Tran et al., 2015). However, the effects of land use type are not all negative, as some are associated with increase in food and fiber yields, improved human health, wealth and well-being (Lambin and Geist, 2006).

Since land use is a human related phenomenon, decrease or increase in human populations consequently results into its change in an area. However much of world populations have been increasing thus more land is being put under use than before and that natural resources are under intense pressure with likely consequences of degradation and extinction. Tilman et al. (2015) reports that land use types are changing land ecosystems at unprecedented rates that is, in the last 40 years, natural vegetation has been cleared at 4×10^6 ha/yr for agricultural activities. Croplands and rangelands now constitute approximately 40% of the ice-free terrestrial surface (Ramankutty and Foley, 2009). Development trends have created large divergences in the land cover patterns. Many developed countries have experienced an expansion of native vegetation over formerly cultivated land (Grau et al., 2003; Kauppi et al., 2006), whereas most developing countries have undergone the fastest expansion and intensification of cultivation in their history (Ramankutty et al., 2012).

Changes in land use represent a complex environmental, socioeconomic, and technological problem. On one hand, agriculture is essential to human subsistence as it provides food, fiber, fuel, and construction materials and globally enhances economic development and human welfare (Millennium Ecosystem Assessment, 2005). On the other hand, agricultural activities generate cascading impacts that modify the fluxes of energy and materials, the structure and functioning of natural ecosystems, and the supply of goods and services, affecting human well-being (Foley et al., 2005; Ehrlich and Ehrlich, 2013). Changes in the different socioeconomic activities occurring in a particular area, and the human behavior patterns they create, affects the environment (FAO, 2017; Kanianska, 2016; Majaliwa et al., 2020). While these activities take place at the local level, they can also contribute to global processes, such as climate change (Coulston et al., 2013. Thus, land use planning is an essential tool for natural and human ecosystems stability and control.

Vegetation cover is one of the land components that is not spared by land use and land use change. Archibold (1992) recognizes major vegetation types to include tropical forests, tropical savannas, temperate forests, temperate grasslands, coniferous forests, tundra (both polar and High Mountain) among others. This breadth of vegetation shows the complexity of plant ecology, since it includes plants from floating single-celled algae up to large canopy forming trees etc. Mountain Elgon (Bubyangu) is one of such valuable ecosystems, which is important for environmental and economic goods and services such as water, wild life habituation, climatic modification from the mountain forest and other vegetation.

Generally, land use changes affect forest ecosystem services derived not only from a reduction in the area of the original cover, but also from a transformation of the landscape structure (FAO, 2016). The spatial distribution of different land cover patches modifies the land atmosphere interaction (Pielkeand, 1990) and hence, the exchange of water, energy, and materials (Nosetto et al., 2005; Naef et al., 2012). The landscape configuration affects the horizontal redistribution of materials between patches and the magnitude of outputs (Saunders et al., 1991). The spatial distribution of different patches also affects the abundance and persistence of local plants because it determines factors such as Meta-population dynamics, dispersal routes, and carrying capacity (Fahrig and Merriam, 2012). The development of land-use policies that are oriented to guarantee food security and the provision of both market goods and ecosystem services requires as basic input the assessment of landscape structure and dynamics.

The global forest resource assessment by FAO (2016) indicates a marked change in forest management over a twenty-five-year period (1990-2015). This period saw as series of negative developments. The report shows that the extent of the world's forests continues to decline as human populations continue to grow and demand for food and land increases. The rate of net forest loss is noted to have increased by over 50% in the tropics over the 25 years (FAO, 2015). The world had 4128 million ha of forest in 1990 and by 2015: this area had decreased to 3999 million ha (FAO, 2016). This is a change from 31.6% of global land area in 1990 to 30.6 %1 in 2015 (FAO, 2015). This represents a net loss of some 129 million ha of forest between 1990 and 2015, about the size of South Africa, representing an annual net loss rate of 0.13%. Between 2010 and 2015, there was an annual loss of 7.6 million ha. The largest forest area loss occurred in the tropics, particularly in South America and Africa. While per capita forest area decline is greatest in the tropics and subtropics, this therefore indicates that forest losses are occurring in every region. FAO (2010) estimates that 13 million hectares of natural forests are lost each year worldwide. The native species are much at risk of extinction because little effort has been put to regeneration and long-term restoration. Natural forests therefore, are currently being depleted at a fast rate probably due to ever-increasing population, clearing land in the forest for more food production, trading in timber and timber products, high demand for wood fuel etc. Climate change has reduced productivity of existing firm lands therefore pushing humans to open up new firm lands within the forest. It is noted that land use activities are taking place within the forest buffer since 1970 (FAO, 2016).

In developing countries, it is estimated that 15 to 20 million hectares of forest cover disappear every year while West Africa loses more than two third of its wooded surface (FAO, 2011). It is projected that a further 30% loss of vegetation in Tropical Africa and the Sahel zone would occur by 2025 (FAO, 2016). In this regard, deforestation has strongly been labeled as the primary driving force of global environmental change in tropical regions, more so on continental Africa (Roy Chowdhury, 2006; Lambin and Geist, 2012).

In East Africa forest cover dropped by 9% between 2001 and 2009 (Pfeifer et al., 2012). The highlands here have a large potential for agricultural production and, until the mid-20th century, they were resilient to exploitation (McCall, 1985). The favorable climate with abundant rainfall and fertile soils attracted farmers to the region many centuries ago. The productivity of the land also supported chiefdoms and kingdoms with a stratified social structure. The land adequately supported both subsistence and surplus food production. Land cover is in a state of flux at a variety of spatial and temporal scales due to climate variability and human activities that are rather destructive (Kiage et al., 2013). However, today, land degradation is threatening the very basis of the farming communities including Uganda.

In Uganda, approximately 75,000 km^2 (31.7%) out of 236,040 km2 of total land area consisted of forests and woodlands in 1980s. Today, the coverage has reduced to about 15.2% implying that Uganda has lost 16.5% forests and woodlands (Musasizi, 2018). As a result, in the last one decade, several policies, legal and institutional reforms have been instituted aimed at promoting the conservation and sustainable use of the country's natural forest resources (MWE, 2016). Among the key reforms, include the origination of the National Forestry Policy (NFP, 2015), enactment of the National Forestry and Tree Planting Act (NFPA, 2003) and the new institutional arrangements including the Forest Sector Support Department, the National Forestry Authority (NFA) and the District Forestry Services (DFA). Despite these efforts, the country continues to experience a great deal of land use changes like Agriculture, Built up and Roads The ever-increasing human population has resulted into increased pressure on environmental resources (including forests) in order to meet the day-to-day needs of survival thus forcing the country to undergo rapid land use transformations in rural areas in response to the diverse economic, socio-cultural, demographic and political processes that have occurred in space and time (NEMA, 2009).

In Mount Elgon areas in Eastern Uganda where a greater percentage (65%) of the population is engaged in agriculture for subsistence, the rising population over the years (at an average growth rate 2.5% per annum) has exerted a lot of pressure on land resources (Mwagore, 2012; UBOS, 2014). Population increase has resulted into shortage of arable land that has led to expansion of cultivation and settlement into fragile ecosystems including forests thus deforestation and associated negative effects on the environment in the area (Campbell et al., 2003; Mwagore, 2012). There is need to monitor and determine the changing patterns of land use and how they have affected forest cover and the likely future trends to guide land use planning and environmental resources management processes. The available information in the literature on land use changes and forest cover extent in Mount Elgon areas does not cover recent changes and thus limited in guiding these processes. This study was therefore, instituted to determine the extent of forest cover amidst changing land uses and prediction of future scenarios.

1.2 Problem Statement

Mount Elgon forest is of great importance through the ecosystem goods and services it offers in the region. These benefits are however, downplayed by the increasing threats of degradation resulting from high population growth rate and urbanization driving land use changes (State of Uganda's Forestry Report, 2016). With Mbale district population projected to increase by 2.3% per annum (i.e. 488,960 people in 2014 to 657,651 people by 2029), (UBOS, 2014) demand for natural resources especially forests is also likely to increase. The excess population requires more food, which in turn calls for opening up of more land for food production Obua et al. 2010). The high population also puts a lot of pressure on trees and forests for wood fuel, which 90.1% of the population in Mbale district rely on as the main source of energy for cooking (State of Uganda's Forestry Report, 2016; Mbale District Hazard, Risk and Vulnerability Profile, 2016). Thus, there is a growing concern over the future sustainability of these valuable ecosystems (Mbale District Hazard, Risk and Vulnerability Profile, 2016). Management of forest ecosystems is necessary to reverse actual and potential degradation to ensure sustainable provision of ecosystem goods and services (Coulston et al., 2013). However, such efforts require accurate and up to date information especially relating to specific trends in forest cover change vis-à-vis land use changes. This information is limited for this specific area of study, as what is provided by previous studies (Mugagga et al., 2010; Sassen et al., 2012, ACCESS, 2015) does not account for more recent and projected future changes in forest cover. NEMA & UBOS report (2015) indicated that, prediction of future environmental conditions like forest and soil degradation in Uganda is constrained by limited land cover statistics and in some cases lack of updated land cover data. NEMA and UBOS report (2015) indicated that, prediction of future environmental conditions like forest and soil degradation in Uganda is constrained by limited land cover statistics and in some cases lack of updated land cover data. This study was therefore, undertaken to evaluate the effect of land use changes on forest vegetation along the slopes of Mt Elgon in Mbale district using remotely sensed data for 2009 & 2019, and predict forest cover in the area for the period; 2019-2029.

1.3 Objectives

1.3.1 General Objective

The general objective of the study was to ascertain the state of the land cover in the face of changing land use on Mountain Elgon slopes in Mbale district.

1.3.2 Specific Objectives

The specific objectives were:

i. To map and characterize the area coverage of land use/cover changes in Mbale District on the slopes of Mt Elgon between 2009 and 2019.
ii. To assess the effect of land use changes on the structure of the forest ecosystem in Mbale district.
iii. To examine the underlying drivers of land use/cover changes on the slopes of Mt Elgon - Mbale district.
iv. To predict the future land use/cover changes and their implications on the landscape in the study area.

1.4 Research Questions

From the specific objectives of this research study, the following research questions were posed to guide the investigations.

a. What is the extent of change in area coverage of forest vegetation on Mt Elgon slopes in Mbale district between 2009 and 2019?

b. How has the change in land use affected forest ecosystem structure in Mbale district between 2009 and 2019
c. What are the major factors accounting for land use/cover changes in Mbale district?
d. What will be the state of natural forest cover in Mbale on the slopes of Mt. Elgon in by 2029?

1.5 Significance of the Study

The study findings will avail key information on the state of forest vegetation cover on the slopes of Mt. Elgon by highlighting areas with most forest cover loss and damages, which will enable National Forestry Authority and natural resources development agencies to review policies on forest conservation and land management. The study will also serve as a basis for assessing future landscape patterns and their potential negative impact on forest ecosystems and other components of the environment by organs like Ministry of water and Environment and National Environment Management Authority.

The study findings ought to benefit the land use planning and implementation in Mbale district. In the planning process, land uses that are shown in the study to be associated with more negative effect on forest cover will be discouraged or have mitigation measures instituted to enable optimal utilization of land resources and promote sustainability.

The results from the study will enable an inventory of knowledge and opportunities to identify and monitor changing patterns in landscapes that could benefit future research endeavors. The findings will be a contribution onto the existing body of knowledge in relation to the effects of land use types on natural vegetation components in the tropical mountainous areas.

1.6 Scope of the Study

The study was conducted in Mbale District that is located on the slopes of Mt Elgon in Eastern Uganda. The choice of the study area was informed by the importance of Mt Elgon Ecosystem in terms of provision of ecosystem goods and services in the region and increased expansion of anthropogenic activities towards forest zone from Mbale district as reported by ACCESS (2015). The study focused on the effect of land use changes on forest vegetation in Mbale district on the slopes of Mt. Elgon. Changes in land use types were examined in relation to forest area coverage, distribution and projected future changes. The assumption was that changes in land uses bring about changes in forest areal coverage and distribution. The data for determining land use and forest cover changes in this study covered a time interval of ten years (2009-2019) in Mbale district. Basing on this data, a projection of changes in forest and land use/cover was made for the period 2019 to 2029.

1.7 Conceptual Framework

A conceptual framework illustrates the connections that exist between the different variables and shows the direction of the relationships between and among different elements of the variables of the study (Jonker & Pennink, 2010). In this study, it was perceived that the sub-variables in the four dimensions of land use types yield independent effects on forest vegetation (Figure 1.1).

Land use takes place within the frameworks of environmental (physical and ecological), economic, social and institutional frameworks. From the perspective of the framework above the relationship between the independent and dependent variables in the sense that independent variables which is the land use occurrence defines the major aspects of concern according to the study including; the effect of land use types on forests. This scenario has led to the realization of biophysical outcomes of human livelihood, socio-economic transformation, big yield production, improved standards of living, commercial production, land use management strategies and urbanization. Based on such a situation of land use is characterized by the arrangements, activities and inputs people undertake on land, to produce, change or maintain it. Land use types on the other hand according to the framework particularly puts emphasis on its natural properties which means biophysical cover of the forest surface is an expression of human activities which is synthetically a reflection of various elements. In order to realize the value of land use types in a profitable way, the researcher needs to find responsive measures to the moderating variations such as cutting down trees for agriculture settlement, commercial production, urbanization, rigid policies, land technicality absence among others for negative land use types in relation to ecosystem aspects of in Mbale district.

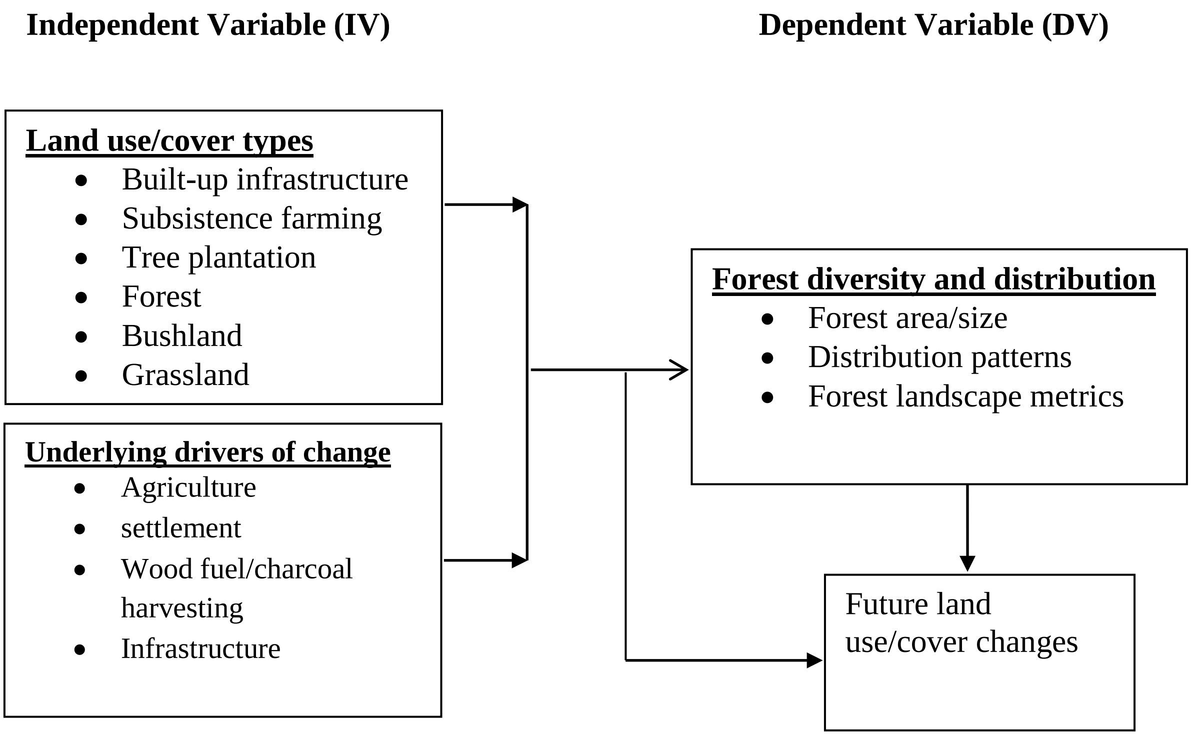

Figure 1.1: Conceptual framework

Source: As modified from Sanderson & Jaiteh (2012)

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter presents the broader context of the study variables in terms of previous scholarly works. It covers the theoretical and thematic review of relevant literature related to the study objectives in terms of the effect of land use changes on forest cover.

2.2 Land use Theory

The study was conducted under the auspices of "Incentive Land Use theory by Karsenty & Ongolo (2012). The theory postulates that, an important issue in worldwide sustainable livelihoods, vegetation and forest status study is essential for understanding the impact of land use activities/change on the human life around the forests. Incentive Land Use theory determines the main factor affecting the sustainable livelihoods such as land use types and forest activities. Heimann (2008) also states that, Land use activities (LUA) and forest activities have a significant impact on human survival and are therefore considered two main global environmental changes, which have major impacts on economic, social, and ecological aspects. LUA are fundamental variables that influence and link with many parts of the human and physical systems, as they are vital data components for many aspects of environmental change. The environmental changes and disturbance of forest ecosystems are widely caused by the humans living in and around the forests (Karsenty & Ongolo, 2012). The environment and LUA have significant effects on the basic ecosystem processes including biogeochemical cycling and erosion of soils and human susceptibility (Quinton, 2013). The demand for agricultural land systems and increased activities of land use patterns have put high pressure on forests. This has led to alteration of vegetation cover in terms of changes in the composition and structure of adjacent forest ecosystems as well as negatively affecting most human living over the past decades (Karsenty & Ongolo, 2012; Kanianska, 2016). Forest provide a wide range of benefits to humans including wood fuel, poles and sawn timber beside non-wood forest products (FAO, 2016). Such benefits draw populations near forested areas and as a result, the forest resources have been subjected to sever degradation.

2.3 Concept of land use/cover changes

Lambin (2015) describes land use as the utilization of the environmental resources to produce goods and services in such a way that, over a long time, the natural resource base is not damaged so that future human needs can be met. It is the human intervention on land and involves both the manner in which the land is manipulated and the intent that motivated that manipulation (TurnerIi et al., 1995; Meshesha et al., 2010). Land cover refers to the biophysical attributes of the earth's surface (Lambin et al., 2015). Human use of land resources gives rise to "land use" which varies with the purposes it serves, either for food production, provision of shelter, recreation, extraction and processing of materials, and the vegetation characteristics of land itself. Consequently, land use is being shaped under the influence of two broad sets of forces: human needs and environmental features and processes (Lambin et al., 2015).

Forest clearing is a fundamental pressure on the environment. It causes the loss, fragmentation and degradation of native vegetation, and a variety of impacts on soil (e.g. erosion and loss of nutrients), waterways and coastal regions (Woinarski et al., 2014). The fragmentation and degradation of remnant vegetation can in turn, disrupt essential ecosystem processes such as pollination, seed dispersal and regeneration. Smaller fragments of remnant vegetation are also vulnerable to invasive species and fire. Half of Australia's species currently listed as threatened under the country's Environment Protection Biodiversity Conservation Act -1999 are at risk from habitat fragmentation (Australian Department of the Environment, Water, Heritage and the Arts, 2009). Habitat loss and fragmentation are identified as major threats that are responsible for the extinction of 11 Australian mammal species, and place significant pressure on a further 19 threatened species and 15 near-threatened species according to Woinarski et al. (2014).

Neldner (2018) notes that, pressure on the environment from forest clearing, and habitat fragmentation and degradation include a legacy of extensive historical clearing, which presents a considerable challenge for land managers because redressing historical impacts can be costly and difficult. Approximately 44 per cent of Australia’s forests and woodlands have been cleared since European settlement; 39 per cent was cleared before 1972. The three most heavily cleared communities (mallee with a tussock grass understorey, brigalow and temperate tussock) together previously covered more than 170,000 square kilometers of Australia, and each has lost more than 80 per cent of its original extent (Tulloch et al., 2015). Legacy effects of past vegetation clearance mean that the associated impacts on biodiversity are not decreasing. High rates of population growth in urban and peri-urban areas result in continued conversion and degradation of the surrounding natural ecosystems. Urban and peri-urban expansion into green field sites have been significant pressure on the extent of native vegetation in southern, eastern and southwestern Australia (e.g. banksia woodlands in southwestern Australia), and on high-value agricultural floodplains around regional cities and near the coast. Since 2011, loss of valuable agricultural lands continued across most states and territories because of urban encroachment.

The most significant global challenges of this time relate to management and the transformation of the forest cover’s surface occurring through changes in land use (Daniel et al., 2008). Daniel et al. (2008) estimated that undisturbed areas represent 46%of the forest cover’s surface and forests covered 50%of the land area 8000yrs ago as opposed to less than 30% today. Agriculture has expanded into forest areas, the most endangered of which are the virgin mountain forests in high lands to meet the demand for food and fiber (FAO, 2017). Land uses result from many natural and human factors with in social, economic and political contexts. The local human activities representing the forest clearance drivers was determined by measuring the rates and types of changes and analyzing other relevant sources of data like house hold characteristics and policies related to land resource management.

In Sub-Saharan Africa, land use trends are extremely fast and the direction and rate of change are unstable (Yeshaneh et al., 2013). Land use changes are often related to both natural and anthropogenic causes. However, the most important driver of land use change is the intensive use of natural resources by local communities to satisfy their daily needs (Nacoulma et al., 2011) particularly in sub-Saharan countries where communities' livelihoods depend mainly on natural resources. Changes in land use contribute significantly to alter the environment and ecosystem services that support human needs (Mayaux et al., 2013). To natural resources dependent-societies, land use change constitutes a major challenge to sustainable livelihoods aspirations. To implement remedial strategies to cope with the issue, a good understanding of the direction of change and their extent is needed.

The causes of land use and land cover change can be summarized in two major categories namely the proximate or direct causes and the underlying causes (Kadeba et al., 2015). The underlying causes are factors that trigger the proximate causes and refer to economic, demographic, institutional, political or technological factors that mostly occur at regional or global levels (Ouedraogo et al., 2010). The proximate causes refer to immediate actions that affect directly the land cover (Hosonuma et al., 2012a). The proximate causes of land use and land cover changes are manifold but the most cited in Africa are wood extraction, agricultural expansion, and infrastructure extension (Norris et al., 2010).

After forest clearing for agriculture, wood extraction mostly for household energy consumption is the major driving force of vegetation dynamics in sub-Saharan countries (Arnold et al., 2005; Kouami et al., 2009) where wood fuel either used directly as firewood or converted into charcoal is the primary source of domestic energy (Karekezi, 2012). Indeed, despite the capacity of tropical forest species to regenerate after cutting for charcoal that allows forest recovery (Aguilar et al., 2012), the pressure exerted by charcoal production sometimes results in devastating ecological and environmental effects (Chidumayo & Gumbo, 2013) particularly deforestation and forest degradation (Mwampamba, 2014).

The environmental effects of deforestation often prompt countries with high dependence on fuel wood to develop strategies for coping with the problem (FAO, 2017). In Senegal, a major charcoal producing country, the concern for unsustainable production of charcoal and the need to halt the process of deforestation and forest degradation induced by charcoal production led to the evolution of forest management in which formal forest regulation backed by management plans was introduced in local communities (Agrawal & Ribot, 2009b). Therefore, if the extent of forest cover (including tropical high forests and woodlands) is taken as a proxy for Uganda's biodiversity, clearly the country has registered significant loss. Drastic changes in the forest cover have taken place in Uganda during the past century. In 1890, forests covered approximately 10,800,000 hectares or 52% of Uganda's surface area. By 2011, forest cover had declined to about 20%. Tropical high forest cover declined from 12% of total land area in 1900 to 4% by 2011 (Ministry of Water Land and Environment, 2003).

The evolution of forest management (Ribot, 2015), role of forest management plans in the new Senegalese Forest code (Ribot, 2009) decentralization of the forest management process (Poteete & Ribot, 2011), and the effects of institutional pluralism on decentralization and the management of forest resources (Faye, 2006) were analyzed. With the exception of a study by Wurster (2010) that examined the effects of charcoal production on woodland regeneration, all these studies focused on the political and institutional framework of forest management. However, the ultimate impact of these new forest management arrangements on deforestation is yet to be determined. Therefore, this study was carried out to find out how these political and institutional changes embodied in the new approach to forest management impact on land use and forest cover change.

Forests in developing countries like Uganda have been inhabited by people for a very long time, certainly tens of thousands of years, although forest clearance, presumably for agriculture, did not begin until about 1980s (Jolly et al., 2009). Consequently, one could argue that no ecosystem in the country is completely ‘natural’, if by that we mean ‘unaffected by human activities’. The degree, to which natural forests have been affected, however, varies considerably. In addition, not all effects originate in Uganda; the upper reaches of the Elgon Mountains are already showing marked changes, which probably result from global warming, with considerable and well-documented glacial retreat on the mountains in Uganda.

Uganda is blessed with a rich diversity of natural habitat, species and genetic resources in its forests. One of the most diverse countries in Africa with great intrinsic value to human health and wealth (Ministry of Water and Environment, 2015). This is provided for by Geographic information systems (GIS) for advanced ecosystem management. Such data facilitates the analysis of Forest cover systems, function patterning and change at local, regional and global levels over time (Kayiranga et al., 2016). Zziwa et al. (2011) has done satellite image analysis of the country between 1985/86 and 2015 and found that croplands have since increased by 4.2%, which largely occurred at the expense of undisturbed land like the forests and slopes of mountains. Furthermore, forest cover was found to have reduced by 0.25%in the same period. Analysis of satellite images and aerial photos provide evidence of changing forest cover. It has been found out that vegetation of most catchment areas including mountain slopes is fast declining (ACCESS, 2015). Around 1980, the number of households nearer to the forested steeper slopes were fewer as compared to now.

The central forest reserves conversion into agriculture, is due to weak monitoring mechanisms poor planning, weak regulation and inappropriate processing technology which have resulted in the unsustainable harvesting of forest products, and the degradation of the resource base (Kayanja & Byarugaba, 2015). The problem of overharvesting manifests itself when the annual harvesting rate exceeds the carrying capacity. These problems are attributed to limited institutional capacity and limited resource in both central and local government to improve planning and regulation, and little incentive for the private sector to improve its performance in the absence of firm regulation and the enforcement of professional standards (IUCN, 2017).

The principle threats to biodiversity in Uganda continues, including habitat loss, modification and alteration, along with unsustainable harvesting, pollution and introduction of alien species (Zulu, 2008). The decline of tree species in Eastern Uganda is considered the largest documented loss of biodiversity ever inflicted by man on an ecosystem (Witte et al., 2009). The rate of biodiversity loss in Uganda is high and was calculated in 2004 to be between 10-11% per decade. While these figures are high, they are below the 1.0% yearly loss that has been recorded for the planet Forest cover as a whole.

The loss of vegetation and tree species has been great in Uganda, and the negative trends are continuing (Musasizi, 2018). Major tree species such as Muvule and Mahogan, were extirpated during Uganda's decades of internal turmoil between 1970 and 1990. Indigenous species continue to decline in numbers and distribution throughout the country. Most of the remaining large indigenous trees are confined to protected areas, where their numbers are small but stable or decreasing still.

The threats to biodiversity are both direct and indirect causes. However, these proximate causes to tree loss in Uganda are not the cause of the problem, and it is the root causes of biodiversity loss in Uganda that will need to be addressed if progress towards conserving forests is to be achieved (MoWE, 2016). There are, also very few long-term studies/monitoring programs to keep track of trends in tree species in relation to the threats. Monitoring programs for conservation purposes could be conducted efficiently if integrated as part of long-term studies of scholars.

2.4 Drivers of land use/ cover change

2.4.1 Agricultural practices

Land use in developing world has been changing since the past decade. Expansion of mixed crop livestock systems into former undisturbed lands and other natural areas and intensification of agriculture are the two largest changes that have been detected (Olson & Maitima, 2006). To this context however, degradation of slope lands over time indicates that there has been expansion of other land use patterns in mountain areas (Sassen et al., 2013). The integrity of water shades is very much and continuously being altered as cultivation extends to higher levels in mountain areas (Mugagga et al., 2012). Continued population pressure poses threat on most high lands resources through settlements which precedes forest cutting and altering vegetation.

Agricultural practice is the major driver of natural vegetation change in the tropical regions (Daniels et al., 2008). Over the past 50 years in East Africa, there has been expansion of agriculture at the expense of other land uses (FAO, 2017). Before 1950, the slopes of mountains were predominantly forested with scattered settlements and cultivation but from then onwards, there has been a significant transformation of mixed crop–livestock agriculture (IUCN, 2017). To understand the mechanism leading to land use and forest cover changes in the past is crucial to understand the current and predict future occurrences. The changes have occurred at different times, paces and degrees of magnitude for which humanity is yet to see the diverse biophysical implications (Meyer, 1995). Thus, factors like poor regulation by weakened institutions, which come as a result of lack of funding, and capacity to implement the government policies of protecting forests however even these institutions are being affected by corruption which takes several forms that relates to granting concessions, embezzlement of institution funds among others

Population growth and migration has increased demand for agricultural land and firewood (Chakravarty et al., 2011) energy, and rural poverty restricts the ability to invest in sustainable land use practices. The population growth rate of 3.4% per annum for Uganda leads to exerted high pressure on the forest resources in order to derive people's livelihoods; higher population makes land for settlement and agriculture inadequate and consequently resort to the forestland. Therefore, Deforestation has been reported to be more intense in areas with high population densities. In districts such as Mukono, and Mbale major tracts of land have been cleared in the last decade. Much of this, which now remains, is secondary vegetation with, secondary woody biomass. Higher poverty levels; over 46% of the people in Uganda live below the poverty line (FAO, 2015) poor people are driven by the higher demand to sustain their livelihoods from the forest resources because they lack alternative sources of income as a consequence depletion of the forests becomes inevitably (Mwavu, 2013).

Forests and high lands have under gone large-scale changes (Kafeero, 2008). He further states that the slopes of mountains have been so much encroached on since 1980. Land use changes that alter natural occurrences are likely to cause changes in abundance and distribution, community composition and highlands ecosystems function. The change in rainfall pattern and amounts and temperature extremes might be contributing to mountain slope encroachment (Zziwa et al., 2011). There has been notable change in the Elgon zone and with a strong bearing on forest encroachment (Kigenyi, 2012). Therefore, forest cover can be altered by natural events such as weather, flooding and fire. On global scale, land cover is altered majorly by direct human use, through agriculture and livestock rearing, forest cutting and urban/sub urban construction and development (Romo-Leon et al., 2014). Acid rain from fossil fuel combustion are reported to have had considerable change on land cover (FAO and UNEP, 2020)

2.4.2 Land Fragmentation

Land fragmentation is a situation where a farming household possesses several non-continuous land plots, often scattered over a wide area (Blarel et al., 2012). Land fragmentation, where a single farm consists of a large number of separate land plots, is a common agricultural phenomenon in many countries (Heltberg & Rasmus, 2008). Land fragmentation is said to be a constraint to efficient crop production and agricultural modernization, and in several countries, this has resulted in the implementation of land consolidation programs (World Bank, 2006). Land fragmentation is an observed phenomenon in many countries around the world, and is often viewed as an obstacle to agricultural productivity and modernization (FAO and ITPS, 2015). The absence of a real standard objective measure of land fragmentation makes comparisons between countries difficult, and makes it hard to decide when a farm is too fragmented (Dollar et al., 2008).

Literature proposes several explanations of land fragmentation. These explanations are often divided into two main categories: demand-side and supply-side factors. The supply-side factor treats fragmentation as an exogenous imposition on farmers, which has an adverse effect on agricultural production, while the demand-side factors assume that the farmers voluntarily choose beneficial levels of fragmentation (Blarel et al., 2012). The disadvantages of land fragmentation are mostly associated with inefficient allocation of recourses yet population is increasing hindering of agricultural modernization (NEMA, 2009).

According to Gaynor (2012), land fragmentation harms land productivity in a number of ways. Fragmented land holdings increase costs of maintenance; harbor individualism making management supervision of the scattered plots more difficult (Gaynor, 2012). Besides, time small-scattered plots waste land area through border constructions, pathways and roads. Land fragmentation also increases the risk of disputes between neighbors. Small fragmented land holdings also cause difficulties to grow certain crops, and prevent farmers from changing to high profit crops (World Bank 2009). More profitable crops, like for example coffee, requires larger plot areas, so if the farmer's only pose small and fragmented plots, they may be forced to grow only less profitable crops (Bentley & Jeffery, 1987). The populace of Mbale district is left with no alternative but to resort to deforestation to create more land to settle and farm

A benefit associated with land fragmentation is the variety of soil and growing conditions that reduce the risk of total crop failure by giving the farmer a variety of soil and growing conditions. Many different plots allow farmers access to land of different qualities when it comes to soil, slope, micro-climatic variations etc. Fields with high yields one year may the following year generate much lower yields, thus several plots of the same crop also spreads out the risk. In addition, a holding with several plots facilitates crop rotation and the ability to leave some land fallow (Blarel et al., 2012).

Another benefit of land fragmentation is the use of multiple eco zones. Different plots enable farmers to grow a wider mix of crops. Since crops ripe at different times when the plots are in different altitudes, spreading out the agriculture work like harvest and sawing during a longer period helps farmers to avoid household labour bottlenecks. This is especially important when the growing season of the crop is short and easily creates seasons of peak labour demand (Quy-Toan and Iyer, 2003). The populace of Mbale exploits the above seeming advantages. Farmers also prefer fragmented land holdings when there are diseconomies of scale. Labour market failure, i.e. the lack of off-farm job opportunities, has also resulted in a large amount of unproductive family members working on small farms due to their low opportunity cost (World Bank, 2006). This could be an explanation offered by the existence of diseconomies of scale and the forest suffers depletion.

2.4.3 Urbanization

There is a growing trend of change of land use of protected areas to industrial expansion (UWS 2005). Politicians and investors perceive the protected areas as land banks for future appropriation for investment. This trend is worrying and has already claimed Bugala Islands for palm oil plantation, Namanve Central Forest Reserve for an industrial park, part of Pian-Upe Wildlife Reserve for large-scale agriculture, and is likely to affect the South Busoga forests, which are some of the few remaining forests on the shores of Lake Victoria. Mbale district is not spared either. The green forest belt that once surrounded the town, all forestry land has been given away for development in anticipation of city status of the town. The industrial park at Namatala forest reserve has already given way.

World tropical forests continue to be cleared at an impressive rate. Clearing starts from roadsides and extends further inland. According to FAO (2014) Canada, a wealthy nation with a high population damages more hectares of natural forests than any other country in the world. Producing large amounts of food to feed urban settlements requires more land and grazing animals too needs space. Often trees are cut down to provide land for agriculture. For example, 70% of the Amazon forests has been cut down to provide land for modern structures and grazing land (FAO and UNEP, 2020).

2.4.4 Settlement patterns

In the Uganda, much clearance of forest areas to make way for settlements were more pronounced in the troubled 1970s and 1980s (Obua et al., 2010). Residual encroachment of the government lands still continues to date (Kayanja & Byarugaba, 2015). Encroachment on central forest reserves has been partly caused by not clearly demarcating boundaries most of which have not been re-opened. This has bred the current confusion. Therefore, dangers of encroachment in forest reserves as a direct result of poor governance and lack of vision about the benefits for forest resources to the people are enormous (Werikhe, 2008) In addition; urbanization and industrial growth are putting pressure on the forest estate. Many urban and peri-urban reserves are under threat of being degazetted. The increasing demand for industrial land has led to the degazetting of nearly 10,000 ha, which will result in a permanent net reduction of the forest estate unless alternative non-forested areas are identified and developed. Today the most affected forest reserves are those close to the urban and industrial centers, for example Musoto and Namatala forest reserves near Mbale town.

The interaction of human settlements on the environment is that they extract non-renewable natural resources on the one hand and, on the other, produce waste products and pollution that has to be absorbed by the environment (Diagana, et al., 2014). In most cases as the population grows, urbanizes and consumes more, the impact of human settlements on the forest vegetation increases. These processes present a considerable challenge to governments and much effort is placed on creating sustainable human settlements (Dagnelie, 2008). Urban and rural sprawl, housing demand, modes and character of transportation and basic service infrastructure, are the physical elements of human settlements that have the most noticeable impact on the natural environment and are the focus for the creation of more sustainable human settlements with a reduced ecological footprint.

According to the provisional results of the 2014 population census (UBOS, 2014), the district of study sums up a total population of over 4,112.000 million people (about 3% of the total population of Uganda). Of these, 4112000 stay in rural areas. The predominance of Mbale district is in part because it is more populated than other neighboring districts. Here, settlements are unique due to historical patterns, creating a legacy of unsustainable, inefficient, inequitable and wasteful settlements (DHS, 2009; Financial and Fiscal Commission, 2011). The challenge presented to government is to find a balance between ecological unsustainability and socio-economic inequalities. Not much has been done to redress settlement patterns and form sustainability since 2012, especially on the policy front (Mugagga, 2015).

The relationship between human settlements and the natural environment or ecological systems is complex. The natural environment provides the basic elements that human beings need to survive such as food, water and shelter. In the process of harvesting the natural resources, human affect the environment by overuse or exploitation of non-renewable resources and through the production of waste materials and pollution e.g. greenhouse gasses, ozone-depleting substances and hazardous materials. This leads to a degradation of the very environment that human beings depend on. The impact of human settlements on the environment increases with population growth, settlement expansion, economic growth and increased consumption. All indications are that the impact of human settlements on environmental resources is increasing (FAO and ITPS, 2015).

The main economic activity in the Mt Elgon region is agriculture. According to their DDP (2016), 71.7% of the total population of Mbale district is engaged in agriculture, the economic activities depend on the landscape conditions of the area, which is divided into three distinct topographical regions: the lowland, the upland and the mountainous landscape of Mt Elgon. Agriculture mainly takes places in the two first topographical regions, and differs between them (Mugagga et al., 2012). The low land has sand to clay loam soils, favorable to cereal crops, while the high land has volcanic soils, more suitable to perennials crops such as coffee, bananas and horticulture (such as tomatoes, onions, cabbages and carrots). In many farms, intercropping is practiced. Coffee is generally intercropped with both perennial (especially bananas) and annual crops (e.g. bean, maize, cassava, etc.) (Jiang et al., 2013). Some households rare on a small-scale cattle, goats and poultry, mainly for subsistence (MDHRVP, 2018).

Uganda's legislation has promoted Collaborative Forest Management agreements to regulate the exploitation of the Mount Elgon National Park (MENP). Under these arrangements, park adjacent communities commit to respect the quotas regarding resources extraction, control the forest and reinforce penalties, while they benefit as well from the existence of the Park. By 2013, the sub counties bordering the MENP had a valid agreement with the Uganda Wildlife Authority (UWA) in charge of promoting these agreements on the government side (Soini, 2013). However, these agreements have not been properly implemented and "illegal access to restricted zones and lack of adherence to resource harvesting quotas are still major management problems posed by the communities" (Mugagga and Buyinza, 2013:257).

Unsustainable processes of land use management characterize the Mt Elgon areas including Mbale district and one of the key issues is deforestation. Mugagga et al. (2012) reports that only 40% of the land of the Mount Elgon region was covered with trees in 2006. The decrease had been very significant from 1995. The land covered with trees represented over 80% in 1960 and only a bit less in 1995. Mugagga et al. (2012) distinguished between woodlands and forests. The former represented over 50% of the land cover in 1960 and only a bit less in 1995; the latter represented 30% of the land cover in 1960 and 1995. By 2006, woodland and forest represented each 20%. The Environmental Conservation Trust of Uganda -Ecotrust (2012) provides similar conclusions. They studied the land use change in Mbale Districts in the period 2011-2005 for various selected vegetation types, namely woodland, broad leaved tree plantation, grassland and farmland. They found a significant reduction of natural vegetation cover in the period. In particular, grassland, woodland and broad-leaved tree plantation cover decreased substantially (72%, 63% and 41%, respectively) from 2011 to 2005. Therefore, deforestation is the result of the development of human settlements, the energy consumption pattern and the expansion of agriculture. The continued increase in human population has resulted in a burgeoning demand of land and forest products for human settlements, including housing and other infrastructures, such as other buildings (administration, cultural sites) and pathways and roads. Although the development of urban agglomerations has not been significant, and urbanization is not particularly strong, increased population has resulted in an increase of human settlements along the landscape, reclaiming land for housing and infrastructure (Girmay, 2017).

2.5 Effect of Land use/cover changes on forest cover

The Forest cover change is resulting from human population and civilization changes (Turner et al., 1990). In Uganda, land use such as the conversion of forests, and undisturbed lands to cultivate, burn and clear woodlands for grazing and fuel wood is common (Zziwa et al., 2011). The main vegetation cover is savanna, which varies according to tree density and species composition (Mbow et al., 2003). About 80 species were reported specifically in this ecoregion (CSE, 2005). Some species like *Bombaxcostatum*, *Combretumelliotti*, *Cordylapinnata*, *Entadaafricana*, *Parkiabiglobosa*, *Prosopisafricana*, and *Pterocarpuserinaceus* are recorded in the south while *Acacia seyal* and *Lophiralanceolate* are recorded in the north. Therefore, direct drivers of deforestation include; conversion of forest land to agriculture, grazing land and forest resource degradation due to wood collection, pit swaying and charcoal burning (NEMA, 2010).

According to Kayanja and Byakagaba (2015), deforestation is rampant on the 70% of forests on private land, which is not regulated or managed. Loss of biodiversity and pressures on ecosystem services are among the most pressing global challenges. Annihilation' land use changes are the leading contributors to terrestrial biodiversity loss (Fandohan et al., 2011). These changes generally occur slowly, but they are associated with declines in species diversity and populations, and can have a major impact on ecosystems. Monitoring the various elements of biodiversity at global scales is difficult (Droppelman & Berlier, 2011). However, it is increasingly possible to measure changes in the extent and spatial structure of natural habitats. Land cover change is the best measure currently available to monitor pressures on ecosystems and biodiversity globally (NEMA, 2009).

Intact forests are associated with highest percentage of soil organic carbon compared to agriculture land (Barasa et al., 2013; Mugagga, 2015). Land use/cover types greatly had an influence on the percentage of carbon stored in the soil according to Barasa et al. (2013). Soil carbon and forest cover are therefore positively related which means interference with forest cover through land use change affects soil carbon which intern affects the internal structure of the forest ecosystem thus forest diversity and distribution.

Galal (2009), conducted a study of the land use/cover changes on the banks of river Nile in Sudan and reported that the area under agricultural, industrial establishment and residential areas had increased while that under forest cover had registered a decrease between. The decline in forest cover definitely infers change in the structure of the ecosystem and normal operation of natural ecosystem processes. The changes in forest cover were accounted for by land use policy changes imposed by both the government and the local population for using land for Kilns, housing and investment buildings. These activities led to land degradation in terms of environmental value and productivity according to the study. The current study area has undergone transformations as reported in the existing literature (e.g., Mugagga et al., 2012a; ACCESS, 2015) which ought to bring about forest ecosystem fragmentation.

2.6 Literature gaps

Land use change begins with the clearing of natural vegetation through slash-and-burn techniques, commonly followed by the planting of annual crops or the creation of pastures. In some cases, fields are kept in cultivation continuously because of relatively high fertility with favorable texture (Moran et al., 2012). In this case, the high population increase dominant in Mbale district present constraints of continuous cultivation, changing settlement pattern and urbanization prohibitively endangering the forest vegetation. The ecosystem supports a variety of plants and the local communities here have greatly benefited from the extensive forests. There is notable continuous encroachment on virgin lands. The extent of forest loss and the driving factors contributing towards this problem are still not extensively explored to capture the recent and projected vegetation cover conditions. This study examined the state of vegetation for the two time periods (2009-2019) and prediction of land cover by 2029.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter presents a description of background information about the study area and the methods employed in data collection and analysis. In addition, it covers the sampling strategy, research design.

3.2 Description of the Study Area

3.2.1 Location

The study was carried out in Mbale, one of the districts on the slopes of Mt Elgon in Eastern Uganda. The District is bordered by Tororo district in the south, Manafwa district in the southeast, Sironko district in the northeast, Kumi district in the north, Budaka district in the north-west, and Butaleja district in the south-west. The district stretches from 0°49'36" to 1°10'19" North and 34°4'24" to 34°20'19" East; covering a land area of approximately 538.16 km^2 (Figure 3.1). The district has three constituencies including Mbale Municipality, Bungokho North and Bungokho South: and 19 sub counties, 1 town council, 1 municipality and three divisions. The main administration center is Mbale town, with several other administrative units that reports to Mbale district local administration.

3.2.2 Geology and Soil

The geology in Mbale district is composed of Pre-Cambrian rock system and Cainozoic formations that include volcanics, granites, and sediments (Lehto et al., 2014; Geological Survey of Finland, 2014). The soils of the study area are classified as; Acric ferralsols, Gleysols, Luvisols, Nitsols, Patric Plathosols, and vertisols. These soils have resulted from past volcanic activities and other geomorphological processes (ACCESS, 2015). On the steep slopes in the high-altitude, very shallow soils are found to exist, while red brown, clay loams have formed on the gentle slopes. These soils support tropical forest vegetation if no human interference takes place and once the forest is cleared, they are highly productive for crop growth (Mugagga et al., 2011). This accounts for their overuse in terms of farming thus accounting for forestland encroachment for agriculture.

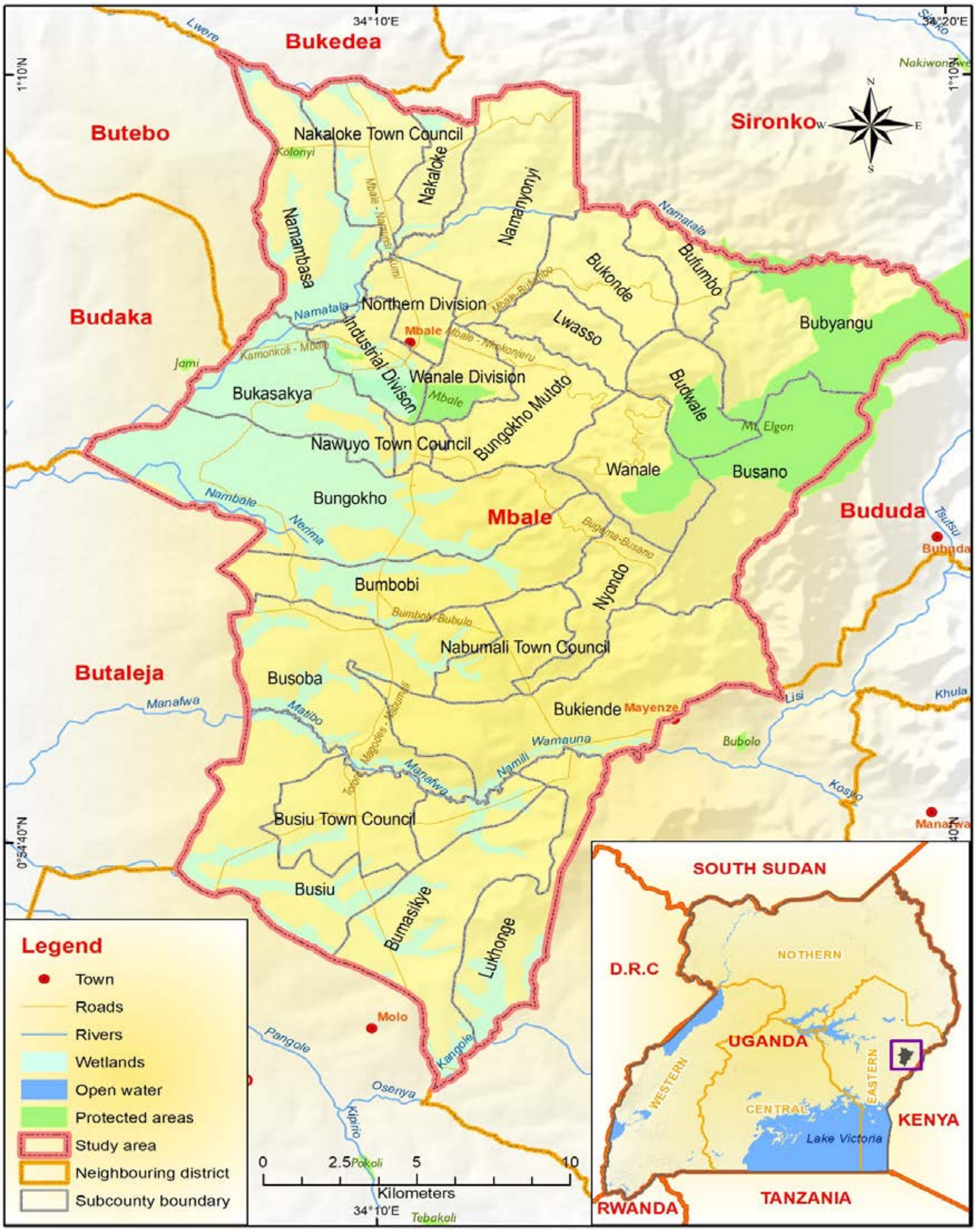

Figure 3.1: Location of the study area

3.2.3 Geomorphology

The geomorphology of Mbale district is part of Mt Elgon volcanic system, which is one of the oldest extinct shield volcanoes, associated with the Great East African Rift Valley System (ACCESS, 2015). The main topographic regions can be classified as highlands, midlands and lowlands. The elevation of Mbale varies from 4,040 in the highland (mountain) area in the southeast to 3,600 feet above sea level in the lowland area (plain) in the west. The southeastern part is made up of a rugged topography characterized by cliffs, ridges, and V-shaped river valleys. Low-lying and flat relief on the other hand characterizes the western parts of Mbale district.

3.2.4 Climate

Mbale district experiences climatic conditions moderated by orographic influence of Mount Elgon, proximity to Lake Victoria and the latitudinal location near the equator (NEMA, 2009). The climate is warm and humid with minimal extremes. The highest rainfall amounts are experienced between March to May and October to November (NEMA, 2009) with mean annual ranges between 1250 and 1750 mm. This coupled with high and distributed rainfall promote and sustain growth of annual and perennial crops. Mean maximum and minimum temperature of 23^{o}C and 15^{o} C are registered in this area which means absence of clearly marked extreme seasons.

3.2.5 Drainage

The town is drained from east to west by three major rivers that have their sources on Mt Elgon (via Wanale Ridge). River Nashibiso and its tributary Napwoli drain into the southern part of Mbale town. These are bound by an extensive plain under forest reserve management. River Nabuyonga and its major tributary: Namatsio drain across the northern area of the town. Several primary and secondary channels have been developed to originate from within the town area and drain into these rivers. All the mentioned rivers drain into River Namatala, which forms the north-west boundary of Mbale Town (Rannveig et al., 2012; Makenzi, 2016). All the rivers draining Mbale district form part of the Mpologoma sub basin and end up into Lake Kyoga.

3.2.6 Vegetation

Mbale district is heavily cultivated, with little to no remnants of natural vegetation in the lower and mid elevation areas **(**Mbogga, 2013; Abwoli et al., 2014). Forest vegetation is mainly existing at higher elevation areas, most of which fall within the Mt Elgon Forest National Park. In the higher altitudes, the natural vegetation changes from montane, to grassland, bamboo then heath and moorland in that order. The supra-tropical forest on the Mountain is dominated by with *Camphor*, *Aningeriaadolfi-friederici*, *Podocarpuslatifolius*, *Oleahochestetteri* and *Prunusafricana* (Hamilton and Perrott, 1981). Mixed bamboo occurs at about 2,500-3,000m, which turns into open woodland dominated by Hageniaabyssinica and African rosewood, the heath zone 3,000-3,500m characterized by giant heath with grassy swards of tussock grass. The Afro-alpine region stretches from 3,500m to 4,321m a.s.l, dominated by Senecioelgonensis. (ACCESS, 2015).

3.2.7 Population and Ethnicity

Mbale region has about 790 persons per square km (UBOS, 2014) making it one of the most densely populated parts of Uganda. Mbale town is the major urban area with a population of more than one million people. There are numerous other smaller towns, including Nkoma, Nakaloke, Jewa that are now growing and soon to host the headquarters of their respective councils. The majority of the people in Mbale district however are rural dwellers. The Bagisu ethnic group are the majority of the people in the Mount Elgon areas of Mbale (MDHRVP, 2018). They are also known as the 'BaMasaba' who consider Mountain Elgon to be the 'embodiment' of their father Masaba which name is used to refer to the mountain (UBOS, 2014; Mugagga et al., 2011).

3.2.8 Land use and socio-economic activities

Land use in Mbale district is not well planned, save for the town. People use their small plots on average of ≤ ½ and 1.5 acres according to their family demands and priorities. The tenure system in Mbale is mainly customary but with few well-placed individuals under free hold tenure. About 96% of the residents have fragmented (scattered) plots, because of high population density and geographical features. Few people in the lower swampy parts practice land conservation. Majority of the rural dwellers in Mbale district are engaged in agriculture, and the major crops grown at high altitudes include bananas, Arabica coffee and Irish potatoes, while at lower elevations the dominant crops are maize, millet, cassava, beans and sweet potatoes, cabbage and tomatoes (Mugagga et al., 2011; & NARO, 2016). There has been increasing concern about climate change and its impacts to the Mbale region. The region is highly vulnerable given its high population, high poverty levels, and mountainous landscape. The region has had numerous occurrences of mudslides in the rain season. Rural areas in mid to high elevation areas have had landslides, siltation of rivers as well as washing away of top soil, which depletes soil nutrients hence affecting forest vegetation (Mugagga et al., 2012). The informal sector is the major source of employment for the residents of Mbale. The sector consists of small entrepreneurs and people with flexible but nonpermanent employment. The lack of opportunities for formal sector employment and the decline in minimum wage has led to the growth of the informal sector whose activities are largely unmeasured, unregulated and unaccounted for.

3.3 Map and characterize the area coverage of land use/cover changes in Mbale district on the slopes of Mt Elgon between 2009 and 2029

3.3.1. Satellite image data

The initial Landsat imagery for use with in the study area was provided by the same source. Landsat (MMS) Multi Spectral Sensor were utilized because of the complete coverage of the area and the presence of brightness grading of features in the imagery. Landsat 8 for the year 2019 and Landsat 7 for the year 2009 with 30 by 30 meter grain size were acquired from USGS data portal (http://glovis.usgs.gov/web-link). Satellite images especially Landsat 7 and 8 imagery have been recognized as important resources for mapping land use types/ land cover and as well as spatial-temporal analysis of land use/ land cover (Samanta, 2015). This study depended mainly on satellite images in two different periods that is 2009 and 2019. The base map i.e. Mt Elgon forest area was demarcated and Mbale district clipped out. A comparison of two Landsat clear images with in the period of study was done. The downloaded images were geometrically corrected by projecting using WGS1984 UTM zone 36N coordinate system, which is the planar coordinate system for Uganda. The geometrically corrected images were atmospherically corrected using DOS1 atmospheric correction in QGIS using the Semi- Automatic Classification Plugin. The images were later masked to the study area using the current administrative dataset for Mbale district. A composite image was created by selecting and combining the bands to form natural color composite image. For this case, bands 4-3-2 and 3-2-1 were used for Landsat 8 and Landsat 7 respectively to represent Red, Green and Blue (RGB) color that form an image with natural color composite. It is also important to relate the image data to ground collected natural vegetation measurements

All the intended outputs of forest vegetation loss and change over time as determined from ground measurements collected with Global Positioning System (GPS) relied on images that are geometrically accurate. Correlation was done using both Topo-maps and ground control points and each satellite image was geo referenced by keeping the GCP for both images (2009 & 2019. The next step involved ortho-correlation with digital elevation model to further enhance the geometry by accounting for the significant spatial distortion caused by relief displacement (Mukhpadhyay et al., 2013). Its application is important because of the high incidences of variation in topography. The application of geometric correction and relief displacement correction procedures helped to maintain spectral integrity by resampling the (NN) algorithm. A number of radiometric corrections were considered for application to the imagery, since more image classification were required. For the outcome of the study (change detection), correcting radiometry between adjacent scenes and across time was considered. Correction methods that attempt to completely remove the varying radiometric errors and produce an output absolute reflectance value for each pixel or account for them. Banding was accounted for by passing a one-dimensional spatial kernel over the dataset as suggested by Helder et al. (1992).

To enable processing and assessment of land use/cover changes in the study area, some data was picked from the field using field mapping with a GPS, direct observation and photography. Direct observation involved appreciation of land use systems including settlement patterns, farming systems, infrastructure developments and sections of the forest area that seemed to have been encroached on. GPS coordinates of these systems were picked for classification accuracy assessment. Digital photographs of some of the areas visited were captured. These indicated landscapes and land use systems in the field, from typical rural to urban setting in Mbale district. These were aimed at profiling evidence of the problem of investigation.

3.3.2 Satellite image data processing

After preprocessing of the Landsat images, delineation of the different land use types in the study area for the two reference periods (2009 - 2019) preceded using maximum likelihood supervised classification algorithm (Conrad et al., 2015; Congedo, 2017). The technique-involved identification of land use types on the remotely sensed imagery following spectral properties of each pixel captured in the mapper bands. Supervised classification algorithm was preferred over other classification algorithms for image classification due to its robust classification precision. The process involved creating a training dataset (pixels that identify and distinguish each land use/cover class) which was transformed into a signature file and later used to perform supervised classification using maximum likelihood algorithm in QGIS software version 3.12.

The classification helped to identify the land cover represented by each pixel based on its spectral reflective value (Lu and Weng, 2007). The process involved labeling each class entities by numerals done using classification rule. The process of clustering also involved an exploratory procedure whose aim was to estimate the size of forest cover in the area for the period 2009-2019. The results were displayed in a table and interpretation derived accordingly basing on a list of ranked images based on forest categories observed for the two maps of the 10-year interval (2009-2019). This was intended to reveal the trend in change over the study period.

Various land-use classes delineated such as built-up/settlement, agriculture, forest and open land were considered during the survey. The classification of image was performed using maximum likelihood classifier in an iterative manner. The changes in area under major land use/land cover types was determined through the comparison of their spatial extent in 2009 and 2019. The system produced multilevel land type of which level classes could be mapped from Landsat data from high altitude air imaging. Seven land use types were identified for this research (Table 3.1).

Table 3.1: Description of land use/ cover classes in the study area

Land cover/use class	**Description**
Built-up	Land consisting of settlements, urban centers roads and related infrastructure
Bushland	Land comprised of scattered shrubs and thickets outside the protected tropical high forest areas
Grassland	Includes areas covered with grass and short scattered trees
Subsistence farming	Land under crop farming and animal grazing. It includes land covered with crops and that prepared for crop farming
Tree plantations	Areas covered by woodlots and plated trees outside the protected forest zones
Tropical high forest	Areas under naturally existing compact tree cover
Wetlands	Water-logged areas with i.e. swamps, wetlands and open water

3.3.3 Satellite image post processing

Post classification included accuracy assessment and change detection. Ground truthing points collected in the field were used to assess the accuracy of the classification algorithm and confusion/ error matrix was generated showing the user accuracy, producer accuracy and kappa (Grizonnet et al., 2017). To conduct a change detection analysis, two images were compared to determine change in the individual classes and a cross tabulation table was generated showing the changes in the land use/cover classes. The classification of 2009 and 2019 images with the highest overall accuracy was used in the change detection process. The classified images were then combined to create a new image indicating the changes from and to that had taken place (Anderson et al., 1979). The image acquisition up to analysis took a procedural flow shown in Figure 3.2

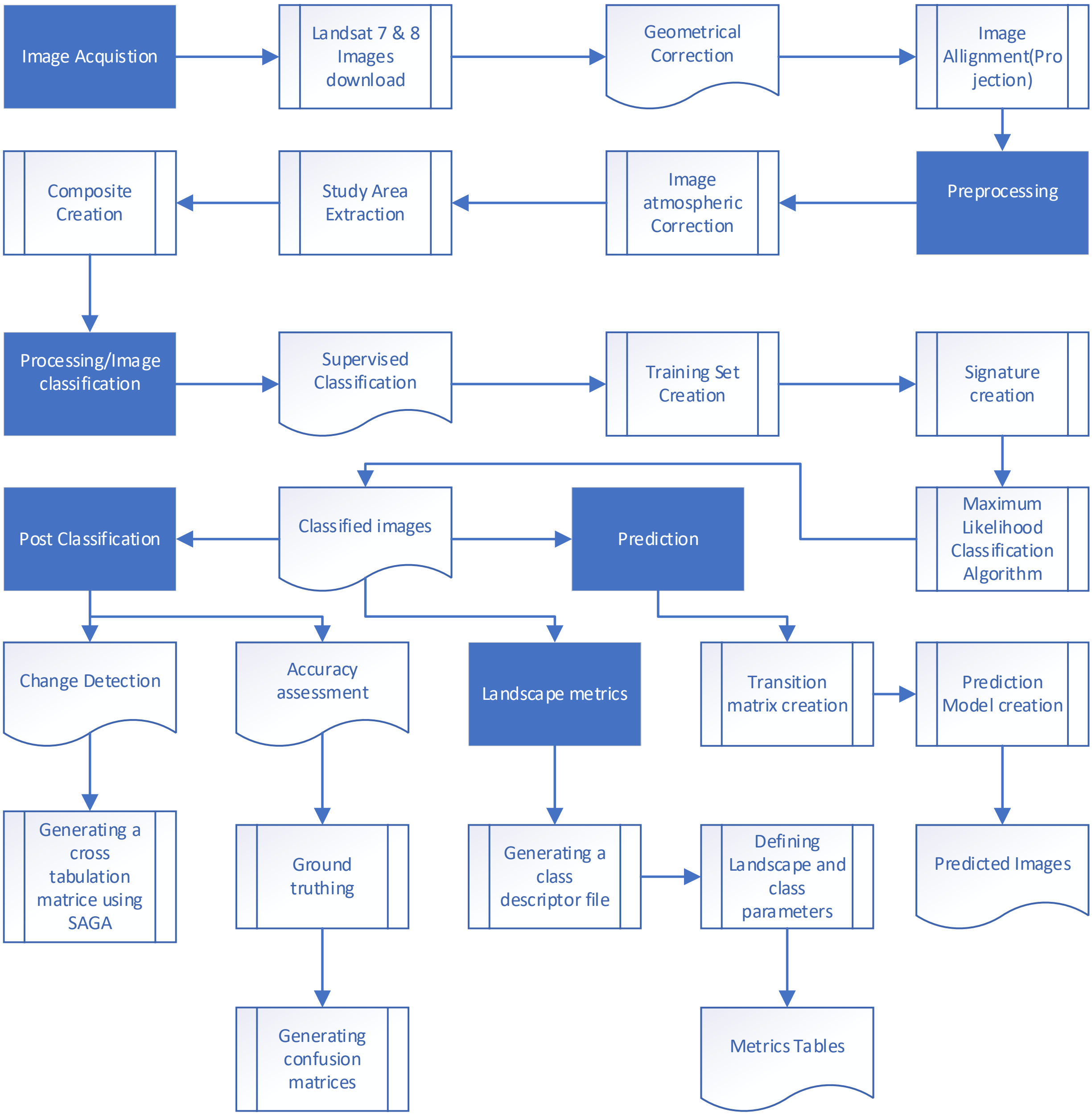

Figure 3.2: Methodological flow chart for satellite image analysis

3.4 Assessment of the effects of land use/cover changes on forest structure and distribution

The outputs from the land use/cover classification process from satellite images (2009 & 2019) formed data inputs into the landscape metrics computations using Fragstats software version 4.2.1 (McGarigal and Marks, 1995). The classified raster images were converted into vector layers, which is a precondition for computation of metrics for analysis of landscape patterns related to discrete phenomena (land use/cover) as these are based on polygon statistics rather than raster characteristics. There are a number of methods for extracting categorical map data for analysis of landscape patterns but the data used in this study was derived via data export, and export format dialog window in QGS 3.10.

Landscape metrics were used to assess the effects of land use/cover changes on forest structure. Landscape matrices are statistics used in interpretation of landscape patterns, which are linked to a heterogeneity of ecological processes (McGarigal et al., 2009). The structure of landscapes can be quantified is several ways depending on the type of spatial data collected such as vector (polygons, lines and points) and raster (continuous data like elevation) data. In this study, class, patch and landscape-level metrics were used to analyze the effect of land use/cover change on forest diversity in the study area. These were computed in Fragstats software version 4.2.1. Fragstats program is one of the spatial analysis software applications for quantifying the structure of landscapes. The program provides a comprehensive set of tools for performing spatial analysis for categorical maps. It computes a variety of landscape metrics using categorical map inputs to show patterns therein. A number of indices reflective of land cover composition, and diversity (Diaz-Varela et al., 2009) for the two reference years (2009 & 2019) were computed. These include, Class Area (CA) of land use/cover types, percentage of Land (PLAND - %), Number of Patches (NP), Largest Patch Index (LPI), Mean shape index (MSI), Total Edge (TE in m/ha), AREA_MN, Area

CV, AHAPE_MN, FRAC_MN, PARA_MN, Total class area (TCA), CPLAND, NDCA, IJI Mean patch size (MPS), and connectedness (McGarigal, 1994; Diaz-Varela et al., 2009). These were computed for each image classification (2009/2019) output in addition to the change detection image. Interest was on comparing descriptive metrics of land cover pattern between forest and non-forest classes, and across categories of land use change. The metrics were grouped into categories of area, shape and diversity (Forman, 1995; Griffith et al., 2000; Diaz-Varela et al., 2009)

3.5 Prediction of land use/ cover changes

The projection of the forest cover changes in relation to land use changes for the period 2019 to 2029 was based on land use and forest cover change detection data for the period 2009 - 2019. The image representing differences in land use/cover between 2009 and 2019 formed the basis of the prediction of changes for the period: 2019 to 2029. The process was handled using Dinamica Ego software version 5.0.0.

Dinamica Ego software version 5.0.0 was used in land use/cover prediction. Dinamica EGO is an open source software developed for environmental analysis and landscape dynamics, which allows for creation of future trends from a self-training procedure using previous situations at different times (Lima et al., 2014). The platform construct models through a graphical interface in which the calculation functions (functors), the initial data (maps and tables) and the results (maps, tables and weights) are incorporated through the connectors of its ports (Lima et al., 2014; Ferreira et al., 2019). Its main use is based on the application of various calculation functions related to changes in land cover and land use structures, as well as a part of the analysis of landscapes available to the platform (Lima et al., 2014; Ferreira et al., 2019). In this study, a transition matrix showing the transitions among the land use/cover classes was generated using the software and later used in the prediction model for land use/cover changes.

3.6 Analysis of the social economic data on drivers of land use/cover change

3.6.1 Research Design

A cross-sectional survey design was adopted to collect data from the study population (Babbie, 2007). Both quantitative and qualitative data were collected. The mixed methods were preferred owing to the ability to use both quantitative and qualitative approaches to address study issues in simple and factual manner. Johnson and Onwuegbuzie (2004) noted that pluralism in methods results into superior research. A survey on land use in Mbale District was conducted. It involved surveying the existing land use types and their impacts on forest vegetation. This was done by identifying land use types, changes and analyzing the effectiveness of the measures that have been put in place to improve land use on forests. The land tenure of the region was analyzed to assess its influence on the land use types and their overall effects on forest vegetation.

3.6.2 Sample Design

The study area was selected on the basis of the fact that Mbale district is ranks highest in terms of annual population increase among all the Mt Elgon area districts in Eastern Uganda besides its boundaries extending into the Mt Elgon national forest reserve. The satellite images with a span interval of 10 years were also selected for forest and land use change assessment because the time is large enough for any such changes to be visible on the landscape. The sample size for social-economic data collection comprised of 191 respondents selected following stratified and non-probabilistic sampling strategy (purposive sampling) procedures depending on the uneven population distribution and convenience. The sample had a representation of opinion leaders from the 19 sub counties and 7 town councils, district forest office, district natural resources office, district agricultural office, district planning office and the district chairperson's office (Table 3.2). This was to ensure proper coverage across the district.

Table 3.2: Sampling strategy

Group/population category	(N)	Sampling Strategy
19 Sub counties	140	Purposive sampling
7 Urban settings/councils	21	Purposive sampling
LC officers/sub/city	21	Purposive sampling
District forest office	3	Purposive sampling
District natural resources office	2	Purposive sampling
District agricultural office	2	Purposive sampling
District planner	1	Purposive sampling
District Chairperson	1	Purposive sampling
Total	**191**	

3.6.3 Social economic data collection

Data on the determinants of land use/land cover change were collected using structured questionnaires and interview guides. The questions were grouped into sections based on the study objectives. The questions were a mixture of open and closed ended structure (Appendix I). The questionnaire was pre-tested in the near-by villages before actual implementation in the field. The questionnaires were hand delivered by the researcher and or research assistants to each of the respondents identified in the sampling. Direct questions were posed to the respondents in the way of sharing views land use/cover change and the respondent would write down the responses as the sharing preceded. This gave time to both the respondent and the researcher to seek for clarification on issues that were not well perceived in the course of the face to face sharing. Key informant interviews were conducted with the district forest officials, the natural resource officer, the district planner and community leaders (LC). An interview guide was used to direct the face-to-face interaction process. The selection of key informants was based on technical expertise. Their fields of jurisdiction make them more knowledgeable on matters, which were central to this study (land use/cover changes and divers).

3.6.4 Data Analysis

Quantitative data on social economic characteristics of the respondents obtained using questionnaires was computer coded using numerical values (1, 2, 3, …). The response sums were analyzed using Statistical Packages for Social Scientists (SPSS) software version 23.0.1 and the data was grouped into descriptive statistics (frequencies and percentages). Qualitative data obtained by way of key informant interviews was analyzed using descriptive narratives and quotes and presented together with results from quantitative data analysis.

CHAPTER FOUR:PRESENTATION OF RESULTS

4.1 Introduction

This chapter entails data presentation of research findings. The data is presented following the order of the study objectives. First, focus is on detailing the maps and characterization of the area coverage of forests vis-à-vis other land use/cover on the slopes of Mount Elgon-Mbale District between 2009 and 2019. Secondly, the effects of land use types on diversity and distribution of forest cover are examined. Thirdly, the underlying drivers of land use/cover change as perceived by the residents are analyzed. Lastly, a prediction of land use/cover trends between 2019 and 2029 on the slopes of Mount Elgon-Mbale is made.

4.2 Mapping and characterizing the area coverage of land use/cover changes

4.2.1 Changes in land use/cover characteristics

Results in 4.1 reveal that in 2009, built area covered 11.9 km^2 (representing 2.3%), bushland; 48.4 km^2 (9.3%), grassland; 11.7 km^2 (representing 23.1%), subsistence farming; 198.9 km^2 (38.4%), tree plantation; 34.6 km^2 (6.7%), tropical high forests; 19.5 km^2 (3.8%) and wetlands covered 85.2 km^2 representing 16.4% of the total land area. In 2019 built area increased to 40.2 km^2 (representing 7.7%), bushland reduced to 25.6 km^2 (4.9%), grassland reduced to 70.2 km^2 (13.6%), subsistence farming increased to 242.9 km^2 (46.9%), tree plantation increased slightly to 34.9 km^2 (6.8%), tropical high forests reduced to19.02 km^2 (3.7%) and wetlands covered 85.2 km^2 (16.4%).

Table 4.1: Changes in land use/cover characteristics between 2009 and 2019

	2009		2019		2009-2019	
Land use/cover types	Area(km^2)	Area (%)	Area(km^2)	Area (%)	Area(km^2)	Area (%)
Built-up	11.89	2.29	40.22	7.76	28.33	5.47
Bushland	48.37	9.34	25.57	4.94	-22.80	-4.40
Grassland	119.66	23.10	70.20	13.55	-49.46	-9.55
Subsistence farming	198.95	38.40	242.94	46.89	43.99	8.49
Tree plantation	34.56	6.67	34.94	6.75	0.38	0.07
Tropical high forests	19.47	3.76	19.02	3.67	-0.44	-0.09
Wetlands	85.16	16.44	85.16	16.44	0.00	0.00

The results in Table 4.1 signify that in 2009, subsistence farming with 38.4% land coverage was the most dominant land use followed by tree plantation (6.7%) and built-up (2.3%). The most dominant land cover was grassland (23.1%) followed by wetlands (16.4%), then bushland (9.3%) and tropical high forests (3.8%). In 2019, the dominant land use was still subsistence farming (46.9%) followed by built-up (7.8%) and tree plantation (6.7%) respectively. The dominant land cover was wetland (16.4%) followed by grassland (13.6%). It is further observed in Table 4.1 that land for subsistence farming increased by 8.5% and that for built-up increased by 5.5% while grassland cover registered a decrease that is by 9.6% followed by bushland (4.4%). Thus, over the assessed period, there was a decreasing trend in spatial coverage for grasslands and bushlands. The tree plantations and wetlands registered minimal changes in terms of spatial extent gains (0,07%) in terms of losses while wetlands remained unchanged. The land use types increased at the expense of land cover type especially for those in not protected areas. The significant change in grassland cover could be due to the ease with which it can be cleared (e.g. by fire) for other land uses like subsistence farming. The changes in land use/cover experienced in the study area between 2009 and 2019 was depicted in map comparison shown in Figure 4.1.

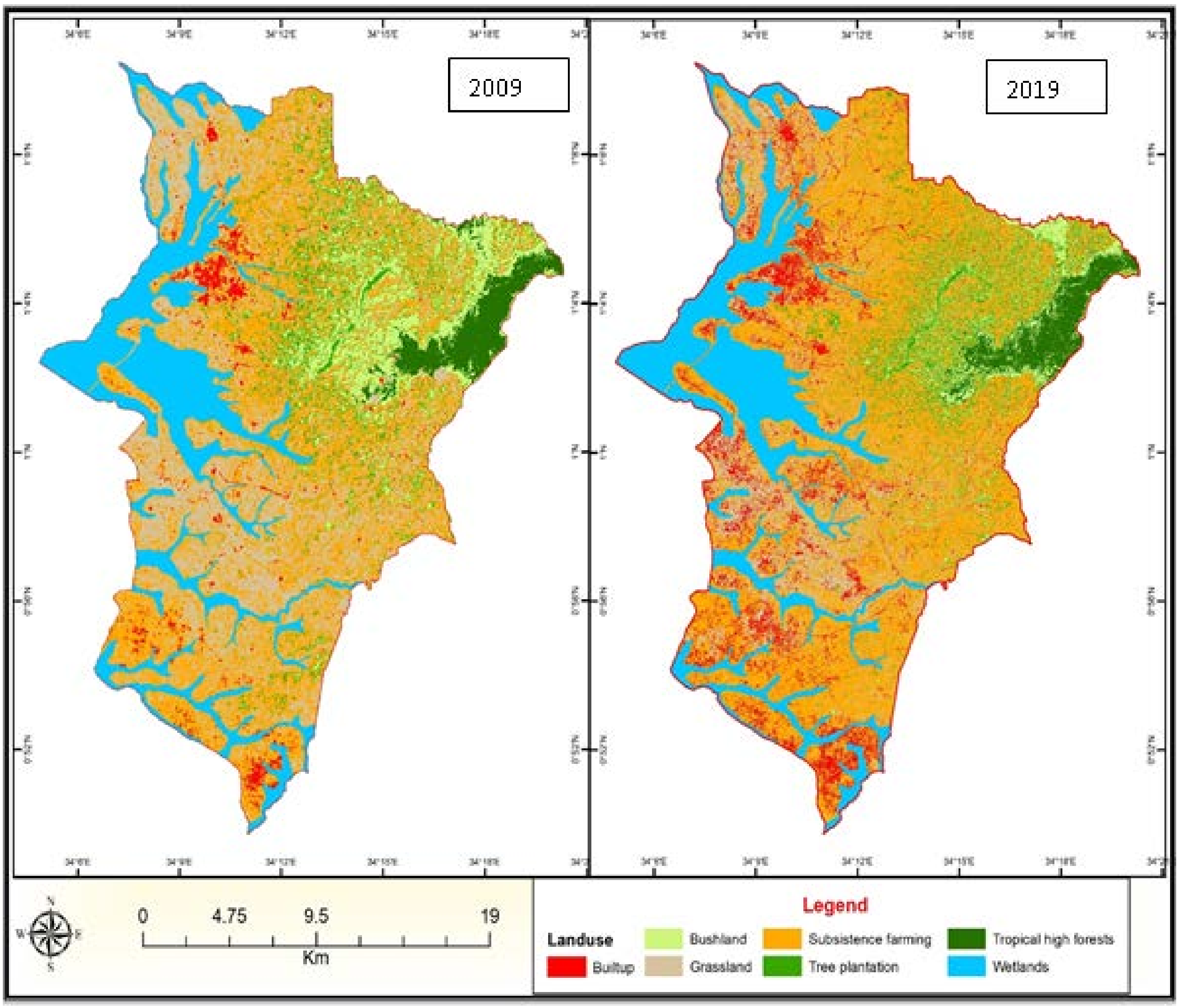

Figure 4.1: Changes in land use/cover experienced in the study area between 2009 and 2019

Figure 4.1 shows that built-up areas were highly concentrated around grasslands. The morphology of wetlands appears to have maintained shape and size over the studied period (2009 - 2019). Furthermore, subsistence farming was wide spread throughout the district, with potential threats to existence of tropical forest cover and other cover types. The increase in spatial coverage of subsistence farms and built-up means that land was lost from other land covers that indicated. It may imply for example that buildings and farmlands spread to the higher slopes of Mt Elgon into the forest zone. Subsistence farming increased also possibly having gained from grasslands and bushlands. The gains and losses in land use/cover experienced during 2009 -2019 was depicted in Figure 4.2.

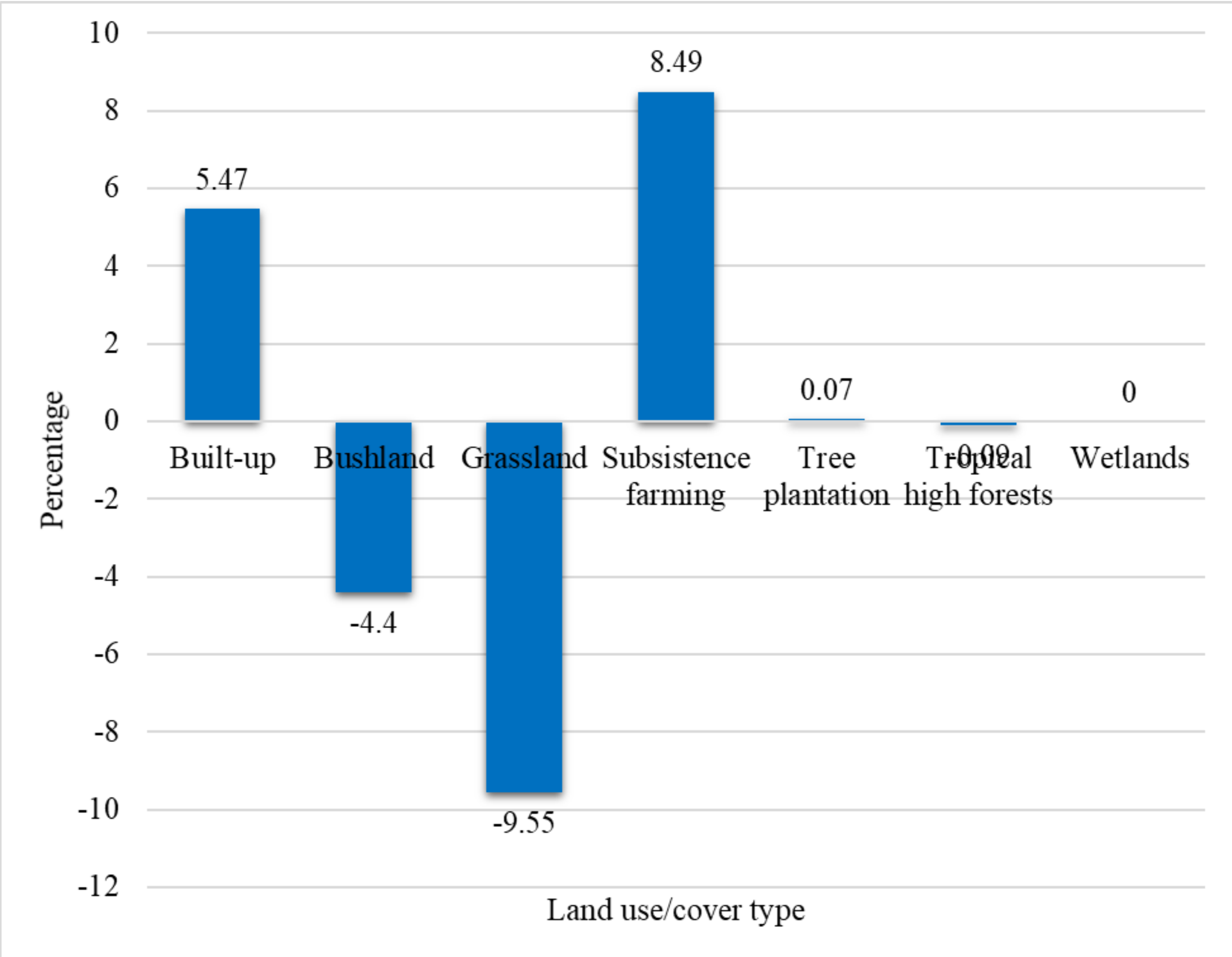

Figure 4.2: Relative change in land use/cover between 2009 and 2019

Figure 4.2 shows gains and losses in land use/cover types between 2009 and 2019. Built-up, subsistence farming and tree plantation spatial extent increased by 5.5%, 8.5% and 0.1% respectively while bushland, grassland, tropical forest land decreased by -4.4%, -9.6% and -0.1% respectively over the studied period. These imply that large changes in spatial extent occurred in subsistence farming, built-up, bushland and grassland. The least changes occurred in tree plantation and tropical high forests while wetland areas remained intact over the study period (2009-2019).

Change detection was carried out to establish loss or gain experienced for each land use/cover type and results were presented in Table 4.2.

Table 4.2: Land use/cover change detection and classification change

Year	2019 (sq. km)									
	Land use/cover	Built-up	Bushland	Grassland	Subsistence farming	Tree plantation	Tropical high forest	Wetlands	Sum	Produce Accuracy
2009 (sq.km)	Built-up	5.78	0.06	1.42	4.49	0.09	0.04	0.00	11.88	48.67%
	Bushland	0.22	13.69	1.10	17.32	12.84	3.11	0.00	48.27	28.35%
	Grassland	13.59	1.16	35.08	66.80	2.75	0.19	0.00	119.57	29.34%
	Subsistence farming	20.20	4.07	30.17	132.27	11.88	0.13	0.00	198.73	66.56%
	Tree plantation	0.40	2.86	2.41	21.74	6.95	0.15	0.00	34.51	20.15%
	Tropical high forest	0.00	3.69	0.00	0.09	0.26	15.40	0.00	19.44	79.22%
	Wetlands	0.00	0.00	0.00	0.00	0.00	0.00	85.16	85.16	100%
	Sum	40.19	25.53	70.17	242.72	34.76	19.01	85.16		
	User Accuracy	14.39%	53.60%	49.98%	54.50%	20.00%	80.98%	100 %		

Table 4.2 indicates that, built-up area, the dominant land use gained from grasslands and subsistence farmland. The bush lands lost to subsistence farming which registered an increase and tree plantation. The grasslands lost to subsistence farming and built-up and tree plantation. Tree plantations gained from subsistence farming by those who took on tree growing rather than crop farming while tropical high forest lost to bushland.

4.3 Effects of land use changes on forest structure and distribution

Table 4.3 indicates that subsistence farming (20,046 ha), grassland (11,873 ha), wetland (8,495 ha), and bushland (4,756 ha) had the highest-Class Area (CA) followed by tropical forests (1,899 ha) and built-up had the lowest (1,187 ha). The Percentage Land (PLAND) was highest for subsistence farming (38.8%), followed by grasslands (23%), wetlands (16.4%), bushlands (9.2%), tree plantation (6.7%) and the least percentage taken by built-up (2.3%). The land use/cover type with the highest Number of Patches (NP) was tree plantation, followed by grasslands, bushlands, subsistence farming, and Tropical forest while the least number of patches were recorded under wetlands. Subsistence farming and wetlands recorded the largest Patch Index (LPI) whilst tree plantation and built-up recorded the lowest (LPI). Total Edge (TE) was highest for grasslands, followed by tropical forests, then bushland and the least were for built-up. Mean patch area for tropical forests, subsistence farming and wetlands were higher and the least was for tree plantation. Mean Patch Size (Area_MN) showed grasslands to have been the highest, followed by bushlands and subsistence farming while built-up recorded the least value. Wetlands and subsistence farming registered the highest shape min followed by tropical high forests, grasslands, bushland, tree plantation and lastly built-up area. Frac min was highest for wetlands, subsistence farming grassland and tropical high forests vis-a-vis tree plantations, bushlands and built-up areas.

Table 4.3: Class metrics for 2009

TYPE	CA	PLAND	NP	LPI	TE	AREA_MN	AREA_CV	SHAPE_MN	FRAC_MN	PAFRAC	TCA	CPLAND	NDCA	PROX_MN	ENN_MN	IJI	CONNECT
Grassland	11873	22.9541	1331	7.3891	2515000	8.9204	1289.3237	1.3005	1.0379	1.6827	992	1.9178	283	87.3096	230.1745	38.6933	1.0812
Wetlands	8495	16.4234	30	10.6235	410400	283.1667	349.9775	2.2199	1.0955	1.4837	5473	10.581	63	140.4127	327.6665	53.7669	11.2644
Subsistence farming	20046	38.755	678	12.9512	3600700	29.5664	1138.6497	1.4768	1.0441	1.6872	2140	4.1373	589	531.887	217.1318	68.8602	1.9682
Bushland	4756	9.1948	719	3.5766	987200	6.6147	1144.3517	1.1957	1.0261	1.6344	500	0.9667	113	63.5385	322.1065	69.0433	1.6128
Tree plantation	3469	6.7066	1348	0.116	1072900	2.5734	165.587	1.1737	1.0282	1.6815	18	0.0348	17	4.7525	264.8787	57.5042	1.2072
Built-up	1187	2.2948	460	0.2243	324500	2.5804	305.207	1.0922	1.0157	1.5544	59	0.1141	25	2.8785	394.0806	47.1884	1.3176
Tropical high forests	1899	3.6713	43	3.2402	127300	44.1628	570.9679	1.334	1.0323	1.5363	1150	2.2233	16	101.4463	292.296	17.197	12.4031

CA=Class Area, PLAND=Percentage Land, NP =Number of Patches, LPI = Largest Patch Index, TE=Total Edge, AREA_MN= Area Mean, FRAC_MN= Mean Fractal Dimension Index, PAFRAC = Perimeter-Area Fractal Dimension, TCA= Total Class Area, CPLAND= Core Area Percentage of Landscape, NDCA= Number of Core Areas, PROX_MN= Proximity Mean.

Subsistence farming had the highest Perimeter-Area Fractal Dimension (PAFRAC), followed by grasslands, tree plantation, bushland built-up tropical high forest and the least as wetlands. Total Class Area (TCA) was highest for wetlands, followed by subsistence farming, tropical high forests, grasslands, built-up, bushland and least was for tree plantation. Core Area Percentage of Landscape (CPLAND) was highest for wetlands, subsistence farming and tropical high forests followed by grasslands, built-up areas, bushlands and tree plantation.

Subsistence farming had the highest Number of Disjunct Core Areas (NDCA) followed by grasslands, bushlands, wetlands, built-up areas, tree plantation and least was for tropical high forest. Proxi Min was highest for subsistence farming, then wetlands, tropical high forests, grasslands bushlands, tree plantations and the least were for built-up areas. Built-up had the highest Euclidean Nearest Neighbor Distance (ENN-MN) followed by wetlands, bushlands, tropical high forests, tree plantation, grasslands, subsistence farming and the least was for built-up. Interspersion & Juxtaposition Index (IJI) shows bushland as highest, followed by subsistence farming, tree plantations, wetlands, built-up, grasslands and tropical high forest. Connectance index (CONNECT) showed tropical high forests and wetlands with more connectivity as compared to subsistence farms, bushlands, built-up areas and lastly grassland. All the matrices indicated variation among the different land uses/covers for the base year 2009.

Results of the assessment of landscape metrics depicting the trend for the final year 2019 are presented in Table 4.4. Results show that subsistence farming had the highest CA followed by grassland then tropical trees, wetlands built-up and bushland and finally tree plantation with the least CA. Subsistence farming still took the lead in PLAND, followed by grasslands, wetlands and the least was tree plantation. Grassland had the highest number of patched followed by built-up, subsistence farming and the least patches recorded were for tropical high forests. The largest patch index recorded was for subsistence farming and wetlands while the least was for built-up and tree plantations. Grassland maintained the highest total edge followed by wetlands and subsistence farming. Built-up and tropical high forests trailed. Mean patch area for wetlands were highest, followed by tropical forests. The least was for tree plantation. Mean proximity index for grasslands was the highest figure, followed by bush lands and wetlands while tree plantation had the least. Connectance index for tropical high forests and wetlands was higher than that for subsistence farming, bush lands, built-up and lastly grassland. The assessed landscape metrics depicting land use/ cover trends during the period 2009 – 2019 was presented in Table 4.5.

Table 4.4: Class metrics for 2019

TYPE	CA	PLAND	NP	LPI	TE	AREA_MN	AREA_CV	SHAPE_MN	FRAC_MN	PAFRAC	TCA	CPLAND	NDCA	PROX_MN	ENN_MN	IJI	CONNECT
Subsistence farming	17590	33.9241	1058	19.018	3199300	16.6257	1872.4713	1.3238	1.0384	1.6618	2180	4.2044	552	440.9428	233.0484	73.6643	1.4034
Wetlands	8501	16.3951	28	10.5977	410400	303.6071	336.8787	2.3159	1.1033	1.4831	5476	10.561	63	149.8561	338.4717	60.5915	10.3175
Grassland	12075	23.2879	1417	8.0056	2620100	8.5215	1358.5824	1.2731	1.033	1.6802	958	1.8476	299	98.5387	235.7938	56.3375	1.1033
Bushland	4291	8.2756	692	4.5052	928900	6.2009	1438.2736	1.1785	1.0241	1.667	458	0.8833	98	92.9015	287.0698	69.0034	1.85
Tree plantation	855	1.649	595	0.0675	308700	1.437	135.6387	1.0601	1.0115	1.7093	1	0.0019	1	1.3506	370.003	63.3923	1.7327
Built-up	6977	13.4559	1327	0.9412	1637500	5.2577	499.3544	1.2358	1.0312	1.6575	591	1.1398	131	14.1281	260.1151	53.3197	0.9406
Tropical high forests	1562	3.0125	57	2.7502	165500	27.4035	682.403	1.22	1.0193	1.5877	626	1.2073	25	130.4405	275.5604	16.5302	12.594

CA=Class Area, PLAND=Percentage Land, NP =Number of Patches, LPI = Largest Patch Index, TE=Total Edge, AREA_MN= Area Mean, FRAC_MN= Mean Fractal Dimension Index, PAFRAC = Perimeter-Area Fractal Dimension, TCA= Total Class Area, CPLAND= Core Area Percentage of Landscape, NDCA= Number of Core Areas, PROX_MN= Proximity Mean.

Table 4.5: Landscape metrics

Year	Units	2009	2019	2009 - 2019
Total Area (TA)	Hectares	51725	51851	126
Number of Patches (NP)	None	4609	5174	565
Patch Density (PD)	Number per 100 hectares	8.9106	9.9786	1.7
Largest Patch Index (LPI)	Percent	12.9512	19.018	6.7
Total Edge (TE)	Meters	4519000	4635200	116200
Mean patch size (AREA_MN)	Hectares	11.2226	10.0215	-1.2
Shape Index (SHAPE_MN)		1.2585	1.2418	-0.0
Fractal Dimension Index (FRAC MN)	None	1.0322	1.0302	-0.0
Perimeter-Area Fractal Dimension (PAFRAC)	None	1.6518	1.6521	0.0
Proximity Index Distribution (PROX_MN)	None	116.9056	135.6044	18.7
Mean Euclidean nearest-neighbor distance (ENN_MN)	Meters	270.3199	264.7557	-5.6
Contagion (CONTAG)	Percent	31.2097	28.4611	-2.7
Percentage of Like Adjacencies (PLADJ)	Percent	55.2093	54.4763	-0.7
Connectance (CONNECT)	Percent	1.2884	1.2209	-0.01
Patch Richness	None	7	7	0
Shannon's diversity index (SHDI-units=information)	Information	1.6105	1.6519	0.0
Shannon's evenness index (SHEI)	None	0.8276	0.8489	0.0

Table 4.5 shows increase in total area by 126 ha between 2009 and 2019, Number of patches increased by 565 in 2019 as well as PD by 1.1%. Largest patch index increased by 6.1%, Total edge also increased by 116, 200 meters. The area-mean on the contrary declined from 11.2 ha in 2009 to 10.0215ha in 2019. The Mean Patch Shape Index (Shape–Mn), too declined by 0.0167, Frac–Min declined by 0.002, PAFRAC increased from 1.6518 in 2009 to

1.6621 in 2019 that is by 0.0003. PROX-MN increased from 116.9056 in 2009 to 135.6044 in 2019. ENN-MN decreased from 270.3199 in 2009 to 264.7557 in 2019 that is by 5.5642, Contag reduced by 2.7486 in 2019, PLADJ declined by 0.7. CONNECT too declined by 0.0675. There was not any change detected for PR with in the two-reference periods. SHDI increased by 0.0414 and SHEI increased by 0.021.

4.4 Drivers of land use/cover change along the slopes of Mt Elgon in Mbale district

The analysis concentrated on the demographic characteristics of respondents that relate with change in land use/cover in the study area as well as the perceived causes of land use/cove change.

4.4.1 Demographic characteristics of the respondents

The first section of the research tools probed for information about the respondents' aspects of gender, age and duration of stay and a summary of their results is shown in Table 4.6.

Table 4.6: Demographic characteristics of respondents

Variable	Description	Frequency (N=191)	Percentage (%)
Sex	Male	79	41.4
	Female	112	58.6
Age bracket	(18-30)	41	21.5
	(31-60)	124	64.9
	(60-above).	26	13.6
Duration of stay	1-5 years	24	12.6
	5-10 years	41	21.4
	10 years-above	126	65.9

Table 4.6 indicates that number of female respondents was greater (59%) than their male counterparts, probably an indication of engagement in field activities. It further depicts that majority of the respondents (64.9%) were in the age bracket of 31-60 and the biggest percentage (66%) had lived in Mbale for more than 10 years. The majority of the respondents in the study area being female implies that much more intensive activities on land since women in Uganda do more garden work, spending most of the day with their children in the farms. They engage in bush clearing, burning grass and preparation of gardens for crop growing. Men on the other hand fell bigger trees; uproot tree stamps cutting them into logs for charcoal burning and timber for sale. Thus where as women increase on area under agricultural production that indirectly affect vegetation cover, men are engaged in activities directly affecting vegetation cover (forest loss). Majority of respondents comprise of middle-aged persons between 30-60, and few people aged below 30 years and above 60 years. This implies that strong and able-bodied active people form the greater populace group than elderly and young. It's thus a district of active and productive inhabitants expected to utilize land maximally.

4.4.2 Occupational characteristics of the respondents

Results in the Table 4.7 show that majority of residents were farmer (36.6%) who practice some sort of farming ranging from small to medium farms of mostly food crops like maize, beans, potatoes, bananas and coffee. 50 of the respondents representing 26.1% were public servants, 26 representing 13.6 % were community leaders representing 20 (10.4%) were religious leaders and 25 accounting for (13%) were people engaged in business. These results point towards the fact that more pressure is placed on land for farming activities since it is the main form of livelihood employing the biggest percentage of people. This has a potential negative impact of natural vegetation like forest cover.

Table 4.7: Occupational characteristics of respondents

Occupation	Frequency	Percentage
Community leaders	26	13.6
farmers	70	36.6
Public servant	50	26.1
Religious leader	20	10.4
Business person	25	13
Total	**191**	**100**

4.4.3 Forms of land ownership

Results of the analysis showed that majority of residents (57%) had inherited land from their fore fathers. 19% had bought it, 12% had leased while 13% had hired land (Table 4.8). The results here signify that land inheritance is the most dominant form of land holding and that most parents divide and subdivide land amongst children, which has been passed on from generations. This means that much of the land in Mbale is fragmented and associated with land conflicts, thus reduced productivity. Reduced land productivity drives the farmers to encroach on land under conservation and forestland, which is usually the most productive, is never spared. Respondents confirmed to owning small pieces of land acquired customarily. Land in Mbale has become scarce due to the high population. No wonder people resort to clearing the bushes and forest to create space on which to live. In terms of land use systems, the study revealed that the major land use systems in Mbale District include built-up/settlement, agriculture, and infrastructure and forestry.

Table 4.8: Land ownership forms in Mbale district

Land holding form	Frequency	Percentage
Inherited	108	56.5
bought	37	19.4
Lease	22	11.5
Hired	24	12.6
Total	**191**	**100**

Majority of the respondents admitted to rearing two or more goats, a cow on zero grazing to supplement family income. The main source of animal feeds indicated is grass, gathered from the bush and tree cuttings/leaves, which is supplemented by food peelings. The study also shows that most households use family labor to till the land and all other farm activities, the reason why they produce many children. Need for more children increase natural birth rate which in turn increases population pressures on land resources.

4.4.4 Preferred place of stay

Results indicated that residents prefer to stay in grasslands, wetlands and slopes of Mt Elgon to acquire more land for agriculture (Table 4.9). Table 4.9 indicates that, 18% of respondents prefer to settle in grasslands; 35.6% preferred to stay in wetlands, citing the need to acquire fertile land for cultivation; 25.6% preferred mountain slopes; 19.8% would like to live in bush lands which offer plenty of animal feeds, whilst 1% indicated no preference. The main reason cited for preferred residence was the need for more productive (fertile) land to carryout agriculture. This means that land in the current localities has been over used either such that output from it has reduced or the number of competing land uses have increased leading to reduced output. In either way, land use changes are the outcome.

Table 4.9: Preferred place of stay

Place	Frequency	percentage
Grasslands	36	18
Wetlands	68	35.6
Mountain slopes	47	25.6
Bushlands	38	19.8
Non	2	1
Total	**191**	**100**

Respondents indicated that crop production has declined over the past 10 years and the factors identified include decline in soil fertility, unreliable rain, poor agriculture inputs, poor seeds and pests/ crop disease.

4.4.5 Drivers of land use/cover change

With regard to drivers of land use/cover change in Mbale district, Table 4.10 reveals that 40.8% of the respondents indicated agriculture/ farmland expansion, 20% attributed it to population increase, 1.8% attributed it to firewood/charcoal production, and 10.4% attributed it to timber production. In addition, 3.1% the respondents indicated that land use/cover change was caused by lack of financial resources, 4.7% indicated poor law enforcement and only 1% indicated that land use/cover change results from bush fire. The significance of these findings is that land use/ cover change in Mbale are caused by four major factor, that is agriculture land expansion followed by population growth, followed by wood fuel/charcoal production and timber extraction, while lack of financial services, lack of enforcement and bush fire account for a small percentage of land use/cover change.

Table 4.10: Drivers of land use/cover change in Mbale district

Cause	Frequency	Percentage
Agriculture/farm land	78	40.8
Population growth	40	20.9
Wood fuel/charcoal	36	18.8
Timber harvesting	20	10.4
Lack of financial resources	6	3.1
Lack of law enforcement	9	4.7
Bush fire	2	1.0

Respondents were also asked to indicated whether they were aware of policies for land use mornitoring and whether these are enforced or not, in the study area. Blackmore and Kent (1998) define a policy as a statement of intent, which is implemented as a procedure or protocol. Policies are generally formulated and adopted by boards or governing agencies. Results on status of land use policy awareness and enforcement obtained in this study are indicated in Table 4.11.

Table 4.11: Responses on knowledge of land use policy

Knowledge of policy monitoring land use	yes	146	76.4%
	no	45	23.6%
Policies are being enforced	yes	32	16.8%
	no	159	83.2%

The findings in table 4.11 revealed that most residents 76.4% of Mbale have clear knowledge about the existence of land use/cover management policies/ by-laws. In addition, majority (76.4%) of the respondents disregarded the assertion that the policies were in existence and fully operational. The results signify existence of some missing links in the implementation of land use/cover policies as 76.4% of respondents said they know policies exist and again 83.2% of them said the policies are not enforced. 23.6% of the respondents indicated that they were not aware of any land use policy, which means that sensitization about the policies has not been attended to despite existence of the policy.

Data obtained from key informants indicated varied but not so different information on key aspects of the study. The district forest officer admitted to existence of land policies meant to monitor land use/cover change such as the National Environment Management Plan NEMP, Wetlands Policy, Land Use Policy, and Climate Change Policy among others. She noted that government institutions like National Forest Authority (NFA) and National Environment Management Authority (NEMA) are mandated to monitor land use and land cover. However, little is being realized from their efforts because of due to limited capacity for enforcement, contradicting policies for example the industrial park in Namatala wetland set up by government, standalone policies that are never integrated with local initiatives and weak institutional functionality.

The district natural resources officer noted that, trainings and demonstration are done on schedule to equip residents with knowledge on how to utilize the land resource sustainably without altering the land cover. Demarcation of protected lands that seem endangered and, revision of the bylaws to reprimand the offenders is being done. Respondents are aware of government programs that have improved land use/cover systems such as the wetland restoration projects, boundary opening and restoration of protected areas, and Northern Uganda Social Action Fund- NUSAF.

The respondents in this study indicated a number of constraints on forest and policy enforcement, which include limited technical capacity, small land holdings, non-alignment of land to appropriate usage, non-intensification of production (market production). On the other hand, the study indicated existence of a number of opportunities that is; the land is very productive as indicated by the output per hectare and whatever crops are grown, whether annual or perennial, one expects a good harvest. The region is naturally endowed with natural landscape aesthetics, which are a potential for tourism. Trees that occur naturally (the Mt Elgon Forest) needs to be conserved and exploited purposefully. The scattered trees all around thrive on their own. There is little or no attention given for trees to grow. Several wetlands exist within the district, stretching along the many streams radiating from the high mountain Elgon.

The study therefore clearly reveals that, land use/cover change in the study area is mainly caused by agricultural land expansion, population increase, wood fuel and timber production, Farmland expansion and settlement resulting from population growth has had greater impact and is likely to continue to drive high rates of deforestation. Forest loss in Mbale is mainly caused by clearing of land for farming and for settlement, (small patches of land less than 1 ha), and illegal logging, wood harvesting by rural households for domestic fuel most likely has had much impact.

4.5 Prediction of future land use/cover changes on the slopes of Mt Elgon in Mbale District

Table 4.12 shows the predicted rates of change in land use/cover for the period 2019 – 2029. It indicates that by 2029, built-up area will have increased to 60.4 km^2 from 40.2 km^2;

indicating 3.9% positive change. Area under subsistence farming too will have increased by 6.5%. Land cover types are however, predicted to experience a negative change (decline in land area). The biggest decline will occur in grassland (-5.9%) followed by bushland (-2.1%), tropical high forests (-0.2%) and the least being wetlands (-.02%). Grasslands, bushlands and tree plantation (-2.1%) will experience more decline compared to tropical high forests and tree plantations. These changes are visualized in Figure 4.3.

Table 4.12: Predicted land use/cover changes between 2019 & 2029

	2019		**2029**		**2029-2019**	
Land use/cover	**Area(km^2)**	**Area (%)**	**Area(km^2)**	**Area (%)**	**Area(km^2)**	**Area (%)**
Built-up	40.22	7.77	60.40	11.66	20.18	3.89
Bushland	25.57	4.94	14.70	2.84	-10.87	-2.10
Grassland	70.20	13.56	39.18	7.56	-31.03	-5.99
Subsistence farming	242.94	46.91	276.48	53.39	33.54	6.48
Tree plantation	34.79	6.72	23.97	4.63	-10.82	-2.09
Tropical high forests	19.02	3.67	18.13	3.50	-0.89	-0.17
Wetlands	85.16	16.44	85.04	16.42	-0.12	-0.02

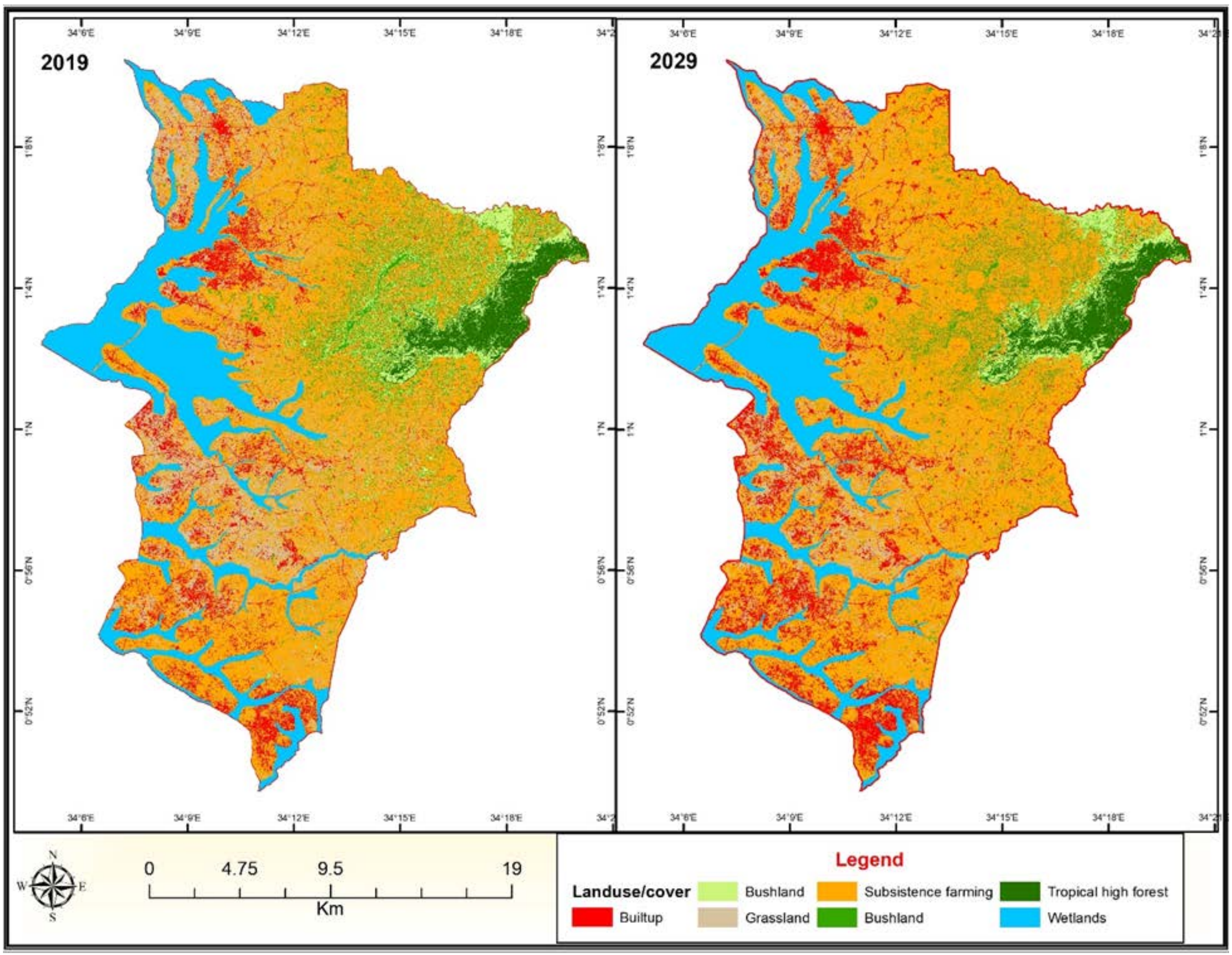

Figure 4.3: Predicted land use land use/cover change in Mbale between 2019 and 2019

Table 4.13 shows the transition in land cover/use changes between 2019 and 2029 and the prediction accuracy. The table indicates that built-up area will cover the largest area by 2029. Bush land will lose land area to subsistence farming and tree plantation. Grassland will lose to build up and subsistence farming. This means that subsistence farming will gain from grassland and tree plantation. Moreover, tree plantations will lose to subsistence farming. Tropical high forests will lose to bushland and some wetlands shall be converted to subsistence farming.

Table 4.13: Year 2029 (sq.km) land use/cover change prediction assessment

Land use/cover	Built-up	Bushland	Grassland	Subsistence	Tree plantation	Tropical high forest	Wetlands	Sum	Produce Accuracy
Built-up	40.2	0.0	0.0	0.0	0.0	0.0	0.0	40.2	100.0%
Bushland	0.02	8.93	0.03	10.42	4.06	2.07	0.01	25.5	34.9%
Grassland	6.23	0.04	36.31	27.11	0.34	0.00	0.15	70.2	51.7%
Subsistence farming	13.65	0.97	2.63	216.20	8.27	0.04	0.98	242.7	89.1%
Tree plantation	0.12	1.88	0.09	21.47	11.09	0.09	0.03	34.8	31.9%
Tropical high forest	0.00	2.80	0.06	0.13	0.15	15.88	0.00	19.	83.5%
Wetlands	0.16	0.00	0.05	1.04	0.02	0.0	83.72	85	98.5%
Sum	60.39	15	39.2	276.37	24	18.1	85	517.5	
User Accuracy	67%	61%	92.7%	78.2%	46.3%	88%	99%		

The predicted land use/cover for the period 2019-2029 is depicted in Figure 4.4. Figure 4.4 indicates clearly the pattern of decline that will be registered under grassland, bushland, tropical high forest, and wetland by 2029. It however shows the pattern of gain in subsistence farming and built-up environments. The built-up environment seems likely to extent to higher slopes though majorly concentrated around the wetlands.

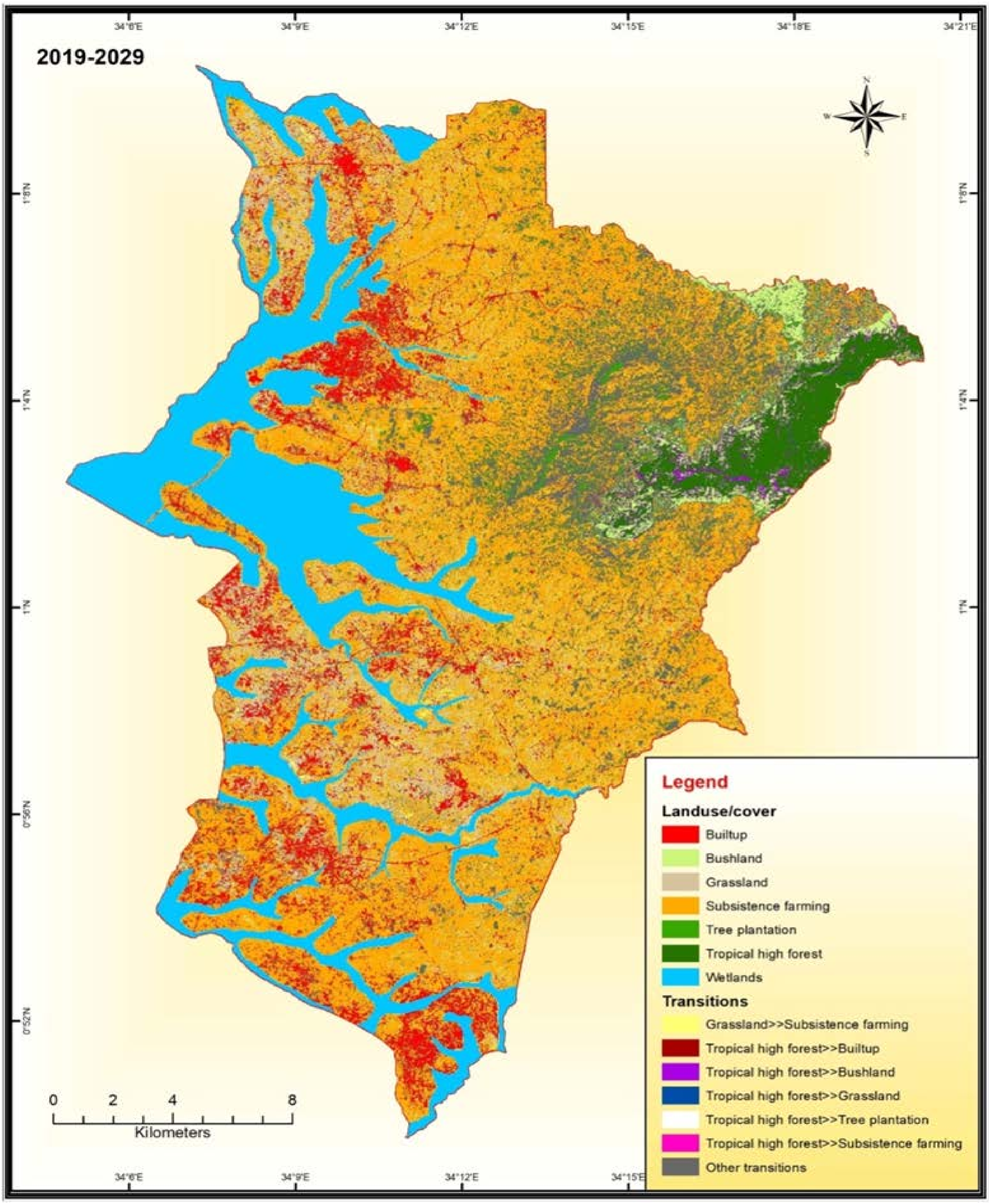

Figure 4.4: Land use/cover transition map for the period: 2019 and 2029

CHAPTER FIVE: DISCUSSION OF RESULTS

5.1 Mapping and characterizing land use/cover changes

In the current study, seven land use/cover classes were mapped and characterized basing of area coverage. The results indicate changes in the mapped land use/cover over the reference period. Land cover mostly experience negative changes as compared to land use types, which registered positive changes. Forests took up a small percentage of land and yet still the cover is faced by conversion to land use. According to the information collected from farmers, the 1970s and 1980s were the good old times of low population, high soil productivity. However, with the increasing population over time, former bushlands and forested areas have been cleared for settlement and farming to meet the demands of the populace. The minimal surveillance from local authorities gave an opportunity to locals to clear vast areas from there natural state. This gave multiple benefits like; gaining new fertile land for agriculture, land for settlement, selling of timber and wood products among others. Forest vegetation loss is an indicator of serious land degradation, which also reflects alterations in the forest ecosystem like water transfer.

Majaliwa et al. (2018) in their study identified 29 classes of land use systems in Uganda that were broadly categorized as agricultural, bush land, forest, grasslands, impediments, wetlands, woodland, open water and urban settlement. Although these systems were more detailed than in the current study, all the classes applied fall under the broad categories originated by Majaliwa et al. (2018). The current study findings on forest cover mapping and characterization are more or less reflective of previous scholars (Mugagga, 2011; ECOTRUST, 2012; Mugagga and Buyinza, 2013). Over the assessed period (2009-2019), there was an intense clearance of natural vegetation due to expansion of subsistence farming and built-up area.

There was a decreasing trend of area covered by grasslands and bush lands in Mbale district. With this trend, grasslands and bush land are on the verge of undergoing extinction in the district, given the pressures they are subjected to from the ever-increasing human activities. Subsistence farming on the other hand is on the rise at the expense of grasslands. Tropical forests are being lost to land uses through conversion. Subsistence and built-up are the most dominant land uses. By this rate, these land cover types in the district could easily be converted to land use types with minimum efforts in terms of labor and time. Secondly, these vegetation cover types are found in areas that are not clearly demarcated and unclear land ownership. The finding is similar to the results obtained by Mouhamed et al. (1996) who also found out that several regions of sub Saharan Africa face intense clearance of natural vegetation due to expansion of farming and settlement. The tree plantations and wetlands were seen not to be highly affected in terms of losses or gaining of land. The land use types are increasing at the expense of land cover type especially for those that are found in the areas that are not protected.

The results here are reflective of those by Zziwa et al. (2011) who analyzed land use/cover changes using satellite images and established that between 1985/86 and 2015 cropland in Uganda increased by 4.2%, which largely occurred at the expense of undisturbed land like the forests and slopes of mountains. Similarly Majaliwa et al. (2018) in their assessment of the extent of historical, current, and future land use systems in Uganda, discovered that the highest gains in the land amongst the land use systems were experienced in subsistence agricultural land and grasslands protected, while the highest losses were seen in grasslands unprotected and woodland/forest with low livestock densities.

5.2 Effects of land use change on forest structure and distribution

The results indicated that the structure of forest cover on the slopes of Mt. Elgon has changed in terms of number of patches, patch density, Total edge and connectedness. This implies that the cover type is undergoing fragmentation, which is creating more patches, reducing on density, cover boundary and connectedness. Reduced cover boundary means forest are not expanding but rather contracting and thus reduced diversity of the habitant. Majaliwa et al. (2018) reported that the high demand for agricultural and settlement land are mainly responsible for land use systems patchiness. This study envisages that more land degradation and disasters such as landslides, floods, droughts, and so forth to are likely occur in the Mt Elgon, causing more deaths and loss of property, if the rate at which land use systems are expanding is not closely monitored and regulated in the near future.

Diversity and composition indices for the natural forest ecosystem in the landscape showed an obvious zonation and patches in ring form. The main patch size being settlement and subsistence farming. Tropical and planted forests had relatively large size but diminishing in successive images. Tropical forests are rich in diversity as observed in Central Forest Reserves (CFRs) known to consist of 1,259 species of trees and shrubs (NFA, 2011). Uganda's present policies and legislation for management of natural vegetation (Forests and Wetlands) outside protected areas (PAs) is inadequate. The existing land tenure systems of land holdings, especially customary holdings offer little incentive for protection and management of vegetation outside PAs. Maintenance of natural vegetation is at the mercy of individual landowners. While forests, grass, bush and wetlands are under considerable pressure and require more attention for conservation. A few areas outside the PA system with considerable populations have been identified in several sub counties in Mbale district e.g.

Bubyangu, Bungokho Mutoto has viable land cover of forest. Other areas in district such as Budwale also have forests worth protecting.

The bulk of the forests (64%) in Mbale are found on private land (NFA, 2011) which is outside protected areas. This situation shows that private landowners and communities could play a significant positive role in managing forest diversity in Uganda given the right incentives to do so. Grasslands/bush lands cover a bigger percentage of the land area in Mbale and are dominated by species of grasses in different locations. Much of this habitat has been converted to human use for agriculture, settlement and grazing. These finding relate directly to what other studies revealed.

Zulu (2008) stated that the principle threats to biodiversity in Uganda continues, including habitat loss, modification and alteration, along with unsustainable harvesting, pollution and introduction of alien species. Biodiversity loss in Uganda is indicated by the decline in tree species in Eastern which is the biggest threat ever inflicted by man on forest ecosystems according to Witte et al. (2009). Just like in the current study's findings, Witte et al. (2009) indicates that man's actions through land conversion affects the density of trees and connectedness of forests thus reducing on forest ecosystem diversity.

A study of land use and land cover changes in the Murchison Bay catchment of lake Victoria basin in Uganda by Kiggundu et al. (2017) indicated that the catchment has undergone huge land use and land cover transformations over the last three decades (1984-2015) in terms of expansion of built-up land (20.58% to 49.59%) and open water (~ 1.74%). Whereas negative changes (decrease) occurred in agricultural lands (from 43.88% to 26.10%) forestland (from 23.78% to 17.49%) and wetlands (from 11.76% to 5.08%). The emergent difference when these results are compared to the previous study is in terms of agricultural land decline. This however can be explained by the fact that Murchison Bay catchment is dependent on other forms of livelihood as compared to Mbale rural livelihood forms. However, in either cases, forestland is noted to decrease.

While analyzing forestland use, forestland cover and change at policy relevant scales, Coulston, Reams, Wear, & Brewer (2013) discovered that forestland cover and forestland use were related though moderately and that net change estimates are independent of the gross forest cover loss estimates. These findings signify that changes in land use definitely affect forest cover and have the potential to account for forest cover loss just as the current study has indicated inverse relationship between land use change and forest cover change.

5.3 Drivers of land use/cover change

The study has revealed that land use/cover changes in Mbale district result from several drivers but the major ones include; subsistence farmland expansion, population increase, wood fuel and timber production. Forest loss in Mbale is mainly caused by clearing of land for farming and for settlement by the ever-increasing population on small patches of land less than 1 ha. This trend is likely to continue to account for deforestation not only in Mt. Elgon areas but also in other forested areas. Stibig (2007) reports that agricultural expansion is the single greatest current cause of direct and indirect deforestation. When the respondents were asked why they preferred to move to the various locations they indicated need for fertile land to carry out agriculture. This rhyme with the findings by Nangware et al. (2010) who observed that intensification of human activities seeking to ensure food security and improve on income of the growing population by expanding farmland, searching for wood fuel and extra land to settle are among the drivers of land use/cover change in the world.

Pomeroy et al. (2015) reported that much of Uganda's natural vegetation losses are due to the rapidly growing population. While agricultural output needs to rise to match the food demands of the rising population, it happens at the expense of natural vegetation cover. This has been happening through expansion of the areas devoted to crops rather than intensification and rising productivity, which in general is very low. Aleper and Moe (2006) too noted that the principal cause of habitat conversion is human population pressure. Human population growth rates for Uganda are approximately for rural areas in Uganda 3%, which is higher than the global average of 1.3%. Human density estimates are equally astonishing, with Uganda's national average standing at 102 people/km^2 compared to the world's average of 42 people/km^2. Land area on the other hand has remained static thus; the seemingly unutilized but agriculturally productive land is that under forests and wetlands. Annually, more forestland and wetland must be brought under cultivation to feed the increased number of people. In places such as Elgon, Kigezi and Rwenzori regions, increased demand for agricultural land has led to land fragmentation, land degradation, and environmental hazards like landslides. Just like in the current study, Kigundu et al. (2017) attributed huge land use and land cover transformations in Murchison Bay catchment over the last three decades (1984-2015) to rapid population growth and urbanization. Mbale district has experienced spatial changes over time having mothered six other districts and recently upgraded to city status. The population in the district has more than tripled since independence. Land uses have changed over time mostly with conversion of land to settlements, infrastructure development and farming at the expense of other the natural vegetation.

Among the key drivers of land use/cover change in Mbale district was wood and timber harvesting. These are extracted from the forest ecosystem and thus affect how much land area remain with forest cover. Stibig (2007) notes that, illegal logging and wood harvesting by rural households for domestic energy use has also had much significant impact on forest cover. The current study findings are echoed in Stibig (2007)'s study. Long-term deforestation sequences usually start with commercial or illegal logging operations entering areas of dense primary forests, often in inaccessible and remote areas (Olson & Maitima, 2006). The findings by Kary et al. (2010)'s study revealed that logging causes forest degradation and uncontrolled timber extraction also results in damage to remaining stands, while the construction of logging roads provides access for settlers and allows activities such as subsistence farming to commence. This sequence of deforestation applies not only to Mbale district but also to all other districts in the region and beyond as documented by Thomas et al. (2009). In many areas, dramatic increases in the extent of coffee, and eucalyptus tree plantations have resulted in the fragmentation and loss of large areas of natural forest. In other areas such as "Kisali", although the overall total area of forest appears to be relatively stable there are extensive changes occurring due to eviction and boundary opening by UWA followed by rapid re-growth.

Repeated uncontrolled logging, often in combination with illegal timber extraction and small-scale cultivation, causes loss and fragmentation of contiguous forests. Once fragmented and degraded, forests become more vulnerable to permanent conversion to farmland. As a result, conflicts over remaining forest resources continue to increase. This is in line with findings of Thomas et al. (2010) in his book "Analysis of land use and forest changes and related driving forces".

In the current study, 23.6% of the respondents were ignorant of existing land use policies, which means residents don not put into consideration such policies related to environmental protection when carrying out their activities on land. The study also revealed that land policy implementation is not strictly adhered to by the implementers as well. It is thus agreed in this study that land use management policies do exist but are not being effectively implemented. Implementation of land use policies has been left to wild life authority and army attaché who have a seemingly strained working relationship with the locals. This is in agreement with National Environment Management Authority (NEMA, 2004 ⁄2005) which documented a number of underlying factors that have contributed to the decline in the quality and extent of Uganda's forest resources. Among them being poor administration of forest policy and non-adherence by the citizens.

Institutional issues such as weak and insufficient capacities within agencies and local authorities observed by the district forest officer in the areas of study contribute to the failure to properly plan supervise and control forest-related activities. Such weakness leads to a range of resource management and protection issues such as non-existent or inappropriate boundary demarcations for protected areas. Lack of information exchange and insufficient extension services leading to inadequate knowledge of legislation and regulations by residents and resulting clashing between forest workers and the residents.

A number of regulatory framework issues emerge when the results of the study are put into context. The Uganda Investment Authority (UIA) for example allocated wetlands to industrial park establishment such as (Doho Wetland) and cleared away all the existing trees and other vegetation for industrial works. The main issues such as inappropriate implementation of Government policies, regulations and programs; inconsistencies in legislation, investment promotion measures, and shortcomings in implementation of land use planning/land allocation due to lack of qualified staff, equipment and funds should be thought about by relevant authorities. Inadequate financial incentives to maintain and sustainably manage forests yet there are higher profit openings gained by conversion to other land uses such as agriculture or Eucalyptus tree plantation and even illegal logging.

5.4 Prediction of future land use/cover changes on the slopes of Mt Elgon in Mbale District

The analysis of land cover change between 2009 and 2019 allowed for assessment and prediction of changes for the period 2019 to 2029. Land use predicted to change more is subsistence agriculture which will have increased by 6.48% followed by built-up area with 3.89% an increment against Bushland 2.10%, Grassland will reduce to 5.99%, Tree plantations will be 2.09%, Tropical forest will reduce by 0.17% and wetlands will register -0.02% loss. These results imply that at demand for agriculture will increase as the urban population increase. This will also drive the need for built-up infrastructure and since the seemingly free land is that under natural covers like wetlands, forests, grass and bush land; these will be targeted for conversion.

These results are in line with the findings by Majalwa et al. (2018) although the later study was applied on a national spatial scale. In Majaliwa et al. (2018)'s, study it is predicted that by 2040, subsistence agricultural land in Uganda will likely increase by about 1% while tropical high forest with livestock activities is expected to decrease by 0.2%, and woodland/forest unprotected by 0.07%. Mugaga et al. (2015) while analyzing differences in carbon stocks in various land uses on the slopes of Mt Elgon reports that intact forest stored more carbon (>45t/ha) whereas agricultural land stored the least carbon (approximately 1.5 t/ha). Loss in forest over and increase in subsistence agriculture in future implies that significant losses in carbon storage amidst already existing global climate change with adverse impacts will likely occur. Future increase in area under agriculture on the other hand would imply decline in primary characteristics of forest soil making it susceptible to other environmental risks like severe erosion and landslides (ACCESS, 2015). Such potential dynamics in land cover are a thus cause for worry but should also upsurge interventions where critical losses are anticipated. The interventions can include population growth control, community participation in forest and wetland conservation and law enforcement as suggested by Musa (2018).

CHAPTER SIX: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter presents summary of major findings and conclusion based on the study findings in line with the study objectives.

6.2 Summary of major findings

Seven land use/cover classes were mapped and characterized. The results indicate changes in the mapped land use/cover over the 10 year reference period 2009 -2019. There is a negative trend of change in land cover as compared to land use types, which keep gaining in terms of area. Despite the small percentage of land occupied by forests, it still faces the threat of conversion to other land use. The increasing population over time, has prompted the clearing of former bush lands and forests for settlement and farming to meet the demands of the populace

The structure of forest cover on the slopes of Mt. Elgon has changed in terms of number of patches, patch density, Total edge and connectedness. This implies that the cover type is undergoing fragmentation, which is creating more patches, reducing on density, cover boundary and connectedness. The implication is that forests are contracting and thus reduced diversity of the habitant

Several drivers are responsible for land use /cover change in the district but the major ones include; subsistence farmland expansion, population increase, wood fuel and timber production.

Notable among the drivers of land use/cover change in Mbale district was wood and timber harvesting. Trees are extracted from the forest ecosystem and thus affect how much land area remain with forest cover

Forest loss in Mbale is mainly caused by clearing of land for farming and for settlement by the ever-increasing subsistence population on small patches of land less than 1 hectare. This trend is likely to continue as long as population continues to increase

The study involved assessment and prediction of changes for the period 2019 to 2029. Subsistence agriculture is predicted to change more by gaining followed by built-up area with an increment against Bush land Grassland, Tree plantations Tropical forest and wetlands which will register losses. The implication is that demand for agriculture land will increase as the population demands food and infrastructure the seemingly free land is that under natural covers like wetlands, forests, grass and bush land; these will be targeted for conversion.

6.3 Conclusions

A number of conclusions are drawn basing on the field findings in this study.

Forest cover in Mbale district is declining at the expense of land uses including farming, building infrastructure and tree plantations. The results showed that there were negative changes in land cover types including forests, bushland and grassland for the period 2009-2019 in the district whilst positive changes were registered for the various land use types including farming, built-up environment and tree plantations. Areas covered by grasslands and bushlands are most altered.

Positive changes in land use negatively affect the structure and distribution of forest vegetation on the slopes of Mt Elgon in Mbale. This study revealed increase in patch number but decline in class area, total edge and connectedness for forest cover over the study period (2009 – 2019) all of which implied an altered structure of the forest ecosystem.

Demographic pressure is the overall driver to land use change through its effect such as intensification and extension of farming activities and built-up infrastructure developments. The land use changes are complex in such a way that the factors discussed earlier keep interacting whose magnitude differs in time and space to cause change.

Losses in natural forest cover will most likely increase in magnitude given prolonged land use alteration. These will greatly affect natural forest vegetation functions in future and if no interventions are put in place, it will compromise not only natural forests but also whole ecosystems functionality and sustainability.

6.4 Recommendations

Basing on the findings in this study, a number of recommendations are made to address the outstanding issues.

There is need to control land conversion to agriculture from forest and wetland covers given their sensitivity. Agricultural communities living should be sensitized to adopt modern farming methods and technologies especially in areas neighboring the forest zone in Mbale district to maximize output from existing small farmlands and save the natural vegetation.

Government through NFA should enforce forest management and conservation efforts like forest zoning and forest edge monitoring so as recover encroached-on areas to allow for forest regeneration and avert encroachment further encroachment. Also, appreciate efforts by individuals to restore forests. Increased national dialogue is necessary to develop the art of forest treasure and protection and design implementation practices for both forest and diversity outlook.

The main drivers of land use change included agricultural land expansion and increase in population. The government should review the existing population policies and put in place stringent measures to control population growth if forest ecosystems are to be sustainably managed.

The study indicates limited enforcement of land use policies thus, there is need to provide for sensitization programs about generally environmental policies especially with communities living in close proximity to protected ecosystems like forests and wetlands.

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APPENDICES

Appendix I: Questionnaire/Interview Guide

Iam Minjo Mwinike Samali, a student of Kyambogo University pursuing a Master Degree of Arts in Geography.

I am carrying out a research on the effects of land use change on forest cover on the slopes of mt Elgon for academic purpose. I would like to ask you questions about issues related to land use/cover types and the causes for change. The research is intended to conserve the environment by regulating land use for sustainable livelihood. The information you give will be used for academic purpose and treated confidentially.

Thankyou; Subcounty ………………Parish: ……………… Zone/Village…………..…….

Date: ………………………………….

Section A:Social characteristics

1. Sex of the Respondents.

.(i). Male (ii). Female

2. Age of the Respondent……………….

3 Married No……...Yes…………..

4. Major occupation of the respondent.

(i). farmer (v) (not occupation)

(ii). Public Servant (vi). Community Leader

(iii)Business person (vii). Religious leader

(iv). Others (Specify)………………

5. How many household members stay in this premise?

ii)Please specify above 18……. Bellow 18……….

Section B Economic Characteristics

6 i)What is your major source of livelihood and survival?…………………..……………..

ii) Do you sale any of your farm produce…Yes…………..…….. No……………………..

iii) If yes, how much do you earn from the sales……………………….…………………

iV)How do you spend the money earned …………………………………………………

7 How much land do you own?state in acres eg ½ ,1,2……………………….……………..

8 How did you acquire the land you own …………………………………………………

9 What is the land tenure system in Mbale …………………….…………………………

10 Is it enough for your house hold? Yes/No……………………………………………….

11 What activities do you carry out on your land……………………………………………

12 How long have you lived in this community……………………………………………

13Have you migrated recently (Yes/No)…………………………………………………….

14 If yes give reason for migration……………………………………………………..

………………………………………………………………………………………………

15 Other than your locality, where else would you prefer to stay (grassland, bushlands wetlands, high slopes)

……………………………………………………………………………………………….

16 Give reasons why you would prefer to stay in the area chosen in 9 above…………………………………………………………………………………………

17. How do you hope to acquire more land for yourself and family?

………………………………………………………………………………………………..

18 Do you think the population of your community has increased over the past 10 years?

Yes No………………………..

19 If YES, what do you think have caused the population increase?

(Specify)………………………………………………………………………………

20 Do you think that more land will be needed as your family grows? Yes

/No………………… ……………………………………………………………………..

21 If YES, how much extra land do you think you will need when you have a new family member? 0.5 acres 1 acre 2 acres > 2 acres Don't know 9.

22 What kind of land would you clear when your family size increases? Forest land Grass Land Other (specify)

………………………… ………………………………………………………………...

Section C **AGRICULTURE**

23 List the major crops easily grown in your community (Start with the most important crops) . . . . …………………………………………...

24 What is the number of farms you have, Their size, purpose, and distance from home. Farm land Size (acres)……………………………………………………………………….……

25 Purpose/Use…………………………………………….…. (consumption, sale, or both)

26 Distance from home for each farm………… Farm 1……. Farm 2……. Farm 3……..........

27 Has crop production declined or increased over the past 10 years in your community? Declined, Increased, Stayed the same, No idea.

28 If you indicated that crop production has declined, which, in your opinion, are the main reasons for this decline in crop production?

……………………………………………………………………………………………..

…………………………………………………………………………………………….

29. (CHECK THE ONE THAT APPLIES) Soil infertility, Unreliable rainfall, Pests and diseases Limited land, Lack of improved seed, Lack of agricultural inputs, Lack of knowledge and skills inadequate labor Fluctuating markets/prices Lack of money for inputs Other

30 What do you think are the causes of land-use and land-cover changes in your area?

(RANK ON A SCALE OF 1 TO 5;

5 = least important and 1 = most important).

31 Underlying cause Rank 1 2 3 4 5

Firewood, Charcoal production, Timber, Construction, Agriculture expansion, Bush fires Settlements, Poverty, Population growth, Lack of financial resources, Lack of law enforcement.

Livestock

30 Do you rear any animals Yes………………………….No……………………………..

32 How do you graze your animals?

1Free range, Zerro grazing indoor, Zerro grazing out door……….

33 What is the major source of animal feed?

Buyanimal feeds from shop,……………..Gather grass from the fields

Food Peelings …………Tree cuttings………. Others(specify)……………

Section D Forestry

34 Do you know of any forests in your area? Yes No Name them:___________

35 If YES, how do you think these forests came into existence? Natural Man-made Both

36 What has happened to forest cover in your community over the past 10 years? Increased Declined No change

Section EINSTITUTIONAL

Please fill out the following

Name: ______________________________ Designation: ______________________

37 What are the major Land Use System in Mbale District

Which government institutions are in charge of monitoring land use/cover in the district

- **……………………………………. …………………………………………..**

…………………………………… ………………………………………………………

- What are the weaknesses of institutions in monitoring land use/cover changes?

……………………………………… ……………………………………………………….

- Which government programmes have improved the coverages of land uses and cover type (e.g. operation wealth creation etc)

…………………………………….. ……………………………………………………

- Are you aware of any policies that are in place to monitor land use/cover changes? If yes, name them

……………………………………………………………………………………………

. ……………………………………………………………………………………………..

- Are The policies well enforced, if no, why

……………………………………………………………………………………………

……………………………………………………………………………………………

38 What has been done to ensure proper land use management in this area?

……………………………………………………………………………………………

……………………………………………………………………………………………

39 What is done to people that violet land policies

……………………………………………………………………………………………

……………………………………………………………………………………………

40 What are the Constraints and opportunities of land use/cover trends noted above?

……………………………………………………………………………………………

………Expert recommendation/interventions

THANKYOU

Appendix II: Introductory Letter

KYAMBOGO UNIVERSITY

P. O. BOX 1 KYAMBOGO
Tel; 041-286237/8, 285001, Fax 041-220464, 222464
E-mail:www.kyu.ac.ug.

FACULTY OF ARTS AND SOCIAL SCIENCES
DEPARTMENT OF GEOGRAPHY AND SOCIAL STUDIES

Ref:

Date: 5th/February/2020

To: Mbale District Local Government

Dear Sir/Madam,

RE: REQUEST FOR MINJO SAMALI TO CONDUCT RESEARCH IN MBALE MUNICIPALITY

The above mentioned is a Bonafede student of Kyambogo University perusing a degree of Master of Arts in Geography. She is currently conducting a research entitled; *THE EFFECTS OF CHANGES IN LAND USE TYPES ON NATURAL FOREST VEGETATION ON MT. ELGON AREAS: A CASE OF MBALE DISTRICT*

Mbale District Local Government has been identified as a valuable source of information pertaining to her research project. The purpose of this letter therefore, is to request you kindly avail her with pertinent information she may need.

Any information shared with her from the engagement shall be treated with utmost confidentiality.

We always appreciate your good cooperation.

Yours sincerely,

Barasa

Barasa Bernard (PhD)
Senior Lecturer
Head,
Department of Geography and Social Studies
0701-712526

Appendix III: Permission Letter from the district

MBALE DISTRICT LOCAL GOVERNMENT

Tel: General Line: 045 433401/4
Direct Line: 045 4 33458
Fax: 045 4 33987
Mobile: 0774 330 564
Email: ekachelane@gmail.com

FOR GOD AND MY COUNTRY

THE REPUBLIC OF UGANDA

CHIEF ADMINISTRATIVE OFFICER'S OFFICE
P.O. BOX 931
MBALE

IN ANY CORRESPONDENCE ON THIS SUBJECT PLEASE QUOTE NO: ***CR/164/2***

February 7, 2020

The District Natural Resources Officer,
MBALE.

RESEARCH – MINJO SAMALI

This is to introduce to you the above mentioned who is a student of **Kyambogo University** pursuing a Master of Arts in Geography. As a requirement she is to carry out a research on **"the effects of changes in land use types on Natural Forest Vegetation on Mt. Elgon areas. A case study of Mbale District".**

The purpose of this communication is to introduce her to you for assistance in regard to his research.

CHIEF ADMINISTRATIVE OFFICER
MBALE DISTRICT
07 FEB 2020

Wabomba Anthony
FOR: CHIEF ADMINISTRATIVE OFFICER