LAND USE CHANGES AND THEIR EFFECTS ON MT ELGON FOREST ECOSYSTEM, KENYA

BY

MASAYI NELLY

A Research Thesis Submitted to the School of Arts and Social Sciences, Department of Geography and Environmental Studies in Partial Fulfilment of the Requirements for the Award of Degree of Doctor of Philosophy in Geography

Moi University

2021

DECLARATION

Declaration by Candidate

This thesis is my original work and has not been presented in any other University. No part of this thesis may be reproduced without the prior written permission of the author and/or Moi University.

Signed: ________________________________ Date: __________________

Nelly Masayi

SASS/DPHIL/GEO/010/14

Declaration by the Supervisors

This thesis has been submitted for examination with our approval as University Supervisors.

Signed: ________________________________ Date: ___________________

Prof. Paul Omondi.

Department of Geography,

Moi University,

Eldoret, Kenya

Signed: ________________________________ Date: ___________________

Prof. Mugatsia Tsingalia

Department of Biological Sciences

Jaramogi Oginga Odinga University of Science and Technology

Bondo, Kenya

DEDICATION

This thesis has been dedicated to my sons Sammy Luyali Mayeya, Gian Buyanzi Mayeya and Shawn Bukosia Mayeya. You are the best.

ACKNOWLEDGEMENT

I would like to acknowledge my supervisors Prof Paul Omondi and Prof. Mugatsia Tsingalia for having tirelessly guided me throughout the entire study. I also would like to thank the staff of Moi University and Kibabii University for supporting me throughout the entire work. I also would like to thank my husband Hudson Anyonje and the family of Mr. and Mrs. Peter Masayi for their financial and moral support. I would also wish to thank Mr Tom Esipila, Aggrey Osogo, Francis Muema and Mulati Omukoba for assisting me with data analysis. Special thanks to Martin, Samuel and Juma who helped me in data collection and language interpretation. I would also like to thank the local community who accepted to be interviewed and provide the information needed. Thanks to Esther Kharoya, Ann Nechesa Lutomia, Christine Watai and Carolyne Khandasi Kisika for assisting in taking care of my babies during my period of study.

ABSTRACT

Mt. Elgon forest ecosystem provides the forest adjacent communities with varied ecosystem services**.** Consequently**,** changes in land uses in Mt. Elgon forest ecosystem could lead to a decline in biodiversity and the livelihoods of the forest-adjacent communities. This study assessed land use changes and their effects on biodiversity and livelihoods in the Mt. Elgon forest ecosystem. The study used systems theory to demonstrate the complexity of the interrelationships of variables. Quantitative research approaches were used whereby used in collecting data on floral diversity and by use of questionnaires. Landsat imageries were used to assess land use changes between 1977 and 2019. Drivers of land use changes were determined using questionnaires administered to three hundred and eighty-seven (387) respondents that were purposively sampled from Mt. Elgon forest ecosystem. Effects of land use changes on floral diversity were evaluated using 50m x 50m duplicate quadrats that were placed in different land uses. Impacts of land use change on the forest-adjacent communities livelihoods was determined using questionnaires, Key Informants and Focus Group Discussion. Data collected from satellite imageries were analyzed by applying supervised classification using Arc GIS 10.5. The Shannon-Weiner diversity index and Whittaker beta diversity index was used to determine changes and similarities in floral diversity, while Kruskal Wallis test and chi square test was used to determine differences in species abundances. Questionnaires were analyzed using Statistical Package for Social Sciences (SPSS). Results established that there has been an 18% decline in the natural forests between 1977 and 2019. A similar decline of 15.19% was recorded in bamboo forest. Plantation forests established in the 1990s, have also experienced a 16% decline between in 1999 and 2019. There was a 29% increase in mixed farming, and a 0.13% increase in tea farms. Increase in population was reported by 76.7% of the respondents as the major driver of land use changes. Ninety-one (91) percent of the respondents obtained their livelihoods from the forest and the decreasing natural forest area has negatively impacted livelihoods of the forest-adjacent communities with herbal medicine experiencing the highest decline of 28% followed by timber and fodder. This study established that there were differences in floral diversity in relations to land use changes. The Shannon-Weiner diversity index revealed that control (natural forest) site had the highest species diversity (H=2.07331, evenness=0.884), followed by indigenous plantations (H=1.93962; evenness 0.69957), urban settlements (H=1.85081; E=0.66754), Nyayo Tea Zone (H=1.5324, E=0.56), mixed farming (H=1.43694, E=0.43694) and exotic plantation (H=1.28231, E=0.61612). Whittaker beta diversity index for control site verses urban settlements was (0.5385), indigenous plantations (0.2222), Nyayo Tea Zone (0.1429) while mixed farming and exotic plantations (0.000). Kruskal-Wallis test revealed a statistically significant differences in total number of plant species in the various study sites (H=8.288; P=0.049). Similarly, the results revealed a significant difference between specific plant communities in the study area (H=38.116; P=0.000). Chi square test revealed that the difference in distribution of species communities in different location were insignificant. Results of species diversity analysis show that land use changes may be responsible for changes in floral diversity. There were insignificant differences in the species diversity between the control and indigenous forest suggesting that such a change can restore floral diversity on a proximal time scale. Changes in land uses to NTZ and exotic plantations have led to an increase in herbs and a decline in tree species. Land use changes have significantly impacted floral diversity and livelihoods of Mt. Elgon forest-adjacent communities. The study recommends the use of mixed indigenous plantations to restore floral diversity of Mt. Elgon forest ecosystem

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ACRONYMS AND ABBREVIATIONS

CBD	Convention on Biodiversity Conservation
CBS	Central Bureau of Statistics
E. P	Exotic Plantations
FAO	Food and Agricultural Organisation
FGD	Focus Group Discussion
I.P	Indigenous Plantations
IUCN	International Union for Conservation of Nature
KI	Key Informants
LULC	Land Use Land Cover Change
MERECP	Mount Elgon Regional Ecosystem Conservation Programme
NTZ	Nyayo Tea Zone
NTFPs	Non-Timber Forest Products
PRA	Participatory Rural Appraisal
ROK	Republic of Kenya
SPSS	Statistical Packages for Social Sciences
TM	Thematic Map
UNEP	United Nations Environment Program
USA	United States of America
UTM	Universal Transverse Mercator
WWF	World Wildlife Fund

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Land use is a term used to define the management and modification of natural environment or wilderness into built environment such as settlements and semi-natural habitats such as arable fields, pastures and managed woods (Mungo, 2003). Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover types to produce, and maintain change. Land use changes worldwide have become a global concern because of the negative impacts often associated with them (Lambin and Meyfroidt, 2011). These changes have been increasing at a high rate especially in the past few decades. Land use changes may occur in the form of intensification and extensification in which case one or more land uses expand at the expense of other land use type. Intensification of agriculture, for example, can be at the expense of grazing land, forestry, and settlement (Mungo, 2003).

One of the worrying land use changes is the conversion of forests to other uses. According to (FAO 2015) the global forest area declined by 129 million hectares (between 1990–2015, to just under 4 billion hectares. This includes both tropical and temperate forests. Despite a number of initiatives to reverse forest decline, the world has continued to lose some 15 million hectares of forests annually (Nzeh, 2012). For instance, deforestation over the period 1980-1990 reached 8.2% of total forest area in Asia, 6.1% in Latin America and 4.8% in Africa (Arnoldo, 2000). In the first decade of this century, the rate of deforestation was slightly lower, but still, a disturbingly 13 million hectares were destroyed annually (Nwosu, 2014).

In the period 2000-2005, South America reported the largest net loss of forest of about 4.3 million hectares per year, followed by Africa which lost about 4.0 million hectares annually (FAO 2010). In Australia, land use change from forestry to woodland led to the clearance of half of the forest to agriculture (Corey, 2011). These changes were necessitated by the desire to increase agricultural production to improve the citizen's living standards (FAO 2016). In Brazil, the land use change from forestry to agriculture and livestock keeping were linked to government policies that encouraged plantation agriculture (Garrett *et al.*, 2018).

Dynamics of Land use and land cover (LULC) changes have not been similar in all parts of the world as a result of different driving forces (Berihun *et al*., 2019). The acquisition of natural resources for immediate human needs, often at the expense of degrading environmental conditions is often the ultimate goal of land use change (Foley *et al*., 2005). Many land-use practices are essential for humanity because they provide critical ecosystem services, such as food, fibre, herbal medicines, shelter and freshwater. On the other hand, some forms of land-use changes undermine the ability of the ecosystem to sustain food production, maintain fresh water and forest resources, regulate climate and air quality and ameliorate infectious diseases (Foley *et al*., 2005). Kanianska *et al*. (2014) indicated that changing land-use practices have enabled world grains harvest to double from 1.2 to 2.5 billion tonnes per year between 1970 and 2010. Smith *et al*. (2014) confirmed that globally since 1970's, a 1.4-fold increase in numbers of cattle, buffalos, sheep and goats and a 1.6- and 3.7- fold increase for pigs and poultry, respectively. Land-use changes such as afforestation could be associated with the improvement of atmospheric condition and increase in biodiversity. Pejchar *et al.* (2005) observed that plantation forests play an important role in biodiversity conservation and restoration of forest species and that enhanced biodiversity outcomes are expected with plantations that utilize indigenous tree species.

Although land use change to modern agriculture has been effective in increasing food production, it has also extensively degraded the environment thus gaining a lot of interest because of its role in driving environmental changes (Hosea *et al.*, 2017). One of the worrying land-use changes is the conversion of forests to other uses. Kees and Navin (2010) reported that in the past 300 years, land use changes, for agricultural production and timber extraction, have led to a global net loss of 8–13 million km2 of forest. Gibbs *et al*. (2009) established that across the tropics, between 1980 and 2000 more than 55% of new agricultural land came from intact forests, and another 28% came at the expense of disturbed forests. Despite various initiatives to reverse forest decline, the world has continued to lose some 15 million hectares of forests annually (Nzeh, 2012). For instance, deforestation in the 1980's and 1990's reached 8.2% of total forest area in Asia, 6.1% in Latin America and 4.8% in Africa (FAO 2016). Odada *et al*. (2020) reported that the most significant changes on the earth surface include increased degradation of land, siltation of water bodies, deforestation and extinction of key terrestrial and aquatic species and majority of these changes are mostly associated with over-exploitation of natural resources, extensive land degradation and agriculture.

Africa suffers from extensive deforestation, having lost 34 million hectares from 2000 to 2010 (Earth Policy Institute, 2012). Firewood harvesting and charcoal production are some of the important drivers. In the African Sahel agricultural land use and livestock keeping replaced some of the forested areas (Nkonya *et al.*, 2016). Four sub- Saharan nations Nigeria, Tanzania, Zimbabwe, and the Democratic Republic of the Congo each cleared more than 300,000 hectares per year (FAO 2012).

Maitima *et al.* (2010) The largest conversion of land use in east Africa over the last 50 years has been the expansion of agriculture at the expense of grazing land. Prior to 1950, semi-arid and sub-humid areas were predominantly pastoral with scattered settlement and cultivation. From the 1950s to the present there has been significant transformation of natural forest and grazing land to mixed crop-livestock agriculture. Olson *et al.,* (2004) confirmed that Land scarcity in the highlands of East Africa has led farmers to convert land to agriculture, reducing the areas that are under forest cover. He indicated that during the last few decades, the area under cultivation has more than doubled in East Africa. In Tanzania, Kideghesho (2015) reported a declining trend for forests and other wooded lands. Between 1990 and 2010, Tanzania lost a mean of 403,350 ha per annum. The total loss was estimated to be 19.4% (about 8,067,000 ha) of the forest cover. In this period, Land use changes in Tanzania that led to depletion of forests were associated with population increase, intensification of agriculture and increased demand of forest products (Kideghesho, 2015)). The sectoralization of forestry activities in different ministries and agencies with overlapping mandates, jurisdiction conflicts and confusion have also been blamed for forest depletion.

Kenya is endowed with diverse ecosystems and habitats that are home to unique and diverse flora and fauna (GOK, 2015). This rich biodiversity can be attributed to factors that include a long evolutionary history, the country’s varied and diverse habitat types and ecosystems, diversity of landscapes and variable climatic conditions. Kenya’s indigenous forest canopy is approximately 6.1% (3,467,000 ha). However, the current coverage is very low compared to the globally recommended ten percent (10%). These forests include the high volcanic mountains and high ranges (Elgon, Kenya, Aberdares, Cherangani and the Mau), forests in the western plateau (Kabarnet, Kakamega, Nandi, Trans-Mara), forests in the northern Mountains (Ndotos, Mathews, Leroghi, Kulal, Marsabit), Coastal Forests (Arabuko – Sokoke, Tana, Kayas, coralrag and mangrove forests) and forests located in the southern hills (Taita Hills, Kasigau, Shimba hills Chyulu hills Nguruman). Kenyan forests are biologically diverse and contain numerous local endemic species.

In Kenya, forests are estimated to cover about 6% of the total land-cover, which is below the 10% threshold recommended by the United Nations (FAO 2010). This forest cover is low as compared to forest covers of 55% for Tanzania, 43% Mozambique, 12.4% Uganda, respectively (Mwangi *et al*., 2018). This current coverage is below the globally recommended ten percent (10%) (GOK, 2010). The country's forests decreased by 0.34% (12,050 ha) per year between 1990 and 2000 and a 6.5% (241,000 ha) forest loss between 1990 and 2010 (FAO, 2010). The degradation of the forest has been attributed to various factors that include illegal logging and encroachment on forest land for farming and charcoal-burning (Ongong'a, and Sweta, 2014).

Current land use trends in Kenya's mountain forest ecosystems shows that land uses are changing fast due to natural and anthropogenic processes and this speed of change could have a devastating effects on the environment both locally and globally (Liu *et al*., 2003). The main drivers of these changing land uses vary in different countries. These drivers include; changes in population, institutional changes, changes in development policies, changes in social cultural forces, development of infrastructure, war and environmental changes (FAO, 2016).

The Mau forest is the largest remaining block of moist indigenous montane forest in East Africa (BirdLife International, 2013). The forest covers an area of 400 000 ha (UNEP, 2008), comprising both indigenous and plantation forests. The Mau forest is a major water reservoir and forms the catchment of Rivers Sondu Miriu, Mara and Ewaso

Ngiro, and nine other small rivers (Obare and Wangwe, 1998). At present The Mau complex covers an area of about 270000 hectares (Olang and Kundu 2011). These changes could be attributed to changes in management policy, which led to excisions, boundary alterations and fragmentation (UNEP 2009). Degazettement of forest reserves and continuous widespread encroachment have led to the destruction of over 100 000 ha of forest since 2000, representing roughly one-quarter of the Mau Complex's area (UNEP 2009).

The Aberdares forest is faced with many similar challenges which include the demand for forest goods and services for the city of Nairobi population. The adjacent communities completely destroyed the once luxuriant bamboo forest and only a remnant of the forest remains (Ongugo and Njuguna, 2004). In Mt Elgon forest, the land use changes appear to be fueled by a growing demand for agricultural products that are important for food security and income generation for the forest adjacent communities and the large-scale investors in commercial farming sector.

In Kenya, approximately 2.9 million people accounting for six (6%) of the total current population of 48,000,000 live adjacent to forests on which they depend for livelihoods (Wass, 1995). Such forest-dependent communities include the Ogiek in the Mau and Mt Elgon forests, the Luhya that live adjacent to Kakamega forest, the Kikuyu that live adjacent to Mt Kenya and Aberdare forests and the Sabaot communities that live adjacent to Mt Elgon forest. The resources derived from these forests include, food, fruits, timber for building and construction, thatching grass and medicine. According to Indigenous Information Network (2008), the significance of the Mt Elgon forest resources to the Sabaot, Ogiek and other forest adjacent communities is crucial to their livelihoods. They source their food through subsistence hunting, gathering of wild fruits, honey, thatching materials and medicine from the forest, as well as perform their traditional rituals and religious ceremonies. The forest is also a habitat to flora and fauna of the region. The forest ecosystem is therefore vital to the social and economic functioning of the Mt Elgon region.

The traditional land uses in Mt Elgon forest ecosystem included animal grazing, subsistence hunting and gathering of wild fruits, honey and herbal medicines. However, (Ongugo *et al*., 2012) reported that recent data show that about one quarter of indigenous forest cover has disappeared due to clearance for farming activities. This decline could have had a negative impact on the livelihoods of the forest adjacent communities.

The continued loss of Mt Elgon forest ecosystem requires mitigative measures that will increase conservation and reverse the decline. However, the main challenge is to seek a balance between conservation, sustainable livelihoods and the country's development goals. Scott (1998) reported that forest conservation management strategies are likely to have direct effects on the people's livelihoods and well-being.

One notable effect of unsustainable land use changes in Mt Elgon forest is the drying up of rivers which could turn up to be disastrous for the agricultural sector. These rivers include river Kamukuywa, Kibisi, Sosio, Sit and the transboundary river Lwakhakha. Kenya, being an agrarian country will face serious food insecurity challenges. There is need for urgent actions to identify the nature of land use changes in the study area and the main drivers of land use change. This study sought to analyze and document land use changes that have occurred in the Mt. Elgon forest ecosystem between 197 and 2019. This time frame was preferred because it is during this period that Mt Elgon region experienced severe land use changes due to the first resettlement of the Elgonyi Dorobo from Elgon native land unit to 3686 hectares of land that was located at

Chepyuk on the lower slopes of Mt Elgon through legal notice no 51 of 1974. The resettlements were associated with the development of agriculture adjacent to the primary forest which used to cover the slopes of this dormant volcano. It is also during this period that reliable data is available. The study also analyzed the drivers of land use changes and the effects of land use changes on biodiversity and livelihoods of the forest adjacent community. The research significantly contributes to the body of knowledge and literature on land uses changes, and its effects on biodiversity and livelihoods of the forest adjacent communities.

1.2 Statement of the Problem

In the past a hundred years, there have been major land use changes in East Africa. Between 1900 and 1990 cropland increased by 200 percent at the expense of tropical forests (Gunlycke and Tuomaala, 2011). Rusell *et al* (2017) reported that prior to 1986, this forest underwent a period of significant harvesting and, despite government bans on logging, certain politically-connected private companies where able to gain access up to the mid-1990s. Ongugo *et al.* (2014) indicated that Mt Elgon forest currently covers 1,279 km^2, with cypress and pine plantations accounting for an estimated area of 4,500 ha. The original land uses of the indigenous Sabaot and Ogiek peoples were pastoralism and subsistence hunting and gathering (Waweru, 1974). The sources of livelihood of the forest adjacent communities in terms of food, subsistence hunting, wild fruits, honey, thatching materials, medicine, and traditional and religious activities was the forests (Rusell *et al.*, 2017). Currently the adjacent communities majorly engage in agriculture as a source of livelihood.

In 1973, the government agreed to resettle the Elgony Dorobos from Elgon Native land unit due to cold weather to an area covering 3686 hectares to the lower slopes in an area currently known as Chepyuk. Through legal notice no 51 of 1974 (Simiyu, 2008). Most of the inhabitants had migrated from faraway places. The immigrants influenced the local communities who were primarily livestock herders to be agriculturists. This change in the lifestyle of the people has led to encroachment of the forest for cultivation and exploitation of the forest products (Ongugo, 1996). The second and third phase of the Mt Elgon resettlement scheme was established in 1992. Phase two covered an area of 1741.99 hectares while phase 3 covered an area of 2865.42 hectares (Simiyu, 2008)).

Despite these changes, little has been documented on the changes in land uses and their effects in the Mt. Elgon forest ecosystem. Similarly, there has been very little documented information on drivers of land use changes and effects of these land use changes on biodiversity and livelihoods of the forest adjacent community. Myhren (2007) reported that the levels of degradation and depletion of forest resources in Mt. Elgon has been difficult to quantify, due to poor reporting systems by the Kenya Forest Service and the Kenyan Wildlife Service. The then Ministry of Environment and Natural Resources further reported that, this forest is among the least studied forest ecosystems in the country despite being one of the five national water towers that contains species that are globally threatened (Akotsi and Gachanja, 2004). Mt Elgon forest is catchment for two major rivers, Nzoia and Turkwel rivers. These rivers are a source of livelihoods to millions of people both in Kenya and Uganda.

While it is easy to quantify agricultural production in monetary terms, forest products can be difficult to quantify because many of them are derived in the form of ecosystem services. Change in land uses can lead to a decline in these essential ecosystem services and affect the livelihoods of the forest adjacent community. Some of the ecosystem services include provision of food, medicine and purification of the air. There is a strong link between land use change, persistent poverty and sustainable development (Gerber *et al.*, 2014) and unless this is addressed, Sustainable Development Goals that focuses on protecting future generations will not be achieved. It is against this background that this study investigated land use changes, their drivers and their effects on Mt. Elgon forest ecosystem.

1.3 Objectives of the Study

The main objective of this study was to assess land use changes and their effects on biodiversity and livelihoods of the Mt Elgon forest ecosystem.

1.3.1 Specific Objectives

The specific objectives of the study were:

1. To assess land use changes in Mt Elgon forest ecosystem between 1973 and 2019
2. To determine the drivers of land use changes in Mt Elgon forest ecosystem
3. To evaluate the effects of land use changes on floral diversity of Mt Elgon forest ecosystem
4. To evaluate the effects of land use changes on livelihoods of the forest adjacent communities within Mt Elgon forest ecosystem,

1.4 Research Questions

1. How has land uses changed between 1977 and 2019?
2. What are the drivers of land use changes?
3. What has been the effects of land use changes on biodiversity?
4. What are the effects of land use changes on forest adjacent communities?

1.5 Significance

The beneficiaries of this research include; Kenya Wildlife Service, Kenya Forests Service and Kenya Forest Research Institute. This research will provide them with data on changes in the size of the forest, changes in plant species diversity and consequently the effects of the changes on livelihoods of the forest adjacent communities. Findings of this study are of great significance in policy formulation and implementation aimed at achieving the Sustainable Development Goals.

This will inform users of forest resources on best land use that can limit forest degradation. It will also provide managers and conservationist with information on status of plant species in the Mt Elgon forest. This information could advice on possible conservation measures that could be adopted in the region.

This research will contribute to the body of knowledge and literature on land use changes and its effects on floral diversity and livelihoods of the Mt Elgon forest adjacent communities. Academia could use it as a tool to evaluate and project the future of the Mt Elgon forest. Findings of this study are of great significance in policy formulation and implementation aimed at achieving the Sustainable Development Goals.

1.6 Justification

Mt. Elgon forest ecosystem is endowed with rich biodiversity of renowned global importance (Petursson, Vedeld and Kaboggoza, 2011). It harbours a large number of rare and some endemic Afromontane biota (Mazel *et al*., 2014). Montane forests encompass spectacular landscapes, a wide variety of ecosystems, a great diversity of species, and distinctive human communities. Mountain forests support about one quarter of world’s terrestrial biodiversity and include nearly half of the world’s biodiversity "hotspots (Convention on Biological Diversity, 2010). Referred to as the 'water towers of the world', mountain forest ecosystems cover about twenty-seven (27%) of the world's land surface and directly support twenty-two (22%) of the world's population and provide the freshwater needs for more than half of humanity (Convention on Biological Diversity, 2010). Mt. Elgon ecosystem is a habitat to 37 "globally threatened" species (22 mammals, 2 insects and 13 bird species) and is also home to 9 endemic animals, making the area a priority for species conservation (Makenzi, 2016).

The International Congress on Agriculture and Biodiversity (ICAB) opines that more research is needed to establish the link between agriculture, trade, and its effects on biodiversity (UNEP, 2002). Unfortunately, political instability in the Mt Elgon region has made it difficult for research to be carried out on the Kenyan Mount Elgon region (Masika, 2009). There was urgent need for research on the effect of land use change on biodiversity and livelihoods of the forest adjacent forest adjacent communities.

Previous research carried out in Mt Elgon region focused on trans-boundary biodiversity management challenges and the local and stakeholder perceptions of the management policies and conservation of the various protected areas (Kaboggoza *et al*., 2006). Little has been reported on effects of land use changes on biodiversity and livelihoods of the forest adjacent communities in the Mt. Elgon forest ecosystem.

1.7 Scope of the Study

The study was limited to the Kenyan side of the Mt. Elgon forest ecosystem. The forest ecosystem was studied as a representation of montane forests in the country. In particular, the study was limited to Mt Elgon forest and the wards that are adjacent to the forest. The study focused on land use changes between 1977-2019.

1.8 Limitations to the Study

During fieldwork, the researcher faced various limitations, including:

1.8.1 Bad Weather

Mt Elgon forest reserve lies within the Lake Victoria basin and experiences a modified equatorial climate which is characterized by two rainy seasons. The heavy rains worsened the conditions of the roads and delayed access to study sites. The researcher however used rain coats and umbrella to counter this.

1.8.2 Low literacy level and poor record keeping

Ignorance and low literacy levels of some of the respondents, made it difficult to establish the various land uses carried out between 1977 and 2019. Estimating individual acreage per crop especially for vegetables was not possible since intercropping is quite common for the farmers in the study area and vegetables are grown in small kitchen gardens. The researcher however used approximations to estimate the sizes of land under indigenous vegetables.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Anthropogenic activities are altering the environment at unprecedented rates, and magnitudes. The most important human uses of land globally include cultivation, livestock grazing, settlement and construction, reserves and protected lands, and timber extraction. These land uses are transforming land cover at both local and global scales. The consequences of these changes are significant on biodiversity, ecosystem services and livelihoods.

Over years, land use has been changing and the changes in land use are driven by a variety of factors that vary from region to region. It is evident that land use change has had negative impacts on biodiversity in various regions of the world. However, it is also clear that land use changes have had both negative and positive impacts on the livelihoods of forest adjacent communities in various regions of the world.

2.2 Nature of Land Use Changes

Land use is often associated with economic change given that land is a key and finite resource for agriculture, industry, forestry, energy production, settlement, recreation, water catchment and storage (Kanianska, 2016). In the recent past, land uses have kept changing, for instance transformation of land from forests to agriculture, settlements and urban centres (FAO, 2016). These changes vary spatially and temporally according to specific human-environment interactions (Lambin and Geist,2003).

Despite decades of international conservation efforts, tropical forests are still shrinking to pave way for agriculture (Hansen *et al*., 2013). The loss of these important reservoirs of biodiversity and biomass has numerous repercussions for the provision of ecosystem services (ES) to local, regional and global human populations (Costanza *et al*., 2014; Foley *et al*., 2005).

Geographic Information System (GIS) and remote sensing are powerful and cost-effective tools for assessing spatial and temporal dynamics of Land Use Land Cover Change (LULC) (Lillesand and Kiefer, 2000). Remote sensing data provide important spatial data on the processes and patterns of LULC change, and GIS is useful in mapping and analyzing these patterns (Taubenbock *et al*., 2009).

Emergence of low-cost satellite imageries from Global Land Cover Facility has now made it possible to study the historical LULC data and monitor changes at regular time intervals. Xiaomei and Ronqing (1999) noted that information about change is necessary for updating land cover maps and the management of natural resources. Natural forests in Kenya are among such important natural resources

LULC change has become a major issue of concern with regards to change in the global environment and sustainable development (Yunfeng *et al* 2019). The rapid growth and expansion of urban centres, rapid population growth, scarcity of land, the need for more production, changing technologies are among the many drivers of LULCC in the world today (Cheruto *et al.*, 2016). It is increasingly acknowledged that land-use and land-cover change has become a key subject of concern by researchers and decision makers around the globe that urgently needs to be addressed in the study of global environmental change.

According to Masek *et al*. (2000), land use and land cover changes respond to forces which are largely associated with the high human population such as socioeconomic, political, cultural, demographic and environmental. According to Zubair, (2006), land use and land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. A change in land use and land cover is increasingly rapid, and can cause adverse impacts and implications at local, regional, Journal of Sustainable Development in Africa and global environments (Abate, 2011).

The use of remote sensing data and analysis techniques provide accurate, timely and detailed information for detecting and monitoring changes in land cover and land use. Remote sensing (RS) is a powerful tools in deriving accurate and timely information on the spatial distribution of land use/land cover changes over large areas. According to Lillesand *et al*. (2004), change detection involves the use of multi-temporal datasets to discriminate areas of land cover change between dates of imaging. Thus, the materials used to create spatiotemporal database needed for this study were three sets of satellite imageries. To analyze and quantify the spatial-temporal LU/LC dynamics the GIS and Remote sensing technologies were used. This is because of the fact that Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management.

Land use changes vary across the globe. Karina *et al.* (2021) reported a global net loss of forest area of 0.8 million km^2, but an expansion in global agriculture (i.e. cropland and pasture/rangeland) of 1.0 and 0.9 million km^2, respectively. However, the global trends in land use change conceal many regionally different trajectories. Whereas forest areas in the Global North (including China) have increased, forest areas in developing countries of the Global South have strongly decreased. The North-South difference in gains and losses of forests, is the opposite for global cropland areas, which have decreased in the Global North and increased in the Global South.

Between 1990 and 2016, cropland declined slightly throughout much of the Europe. Hotspots of decline occurred mainly in Eastern Europe (e.g., north- and southeastern Poland, southeastern Czech Republic, southern Romania, northern and central Bulgaria) and the Mediterranean (e.g., central and southern Italy, southern Spain, northern Portugal. Cropland expansion was rare overall, and occurred mainly in the Netherlands, northern Germany, some areas in central France, and Ireland (Kuemmerle *et al*.,2016).

Indonesia has experienced massive land conversion from lowland forests to intensive commercial agriculture (Rudel *et al*., 2009) and reports the second highest rate of deforestation among tropical countries (Margono *et al*., 2012). This expansion generally leads to a decrease in terrestrial carbon stocks, consequently causing higher carbon emissions, along with a loss of biodiversity and changes to hydrological functions.

USGS (2013) reported that the major land use land cover change in West Africa is the loss of forest. The forests of the southern tier countries of Africa have become fragmented and degraded where they occur outside of protected areas. Between 1975 and 2013, forest cover was reduced by 37 percent. Côte d'Ivoire lost 60 percent (22,000 km^2) of its forest in 38 years, Ghana lost 24 percent (4,000km^2), and Nigeria lost 45 percent (9,570km^2). In Guinea, Sierra Leone, and Togo, little remains of the once-extensive forests.

In sub-Saharan Africa, Brink and Hugh (2009) reported a 57% increase in agriculture area at the expense of natural vegetation which has itself decreased by 21% between 1975 and 2000, with nearly 5 million hectares forest and non-forest natural vegetation lost per year. Amsalu (2006) reported that in the Beressa watershed (central Ethiopia), there were substantial land use changes in the area during the second half of the 20th century. The most important changes were destruction of the natural vegetation, increased plantations, and expansion of grazing land. Cropland increased slightly in the 43 years' period. Moreover, Bezuayehu and Geert (2008) reported that the decline of natural forests and grazing lands was due to the conversion to croplands between 1957 and 2001. Olson, Misana., Campbell, Mbonile., and Mugisha, (2004) indicated that during the last few decades, the area under cultivation has more than doubled in East Africa. In Tanzania, FAO (1993) estimates that natural forests decreased by about 12.7% between 1980 and 1990.

Land-use changes have not always led to decline in forested land. For example, in Madagascar, Zaehringer *et al.* (2019) reported that in 1997 and 2012, the establishment of Makira Natural Park and Masoala National Park respectively, led to the closure of large tracts of agricultural frontier, making many local land users to lose current and future access to agricultural land and financial resources associated with agriculture. Particularly in Beanana, secondary forest increased from 0–49.3 ha whereas in Fizono, secondary forest increased from 0.2 to 46.6 hectares between 1990 and 2017. Bamboo forest increased from 0.2 hectares to 0.3 hectares between 1990 and 2017 in Beanana over the same period (Zaehringer *et al*., 2015). The analysis of this study had an overall accuracy of 87% and a producer accuracy of 86%. Allnutt *et al*. (2013) revealed that in Masoala National Park the annual rate of forest change increased from 0.99% during 2005 and 2008 to 1.27% from 2010 to 2011. In Manompana forest corridor, Eckert *et al*. (2011) reported that the annual deforestation rate remained almost stable with 1.07% between 1991 and 2004 and 1.09% between 2004 and 2009. Examining the process and trends of LUCC via quantitative analysis is essential in gaining a deeper understanding of LUCC and help policy makers set improvement targets in specific areas and adopt appropriate practices while also keeping in line with other fields of sustainability.

2.3 Drivers of Land Use Change

Land-use change is driven by a variety of forces. According to Veldkamp and Fresco (1996), land use change is determined by spatial and temporal interaction between biophysical factors (e.g., soil, climate, vegetation and topography) and anthropogenic factors (e.g., population size and density, technology levels, economic conditions e.g. war and government policies, the applied land use strategy, and social attitude and values and demand for agricultural products). Consequently, land-use changes tend to be driven by a combination of factors that work in harmony and happen intermittently (Lambin *et al.* 2001). The mix of driving forces of land-use change varies in time and space, according to specific human-environment conditions.

Driving forces which also referred to as factors, can be categorized as natural and human induced were recognized in the study area. The natural factors in the study area include high intensity of rainfall and steep relief (Benin and Pender, 2001) and soil types as well as Climate change are also driving forces for land use/land cover change. Among the straightforward identified human causative factors includes Population growth and density, over intensification of land use, Farm size, Land tenure status and Lake of Policies on land use.

The twentieth century has been a century of unprecedented population growth and economic development. According to the United States Census Bureau, the global population was 2.5 billion in 1960; 3.5 billion in 1975, 5 billion in 1999, 6.5 billion in 2006 and 7.8 billion in 2020. The rate of increase of world population is alarming as it creates increased demand for food, shelter, clothing and other life-supporting needs.

Turner (1995) confirmed that rapid growth of human population has been identified as one of the drivers of land use change. This is because the increase in food production is often associated with increased pressures on water, forests, soil and air.

Rapid population growth and development has occurred unevenly throughout the world leading to unsustainable land use practices and land degradation. According to Mohanty (2009), India accounts for 18 percent of world population, and is growing at 1.93 percent per annum. Increase in population in India has led to changes in land use, increase in toxic chemicals released into the environment and depletion of natural resources. According to Mishra (2002), population density in India, has had significant impacts on agricultural intensification over the decades which has led to unsustainable agricultural and industrial practices.

Other demographic factors that influence land use changes include age and gender of members of the household. Older male household heads exhibit a greater inertia to change than younger ones, family status and the size of the household. Single (and frequently female) heads of households have different outlooks and life expectations than those married and with many children (Briassoulis, 2000). The demographic status of the household is therefore a significant determinant on the type of land use employed by the individual.

A growing body of literature attests to the inequity between men and women in terms of access to decision making relating to resource management, land use and climate change negotiations (Peach, 2011). Despite the increase in the participation of women at policy forums, and in forest resource negotiations, women's voices in the decision process in matters pertaining land uses at local and national levels remains limited (Hemmati and Röhr 2009). Villamor *et al.*, (2013) reported that in in the tropical forest margins of Jambi, Indonesia, the probability of changing land use for a male is 33 % and the average probability of changing land use for a female is 17 % in the lowlands while the average probability of changing land use for males is 70 % and 51 % for females in the uplands.

The relationship between population increase, economic development and land use changes has generated research interest over two and half decades. Population increase within urban systems creates adjustment and readjustment of human and land use activities in space, which causes lateral and structural land use changes. Lambin *et al.,* (2001) reported that at longer timescales, both increases and decreases of a given population have a large impact on land use. Kanianska *et al.,* (2014) reported that migration in its various forms is the most important demographic factor causing land-use change at timescales of a couple of decades. Migration operates as a significant driver with other non-demographic factors, such as government policies, changes in consumption patterns, economic integration, and globalization (Aladjadjiyan, 2012). Some policies on land-use change either provoke or are intricately linked with increased migration (Lambin, 2008)

Mitra *et al.,* (2011) reported that changes in the distribution of urban-rural population, and the impact of rapidly growing cities on ecosystem goods and services are likely to become dominant factors in land-use changes in future, be it in major urban or peri-urban areas or in remote hinterland or watershed areas.

Land-use changes are influenced directly by political, legal, economic, and traditional institutions and by their interactions with individual decision-makers (Lambin *et al* 2003). Access to land is structured by local and national policies and institutions. These institutions play a critical role in determining the distribution and access to land resources. Land users differ in their ability to participate in and to define these institutions. Land use changes and associated negative environmental consequences are often a result of poorly-defined policies and weak institutional framework, agricultural production and widespread illegal exploitation (Lambin and Geist, (2007).

Land ownership and tenure are also influential factors that drive land use changes. In individual land ownership, decision-making differs from land that is communal or under State ownership (Briassoulis, 2000). Other influential institutional factors include national, and international environmental and resource policies and regulations that govern nature conservation, pollution control, spatial planning and development policies (Briassoulis, 2000). Equally important are economic, financial, and social policies and institutions that affect the availability of capital, finance, labour, level of profitability, institutions associated with factors of production and their respective markets.

It is therefore critical that institutions that influence land management decisions are built around stakeholder participation and concern for the environment. In Mt. Elgon forest ecosystem, it is now clear that government policies and institutional factors could be key drivers of land use changes. In Nigeria, Government efforts towards the provision of infrastructure and direct land allocation through various agencies at the state levels caused major land use changes (Bello and Arowosegbe, 2014). Bello and Arowosegbe, (2014) further reported that there have been a series of illegal structures and non-conformity of development with original designs of the government of Nigeria.

In total, between 1990 and 2010, Kenya lost 6.5% of its forest cover or around 241,000 ha (FAO 2010). The degradation of the forest has mainly been attributed to various factors which include illegal logging, encroachment on forest land for farming and charcoal burning.

Ongugo *et al.* (2014) reported that one quarter of indigenous forest cover in Kenya has disappeared due to clearance for farming activities. He indicated that there has been considerable forest disturbance and further deterioration, degradation and deforestation is continuing at an alarming rate through cultivation and other human activities mostly by communities from outside the area who have invaded the forests.

Socio-cultural and economic factors can also act as drivers of land use change. Cultural factors influence consumption behaviour of the society and determine the kind of crops grown by communities. Other Cultural factors that drive land use changes include information technology, biases and taboos. Production of a given land unit depends on the knowledge of the resource manager, local taboos, the availability of appropriate technology, and the willingness of the local culture to accept the proposed land use changes (Briassoulis, 2000). The motivations, collective memories, personal histories, attitudes, values, beliefs, and individual perceptions of land users influence land-use decisions, sometimes to a very large extent.

The socio-cultural characteristics of land owners are also influential; they include education, place of living (urban vs. rural), employment status (single or multi-employment), attitudes, values, and personal traits (e.g., perception of problems of alter indigenous uses of land, of external influences on land and its productivity (Lambin and Geist 2007). Other social cultural factors influencing land use change include immigrants who buy or lease land from the indigenous communities. These processes are intimately linked to agricultural intensification and rural immigration. Weber *et al.* (2007) showed that, the impact of migrants on deforestation is mostly indirect, as they tend to buy land from locals, rather than to cut the forest themselves. As a consequence, locals either replace the land sold, opening new plots for agriculture or agro-forestry, or move on to new forest frontiers (Joerg *et al.*, 2007). Socio-cultural factors could also be drivers of land use change and degradation of Mt Elgon forest ecosystem.

Numerous cultural factors also influence decision-making on land use. Land managers have various motivations, collective memories, and personal histories. Their attitudes, values, beliefs, and individual perceptions influence land-use decisions, for instance through their perception of and attitude towards risk. Culture is often linked to political and economic inequalities, e.g., the status of women or ethnic minority that affect resource access and land use. Understanding the controlling models of various actors may thus explain the management of resources, adaptive strategies, compliance or resistance to policies, or social learning and therefore social resilience in the face of land-use change (Lambin *et al.*, 2007).

Economic considerations are critical land-use determinants as von Thunen's "land rent theory" emphasizes (Briassoulis, 2000). The cost of transportation to the market and the cost of buying input could influence the choice of land use changes. The anticipated profits often depend on the demand for the goods and services associated with a given land-use type. Changes in demand trigger changes in land use as they affect the associated profits. Profits are also determined by other factors such as cost (and availability) of labour, capital, and primary inputs (raw materials), the prices of final products and services associated with a particular land use, and state support (price supports, subsidies, tax exemptions, various economic incentives). Finally, the size of the parcel and the competition from other (usually, neighbouring) land parcels affect the expected profits and, hence, the land-use change decision. In cases of keen competition, small parcels are usually the first to be bought out by strong land development interests.

Agriculture can be considered as a key driver of land use change. Most populations across the globe rely on agricultural products as a source of livelihood and raw materials for industrial use. In particular, most cash crops provide the farmer with more income and are good options where food crops do not thrive well. Similarly, in cases where soil nutrients have declined, it is possible for household to alter the land uses so as to meet their livelihoods. A sharp rise in selling price of agricultural lands on the pretext that the country should develop industrially has resulted in serious land use changes (Bello and Arowosegbe, 2014). Farm units are considered drivers of most land-use change decisions, as agriculture is often the most extensive use of land. In Australia, land use changes were necessitated by the desire to increase agricultural production to improve the living standards (Miller and Roots, 2012).

Boateng (2021) indicated that increased economic values let to the increase in land allocated to cultivation of cash crops such as cotton, tobacco, rice, and vegetables in Ghana during colonial period at the expense of bushland. Kanianska (2016) confirmed that the dramatic growth and globalization of China's economy and market since economy reforms in 1978 had brought about a massive loss of croplands, most of which were converted to urban areas and transportation routes during 1978–1995. Waswa *et al*., (2009) have also reported that sugarcane is now the widely grown commercial crop, having replaced indigenous crops like cassava and vegetables, despite their ecological suitability and high nutritive and income value in Nzoia sugar belt in Kenya.

2.4 Effects of Land Use Changes on Biodiversity

Land use changes are some of the key factors that affect biodiversity across the globe. They are the greatest cause of biodiversity loss (Diego and Newbold, 2020). Biodiversity performs key ecosystem services and if correctly assembled in time and space, can lead to sustainable agro-ecosystems (Young and Young, 2010). Biodiversity therefore, underpins all ecosystem processes and is the foundation of Kenya's rich natural heritage.

Biological diversity is being irreversibly lost through various land uses such as monocultures, habitat fragmentation and degradation, destruction of natural habitats, pollution, over-exploitation, and introduction of exotic species. Agricultural encroachment, grazing, poaching, deforestation and forest degradation are often identified as major environmental threats to the forest ecosystem (Svein *et al*., 2002).

Land use changes alters biodiversity at various levels. Reduced habitat from land use change decreases population size and reduces genetic diversity within a species (Hansen *et al.,* 2012). In Catolonia, Stefanescu *et al.* (2011) established that land use intensification is responsible for declines in generalist butterfly species in lowland regions.

Agriculture as a land use affects biodiversity in various ways. Increasing productivity and cultivation requires more land for cultivation; more water for irrigation, and more chemical fertilizers and pesticides that lead to pollution of the environment and destruction of habitat for many species thus leading to their death. Changes to the management of land (e.g., grazing regime) also have large direct impacts on biodiversity (McGovern *et al.,* 2011). Intensification often leads to an increase in nitrogen supply, as a result of atmospheric deposition as well as direct fertilizer application. This leads to an increase in soil fertility and increased dominance of plants adapted to high-nutrient soils, which often out-compete other species.

Similarly, the pressure to increase crop production in many countries have led to an expansion of land dedicated to agriculture and intensification of agriculture through practices such as irrigation, use of inorganic fertilizers and synthetic pesticides (Oldfield *et al.,* 2019). These practices have resulted in degradation of soil properties and water quality, acceleration of soil erosion, contamination of groundwater and decline of food quality. This has prompted sustainable intensification initiatives to increase yields on existing farmland while decreasing the environmental impact of agriculture (Wang ,2014).

The greatest impact of agriculture on biodiversity arises from clearance of land for cultivation (World Wildlife Fund, 2017). Agricultural expansion is the most dominant driver of habitat loss, which, combined with unsustainable forest management, contributes to the greatest cause of species loss (Population Action International, 2011). While land uses such as monoculture farming involves more investments in inputs and technology to increase yields, such practices often involve encroachment on other forms of land such as forests, steep lands and wetlands (Netondo *et al*., 2010). UNEP (2002) noted how 16^{th} century Spanish and Portuguese colonists began converting land in Latin America to large-scale cultivation of crops. This led to a decline in indigenous plant species and crops such as maize. Intensive agriculture, as currently practiced in Europe, is centred on monoculture with minimal indigenous species (CBD, 2010).

Commercial sugarcane farming completely transformed large tracts of land especially in the coastal regions north and south of Durban, South Africa (Cheesman, 2006). According to Netondo *et al.* (2010), commercial sugarcane farming has been practiced in western Kenya for nearly forty years and is associated with loss of natural vegetation and cropland. Pereira *et al.* (2012) the major human impacts on biodiversity to date are probably through land use changes and habitat loss

The unsustainable use of natural resources and overexploitation, which occurs when harvesting exceeds reproduction of natural flora and fauna, continues to be a major threat to biodiversity (CBD, 2010). For many centuries the world‘s forests have been under pressure from expanding human population mainly through deforestation (UNEP, 2001). This has led to a serious decline in animal species. Vitonset *et al*. (2007) opined that human use of land has altered the structure and functioning of the ecosystems. The most spatially and economically important human use of land globally include cultivation, construction, reserves, protected lands and timber extraction (Turner *et al*., 2007).

Elephants, leopards, impala had by mid-1970s virtually disappeared from Mt Kilimanjaro due to heavy disturbance and encroachment on the forest for agriculture, logging and other human activities (Mbonile *et al.,* 2016). Mbonile *et al.,* (2016) further reported that encroachment on forests has led to decline in hunting and game meat in the region. On the other hand, Myhren, (2007) reported that poaching is one of the most serious threats to biodiversity and to sustainable development in Kenya. It is not clear whether human encroachment on Mt Elgon forest and poaching have led to the decline in animal species in Mt Elgon region.

Habitat fragmentation, the emergence of discontinuities (fragmentation) in an organism's preferred habitat, causes metapopulations and ecosystem decay. In most countries, habitat fragmentation is caused by increase in human population. Households often subdivide the pieces of land making the farms too small to sustain agricultural productivity. Habitats which were once continuous become fragmented. Gutierrez *et al.* (2019) reported that habitat fragmentation and habitat loss have the greatest impact on biodiversity in human-dominated landscapes where the natural vegetation has been replaced by crops and concrete.

One of the major ways that habitat fragmentation affects biodiversity is by reduction in the amount of available habitat for organisms. Habitat fragmentation invariably involves some amount of habitat destruction. Plants and other organisms in these areas are usually directly destroyed. Mobile animals retreat into remnant patches of habitat. This can lead to crowding effects, competition, inbreeding and human wildlife conflicts. Deforestation and habitat fragmentation have increased drastically in developing countries in the last 50-100 years, seriously threatening tropical forest ecosystems resulting in biodiversity loss (Lung and Schaab, 2009). Little is known on how depletion of biodiversity impacts livelihoods of the forest adjacent community.

During the past 25 years, there has been considerable concern about the depletion of natural resources and biodiversity. According to the Millennium Ecosystem Assessment (MEA 2005), major habitats including forests, grasslands and coastal zones have been heavily impacted by various land uses leading to degradation**.** If ecosystems continue to be too small or isolated, they may stop providing us with valuable services such as food and freshwater**.**

The Mt Elgon ecosystem houses a rich and unique fauna and flora. There are 37 globally threatened faunal species (22 mammals, 2 insect, and 13 bird species, of which 9 species are endemic), making the area a priority for species conservation (Muhweezi *et al*., 2007). The renowned dominant tree species include Elgon teak, cedar, Podocarpus spp., rosewood, and others. Intriguing and unique plants include giant groundsel, giant lobelia, and giant heather. This study will mainly focus on the effects of land use change on floral diversity of Mt Elgon forest ecosystem.

2.5 Effects of Land Use Change on Community Livelihoods

Many indigenous plants are harvested for food, animal feed, and fibre. For example, sesame, Bambara nuts and indigenous vegetables have traditionally been important foods in many cultures. Indigenous trees and shrubs are also harvested for firewood, and as wood for building or pulp for paper products. Some indigenous plants are used as medicines in many cultures and in pharmaceutical industries. Land use changes have the potential to interfere with essential ecosystem services such as medicinal benefit, purification of the air, provisioning of food such as wild fruits and tubers and timber for building and construction.

Indigenous plants are valuable to human cultures for recreational and spiritual uses. Historically, indigenous Americans used black ash (Fraxinus *nigra*) tree to make baskets for both functional and ceremonial purposes. Today, many people in Africa appreciate a wooded park-like setting for camping, picnics and other family gatherings. Among the Luhya community of western Kenya, forests are utilized as important cultural sites for circumcision ceremonies and worship.

Despite the important services provided by forests, land use changes may interfere with the livelihoods of the forest-dependent communities. FAO (2004) reported that the expansion of land under sugarcane in Swaziland has led to a decline in the community livelihoods which includes timber and game viewing in the savannas. IUFRO (2005) reported that forest ecosystem services are generally ignored until the negative human consequences of their disruption highlights their loss. Currently, the capacity of tropical forests to sustain and improve livelihoods has declined (Githae *et al*., 2007).

Gautam (2008) reported that in Bangladesh, land use changes to build up areas affected rural economy and changed the livelihood pattern of the residence. On the Contrary, Kamwi *et al.* (2015) indicated that land use changes in Zambezi region, Namibia led to an increase in forest cover. This in turn led to a change in livelihood coping strategies and these strategies included piecework, food aid, borrowing from relatives and wild food collection.

In Myanmar, Schneider *et al*. (2020) reported that land-use changes include deforestation, creation of large monocultural plantations (oil palm, maize, rubber), special economic zones and increasing presence of NGOs concerned with the conservation of Myanmar's forests, which belong to the biodiversity hot spots. Schneider *et al*. (2020) further reported that compared with the 1990's, when the landscape in northern Tanintharyi was predominantly under forest and shifting cultivation, land-use changes have led to the decline in the availability of essential ecosystem services such as biodiversity, water, regulation of microclimate, wild plants, wood fuel and livestock while a few have increased (mainly commercial crops such as cashew, rubber, betelnut and lime). Land-use changes are therefore very complicated since increase in agricultural land would reduce the availability of non-timber forest products, firewood and increase global greenhouse gases. On the contrary, it greatly increases the availability of financial resources to the land users.

Kenya on the other hand is highly dependent on natural resources through the services they provide provisional, ecological, social and cultural services. Provisional services include food, water, raw materials and medicine which have direct economic value. Ecological services include both regulating and supporting functions associated to indirect use social and cultural services such as aesthetic and recreational (Nahuelhual *et al*., 2007). Forest are an important repository of food and other resources that can play a key role in contributing towards food security (Sunderland, 2011).

Albinus *et al*. (2008) indicated that land-use practices in the Mara and Sio River basins included the transformation encroachment on forest and wetland areas for agricultural purposes. The land use change had multiple, negative impacts upon life-support functions of terrestrial ecosystems (including water resources), human well-being (including health), economic livelihoods, societal development, vulnerability and security.

Kisiwa *et al*. (2013) noted that there was enhanced use of Mt Elgon forest for game meat during dry months. Firewood was extracted by children more during the months of July, August, November and December. This is consistent with suggestion by Cooke *et al.,* (2008) that collection of certain resources such as fuel wood is predominantly undertaken by children and women in most rural communities' dependent on environmental resources for their livelihoods.

Other sources of resources acquired from Mt Elgon forest include medicinal plants, fruits. Mt Elgon forests supports up to 2 million people, whose livelihoods and economic activities are largely dependent on the forest ecosystem goods and services of the highlands. Land use change in Mt Elgon forest ecosystem could interfere with these resources that form part of the livelihoods of the forest adjacent communities.

2.6 Theoretical and Conceptual Frameworks

2.6.1 Theoretical Framework

The study used systems theory advanced by von Bertalanffy (1901-1972). Systems theory demonstrates the nature and complexity of the interrelationships and shows the multivariate nature of variables such as land use, biodiversity and community livelihoods. Systems theory offers prospects of a theoretical integration of physical and human aspects. In the system theory, reality is regarded as a collection of elements that influence one another, a unit of interacting entities or a network of relationships. The theory was used to assess the nature of land use changes and integrate various factors that drove land use changes in the study area. The drivers of land use include; demographic factors, socio-cultural factors, institutional factors and economic factors. Demographic factors included, change in population of the household, age and gender of household head, family status and size of the household. Socio-cultural factors included consumption behaviour, biases and taboos, personal histories, attitudes, values, beliefs, education, place of living of household head (urban vs. rural), and personal traits (e.g., perception of problems of altered indigenous uses of land, of external influences on land and its productivity (Lambin and Geist 2007)). Other social cultural factors influencing land use change included migrants who buy or lease land from the indigenous communities. Economic factors included transportation cost to markets, sources of primary farm inputs, demand for the goods and services associated with a given land-use type, size of land parcel and employment status of the household head. Institutional factors included policies and laws governing land use in the study area, role of local authority, governmental and non-governmental organization.

Similarly, system theory was used to link the effects of land use change on biodiversity. Effects of land use change on biodiversity mainly focused on change in plant species diversity. Similarly, this theory was used to link the effects of land use change on livelihoods of the forest adjacent communities.

2.6.2 Conceptual Framework

The conceptual framework focuses on the effects of land use changes on Mt Elgon forest ecosystem (Figure 2.1). DPSIR is short for Driving forces, Pressures, State, Impacts and Responses. Within a short time, the DPSIR framework has become popular among researchers and policy makers alike as a conceptual framework for structuring and communicating policy relevant research about the environment. According to the DPSIR framework there is a chain of causal links starting with 'driving forces' (economic sectors, human activities) through 'pressures' (emissions, waste) to 'states' (physical, chemical and biological) and 'impacts' on ecosystems, human health and functions, eventually leading to political 'responses' (prioritization, target setting, indicators). Describing the causal chain from driving forces to pressure, state, impacts and responses is a complex task.

Driving forces are the factors that cause changes in the forest ecosystem. Sometimes referred to as indirect or underlying drivers or driving forces and refer to fundamental processes in society, which drive activities having a direct impact on the environment. They can be social, economic or ecological and can have positive or negative influences on pressures. In Mt Elgon forest ecosystem, the drivers of land use change include demographic factors (increase in population and migrations, economic factors (increased profits and high demand for forest products and agricultural products), socio-cultural factors (consumption behaviour, biases and taboos, personal histories, attitudes, values, beliefs and political instability) and institutional factors (influence by local authorities, non-governmental organization and government policies). Natural factors that drive land use change include, climate variabilities, change in soil fertility and pests and diseases. Natural factors could also have contributed to land use changes in Mt Elgon forest ecosystems and eventually to the degradation of the Mt Elgon forest ecosystem.

Pressures are the human activities that directly affect the ecosystem and are generated by the driving forces. In Mt Elgon forest ecosystem, the drivers of land use change often lead to processes such as forest encroachment, deforestation, overgrazing, logging and overexploitation of forest resources. For instance, unsustainable charcoal burning may lead to clearing of forested land. One of the most recurrent synergies is, for example, population increase, leading to a pressure on the use of land, leading to deforestation and forest degradation, in turn leading to biodiversity loss, climatic variability and poverty. This is one vicious circle difficult to cope with and to reverse (Nkonya *et al*., 2011).

State is the condition of the system at a specific time and is represented by a set of descriptors of system attributes that are affected by pressures and the type, degree and rate of land degradation (Weldemariam, 2018). As a result of pressures, the 'state' of the environment is affected; that is, the quality of the various environmental compartments (forest species composition, air, water, soil quality,) in relation to the functions that these compartments fulfill. In Mt Elgon forest ecosystem, state involves the degradation of Mt Elgon forest ecosystem. This state of the environment occurs as a result of pressures that include forest encroachment, deforestation, overgrazing, logging and overexploitation of forest resources. Increased pressure is often connected with deterioration of the state of environment.

Impacts are commonly the result of multiple stressors and effects on the forest ecosystems produced by a pressure. Impacts related to Mt Elgon forest degradation are reduction in abundance of floral species, change in floral species diversity, change in floral population size and species distribution and impact on ecosystem services. The affected plant species that could decline may include indigenous plant species that are endemic to the region. All in all, Forest degradation has serious consequences for food security and livelihoods of the forest adjacent communities. In Mt Elgon forest ecosystem, the affected livelihoods included wood products (wood fuel products, timber products), edible products (indigenous fruits and indigenous vegetable) and medicinal products. The study determined the extent to which these livelihoods (wood fuel, timber, edible products and medicinal products) are affected by changes in land uses in the study area.

Responses are the efforts made by communities and government as result of the changes manifested in the impacts. As directed actions, responses typically take the form of programme activities, such as the number of inspections done, training programs, forest conservation efforts, changes in land policies, commitment to international conventions and monitoring and early warning systems. Mt Elgon forest ecosystem, the response measures included introduction of afforestation programs, the creation of Buffer zone, introduction of on farm forestry and development of forest protection and conservation policies.

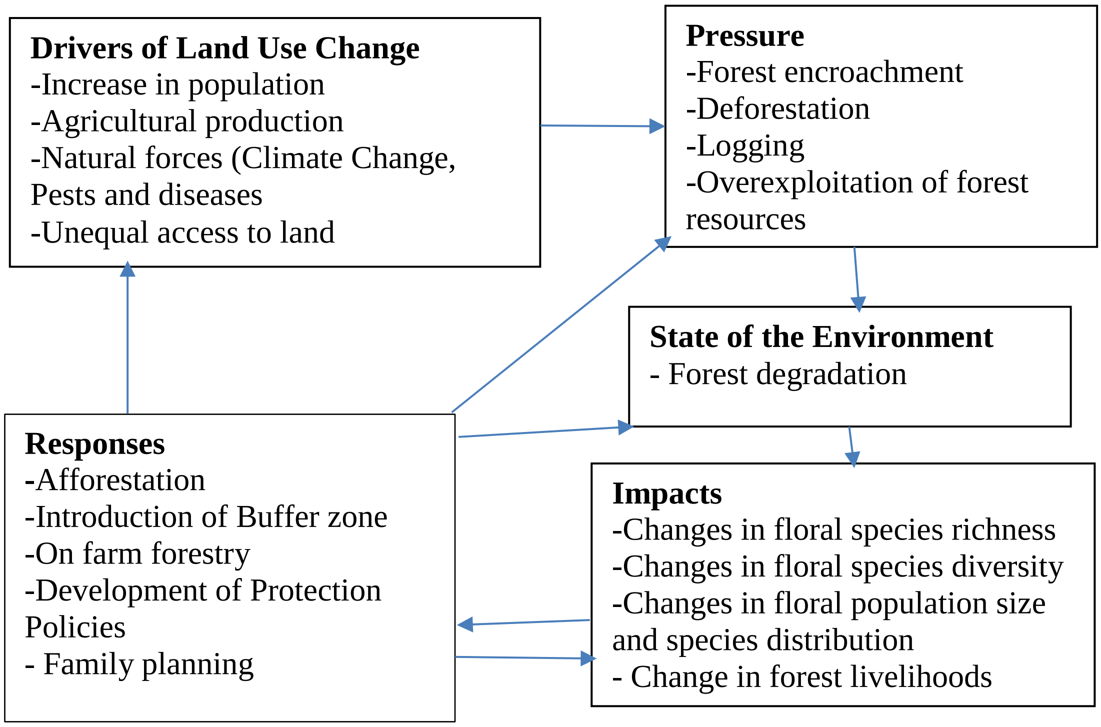

Figure 2.1: Conceptual framework on impacts of land use changes on Mt Elgon forest ecosystem in form of a DPSIR (Drivers, Pressure, State, Impacts, and Responses) scheme, adapted from EEA (2000)

(Source; Researcher 2017)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the research design, the location of the study sites, the study population, sample and sampling techniques, data collection instruments, data collection procedure, and methods of data analysis.

3.2 Study Area

Mount Elgon forest is a transboundary ecosystem located in North-western Kenya and Eastern Uganda. In Kenya it is surrounded by Bungoma County (Cheptais, Kapsiro, Kapsokwony and Kaptama divisions) to the south and Tranzoia County (Saboti, Endebess divisions) to the east. On the Ugandan side, Mbale district is to the south-eastern part, Sironko district to the west and Kapchorwa district to the north. This study mainly focused on Kapsokwony, Kapsiro, Kaptama and Cheptais divisions of Bungoma County (Figure 3.1).

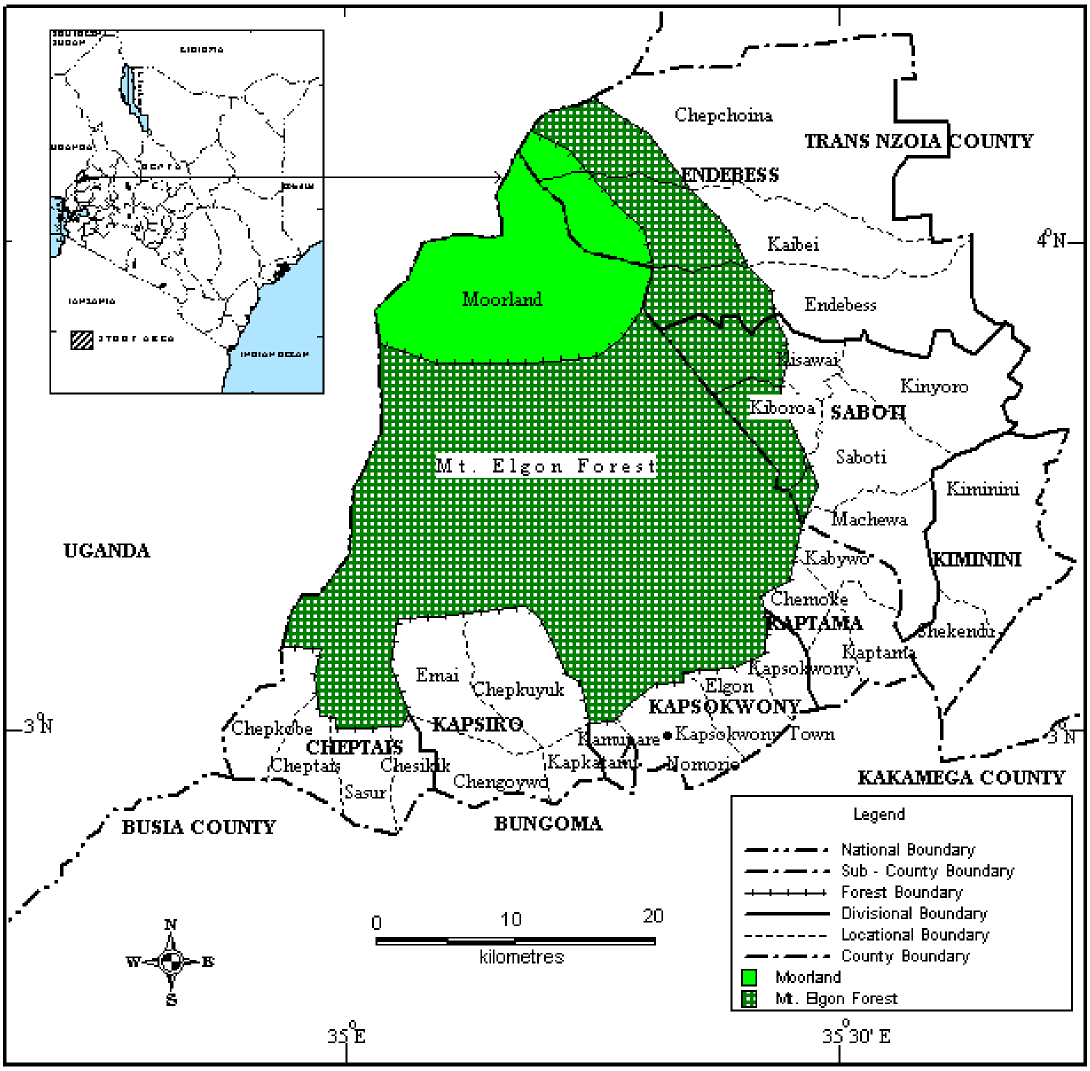

Figure 3.1: Map of Mt. Elgon ecosystem and Adjacent Regions.
(Source: Moi University Geography Laboratory)

Mount Elgon Ecosystem is located approximately 150 km northeast of Lake Victoria. It lies at latitude 1° 08’ N and 34°45’E. The climate of Mt Elgon forest ecosystem is moist to moderate dry. The region receives a bimodally distributed rainfall, with the wettest months occurring from April to October (van Heist, 1994). Rainfall amounts change with altitude where the upper slopes receive relatively heavier rainfall compared to low lying areas.

It receives an annual precipitation of 1280 mm with a minimum of 1000mm per annum and a maximum of 2000mm per annum. The region also receives a minimum and maximum temperature of 9°c and 22°c respectively. The dry seasons run from June to August and from December to March, although it can rain at any time. The forest zone receives the maximum rainfall of ranging from 1400–1800 mm (Masau *et al.,* 2014) and plays an important role as a water catchment for millions of people (Kisiwa *et al.,* 2013). The soils are poorly drained dark peaty loams, ranging in colour from reddish brown to black. They are shallow with rock outcrops (Ongugo *et al.,* 2001).

Mount Elgon's vegetation is grouped into four altitudinal zones (Howard 1991): mixed montane forest up to an elevation of 2500 m; bamboo and low canopy montane forest from 2400–3000 m; high montane heath from 3000–3500 m; and moorlands above 3500 m. The majority of the plant species are found between 2000 and 3500 meters above sea level (Vedeld *et al.* 2005), with changes in topography, slope, aspect, rainfall and soil causing variations in vegetation composition. Common resources from Mount Elgon include firewood, timber, ropes, poles, bamboo shoots, vegetables, honey, bush meat, fruits, medicinal herbs and grass (Sassen and Sheil, 2013). Out of a total area of approximately 772,000 ha, 221,000 ha has been set aside as reserves and national parks (IUCN 2007).

Juniperus procera, Hagenia abyssinica, Olea welwitschii, O. hotstetteri, Prunus africana, Podocarpus falcatus and *P. latifolia* dominate the moist tropical forest. Moorlands, swamps and rocks form a major part of the afro-alpine zone.

3.3 Research Design

The study adopted mixed designs which included cross-sectional survey and evaluation design. Cross-sectional survey design was used to evaluate the nature of land use changes in the study area. The study analyzed Landsat imageries between 1977-2019. The Landsat imageries were obtained from the United States Geological Survey (USGS website) available at https://earthexplorer.usgs.gov/. Landsat imageries were selected because, they provided global coverage on a regular basis and they are available for free, they are less expensive in terms of time, money and effort and Landsat image archive date back to 1973. Dating back to 1973 made it possible to document land use changes that have occurred, while the fine spatial resolutions of Landsat images provided the spatial details necessary for characterizing many of the changes arising from both natural and anthropogenic disturbance. Landsat time series stack interval of 10-20 years was used. This interval was selected as a compromise between data cost and the necessity to minimize possible omission errors. The images used path 170 row 59 that cover the study area.

The images were downloaded from Enhanced Thematic Mapper, Thematic mapper, and Multispectral scanner (MSS). After downloading, band 1234 for Thematic Mappers and band 12345 for Enhanced Thematic Mapper were used because these captures vegetation very well which is near infra-red portion of the electromagnetic spectrum. The images went through the process of geo-referencing, clipping and compositing. Clipping was done to ensure it covers the study area only. Image classification was done in seven classes and the classes included; Natural forests, Plantation forests, Bamboo forests, Tea farming, Mixed farming, Grasslands, and Fallow land. Other minor land uses such as settlements were too small to be identified on the Landsat. Classification was done per the year 1977, 1986, 1999, and 2019. Change analysis was run based on this interval and this created time series maps. These maps were able to show changes in the various land uses and how these had impacted on the natural forest. An accuracy assessment via ground truthing was done to create change maps. This process was done using Arc GIS version 10.5.

Cross sectional survey design was also used to determine the drivers of land use change in the study area. This involved the analysis of data collected by use of questionnaires and Key informants (Appendix 2). Cross sectional design was also used to assess the effects of land use changes on floral diversity. This was achieved by use of random quadrats, 50mx50m that were established in the forest in areas under different land uses and were separated by 100m.The first set of quadrats were established adjacent to the Nyayo Tea Zone (NTZ). The second set were placed adjacent to site under indigenous plantations and exotic plantations plantation forests. The third set were placed adjacent to the site under urban settlements (Chepkitale), the fourth under mixed farming while the fifth was placed in the control site (Labot). The Labot control site was selected on the basis that it relatively did not have an influence of man. Plant species were then recorded to determine their diversity and abundance in each land use. Shannon Weiner diversity index and Whittaker beta diversity index were used to determine changes and similarities in floral diversity, while Kruskal Wallis test and chi square test was used to determine differences in species abundances. In particular, the abundance and diversity of herbs, shrubs, tree, ferns sedge and grasses were computed. It was then easy to clearly compare the changes in plant species and abundance and decide the extent to which each land use affects the plant species diversity.

Evaluation research design was used to assess the effects of land use changes on adjacent community's livelihoods. This was achieved by evaluating changes in land uses shown on the Landsat imageries with changes in the use of forest products that are a source of livelihoods to the forest adjacent community as given in the questionnaires (appendix 1). The specific livelihoods that were analyzed included, forest, farming, government employment, private employment, business and charcoal burning. The specific resources that were acquired from the forest included fodder, wood fuel, herbal medicine, timber, wild vegetables, wild fruits and ornamental products.

3.4 Data Collection

Data for this study were collected from Mt Elgon forest ecosystem and communities living in adjacent administrative units (Cheptais, Chesikaki, Chepyuk, Kapkateny, Kaptama, Elgon, Forest, Saboti and Endebess). These wards were purposively sampled because of their key influence and proximity to the forest ecosystem. Data from these wards was very important in establishing the land use changes and effects of land use change on biodiversity and the livelihoods of the forest adjacent communities. In particular respondents were asked to fill a questionnaire that would provide information on the changes that have occurred in land uses and how these changes have affected biodiversity and livelihoods of the forest adjacent communities (appendix1). Questionnaires were built basing on the researcher's background of the study area. To ensure validity of the testing instrument experts in the field of study including university professors checked at the items in the questionnaires and agreed that the testing instrument was a valid measure of the concepts that were being measured. To ensure reliability of the questionnaires, twenty questionnaires were pretested in Chimuche ward adjacent to Malava forest and the Cronbach alpha value was 0.81 was considered good. The questionnaires produced same results on three repeated trials. The results showed a satisfactory level of construct validity and internal consistency of the questionnaire. Secondly**,** assistants and interpreter were recruited locally to minimize the suspicion towards an outsider intruding their personal space. Similarly, each statement on the constructed questionnaire was reviewed by experts who were university professors in the field to determine the extent to which it is appropriate (Nachmias and Chava, 2002).

The study adopted Yamame (1967) formula used by Israel (2013), Singh and Masuku (2014). A total of 387 respondents were chosen as the desired sample size. Purposive sampling was used to identify members of each ward to be interviewed that was proportionate to 2019 population census. The sample size of each ward was calculated by taking the population of the ward as a fraction of the total population and multiplied by the sample size (Table 3.1).

The sample size was calculated as follows;

$$n = \frac{N}{1+N\,(e)^2}$$

Where n- Sample size

N-Population size

e- Level of precision

Table 3.1: Population and Area of Sampled Wards

	Bungoma County		
Ward		**Total Pop**	**Sample Size**
Cheptais	41.5	28639	26
Chesikaki	39.6	23874	22
Chepyuk	94	25329	23
Kapkateny	48.1	28628	26
Kaptama	66.3	33402	30
Elgon	55.6	31476	28
Total	**618.2**	**171348**	**155**
	TransNzoia County		
Ward			
Saboti	323.6	166,482	150
Endebess	680	91,192	82
Total		**257,674**	**232**
Total Population		**429,022**	
Total Sample Size			**387**

(Source: KNBS 2019)

The sampled respondents included were house hold heads both male and female aged fifty years and above and had lived in the region for more than thirty years.

3.5 Data Collection Techniques

The study was preceded by a reconnaissance survey of the Mt Elgon forest ecosystem. The reconnaissance ensured familiarization with the areas of study, making necessary logistical arrangements with respondents and local authorities, and the collection of background information.

3.5.1 Assessment of Land Use Changes between 1977 and 2019.

Data for objective 1 was collected from both primary and secondary sources. Primary data was collected by use of satellite imageries. To analyze the nature of land use changes between 1977 and 2019, satellite imagery was used. In Kenya, the earliest Landsat satellite imagery available dates back to 1972. However, for this study, the imageries for 1973 had dense cloud cover and thus, the earliest imagery used was Landsat Thematic Mapper for 1977. The Landsat 1-2 Multi Spectral Scanner (MSS) satellite image that was used was taken on 28th December 1977 and had (Path/Row 170/59). The image had a resolution of 60m. In this image, the MTL.txt file was used in classification and analysis. The file utilizes all the bands that is Band 4(Green with wave length 0.5-0.6), Band 5(Red with wavelength 0.6-0.7) and Band 6 and 7 (Near Infrared) with wavelength 0.7-0.8 and 0.8-1.1 respectively.

Other images used included the Landsat 4-5ThematicMapper ™ for 1986 and 1999 taken on 18th March 1986 and 17th December 1999 respectively. For the (1986 and 1999 images,) an image (Path/Row 170/59) was used. It consists of seven spectral bands with a spatial resolution of 30 meters for Bands 1 to 5. Jensen, (1996), indicated that Landsat

TM satellite images are a good tool for mapping vegetation. Table 3.2 show the bands of Landsat 4-5 that were used in this study.

Table 3.2: Bands of Landsat 4-5 Thematic Mappe**r (TM)**

Band	Wavelength	Resolution (Meters)	Useful for mapping
1, Blue	0.45-0.52um	30	Vegetation Mapping
2, Green	0.52 to 0.60um	30	Emphasizes peak vegetation, which is useful for assessing plant vigor
3, Red	0.63 to 0.69um	30	Discriminates vegetation on slopes

(Source: USGS website)

For the 2019 Landsat image, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) images (Path/Row 170/59) were used. It consists of eight spectral bands with a spatial resolution of 30 meters for Bands 1 to 7. In this image, the bands that were of use were band 2-5. According to ESRI (2013), the best bands for mapping vegetation is colour infrared (band 5, 4, 3). Seventy points obtained in the field with a Garmin etrex30x Global positioning Systems (GPS) were used to identify various land uses. Table 3.3 shows the bands and resolutions of Landsat 7 Enhanced Thematic Mapper Plus (ETM+) that was used in this study.

Table 3.3: Bands of Landsat 7 Enhanced Thematic Mapper Plus (ETM+)

Landsat 7	Wavelength (micrometers)	Resolution(meters)
Band 2, Blue	0.52-0.60	30
Band 3Green	0.63-0.69	30
Band 4, Red	0.77-0.90	30
Band 5, NIR	1.55-1.75	30

(Source: USGS website)

Landsat imageries for the year 2009 could not be used because majority of these imageries had strips that would distort the findings of the study. To obtain the best quality of the satellite data, the images were from the dry season, totally or at least almost cloud free. The downloaded satellite images from https://earthexplorer.usgs.gov/ had the global reference system World Geodetic System 1984 (WGS84) and the projection Universal Transverse Mercator (UTM) 37N. Since the study area is located in western Kenya, the data was projected from UTM 37N to UTM 36N.

Landsat time series stack interval range of 10-20 years were used so to enable the detection of critical changes in the forest, such as clear-felling, conversion of forest land into tea farming, mixed farming, plantation forests or conversion of grassland and bamboo to agricultural land. In addition, ground truthing was carried out for several points.

3.5.2 Determination of Drivers of Land Use Change

Data on objective 2 were collected using questionnaires, Focus group discussions (FGD), interviews with Key Informants (KI) and secondary data. Questionnaires were used to determine the drivers of land use change between 1972 and 2019 (appendix 1). Purposive sampling was utilized to ensure equal weighting of respondents from all divisions and villages. The questionnaires included questions on possible drivers of land use change such as; demographic factors (change in population size of a household, age and gender of household head, family status and size of the household), economic factors (amount of profit and availability of ready market), socio-cultural factors (consumption behaviour, personal histories, beliefs, education, place of living of household head and external influences on land), and institutional factors which include; influence by local authorities, non-governmental organization and government policies.

To validate data by questionnaires, two Focus Group Discussions comprised of ten members who included Chief, Assistant Chief, Traditional Medical Practitioners, and village elders was held. In total, two focus groups were carried out. The Focus Group Discussion sought to establish information on land use change and drivers of land use change from 1977.

Interviews were carried out on various stakeholders who included county agricultural officers, county environment officers, chiefs and assistant chiefs, National Environmental Management Authority (NEMA), Kenya Wildlife Service (KWS) and Kenya Forest Research Institute (KEFRI). The interviews sought to identify and analyze the main drivers of land use change in the study area. Secondary data was obtained from documented information obtained from Bungoma and Transnzoia County Ministry of agricultural offices, Ministry of livestock offices, Kenya Forest Research Institute, Kenya Forest Service, journal texts, newspapers, magazines, and government reports relating drivers of land use change.

3.5.3 Determination of the Effects of Land use change on floral diversity

Data for this objective 3 was collected by use of both primary data and secondary data. Primary data was collected by use of quadrats and observation, while secondary data was collected from existing literature.

Three random quadrats, 50mx50m separated by 100m were established in areas under different land uses. The first three quadrats were established in the Nyayo Tea Zone. The second set of quadrats were placed in indigenous plantations and exotic plantations at Kaberwa. The third set of quadrats were placed urban settlements at Chepkitale, the fourth quadrats were placed in area under mixed farming in at Bugaa village in Kapsokwony ward while the fifth set was placed in the natural forest and acted as a control. The control site was located at Labot in Kaptama ward where there were very minimal anthropogenic activities and hence, very minimal land use change. All plant species in each quadrat were recorded to determine their abundance, diversity and evenness in each land use. The location of each land use was mapped by use of a Global positioning System (GPS).

Observations were made on status on land use covers and vegetation types both within the forests and areas adjacent to the forest. Accessible areas of the forest such as Chepkitale and Labot villages were visited and the vegetation cover and plant species diversity recorded. This data was captured by use of a 20.1 Mega pixel, Wide 5x zoom Nikon camera.

3.5.4 Evaluation of the impacts of land use change on livelihoods of the forest adjacent communities

Questionnaires were used to collect data on impacts of land use change on the livelihoods of the forest adjacent community. The livelihoods that were of interest to the researcher included: the use of herbal medicine, timber, wood fuel, fodder, indigenous fruits, indigenous vegetables, game meat and ornamental products. To evaluate impacts of land use changes on these livelihoods, the respondents who were household heads and who had lived in the area for more than thirty years were asked to list their sources of livelihoods. To add on this, the respondents were asked to list the benefits that they acquired from the forest starting from the 1977 to 2019. They were then asked to note the changes that have occurred in the acquisition of this land uses and the reasons for the changes in the benefits that were acquired from the forest. In cases where some benefits had declined, they were asked to indicate the alternative ways of meeting for the declined livelihoods.

Observations were made on status the status of vegetation cover and livelihoods of the local community. Accessible areas of the forest such as Kaberwa were visited by the help of forest guards from Kenya Forest Services and livelihoods such as the use of herbal medicine were captured. Observations were also made on the local markets such as Kapsokwony and Cheptais to capture data on the use of wood fuel, herbal medicines and timber. This data was captured by use of a 20.1 Mega pixel, Wide 5x zoom Nikon camera.

To validate data obtained from questionnaires, two Focus Group Discussions comprising of ten members were constituted. The FGDs were constituted at Chepyuk and in Endebess. The Focus Group discussion comprised of two community leaders, two village elders, two old women and four old men. The selected people were adult male and female aged above fifty years and had lived in the region for more than fifty years. This age group was selected to ensure that the participants had information on land use change and its effects on livelihoods of the local community from 1977. In particular, FGD was used to provide information on observed land use changes in the study area, the divers of land use changes and the communities source of livelihoods. To add on that FGD was also used to provide information on the various community livelihoods that are obtained from the forest.

Interviews with Key Informants were carried out on various stake holders who included Nyayo Tea Zone management, Survey of Kenya, Bungoma County ministry of Agriculture and Livestock, National Environment Management Authority, County Environment officers, Kenya Forest Research Institute, Chiefs, Assistant Chiefs Kenya

Wildlife Service (KWS) and Kenya Forest Service representative (appendix 2). The interviews sought to identify rules and regulations governing the use of forest livelihoods and the changes that have taken place in the utilization of forest livelihoods.

Secondary data was obtained from documented information obtained from Kenya Forest Research Institute, Kenya Forest Service, journal texts, newspapers, magazines, and government reports and libraries of institutions of higher learning such as the Moi university and Kibabii University.

3.6 Consideration of Ethical Issues

The study involved volunteering of personal, confidential and sensitive information from the respondents. The identity of the respondents was protected by including confidentiality clause. The respondents were informed about the purpose of the study prior to the commencement of the interview. The major ethical issues that were addressed by the study included informed consent, privacy and confidentiality, anonymity and researchers' responsibility (Oso and Onen, 2005; Streiner, 2005; Mugenda and Mugenda, 1999).

3.6.1 Informed consent

The participants of the study were provided with adequate information about the study. Some of the information that was supplied to them included the purpose of the study; the expected duration of participation and the procedures to be followed; the benefits of the study to them and the country at large and the extent of privacy and confidentiality to be maintained. This information was the basis upon which the selected respondent made informed decision whether or not to participate in the study.

3.6.2 Privacy and Confidentiality

The study respected privacy of the respondents and maintained confidentiality of all data collected to the extent agreed between the two parties. Some of the data that was collected in the study area were private and confidential as it related to the operations of various activities such as those carried out by traditional medicine practitioners' that are used to gain competitive edge. Some of the data involved illegal activities such as burning of charcoal in the forest. Therefore, all data collected and analyzed was used for the purpose for which the study was undertaken and was not divulged to unauthorized persons.

3.6.3 Anonymity

Following from the need to maintain privacy and confidentiality, the research refrained from collecting data that pertains to the identity of the respondents. Where cases had to be discussed, real names of the respondents were not used.

3.6.4 Researcher's responsibility

The researcher took the responsibility to only collect and analyze data that addressed the objectives of the study.

3.7 Data Analysis and Presentation

Data analysis for objective one involved pre-processing of the Landsat images. This involved various steps which included clipping and compositing. The administrative state boundary map for the area of study were also brought to Universal Transverse Mercator project in zone 37 and later the satellite imageries were clipped with the administrative boundary of Mt Elgon forest and the adjacent region (Figure 3.1) The different False Colour Composite (FCC) of the Mt Elgon region for the different stated periods were prepared. The preparation ensured that the pixel grids of the images of the year 1977 conform to the corresponding images of the year 1986, 1999 and 2019, hence enabling pixel by pixel comparison of the images.

A supervised multispectral classification was performed using Arc GIS 10.5 to distinguish between the six possible classes which included natural forests, planted forests, monocultural tea farming, mixed farming, grasslands, bamboo forest and fallow land. Classification was done per images of 1977, 1986, 1999 and 2019. Change analysis was run between the 1977 and 1986, 1986 and 1999 imageries, and 1999 and 2019 imageries which created change maps. These maps showed the changes that have occurred over the periods under study. An accuracy assessment via ground truthing was done from the change maps so as to verify any land use that may not be clear. The detection of changes involved the comparison of satellite images taken in different years in 1977, 1986, 1999, and 2019 and the creation of change maps for the same periods.

Data obtained by use of questionnaires (objective 2 and 4) was analyzed by use of SPSS. The analysis involved the calculation of the frequency of number of respondents who indicated that a specific factor was a driver of land use change. Similarly, SPSS was used to determine to determine the frequency of a certain factor that was indicated to be a source of livelihood by the forest adjacent community. Similarly, the frequency of number of respondents who relied on the Mt Elgon forest for livelihoods was also identified and converted into percentages.

Data on Objective 3 were analyzed Kruskal-Wallis test and Chi square test of homogeneity. Kruskal Wallis test was used because the data used failed the normality test based on Kolmogorov test for normality. Kruskal-Wallis test was also used to determine the difference in total number of species in various locations and difference in varieties of species (trees, shrubs, herbs, ferns, and climbers) between the different land uses. Chi square test of homogeneity was used to test difference in distribution of species in different location. The Kruskal Wallis test (H and P) values were examined and where $P \leq 0.05$, the difference was termed as significant. Variations in species diversity index, evenness was analyzed using Shannon-Weiner Diversity Index, will the similarity index among species in areas under different land uses were analyzed using Whittaker beta diversity index. This land uses included, exotic plantations, indigenous plantation, mixed farming and urban settlements. Ranking of species diversity and similarity was done to determine the variation in floral diversity index in areas under each land use in comparison to the floral diversity index of the control site.

SPSS was also used to calculate if there was a statistically significant differences in total number of plant species in the various study and if there was a significant difference between specific plant communities (trees, shrubs, herbs, ferns, and climbers) in the study area. This was done by use of Kruskal-Wallis test. Similarly, SPSS was used to test difference in distribution of species communities in different location by use of Chi square test of homogeneity.

Data was presented in the form of diagrams, time series maps, tables, bar graphs, and photographs. Time series maps displayed various changes in land uses as from 1977, 1986, 1999 and 2019. Tables and bar graphs displayed drivers of land use changes, and effects of land use changes on biodiversity and community livelihoods. Photographs were used to display the various land uses in the study area, drivers of land use and effects of land use on adjacent community's livelihoods. Descriptions were used to present qualitative data.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter is a presentation of the results of the study on the effects of land use change on biodiversity and livelihoods of the Mt Elgon Forest ecosystem. This chapter is organized along the specific objectives. The data analyzed in this chapter include data on changes in the various land uses between 1977 and 2019. Secondly this chapter reports the findings of the analysis on the various drivers of land use change and ranks the drivers in terms of their greatest effect. The chapter also provides the analyses of the effects of land use change on biodiversity. Particular emphasis is on how floral diversity and abundance varies in relation to land use changes. The land uses analyzed include: undisturbed Control Site, urban settlements (Chepkitale), mixed farming, indigenous plantations, exotic and plantations. The chapter further reports on the analyses and discusses the effects of land use changes on livelihoods of the forest adjacent community. The livelihoods that were of interest in this chapter include the use of herbal medicine, timber, wild fruits, wild vegetables, wood fuel, and ornamental products.

4.2 Land Use Changes between 1977 and 2019

Results for the year Landsat image for 1977 revealed that natural forest was the dominant land use/ land cover in the Mt Elgon forest ecosystem accounting for 36% (n=671.37 km^2) of the total land area. Grasslands were the second most dominant land use with 28.23% (n=525.35km^2). Bamboo accounted for 16.6% (n=309.7km^2) of the land use while fallow land and mixed farming accounted for 17.68% (n=328.9km^2) and 1.2% (n=25km^2) respectively. Figure 4.1 shows the sizes of land under various land uses in 1977.

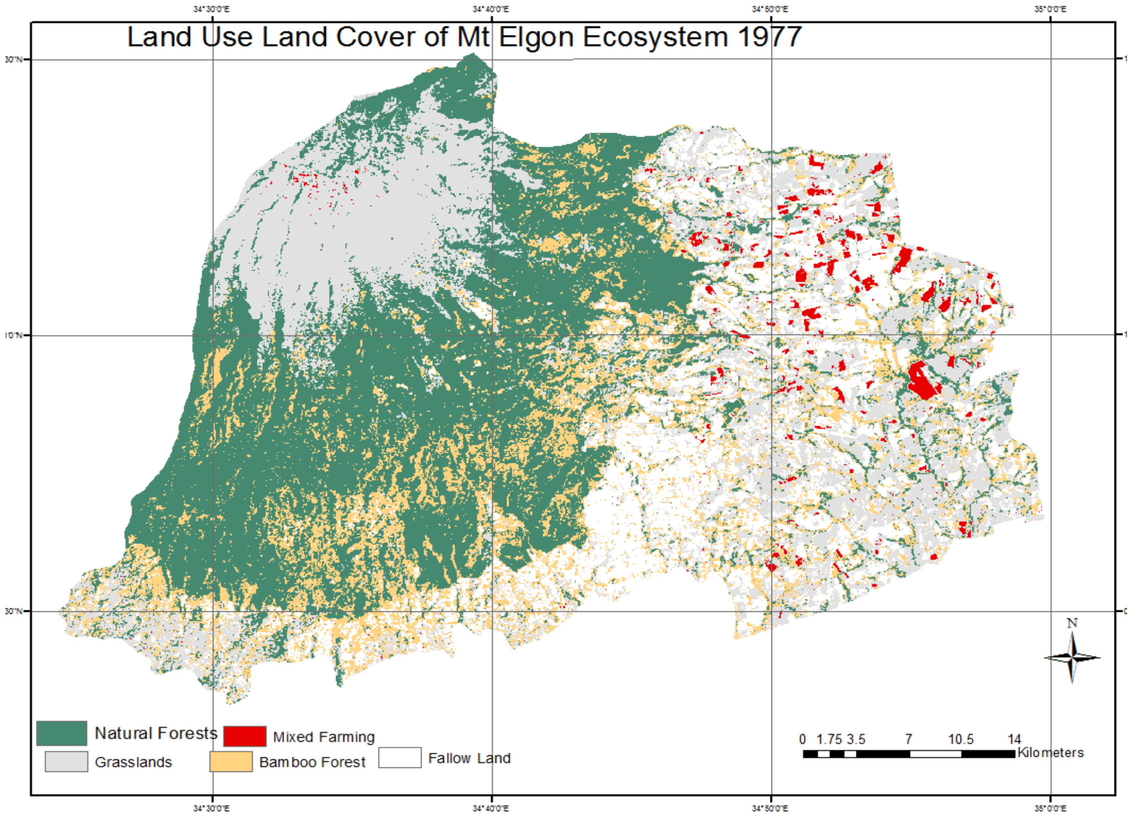

Figure 4.1: Land Use/Land Cover of Mt Elgon Forest Ecosystem, 1977

Land uses and land cover in the study area for year 1986 included, natural forests, mixed farming, bamboo forests and grasslands and fallow land. Other observed minor land uses included settlements, mining and bee keeping.

The major land use in 1986 was natural forest. It covered an area of 31.07% (n=578.11km^2) of the total land area. In our study, the total size of land under study was 1860km^2. Grasslands occupied about 29% (n=546.52km^2) of the land. Domestic animal grazing was mainly done in grasslands that were located within the forests, in areas adjacent to the forests, and on the upper parts of the mountains (moorland). Moorlands occupy about 145km^2 accounting for some (27%) of the grasslands (Table 4.1). Figure 4.2 show the classification of land uses in 1986.

Table 4.1: Trends in Land Use Land Cover between 1977 and 2019

Land Use	1977		1986		1999		2019	
	Area (Km^2)	% Area	Area (Km^2)	% Area	Area (Km^2)	% Area (Km^2)	Area (Km^2)	% Area
Natural Forest	671.37	36.08	578.11	32.13	381.77	19.91	336.88	18.08
Planted Forest	-	-	-	-	407.67	21.89	120.44	6.46
Grasslands	525.35	28.23	546.52	29.37	360.75	18.51	282.89	15.18
Bamboo	309.72	16.64	101.79	2.17	85.22	4.58	27.12	1.46
Mixed Farming	25.39	1.36	235.42	12.65	561.19	30.14	570.76	30.63
Tea	-	-	-	-	1.81	0.1	2.42	0.13
Fallow Land	328.93	17.68	398.94	21.44	62.39	3.35	520.27	27.92

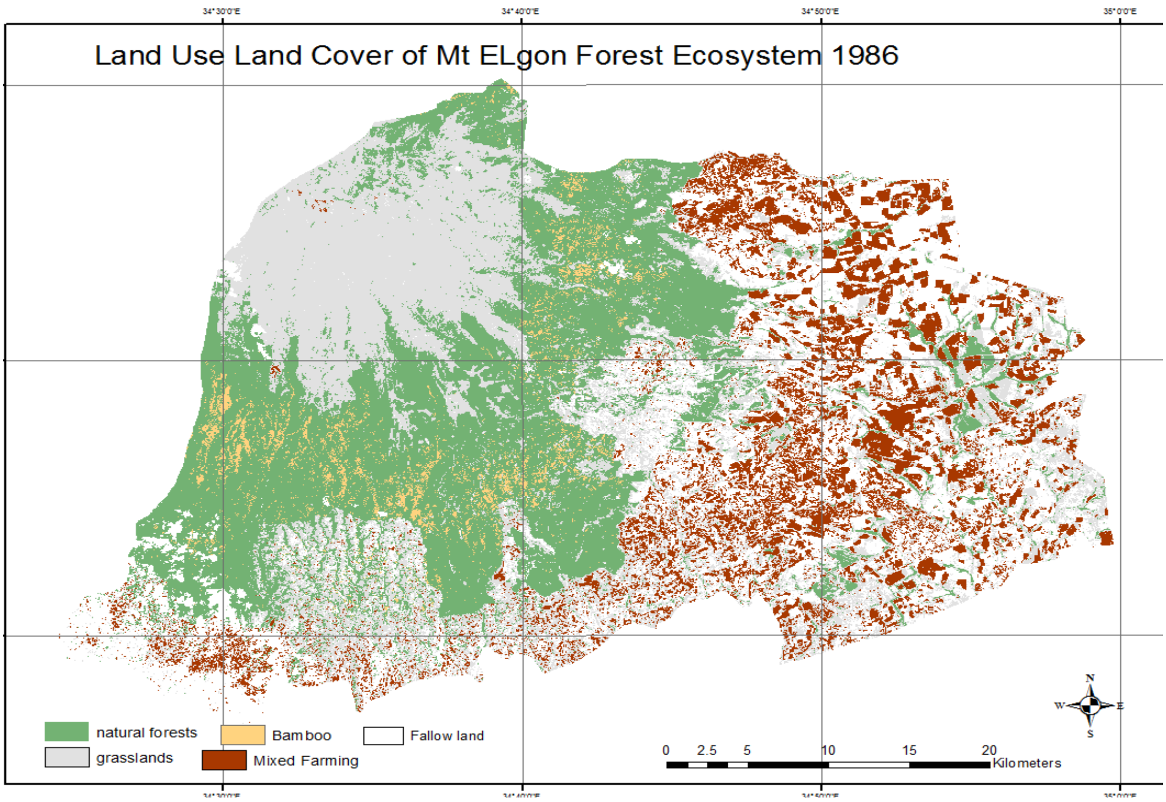

Figure 4.2: Land use in Mt Elgon Ecosystem in 1986

Research findings established that in 1986, fallow land and mixed farming occupied 21.44% (n=398km^2) and 12.65% (n=235km^2) of the Mt Elgon forest ecosystem respectively. It was practised in areas adjacent to the Mt Elgon forest (Table 4.1). Bamboo forests occupied about 5.46% (n=101.79km^2) of the total land area. Bamboo was mainly used as a habitat for the large herbivores such as elephants that were dominant in the region.

The results further showed that there were major variations in the size of land allocated to particular land use and land cover as well as the number of people practising the specific land use. The land uses that experienced a decline between 1977 and 1986 were bamboo and natural forest. The highest decline of 11.18% was reported in bamboo forest from 16.64% (n=309km^2) in 1977 to 5.46% (n=101.79 km^2) in 1986 while natural forest experienced a 5% decline from 36% (n=671.37km^2) to 31% (n=578.11km^2). The highest increase of 11.29% was noted in mixed farming from 1.36% (n=25.39km^2) in 1977 to 12.65% (n=235.42km^2) in 2016. Fallow land showed a slight increase of 3.76% from 17.68% (n=328km^2) in 1977 to 21.44% (n=398km^2) in 1986 while grasslands experienced the least increase of 1% from 28.23% (n=525.35km^2) in 1977 to 29.37% (n=546.52km^2) in 1986 (Figure 4.3).

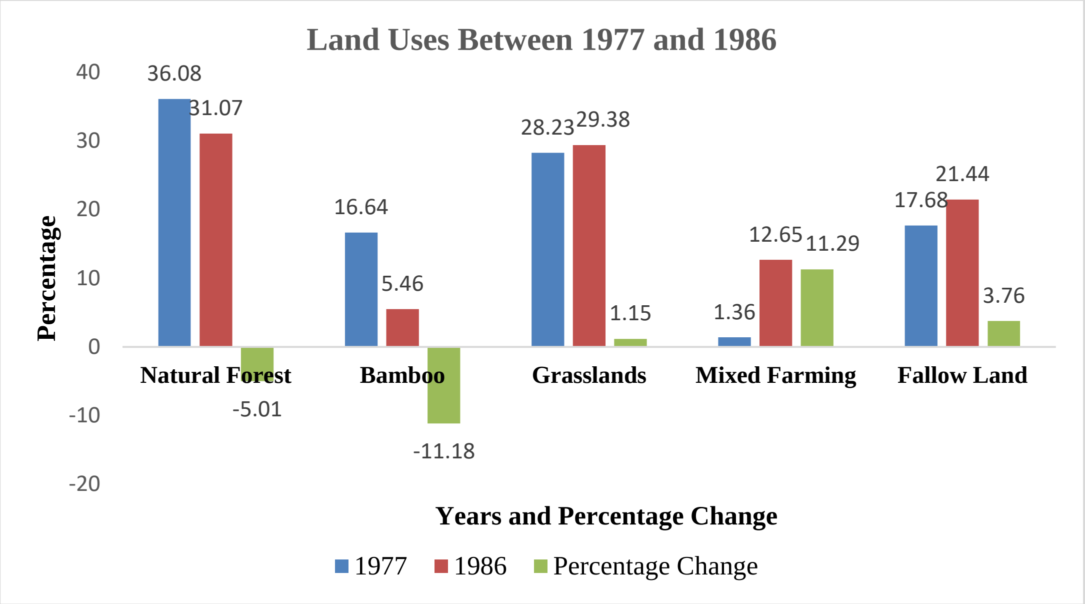

Figure 4.3: Percentage change in size of land under different Land Uses between 1977 and 1986

Further analysis on 1977 and 1986 revealed that 120.33km^2 (17.9%) of area under natural forest was transformed to grasslands between 1977 and 1986. About 30.61km^2 of natural forest was transformed into fallow land. Similarly, 10.16km^2 of natural forest was transformed into mixed farming over the same period. (Figure 4.4). Changes were also noted in the size of land under grasslands. About 138.28km^2 of grasslands were transformed into fallow land between 1977 and 1986. Some 93.32km^2 of bamboo forests was transformed into grasslands over the same period.

Similarly, 89.88km^2 of grasslands were changed into mixed farming over the same period. Some 27.83km^2 of bamboo were transformed into mixed farming between 1977 and 1986 while some 69.02km^2 of bamboo was transformed into fallow land over the same period (Figure 4.4).

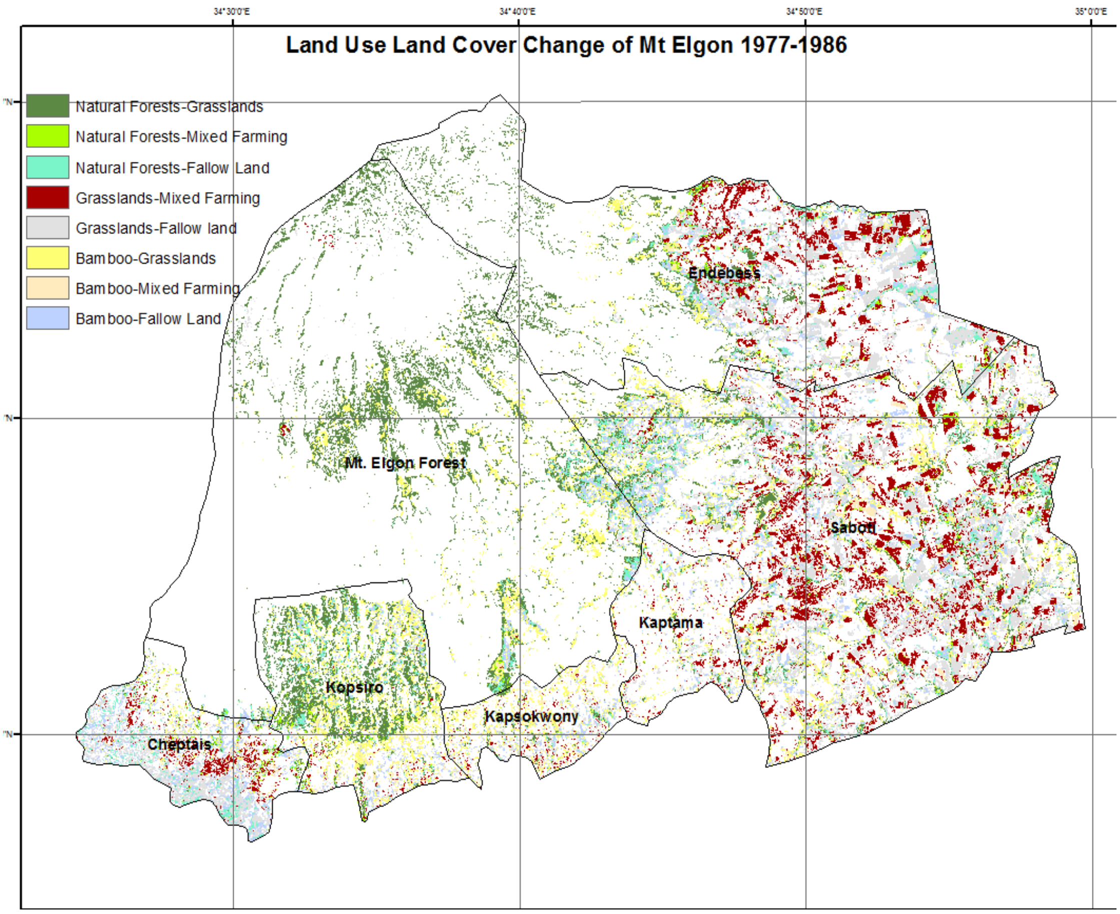

Figure 4.4: Change Map for Mt Elgon forest Ecosystem Between 1977-1986

Findings from Landsat Image of 1999 established that in addition to the 1986 land uses, plantation forest and tea farming were the added land uses to the Mt Elgon ecosystem (Figure 4.5).

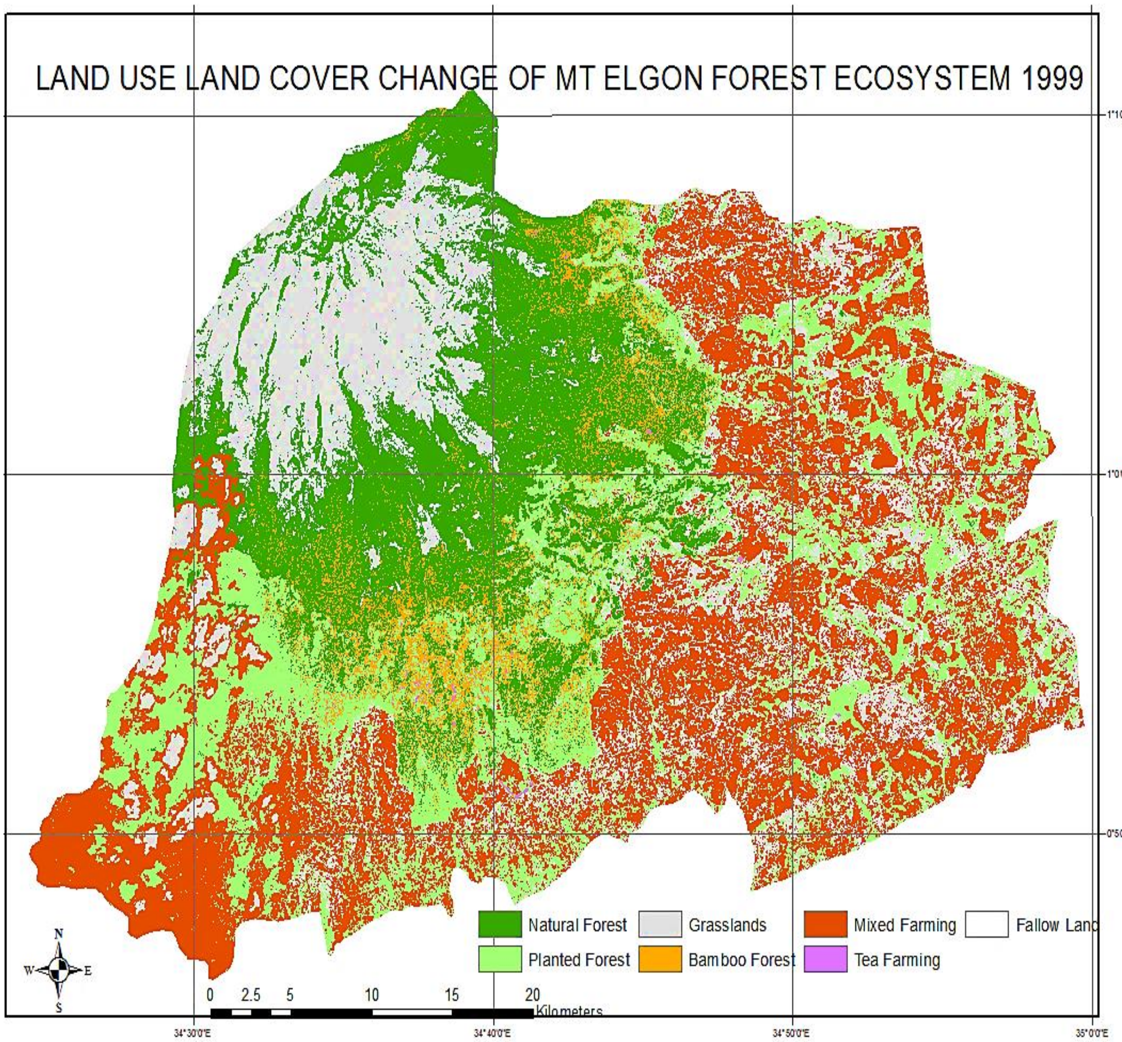

Figure 4.5: Land Use Land cover map of Mt Elgon region 1999

Plantation forest occupied and area of about 23% (n=407.67km^2). Tea farming covered some 0.1% (n=1.81km^2) of the total land area. The introduction of plantation forest and tea farming (Nyayo Tea Zone) led to a decline in the size of land under other land uses. For instance, fallow land declined by 18% from 21.44% (n=398.94km^2) in 1986 to 3.35% (n=62.39km^2).

Another notable land use/land cover change between 1986 and 1999 was the decline in area of natural forest. Approximately, ten (10.55%) of the natural forest cover disappeared over this period from 31.07% (n=578.11 km^2) in 1986 to 20.52% (n=381.77 km^2) in 1999. Over the same period, grasslands declined by 10 % from 29% (n=546.52 km^2) in the 1986 to 19.39% (n=360.75km^2) in 1999. It appears that part of the fallow land, natural forests and grasslands was converted into plantation forest (Figure 4.6).

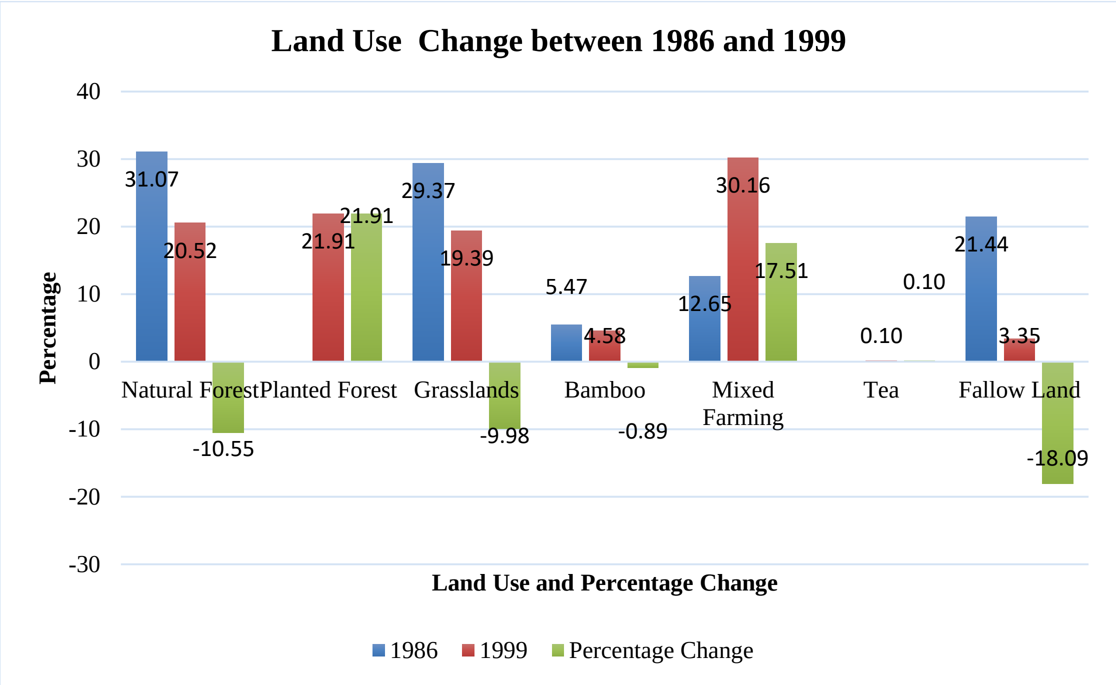

Figure 4.6: Percentage change in size of land under different Land Uses between 1986 and 1999.

Indigenous and exotic plant species were used as plantation forests. Field observation established that the Elgon teak was the main species used in indigenous plantation forests, while Cypress and Eucalyptus species were used in plantation forests. In this study however, exotic plantations were the only species that were represented under plantations. Indigenous plantations data was captured under natural forests. This is because of their close resemblance with natural forests on the Landsat imageries. The area under mixed farming expanded by 17.51% over the same period from 12.65%

(n=235.42km^2) in 1986 to 30.14% (n=561.19km^2) (Figure 4.6). Similarly, an insignificant 0.89% decline in bamboo was noted during this period.

Further analysis on Landsat images revealed that between 1986 and 1999, 102.81km^2 (18.8%) was transformed from grasslands to planted forests. About 106.11km^2(19.4%) of grasslands was transformed into mixed farming. About 0.28km^2 of grasslands was transformed into tea farming over the same period. Over this period, research revealed that about 152.32km^2(26%) of the natural forest was transformed into planted forest. About 59.87km^2 of the natural forests was transformed into mixed farming. Similarly, about 1.05km^2 of natural forests was transformed into tea farming. About 12.14km^2 of bamboo was transformed to planted forests between 1986 and planted forests between 1986 and 1999. About 0.21km^2 of bamboo forest was transformed into tea farming. Figure 4.7 show land uses land cover changes of Mt Elgon forest ecosystem between 1986 and 1999

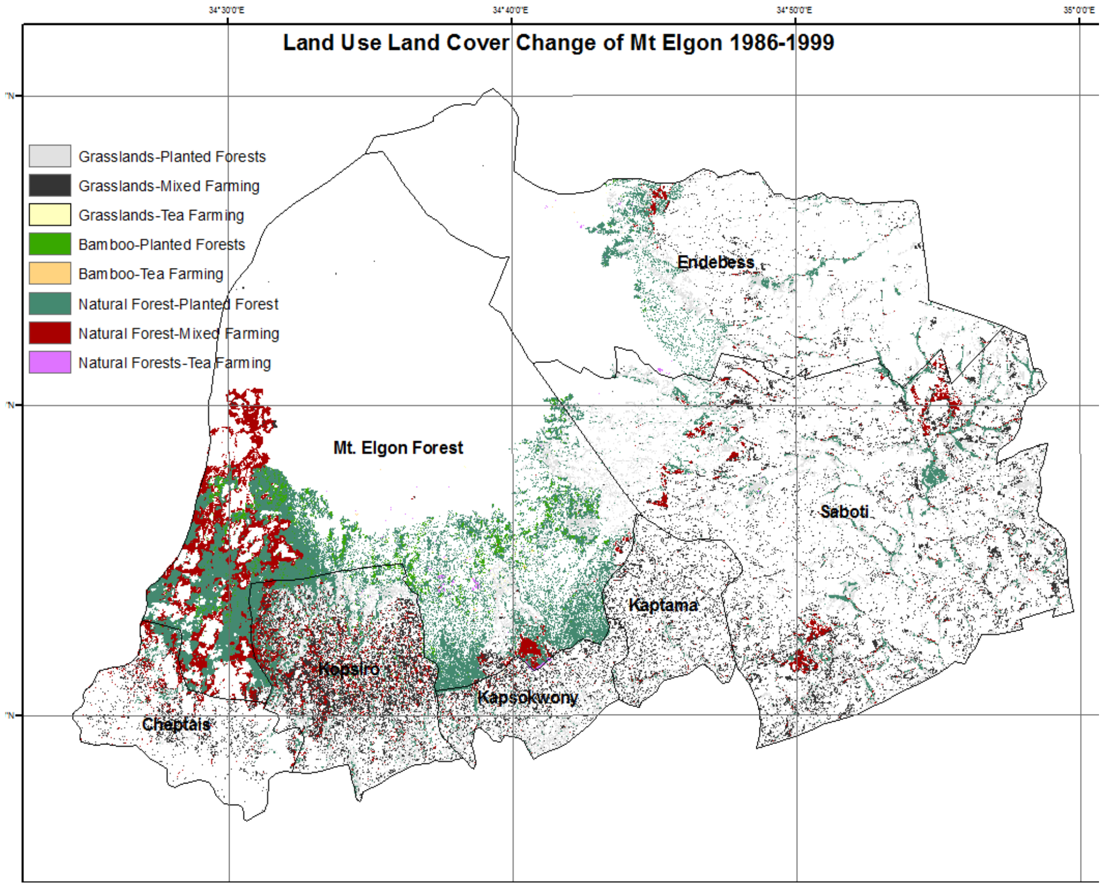

Figure 4.7: Land uses land cover changes of Mt Elgon forest ecosystem between 1986 and 1999

Analysis of the Landsat images for the year 2019 established that mixed farming covered an area of 30.7% (n=570km^2) of the total land area. Fallow land occupied the second largest piece of land accounting for about 27.95% (n=520.27km^2) of the total land area while natural forest occupied a total of 18.1% (n=336.88km^2) of the total land. The size of land under Grasslands comprised 15.2% (n=282.89km^2) while plantation forest occupied a total of 6.47% (n=120.44km^2) (Table 4.6). Bamboo and Tea farming occupy the least size of land accounting to about 1.45% (n=27.12km^2) and 0.13% (n=2.42km^2) of land respectively (Figure 4.8).

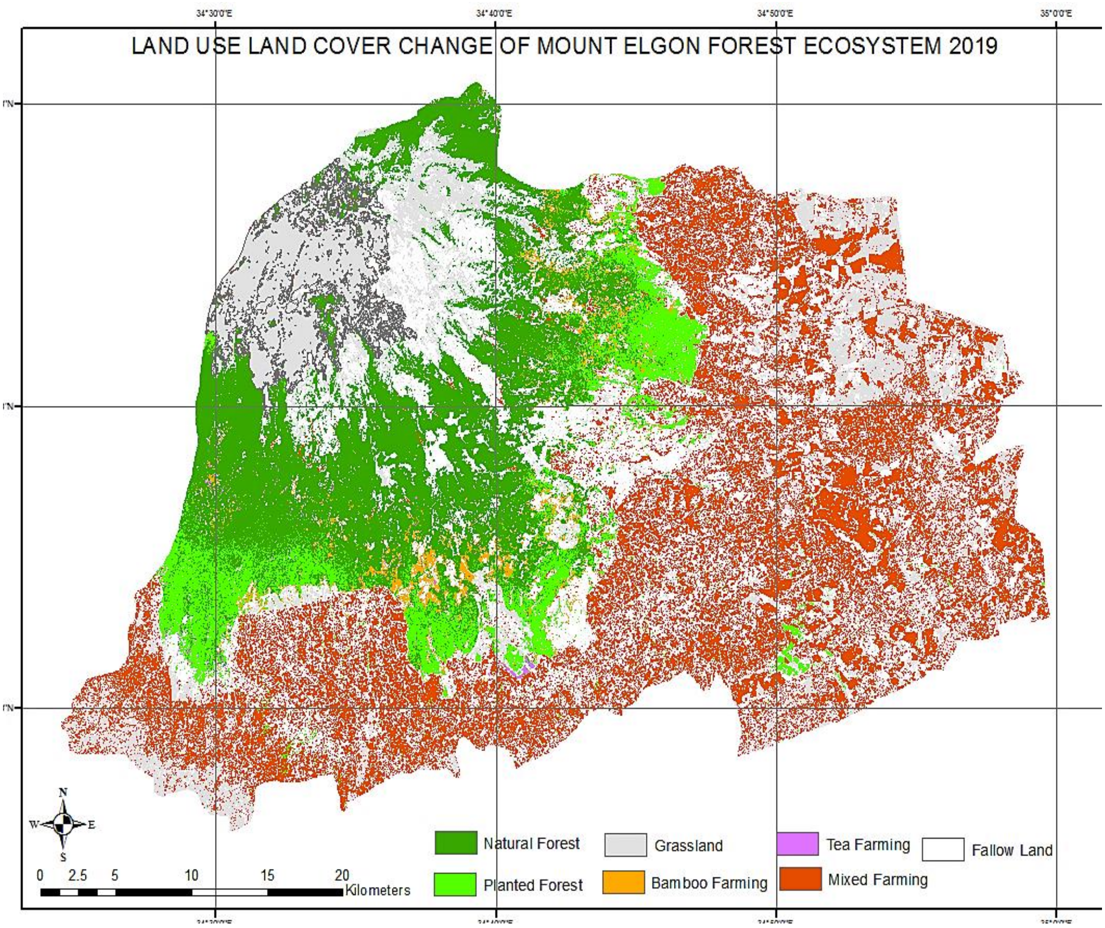

Figure 4.8: Land use of Mt Elgon for the year 2019

Various land use changes were evident between 1999 and 2019 in the Mt Elgon ecosystem (Figure 4.9). For instance, land under plantation forest declined from 407.67km^2 (21.9%) to 120.4km^2 (6.47%) while natural forests declined from 370.72km^2(20%) to 336.8km^2 (18.1%), and over the same period. This accounted for 15.43% decline in plantation forest and a 2% decline in natural forests. The size of land under bamboo forest declined by 3% from 85.2km^2 (5%) to 27.12km^2 (1%) over the same period. The size of land under grassland also declined by 3% from 344km^2 (19%) in 1999 to about 282.8km^2 (15.2%) in 2019 (Figure 4.9).

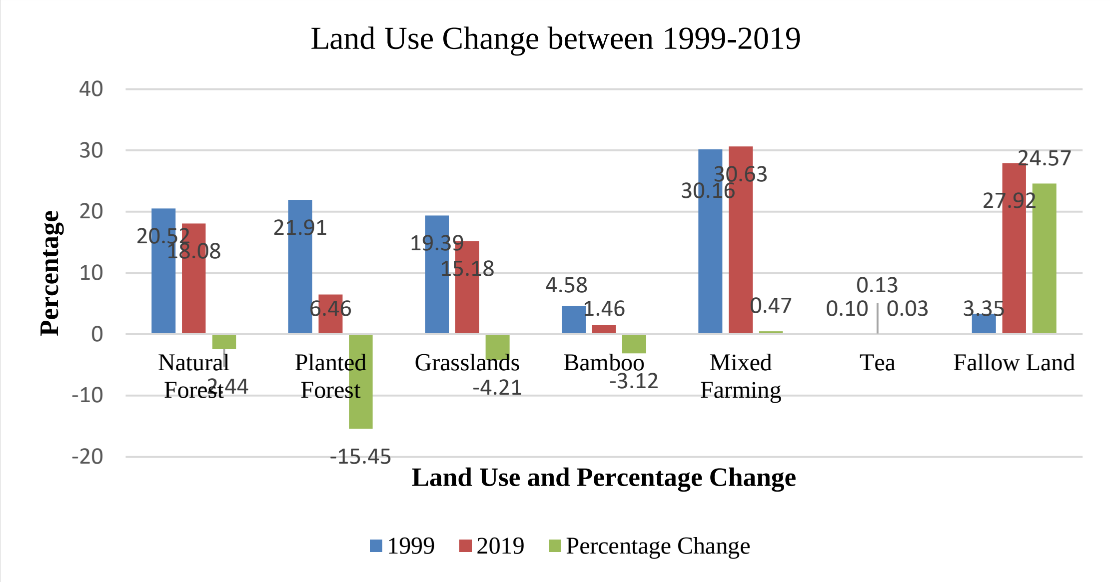

Figure: 4.9: Percentage change in size of land under different Land Uses between 1999 and 2019

There were, however, increases in Fallow land and mixed farming with increase of about 24.55% and 0.5% respectively. Fallow land increased from 3.4%(n=62.3km^2) in 1999 to about 28%(n=520.27km^2) in 2019 while mixed farming increased from 30.14% (n=561.19km^2) to 30.63% (n=570.76km^2) Land under tea farming increased by 0.03%, from 0.1% (n=1.81 km^2) in 1999 to 0.13%(n=2.42 km^2) in 2019.

Analysis of Landsat imageries confirmed that 16.45% (n=61.01km^2) of the land that was previously under natural forests was transformed into fallow land. Between 1999 and 2019, some 34.28% (n=139.78km^2) of the land that was previously under plantation forest was transformed to fallow land (which includes bare land and land that has been cultivated but crops haven't been planted. Similarly, 35.64% (n=122.88km^2) of grasslands were transformed into fallow land and 23.19% (n=19.77km^2) of bamboo was also transformed into fallow land. Some 27.26% (n=153.01km^2) of land that was previously under mixed farming was also transferred into fallow land (figure 4.10). The expansive increase in fallow land may explain why other land cover types and land uses declined in the region over that period.

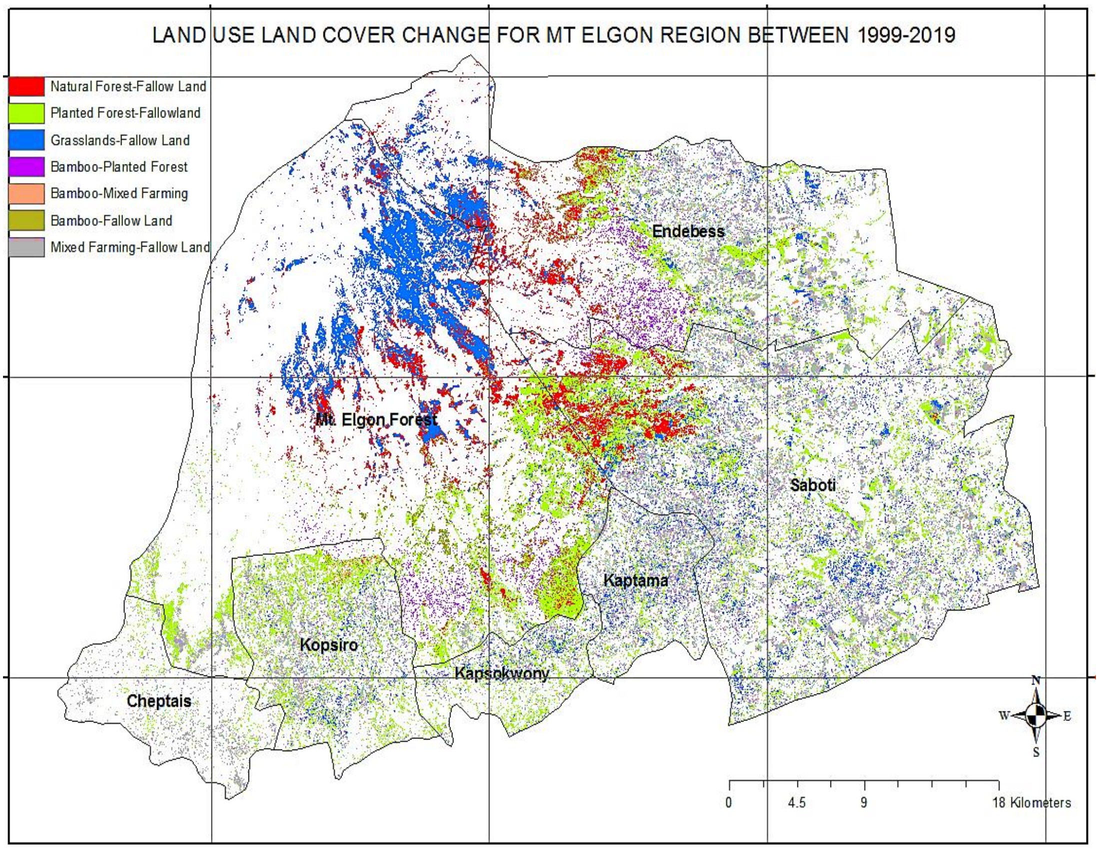

Figure 4.10: Changes in Land Use Land Cover in Mt Elgon Forest Ecosystem between 1999 and 2019.

Figure 4.11 show results of analysis on land use/land cover changes between 1977 and 2019. It is clear that there were notable changes in land uses during this period. The size of land under natural forest also declined by 18% from 671.37km^2(36%) to 336.88km^2(18.1%) between 1977 and 2019. Bamboo forests declined by 15.19% from 309.72km^2(16.6%) to 27.12km^2 (1.4%) over the same period. Grasslands declined by 13% from 525.35km^2 (28.23%) in 1977 to 282.89km^2(15.2%) in 2019 (Figure 4.11).

On the contrary, the sizes of land under mixed farming increased by 29.27% from 1.36% (n=25.39km^2) in 1977 to 30.63% (n=570km^2) in 2019 (Table 1). Fallow increased by 10.25% from 17.68% (n=328.93km^2) to 27.92% (n=520km^2). Similarly, plantation forests increased from 0km^2 to 6.47% (n=120km^2), while land under tea plantation tea also increased from nothing to 0.13% (n=2.42km^2) between 1977 and 2019 respectively (Figure 4.11).

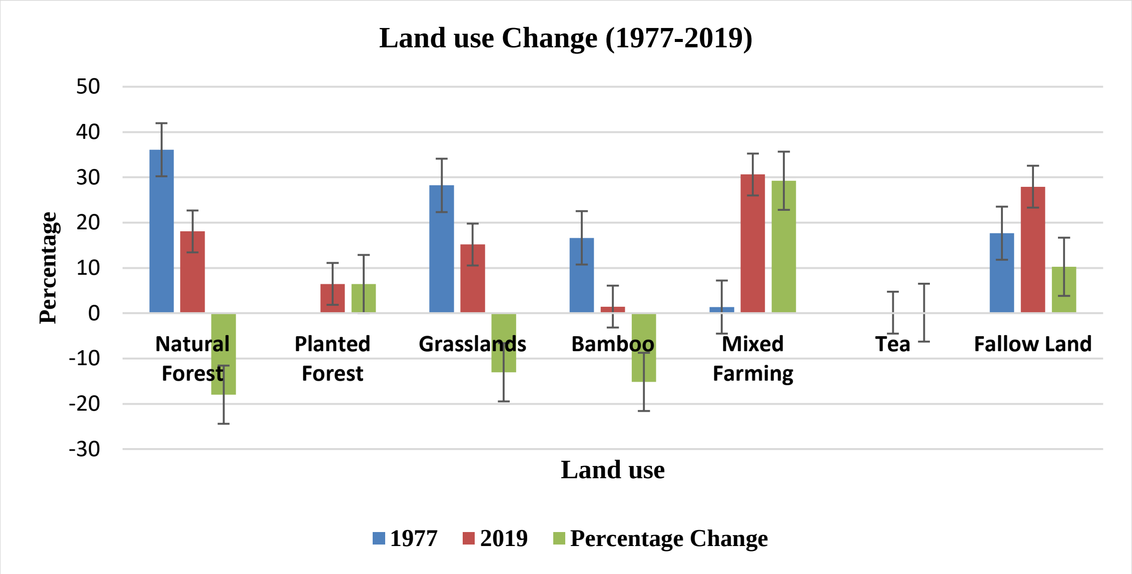

Figure 4.11: Percentage change in size of land under different Land Uses between 1977 and 2019.

The results of this study agree with the findings of (Gunlycke and Tuomaala, 2011) who reported that between 1900 and 1990 cropland increased by 200 percent at the expense of tropical forests. Nield, *et al*., (1999) reported that the levels of degradation and depletion of forest resources in Mt. Elgon has been difficult to quantify, due to poor reporting systems by the Kenya Forest and the Kenyan Wildlife Services. The then Ministry of Environment and National Resources further reported that, this forest is among the least studied forest ecosystems in the country despite being one of the five national water towers and containing species that are globally threatened (Akotsi and Gachanja, 2004).

In 1973, the government agreed to resettle the Elgony Dorobos from Elgon Native land unit due to cold weather to an area covering 3686 hectares to the lower slopes in an area currently known as Chepyuk. Through legal notice no 51 of 1974 (Simiyu, 2008). Most of the inhabitants had migrated from faraway places. The immigrants influenced the local communities who were primarily livestock herders to be agriculturists. This change in the lifestyle of the people has led to encroachment of the forest for cultivation and exploitation of the forest products (Ongugo, 1996). This may partly explain the increase in mixed farming and fallow land in the region. Since the opening of the settlements for the first phase of Chepyuk settlement scheme in 1973, no research has been carried to assess the extent of land use land cover change in this region. Many studies carried out in this region have focused on land tenure, conflicts and resolutions (Soini, 2006). This study has filled this gap of knowledge.

The second and third phase of the Mt Elgon resettlement scheme was established in 1992. Phase two covered an area of 1741.99 hectares while phase 3 covered an area of 2865.42 hectares (Simiyu, 2008)). This resettlement could partly explain the increase in mixed farming in the region. Ongugo *et al*., (2014) confirmed the findings of this study when he asserted that overall, the area under indigenous forests in Kenya has declined by 8.1% between 1990 and 2010 translating into an annual decline of 0.4%.

Ongugo *et al.,* (2014) further reported that in the late 1990s and early 2000s, there were several politically motivated excisions of forested land in Mau and Mount Elgon which happened without regard to due process as envisaged in the Environment Management and Coordination Act (EMCA 1999). In 2001, a total of 67,000 hectares were cleared (Mathu, 2007). Similarly, the creation of Nyayo Zone Corporation in 1986, where forested land was cleared in Mount Elgon and other forests in Kenya for the creation of Nyayo Tea Zone Corporation. It was intended to deter encroachment and support local communities through employment creation. Officially, a '100 m' strip from the forest boundary was nominally used as a guideline. However, this guideline was ignored and resulted in greater deforestation because in some cases, the width of the tea zone strip ranged between 5 and 25 km and by 1990 the total area cleared for tea planting was 11,000 hectares (Mathu, 2007). Additionally, this study's findings agree with Ongugo and Mwangi (1996) who reported that the decline in indigenous forests may have been brought about by more land that was converted to plantation forestry which was being advocated for by the government as a reforestation strategy.

Our study has shown that forest cover is declining in Mt Elgon forest ecosystem and is projected to shrink further over the coming years. Ball, (2001) had indicated that forests covered about 50% of the earth's land area 8000 years ago, as opposed to 30% today. FAO estimated that tropical regions lost 15.2 million hectares of forests per year during the 1990s. Olson, Misana., Campbell, Mbonile., and Mugisha, (2004) indicated that during the last few decades, the area under cultivation has more than doubled in East Africa. In Tanzania, FAO (1993) estimates that natural forests decreased by about 12.7% between 1980 and 1990. Land use changes in Tanzania that led to depletion of forests were associated with population increase, intensification of agriculture and increased demand of forest products (Misana and Nyaki, 1993). In total, between 1990 and 2010, Kenya lost 6.5% of its forest cover or around 241,000 ha (FAO 2010). This study's findings however differ with those of Kenya Water Towers Agency, (2017) that reported that forest land was the dominant land cover between 1990 and 2016 in the 5km buffer around Mt Elgon forest. They further reported that, the land under forest land increased by 7% in 2000s. (KWTA, 2017) further reported a 3% increase in crop land between1990-1995 followed by a 23% reduction in cropland between 1995-2000 indicating intensification of conservation effort.

4.3 Determination of Drivers of Land Use Changes

4.3.1 Respondents Demographic Characteristics

Out of the 384 questionnaires that were administered, 365 were returned translating into a response rate of 90% which was adequate for this analysis and reporting of findings. Mugenda and Mugenda, (2003) indicated that a response rate of 50% is adequate for analysis and reporting; a rate of 60% is good and a response rate of 70% and over is excellent. Based on the assertion, the response rate was considered to be good. The age of the respondents varied between 50 and 95 years with the highest percentage in the age brackets being 50-55(45.48%), 56-65(21.92%) and 66-75(20.27%) (Figure 4.12).

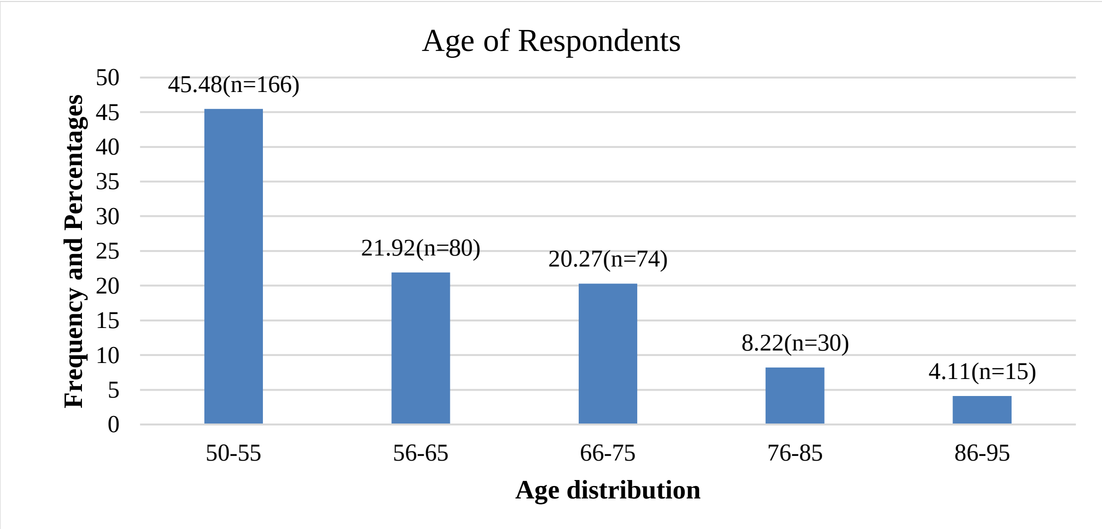

Figure 4.12: Age distribution of Respondents

Some 67% of the respondents were males while 33% were females (Figure 4.13).

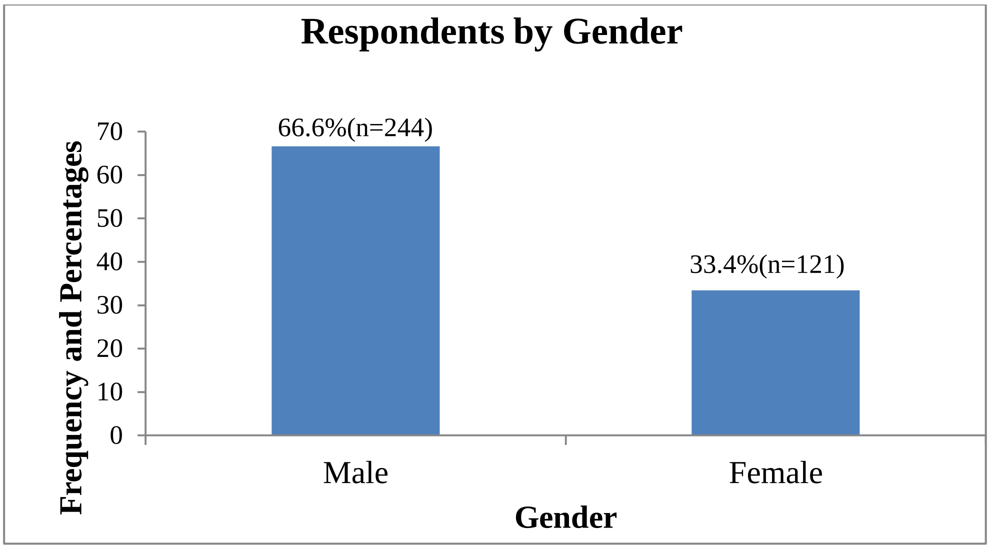

Figure 4.13: The Proportion of Respondents by Gender

4.3.2 Respondents Level of Education

The level of education of the respondents arranged from non-formal education to master's degree. The highest number of respondents in the study area had gone through primary school (47.8%), some 30.4% had attained secondary school education while some 19.6% had tertiary education. The percentage number of respondents who had attained bachelors and master's degrees were 1.7% and 0.6% respectively (Figure 4.14).

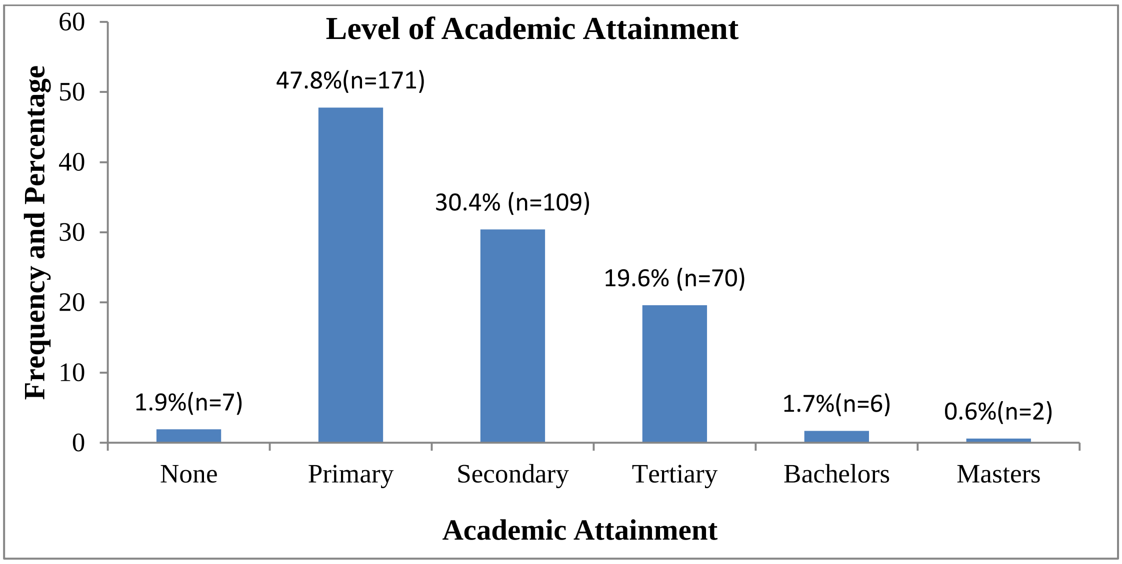

Figure 4.14: Education levels of respondent

4.3.3 Duration of Stay Close to Mt Elgon Forest

The average duration of stay in the study area ranged from 30 years to 90 years. The highest duration of stay of the respondents was 30-50 years with (41.37%). This was followed by 51-60years (27.12%), 61-70(16.44%) and 71-80 (9%) (Figure 4.15).

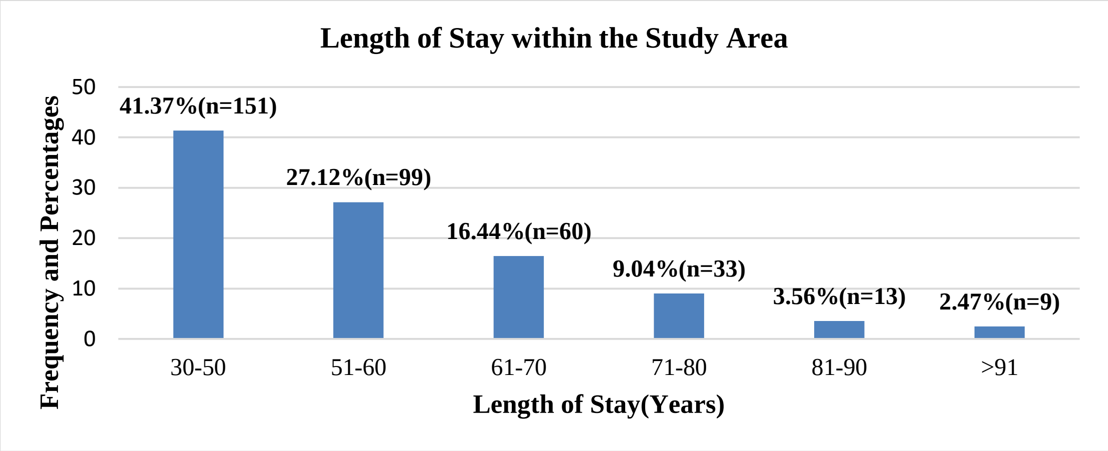

Figure: 4.15: Duration of stay close to the Mt Elgon Forest

4.4 Drivers of Land Use Change

In this study, land use change appears to have resulted from a variety of factors. These factors ranged from natural to anthropogenic factors. The natural factors comprised of the edaphic factors, climatic factors and biological factors while anthropogenic factors comprised of demographic factors, institutional factors, social cultural factors and economic factors. Anthropogenic factors were reported to be the main driver of land use change with 82.5% (n=301). Natural factors accounted for 17.5% (n=64) of the land use change (Figure 4.16).

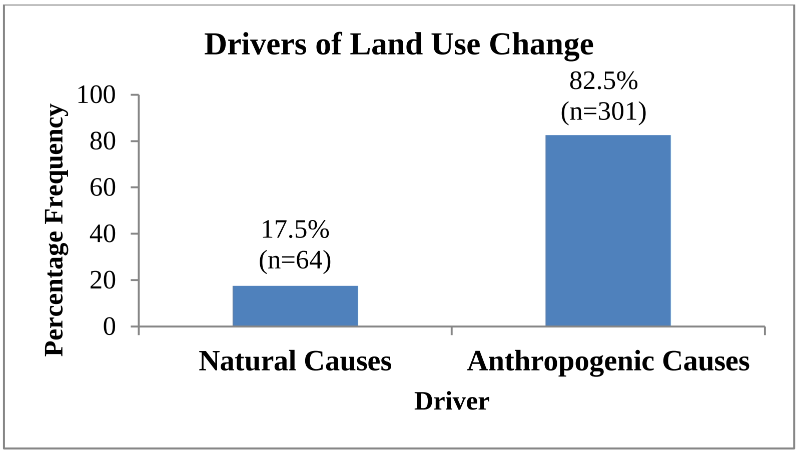

Figure 4.16: Drivers of Land Use Changes

4.4.1 Natural Factors

Climate change was reportedly the major natural factor that drives land use change in Mt Elgon forest ecosystem. This was reported by 53.1% (n=34) of the respondents (Figure 4.17).

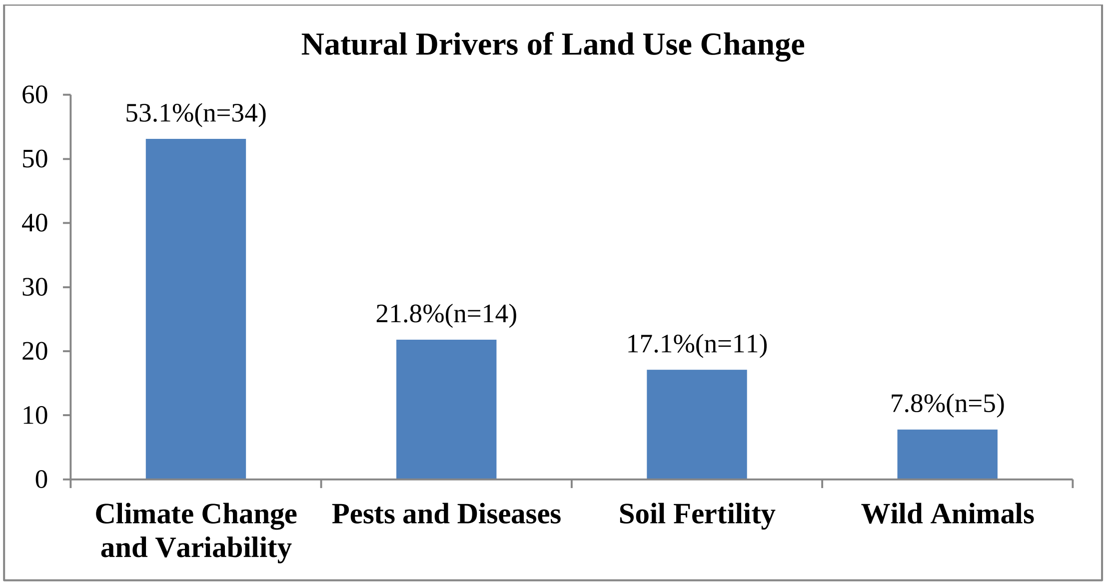

Figure 4.17: Natural Drivers of Land Use Changes

The respondents attributed the increase in tea and coffee farming to favourable weather patterns. Favourable weather was reported to favour the cultivation of various crops such Irish potatoes. On the contrary, climate change was reported to be responsible for the decline in indigenous forests, bamboo and grasslands of the study area. The respondents indicated that temperatures had risen in the study area as well as change in rainfall patterns and these could partially explain the changes in the natural forests, bamboo forest and grasslands.

Pests and Diseases were ranked as the second natural driver of land use change in Mt Elgon forest ecosystem. This was reported by 21.8% (n=14) of the respondents. They indicated that pests and diseases were responsible for the decline in mixed farming. They reported that pests and diseases could explain the decline in the cultivation of sweet potatoes in the study area.

Edaphic factors included change in soil fertility, change in soil type and change in soil ph. In this study, the main edaphic factor that was reported by 17.1% (n=11) to contribute to change in land use was soil fertility. The respondents indicated that soil fertility in the study could explain the increase in mixed farming in the study area.

Wild animals were reported as the least natural factor responsible for land use change in Mt Elgon forest ecosystem. About 7.8% (n=5) indicated that competition of livestock and wild animals for grasslands could explain the decline in grasslands in Mt Elgon forest ecosystem.

Climate is the most dynamic natural factor that affects land use and land cover at annual to decadal time scales. Most agricultural practices are linked to climate either directly or indirectly (Lybbert and Sumner, 2012), making climate change a major and widely recognized driver of agricultural transitions (Zondag and Borsboom, 2009). Climatic factors include variability in climatic variables such as rainfall and temperature. The persistence of drought could lead to desiccation of soils, shrinking of water bodies, stressing the vegetation, and exposing bare soil to erosion. Similarly, drought may also affect the land ability in crop production forcing the resident to secure and alternative livelihoods. This in the end could lead to land use changes. Climatic factors such as temperatures, rainfall and wind affect the supply or constraints of land resources. Nangware *et al.*, (2019) indicated that soil condition; climate variability and terrain characteristics are among the main factors that cause land use change.

4.4.2 Anthropogenic Factors.

The study established that anthropogenic factors accounted for 82.5% (n=301) of the land use changes in Mt Elgon forest ecosystem. These anthropogenic factors included; demographic factors as reported by 76.7% (n=280), socio-cultural factors 74.05% (n=270), institutional factors 58.08% (n=212) and economic factors 50.95% (n=280) (figure 4.18).

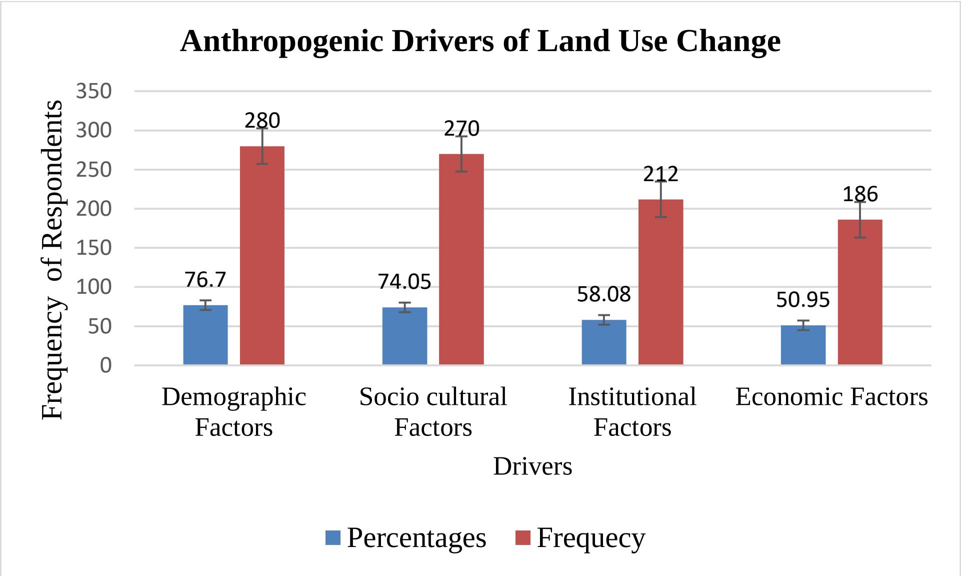

Figure 4.18: Anthropogenic Drivers of Land Use Changes

Mt Elgon ecosystem has experienced population growth within the last four decades. The increase in population ranged from 135,033 in 1999 to 172,377 in 1989 and finally to, 218,529 in 2019 (KNBS, 2019). The increase in population could have been from increased birth rates and immigrants who settle in search for land. Increase in population may have exerted more pressure on natural resources such as Mt Elgon forest that is located in Bungoma and Tranzoia counties. The increase in population could have led to more land being dedicated to mixed farming. This in the end could have led to a decline in natural forests and bamboo forests.

Two hundred and ninety-two (82%) of the respondents, affirmed that the main driver of decline in Mt Elgon natural forest is the increase in population. The respondents indicated that there has been an increase in population especially as a result of increased birth rate in the region. This could have led to a decline in land and forced majority of the forest adjacent communities to encroach and settle in the forest and practice agriculture. Plate 4.1 shows the land that was previously under natural forests transformed into land under mixed farming.

Plate 4.1: Transformation of Land from Natural forests Mixed farming

Results also revealed an increase in the number of farmers growing specific food crops. Figure 4.19 shows the number of farmers growing specific food crops between 1970s and 2010s.

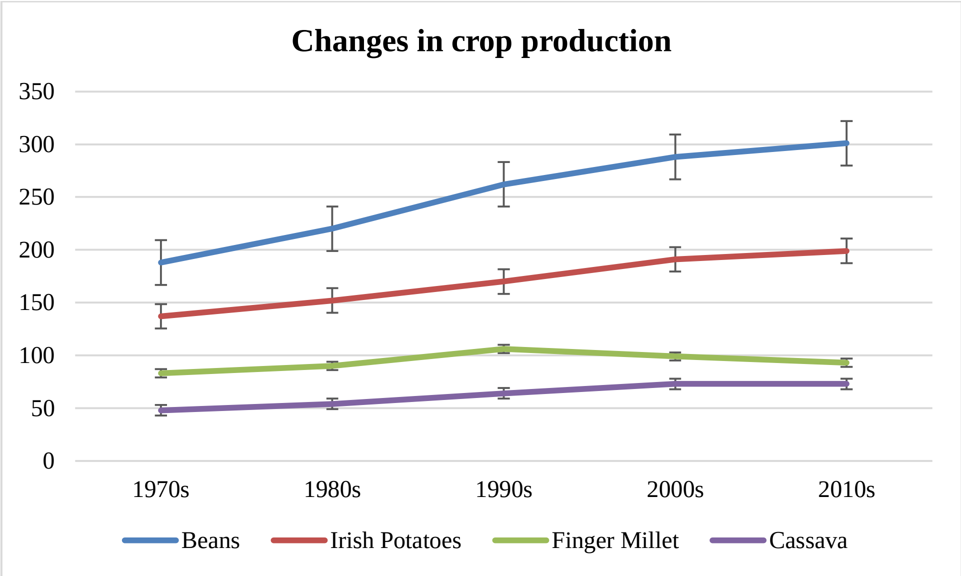

Figure 4.19: Changes in crop production in Mt Elgon forest ecosystem

There was clearly an increasing trend in the number of households cultivating beans in the study area. For instance, in the 1970s some 52% (n=188) of the respondents cultivated beans. This increased to 82% (n=301) in the 2010s (Figure 4.19). About 29% (n=106)) of the respondents attributed the increase in the number of households cultivating beans to an influx of immigrants in the region who leased land to grow the crop. It appears that this influx has led to an increase in population providing a ready market for the crop.

An increasing trend was also observed in the number of farmers growing Irish potatoes. About 38% (n=137) of the respondents cultivated Irish potatoes in 1970s, 42% (n=152) in 1980s, 47% (n=170) in 1990s 52% (n=191) in 2000s and 55% (n=199) in 2010s (Figure 4.19). The 11.5% (n=42) of the respondents were of the opinion that the increase in population had led to increased demand of Irish potatoes thus acting as a driver to increase in number of farmers growing Irish potatoes.

There was, however a decline in the number of farmers growing finger millet in the 1970s. For instance, there were 23% (n=83) of households growing it in the 1970s. In 1980s, finger millet was grown by 25% (n=90) of the respondents. In 1990s the number increased further to 29% (n=106). But in 2000 and 2010s, the number of farmers growing the crop declined from 27% (n=99) to 25% (n=93) respectively (Figure 4.19).

Economic factors are related to financial gains of an individual or a household. This study established that economic factors played a key role as drivers of land use change in Mt Elgon ecosystem. These economic factors ranged from ready market and increased profits for crops and forest products (Figure 4.20).

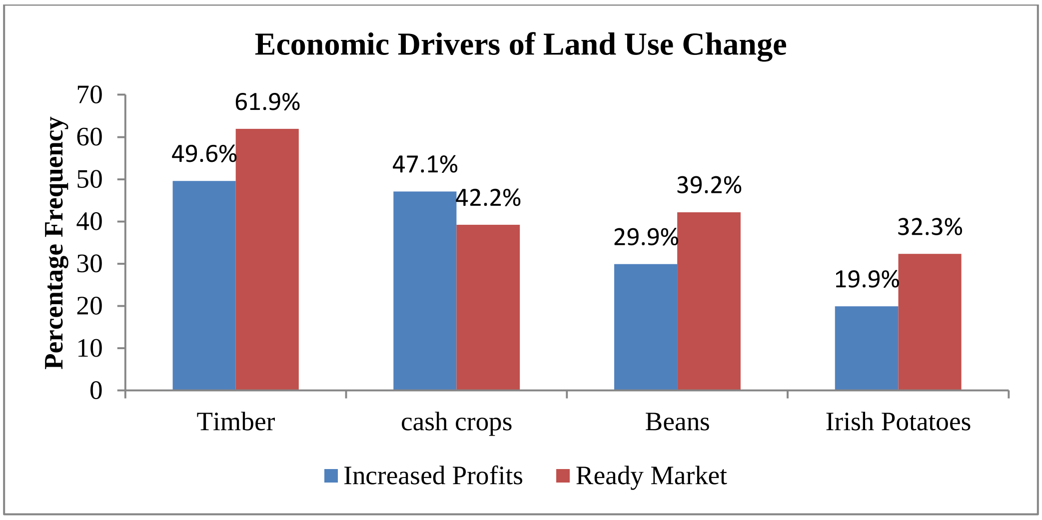

Figure 4.20: Economic drivers of Land Use Changes

Ready market was reported as one of the most important drivers of land use change in Mt Elgon forest ecosystem. Ready markets played a key role in the increase in on farm tree plantation the number of farmers growing food and cash crops. Some 62% (n=226) of the respondents reported that ready market for timber and other wood products had led to increase decline in natural forests. Timber, charcoal and firewood were easily sold in the neighbouring urban centres of Kapsokwony and Cheptais. The respondents indicated that many people illegally excise wood from the forest and sell it in the nearby markets thus explaining the decline in natural forests. Data obtained from Landsat images revealed that the size of land under plantation forests had increased from 0 to 21.9% between 1986 and 1999 (Table 4.5). Favourable government policies which advocated for on farm forestry in forest adjacent areas provided a stimulus for farm forestry.

Additionally, there was a significant increase in the number of farmers growing Irish potatoes 32.3% (n=118) and beans 42.2% (n=154) respectively (Figure 4.19). This was because, the land that was previously under natural forest had been transformed into agriculture. The respondents indicated that the need for food for the ever-increasing population and ready market for the crop could be responsible for the increase in the cultivation of Irish potatoes in the study area.

Plate 4.2: Irish potatoes being transported to Kapsokwony Market.

Ready market was reported by 39.2% (n=143) to have been responsible for the increase in the number of farmers growing cash crops in the region. The main cash crops grown include tea and coffee. The availability of coffee and tea factories in the region provided ready market for the crops prompting many households into growing of the respective cash crops. Increase in the land under cash crops may be responsible for the decline in natural forests in the region. Landsat imageries could not establish the exact size of land under coffee farming due to their close resemblance with plantation forests. Data obtained from the questionnaires established an increasing trend in the number of farmers growing coffee. About 122(33%) of the respondents cultivated coffee in the 1990s in comparison to 73(20%) and 88(24%) of the households that cultivated it in the 1970s and 1980s. Plate 4.3, 4.4 and 4.5 show coffee farming, the Nyayo Tea zone and the Elgon tea and coffee factory in Mt Elgon forest ecosystem respectively.

Plate 4.3: Coffee farming in Mt Elgon forest

Plate 4.4: Nyayo Tea Zone

Plate 4.5: Tea and Coffee Factory in Mt Elgon ecosystem

Additionally, there was an increase in the number of farmers growing tea from 11% (n=44) in the 1990s, to 18% (n=64) in2010s (Figure 4.20). Similarly, Landsat images confirmed a 0.13% increase in the size of land under tea farming between 1970s and 2010s (Figure 4.9).

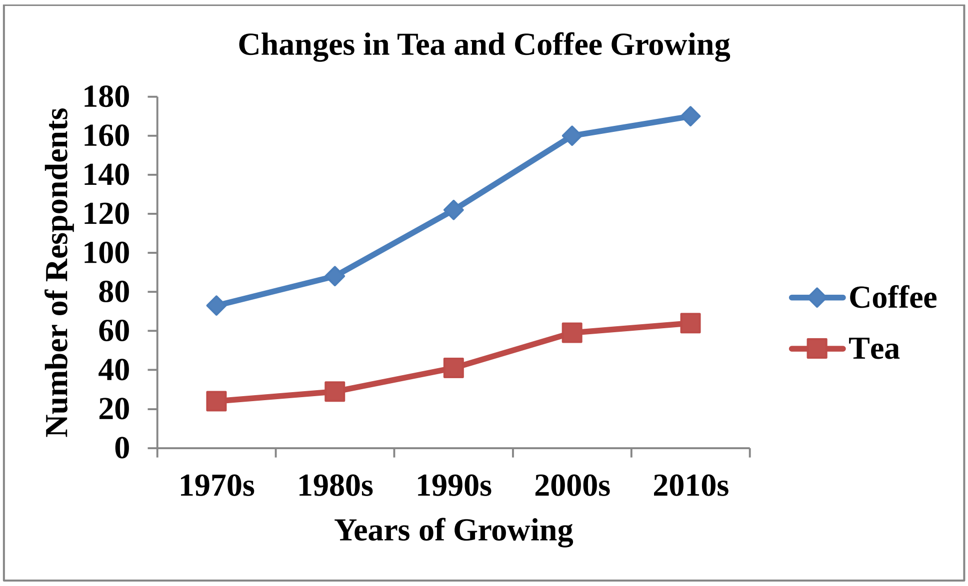

Figure 4.21: Changes in Tea and Coffee growing

4.4.2.1 Increased Profits

Increase in profits was equally an important economic driver of land use change in Mt Elgon ecosystem. For instance, 49.6% (n= 181) of respondents agreed that increased profits from timber and other wood products could have led to an increase in on farm tree plantation forest (Figure 4.20). Cash received from selling timber mainly provides for the family basic needs.

Similarly, increased profits were responsible for the increase in the size of land under cash crop farming and an increase in the number of households growing cash crops between 1990s and 2019 (47%; n=172). Twenty-one (21%) percent (n=75) of the respondents attributed this increase to increased profits in coffee farming while 6.8%; n=25 attributed the increase in tea farming to increased profits (Figure 4.20).

In this study, institutional factors were reported as drivers of land use changes. These institutional factors include policies of natural resource conservation, factors pertaining to land ownership and leasing and policies on logging. Unlike natural forests that have declined in the study area, research findings revealed that plantation forests have increased between 1986 and 1999 (Figure 4.22).

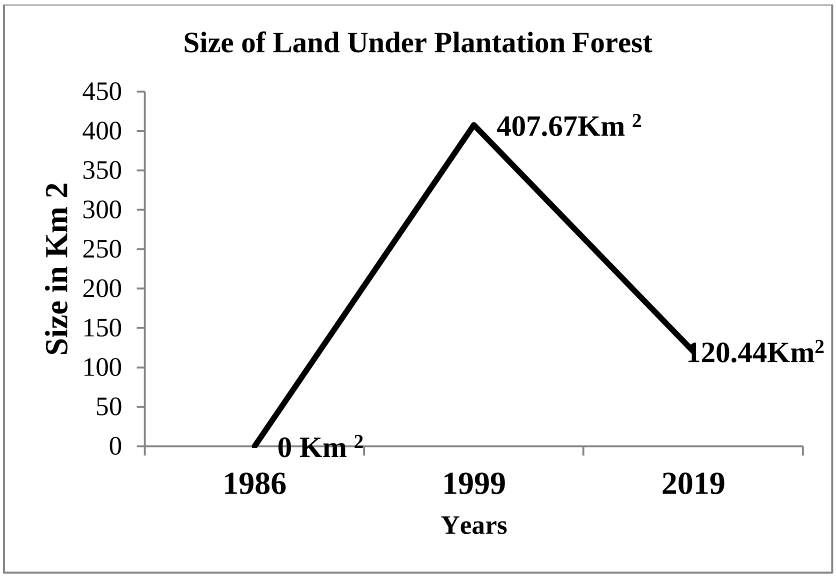

Figure 4.22: Changes in Land under Plantation Forests

Government policies were reported by 72.1% (n=263) of the respondents as the main cause of the increase in land under plantation forests (Figure 4.22). The enactment of the Forest Act (2005) has drastically altered the way forests are managed and conserved. For instance, the sessional paper No. 1 of 2007 on forest policy aims at increasing the forest cover to acceptable international standards of 10%. The paper emphasizes community participation in forest management. Other than this, the policy gives prominence to the role of farm forestry. The policy encourages provision of incentives and extension services to enhance farm forestry. This policy has been critical in encouraging households to put up forest woodlots and thus increasing farm forests.

Figure 4.23 shows the institutional drivers of land use changes as reported by the respondents of Mt Elgon forest and adjacent ecosystem

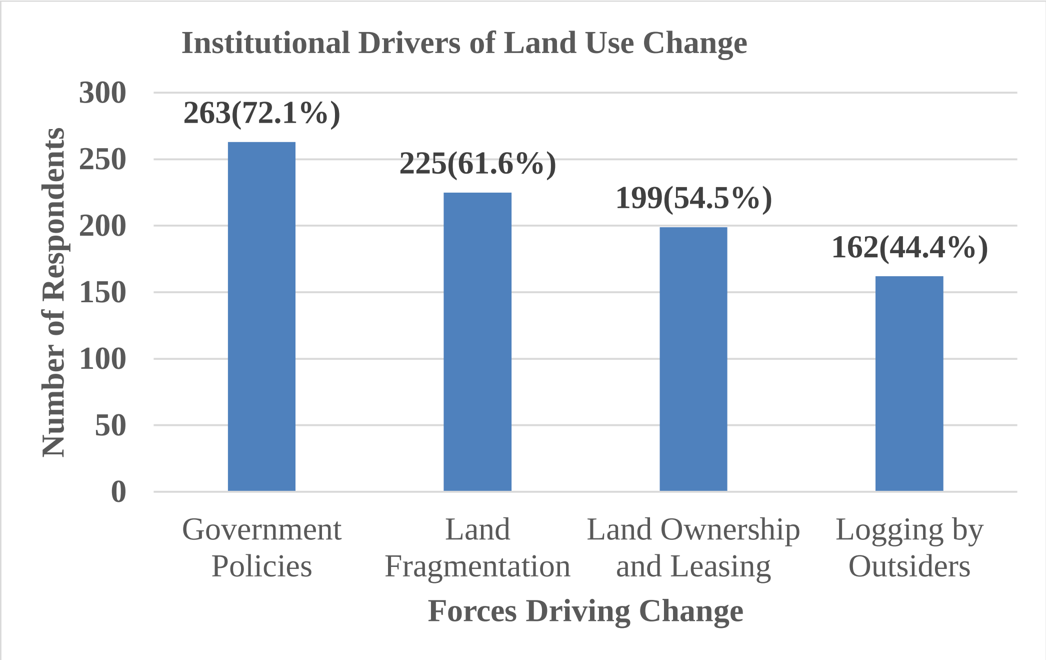

Figure 4.23: Institutional Drivers of Land Use Changes

The forest policy also protects customary rights of local communities to sustainably use of forest resources. In Mt. Elgon ecosystem, the local community have access rights to forest resources which include collection of wood fuel, herbal medicine and grazing of livestock based on permit system. Despite these provisions, the government has not put in place mechanisms to assess the extent to which these ecosystem services are utilised. For instance, the number of livestock owned by each household is not monitored, which may explain the decline in natural forests, bamboo forests and grasslands in the study area.

The Agricultural Sector Development Strategy (ASDS) and Agriculture Act, Cap. 318 has given out a detailed plan on how to make agricultural sector a key driver of economic growth as envisaged under the economic pillar of Vision 2030. Based, on this policy, agriculture is expected to deliver a 10% annual growth rate. The policy emphasizes commercialization of agriculture and intensification of production especially among small-scale farmers (ASDS 2010) as a means of achieving food security. The policy encourages integration of tree agroforestry into agricultural production. In Mt. Elgon ecosystem, the Shamba system was introduced to encourage farmers to grow crops on forest land when the trees are young. The community was allowed to tend seedlings as they weed their crops. This was a reforestation strategy that used subsidized labour, and deterred further encroachment into the forest while at the same time enhanced food security for the local community who own small parcels of land (Plate 4.6).

Plate 4.6: Shamba System in Mt Elgon forest ecosystem

In addition, households are encouraged to engage in farm forestry with the aim of ensuring the availability of wood fuel, timber and food security without degrading the Mt Elgon forest. Data from questionnaires revealed that about 32% (n=117) of the respondents engaged in farm forestry in the 1970s. In the 1980s, 35% (n=128) of the respondents practiced agro-forestry. The number of households in farm forestry rose to 40% (n=144) in 1990s, 43% (n=158) in 2000s and 46% (n=169) in 2010s (Figure 4.24).

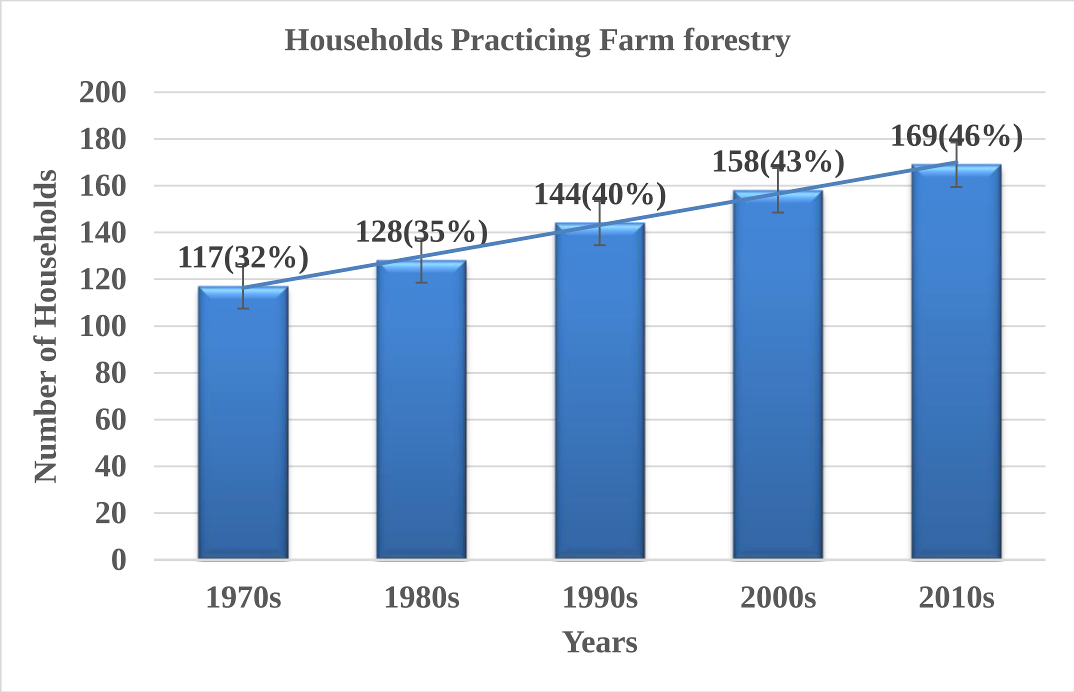

Figure 4.24: Changes in Households engaged in farm forestry in the Study Area

The forest adjacent communities 72.1% (n=263) indicated that the agriculture policy had played a major role in the increase in mixed farming. Surprisingly, the Key Informants revealed that the SHAMBA system had led to a decline in forest cover in the region. They indicated that the local community that has been allocated parcels of the forest for agricultural production tend to encroach further into the forest. They therefore engaged in further deforestation and didn’t care much about replanting of the trees. They also indicated that some of the local community who are allocated land in the forest to tend the seedlings sometimes cut the trees down. According to the Key Informants this explains the decline in natural forests between 1977 and 2019. Field observation within the forest revealed illegal logging in areas adjacent to the Shambas (plate 4.7)

Plate 4.7: Illegal logging in areas adjacent to the Shamba System.

Landsat images confirmed that land under mixed farming had been increasing from 1.4% (n=25.35km^2) to 30.63% (n=570.76km2) between 1977 and 2019 while land under natural forests had declined from 36% (n=671.4km^2) to 18.1% (n=336.9km^2) over the same period (Figure 4. 9).

Land fragmentation was another driver of land use change. Some 61.6% (n=225) of the respondents reported that land fragmentation has been instrumental in the decline in natural forests (Figure 4.23). The increase in population from 135,033 in 1989 to 218, 529 in 2019 has led to land subdivision and consequently, decreased land size for food production. This has led to forest encroachment for more land for settlements and agriculture. Ninety-eight (98) percent (n=358) reported that encroachment into the forest has led to a decline in the natural forests. Land ownership and leasing has contributed to the decline in natural forests. Some 54.5% (n=199) of the respondents were in agreement that the change in land uses was also due to land ownership and leasing (Figure 4.23). Most of the forest adjacent communities had leased their land in exchange for money. This has reduced household land, leading to encroachment and decline in natural forest cover. Legal logging was reported by 44.4% (n=162) of the respondents (Figure 4.23). Many of these legal loggers were large-scale and this has led to a reduction in land under natural forests.

In this study, the social cultural factors that were significant drivers of land use change included food preferences, community's settlement patterns, herding and sources of livelihoods of the forest adjacent community. These socio-cultural factors were reported to be important drivers of land use change by 270 (74.01%) of the respondents

Eighty (80) percent (n=292) of respondents reported that increase in settlements was responsible for the decline in the Mt Elgon natural forest (Figure 4.24). Different types of settlements included urban and rural settlements. Increased settlements were reported to be partly responsible for the decline in natural forest. KNBS (2019) reported that 1,261 people lived in Mt Elgon forest in 2009 compared to 3621 in 2019. These belonged to the Ndorobo community. The rest of the communities live adjacent to the forest. Few settlements were close to the urban centres such as Labot and Chepkitale. The Ndorobo communities mainly engage in trade of non-timber forest products such as herbal medicines and honey; and the rearing of domestic animals. Trading in non-timber products was done in the urban centres such as Kapsokwony and Chepkitale. Field observation revealed that the trading in these non-timber products may also contribute to the decline of indigenous tree species and consequently decline in natural forests. Ground truthing confirmed that increased settlement within and in areas adjacent to the forest may have led to encroachment into the forest and consequently, a decline in the natural forest cover. Plate 4.8 shows Chepkitale urban centre located within Mt Elgon forest. The plate 4.9 shows how the honey is acquired from the back of a tree while plate 4.10 shows the back of tree that has been peeled for the acquisition of herbal medicine.

Plate 4.8: Chepkitale Urban Centre

Plate 4.9: Harvesting of honey within Mt Elgon forest

Plate 4.10: Peeling of Tree Back for herbal Medicine

Food crop farming has been practiced in the region since the 1970s as a source of livelihood to the majority of the households. Data from 1970 t0 2010 shows food crop farming was given different emphasis. Cereals such as maize and beans, were cultivated by the majority of the respondents (95% (n=347), 82% (n=299) respectively), while simsim was cultivated by a mere (2%) (n=8) (Figure 4.25).

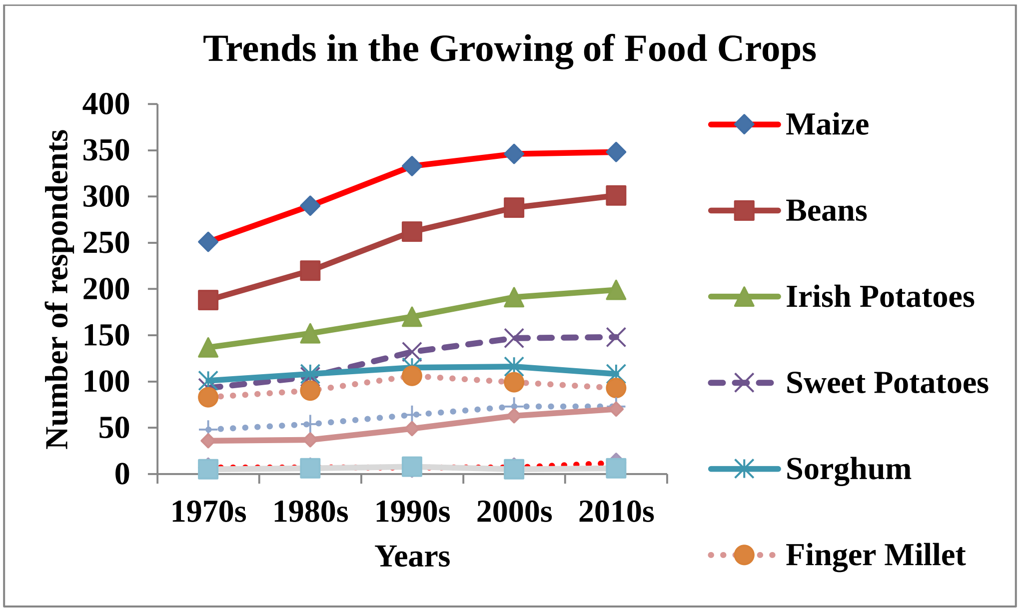

Figure 4.25: Food crops Grown in Mt Elgon ecosystem

The household food security appears to be the main driver for the increase in mixed food crop farming as reported by 64.9%; (n= 237) of the respondents (Figure 4.25).

Animal grazing was another important socio- cultural factor that drives land use change in Mt Elgon ecosystem. Some 60% (n=218) of the respondents reported that there has been an increase in the numbers of livestock herds owned by the forest adjacent communities. Owning large herds is a symbol of wealth among the forest adjacent communities. Statistics revealed that the community owned 45,941 of livestock in 2009 and the numbers are increasing over time (KNBS 2009). This explains why livestock herds have shown an upward trend since the 1970s. The increase in the number of animals have led to an increase in demand for grasslands. This could explain the transformation of natural forests into grasslands. Sixty-eight (68) percent (n=251) of the respondents engaged in animal grazing in the 1980s compared to 62% (n=227) in the 1970s. This was a six (6%) increase in the number of households engaged in animal grazing in the study area. There was a further 8% increase to 76% (n=280) in 1990s and a 4% increase to 80% (n=295%) in 2000s. An insignificant decline was recorded in 2010s (Figure 4.26). The animals reared included cattle, sheep, goats and donkeys (plate 4.11).

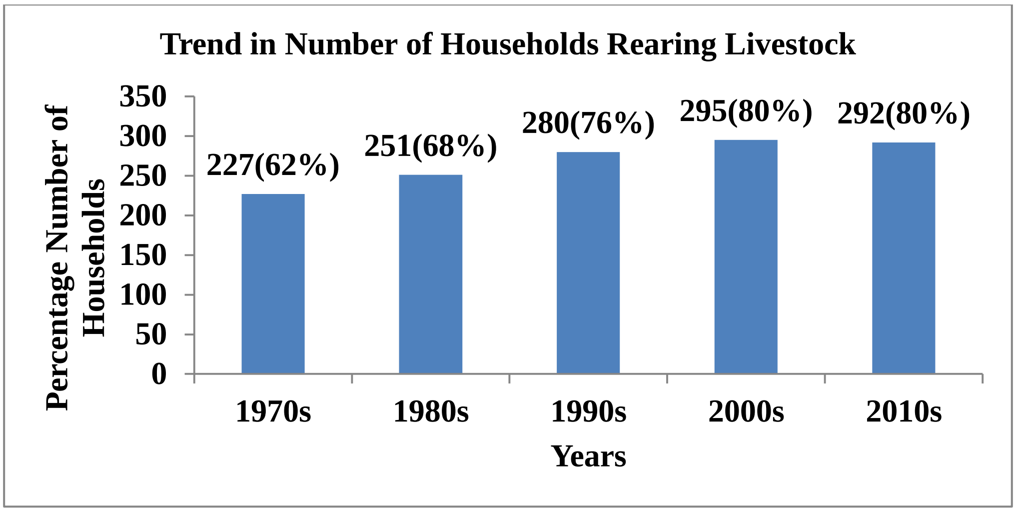

Figure 4.26: Changes in Number of households rearing livestock

Plate 4.11: Animal grazing within the Mt Elgon forest

According to Yongliang *et al.*, (2010), the interaction between population and land use is often embodied in the fact that, with the population growth, arable land increases to meet food demands. Secondly, the immigration population needs residential area and thus it is inevitable to take up arable land, grassland or forest land and other non-cultivatable land for settlements and agricultural production. Indigenous Information Network (2008) confirmed that changes in vegetation cover are mainly caused by population growth and conflicts. Olupot and Chapman (2006) confirmed that an estimated 65.1 million hectares of forests in developing countries were destroyed between 1990 and 1995. Further, they showed that high population pressure caused by high population growth and immigrations are responsible for this decline in natural forests. Many other studies (Vangen, 2009, Uganda Wildlife Authority, 2011, Cavanagh, 2012) show encroachment of protected areas for agriculture and livestock which is big challenge for nature conservation in developing countries. Boserup, (1988) argued that, as the population grows, arable land becomes scarce, which spurs scarcity, driving people to intensify agricultural production. From this perspective, agricultural change is driven primarily by the changing consumption needs of the local population as a result of population growth.

Tea farming was cultivated as a buffer around the natural forest by the Nyayo Tea Zone Corporation (Ongugo *et al.*, 2014). The Mt. Elgon Integrated Conservation and Development Initiative (MEICDI) estimated that the local communities have illegally excised over 5000 hectares of Chepyuk forest and over 2000 hectares of Kitale forest had been cleared and converted to maize and wheat cultivation (Ochuoga, 2002). Similarly, Geist and Lambin, (2002) reported that human activities and increased demand for forest products such as fuel wood and logs were the primary drivers of tropical forest deforestation.

Ongugo *et al.,* (2014) confirmed that authorized logging has been practiced in Mount Elgon forest since the 1930s. For instance, a 1986 Presidential Decree banned all logging in Kenya’s natural forests but excluded Mount Elgon, where legal logging continued. In the 1970s, large tracts of forest land were excised from the Mount Elgon Forest in areas such as Chebyuk, where 600 families were settled. Birdlife International (2012) confirmed that commercial logging has heavily affected the Mt Elgon ecosystem. In addition, they reported that agricultural encroachment and charcoal production continue to degrade many areas in Mt Elgon forest. According to UNEP (2009), deforestation and habitat fragmentation have increased significantly in developing countries in the last 50 to 100 years seriously threatening tropical forest ecosystems and their biodiversity (Lung and Schaab, 2009). According to IBID, logging for commercial purposes has made significant inroads into the forest during the 2000s, opening the way for encroachment by the pastoralist’s adjacent community. Lambin *et al. (*2001) reported that the progressive integration of West Africa into a global market economy has led to expansion of foreign investment in the mining and timber industries of the Guinean forest countries, which increased the rate of forest loss.

Renner (2017) indicated that the Shamba system opposes the practices by which indigenous populations sustain themselves and practices that support forest conservation, as it incentivizes farmers to clear native vegetation and actively hinder the growth of plantation saplings. He further indicated that the Kenyan Shamba system assures the continued degradation of montane forests as well as the disruption of normal soil renewal and irrigation processes essential for successful agriculture. Mt Elgon forest is one such montane forest.

Kironchi (1996) argues that high population density and food insecurity in plantation areas, coupled with the limited number of SHAMBAS available at any given time, make the SHAMBA system untenable in its original form and therefore prone to corruption. Since farmers do not own the SHAMBA land, it is inevitable that what Hardin (1968) terms a tragedy of commons will apply. Many SHAMBA farmers often exploit plantation forests; unsustainably consume forest resources without considering the effects of this consumption on natural ecosystems and to other farmers. As a result, the SHAMBA system is a link to illegal activities such as illegal logging, charcoal burning (Witcomb & Dorward, 2009).

Nangware *et al*. (2019) indicated that the implementation of private investment in the forestry sector encouraged by the Tanzania's national forest policy of 1998 influenced the conversion of Miombo woodlands into teak plantations in Kilombero and Ulanga districts. Additionally, land and agricultural policies provided an enabling environment for the international investment and private–public partnerships in the agriculture sector by influencing the opening of large-scale commercial ventures for rice and sugarcane, such as Kilombero Plantation Limited (KPL). Similarly, Nangware *et al.,* (2019) indicated that the expansion of agriculture was the main driver for LUC, which was reported by 98% (n=59) of respondents, free livestock grazing 90% (n=54)), wood extraction for fuel wood and charcoal-making as well as wood for domestic use 87% (n=52) and settlement expansion 47% (n=28).

Müller and Zeller, (2004) confirmed that the intensification of human activities in the Central Highlands of Vietnam region is the major proximate driver of land use change. According to (Malthus, 1960) growth in rural population increases the demand for agriculture to feed the ever-increasing population. This leads to the expansion of agricultural land into marginal lands, and land fragmentation, decreased productivity and famine, which are pathways to poverty and environmental degradation. The decline in natural and bamboo forests, and grasslands in Mt Elgon ecosystem is one such degradation.

4.5 Land Use Change and Floral Diversity

This study established that land use change had various effects on plant species. These effects varied depending on the land use involved. In this study, the land uses examined included exotic plantations, indigenous plantations, urbanizations, tea farming and mixed farming. The effects were mainly, changes in species diversity and abundance. In particular land uses impacted the abundance of trees, herbs shrubs, ferns, climbers and grasses. There was a significant decrease in the abundance of trees in majority of the land uses but an increase in herbs and shrubs.

4.5.1 Plantation Forests and Floral Diversity

The exotic plantation forest had a lower diversity index (H=1.28131, evenness=0.616182) compared to the indigenous (H= 1.93962, evenness=0.69957) and the natural (control) forests (H=2.07331, evenness=0.864). Within-habitats of planted forests, Whittaker beta diversity index for Indigenous plantation forest verses control site overally ranked higher with β-diversity index of 0.2222 as compared to the beta diversity of the control site verses the exotic plantation forests with 0.0000

These findings show that the diversity of indigenous plantation forest can easily approach that of undisturbed natural forests over a shorter time scale. Results indicated that there was an insignificant difference in the plant species diversity between and indigenous plantation forests (H= 1.93962) and the near natural (control) forest at the Labot site (H=2.07331). Similarly, there was variation in the evenness of plant species in the three study sites. This suggests that planting indigenous forests can restore floral diversity as compared to exotic plantation. On the contrary, the use of exotic plantation forest appears to explain reduction in floral diversity in the Mount Elgon forest ecosystem. The Whittaker beta diversity index reveal a higher similarity in the species between the control site verses the indigenous plantation. It however shows that there is no similarity in the plant species of the control site verses the exotic plantation forests. Plate 4.12 and plate 4.13 below shows exotic plantation and natural forests.

Plate 4.12: Exotic Plantation

Plate 4.13: Indigenous Plantation

4.5.1.1 Comparison of Species abundances

Figure 4.27 shows results of the changes in abundance of species in the control indigenous and plantation forests.

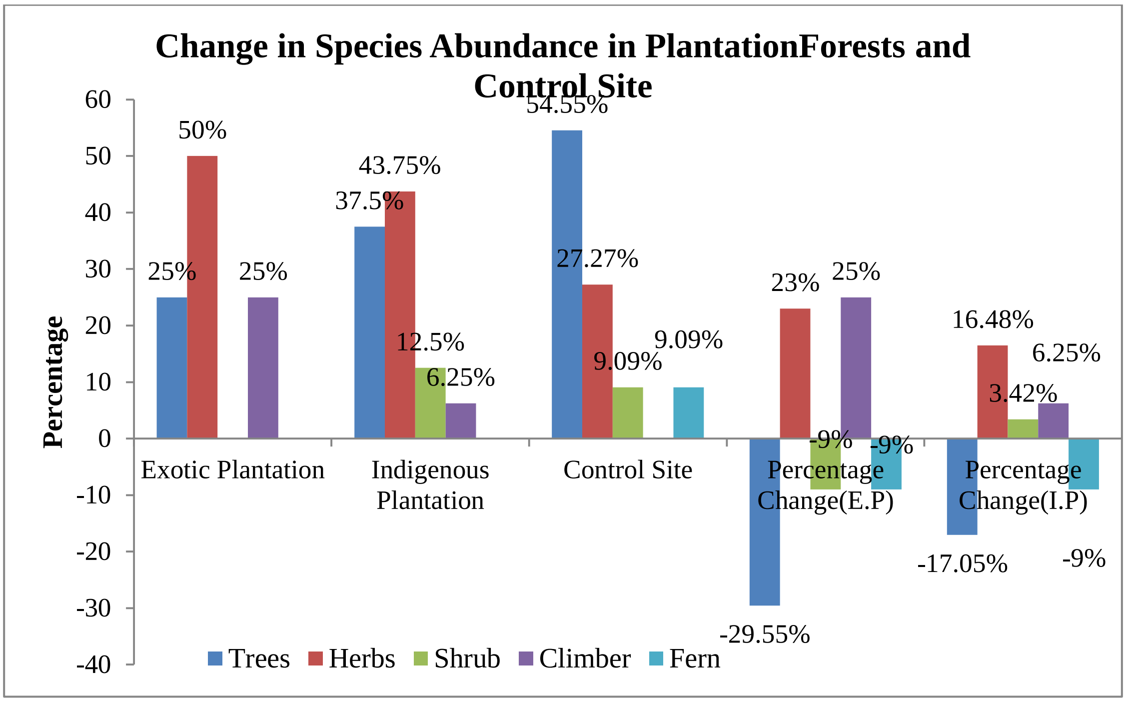

Figure 4.27: Percentage Change in Species diversity Between the Control and Exotic Plantation (E.P) and Indigenous Plantation (I.P) forest.

Herbs were the most abundant species in exotic and indigenous plantation forests. Herbs had an abundance of 50% (n=4) in area under exotic plantation forest and 43.75% (n=7) in the area with indigenous plantation forests. This translated to a 23% increase in herbs in exotic plantation forest and a 16.48% increase in herbs in indigenous plantation forests compared to the control site with herb abundance of 27.27% (n=3).

Results established that 25% (n=1) and 37.5% (n=6) of the plant species in the site with exotic and indigenous plantations respectively were trees compared to the 55% (n=6) trees in the control site. This was a 17.5% decline in the abundance of tree species in the area with both plantation forests. There was one fern species in the control site but was absent in site under both indigenous and exotic plantations. Shrubs also increased by 3.41% in the indigenous plantation site in comparison to the Labot control site but did not exist in exotic plantations (Figure 4.27). It is clear that planting of exotic plantations could favour the increase of herbs in the study area.

Further analysis on herbs in the control site revealed that *Crepis carbonaria* was the most abundant herb with 47.5% (n=3800). *Oxalis anthelmintica* had an abundance of 28.13% (n=2250) while *Isoglossa laxa* had an abundance of 24.38% (n=1950) (Figure 4.28).

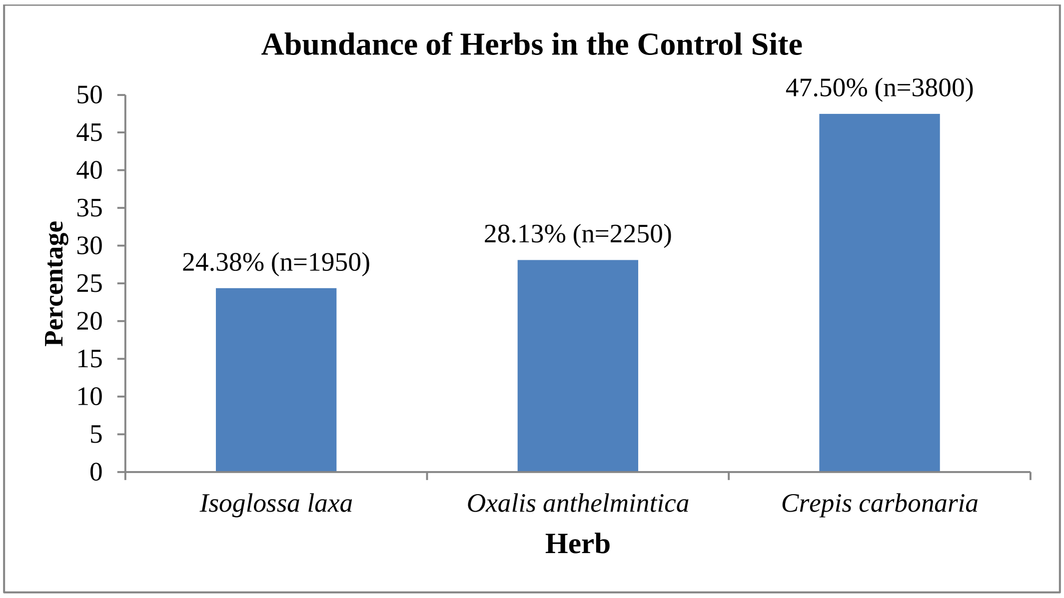

Figure 4.28: Abundance of Herbs in Labot Control Site.

Further analysis on the abundance of herbs in the indigenous forest plantation and control site revealed that, *Isoglossa laxa* was the most common herb in the indigenous plantation forest with an abundance of 66.53% (n=8050). This was a 42.15% increase from the 24.38% (n=1950) abundance in the control site.

Oxalis anthelmintica showed a significant 23.17% decline in abundance from 28.13% (n=2250) abundance in the control site to 4.96% (n=600) abundance for the site under indigenous plantation (Table 4.2).

Table 4.2: Percentage Change in Abundance of Herbs between the Control and Indigenous Plantation

Herb	Indigenous Plantation (%)	n	Control Plot (%)	n	% Change
Isoglossa laxa	66.53	8050	24.38	1950	+42.15
Oxalis anthelmintica	4.96	600	28.13	2250	-23.17
Crepis carbonaria	-	-	47.5	3800	-47.5
Plectranthus comosus	7.02	850	-	-	+7.02
Vernonia auriculifera	17.32	2100	-	-	+17.32
Vernonia hymenolepis	3.31	400	-	-	+3.31
Lantana trifolia	0.83	100	-	-	+0.83

Crepis carbonaria had some 47.5% abundance in the control site but was absent indigenous plantation forests. Some herbs were present in the indigenous planted forests but absent in the control site. These herbs included *Vernonia auriculifera* 17.32% (n=2100), *Plectranthus comosus* 7.02% (n=850), *Vernonia hymenolepis* 3.31% (n=400) and *Lantana trifolia* 0.83% (n=100) (Table 4.2).

The herbs, *Galinsonga parviflora* and *Achyrospermum schimperi* were recorded in the indigenous and exotic plantation forest with an abundance of 34% (n=6000) and 62.5% (n=11000) respectively. These herbs were absent in the control site (Table 4.3). Results further revealed that *Vernonia auriculifera* and *Cymphostemma kilimandscharicum* were present in exotic plantation forest with 2.8% (n=500) and 1% (n=100) respectively. These herbs were also absent in the control plot (Table 4.3).

Table 4.3: Percentage Change in Abundance of Herbs between the Control and Exotic Plantation Forest

Herb	Exotic Plantation **(%)**	**Number**	**Control Plot (%)**	**Number**	**Percentage Change**
Isoglossa laxa	-	-	24.38	1950	-24.38
Oxalis anthelmintica	-	-	28.13%	2250	-28.13%
Crepis carbonaria	-	-	47.50%	3800	-47.50%
Galinsonga parviflora	34	6000	-	-	34
Cymphostemma kilimandscharicum	1	100	-	-	1
Achyrospermum schimperi	62.5	11000	-	-	62.5
Vernonia auriculifera	2.8	500	-	-	2.8

Further analysis of tree species in exotic plantations revealed that *Cuppressus lusitanica* was the only tree species in exotic plantation forest (Table 4.4).

Table 4.4: Percentage Change in Trees Abundance between the Control and Exotic Plantation forest

Tree Species	**Exotic Plantation (%)**	**Number**	**Control Plot (%)**	**Number**	**Percentage Change**
Olea Africana	-	-	1.69	1	-1.69
Erythrina abyssinica	-	-	-	-	-
Cuppressus lusitanica	100	4500	-	-	+91.84
Albiziagummifera	-	-	-	-	-
Acacia lahai	-	-	-	-	-
Cedrus atlantica	-	-	47.46	28	-47.46
Podocarpus latifolia	-	-	22.03	13	-22.41
Olea europea	-	-	11.86	7	-11.86
Hagenia abbysinica	-	-	6.78	4	-6.78
Rapanea melanophloeos	-	-	10.17	6	-10.17

Zanthoxylum giletii was common in the indigenous plantation with an abundance of 39.5% (n=1500) followed closely by *Olea africana 34.2%* (n=1300)), *Erythrina abyssinica*18.4% (n=700)), *Albizia gummifera*, *Croton macrostachys* and *Acacia lahai* with each 2.6% (n=100) abundance (Table 4.5). *Olea africana* was the only tree species that was present in both the control site and the indigenous plantation forest. The results revealed a 32.52% increase in the abundance of *Olea africana* in the site with indigenous plantation (Table 4.5).

Table 4.5: Percentage Change in Tree Abundance between the Control and Indigenous Plantation forest

Tree Species	**Indigenous Plantation(%)**	**Number**	**Control Plot (%)**	**Number**	**% Change**
Zanthoxylum giletii	39.47	1500	-	-	+39.47
Olea Africana	34.21	1300	1.69	1	+32.52
Erythrina abyssinica	*18.4*	700	-	-	+18.4
Croton macrostachys	2.63	100	-	-	+2.63
Albizia gummifera	2.63	100	-	-	+2.63
Acacia lahai	2.63	100	-	-	+2.63
Cedrus atlantica	-	-	47.46	28	-47.46
Podocarpus latifolia	-	-	22.03	13	-22.02
Olea europea	-	-	11.86	7	-11.86
Hagenia abbysinica	-	-	6.78	4	-6.78
Rapanea melanophloeos	-	-	10.17	6	-10.17

In the control Site, *Cedrus atlantica* was the most abundant tree species with 47.5% (n=28) followed by *Podocarpus latifolia* with an abundance of 22% (n=13). Other tree species that were present in the control site included *Olea europea*11.86% (n=7), *and Rapanea melanophloeo*10.17% (n=6) *and Hagenia abbysinica*6.78% (n=4) (Table 4.5).

The two common shrubs in indigenous plantations were *Maesa lanceolatum* had an abundance of 21.7% (n=250) while *Triumfetta rhomboidea* had an overabundance of 78.3% (n=900). Further analysis established that the shrub *Vangueria apiculata* was present in the control site but absent in the both plantation forests. Ferns while present in the control site were absent in plantation forests.

While climbers were absent in the control site, there was one species each in the exotic and indigenous plantation forests. *Stephania abysssinica* was the common climber in the exotic plantation forest while *Dichondra repens* was the common climber in the indigenous plantation forest.

Describing plant communities has been an important area of concern in plant science for centuries, with an ancient focus on the distribution, composition and classification of plant communities (Kashian *et al*., 2003). In this study, differences were observed in the number of trees, herbs, shrub and climber species, between plantation forests and natural forest. Natural forest had a higher richness of trees species while planted forests had a higher richness of herbs and shrubs. Several herbs and shrubs species were restricted only to plantation forests. For instance, *Isoglossa laxa* and *Oxalis anthelmintica* were only restricted to the control site and indigenous planted forests whereas *Achyrospermum schimperi* and *Galinsonga parviflora* were mainly restricted to plantation forests.

The findings of this study partly agree with the findings of Norul and Mizarul (2011) who carried out a similar research in Natural forest and exotic plantations of Rema-Kalenga

Wildlife Sanctuary in Bangladesh. The study revealed a Shannon-Wiener diversity index of 2.70 for tree species of the natural forest while that of the plantation forest was 2.35. While exotic plantations support lower tree diversity, indigenous plantations appeared to support more tree species diversity. Stephens and Wagner, (2007) also found that indigenous plantations are generally more similar in habitat structure to natural forests than are exotic plantations.

The findings of this study differ from those of Norul and Mizarul, (2011) where they reported that 15 species of shrubs under 10 families were identified in the natural forest while 8 species of shrubs of 7 families were recorded from the exotic plantation sites. Norul and Mizarul, (2011) also reported that there were more herb species in the natural forest with a richness value of 21 species in 17 families compared with 12 species of herbs in11 families in the plantation forests.

While many researchers have found low levels of biodiversity in exotic plantations forests (Matthews *et al.*, 2002; Barlow *et al*., 2007; Makino *et al.*, 2007), other studies suggest that plantation forests can play an important role in biodiversity conservation and restoration of forest species. Enhanced biodiversity outcomes are expected with plantations that utilize indigenous tree species (Pejchar *et al.*, 2005).

4.5.2 Urban Settlements and Floral Biodiversity

There was an insignificant decline in the plant species diversity in the urban settlements with a diversity index of H= 1.85081 and Evenness of 0.66754 compared to the Labot Control site with a diversity index of (H =2.07331) and an evenness of E=0.864637. Whittaker beta diversity index for urban settlements verses control site was ranked highest with β diversity index of 0.5385. These results reveal that floral diversity in urban settlements resembled closely those in the control site.

4.5.2.1 Comparison of Species abundances

A closer comparison of species-by-species diversity in the control site and species under urban settlements revealed that trees declined by 29.55% in urban settlement site from 54.55% (n=6) to 25% (n=4). There was one fern species in the control site but was absent in site under urban settlement. There was, however, an increase in herb species in urban settlement site by a 16.48% from 27.27% (n=3) to 43.75% (n=7). Shrubs were the third most common species in urban settlements with 18.75% (n=3) dominance (Figure 4.32). This was a 9.6% increase in urban settlements in comparison to 9.09% (n=1) abundance in the control site. Grasses had a 6.25% (n=1) abundance in the site under urban settlement (Figure 4.29).

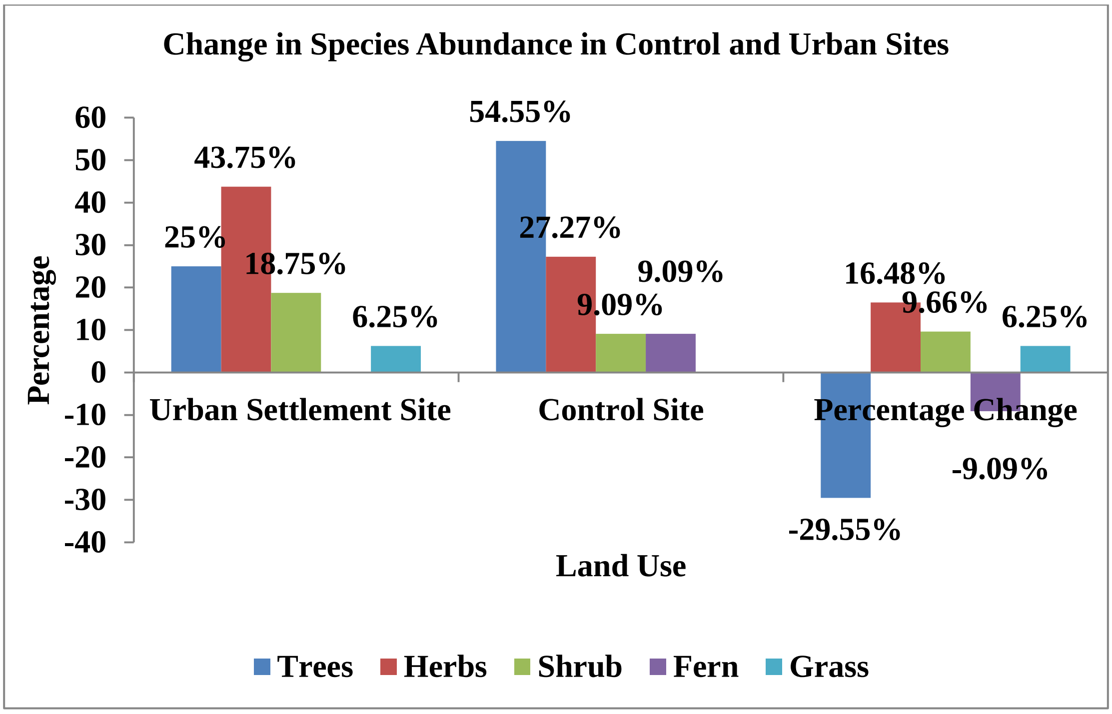

Figure 4.29: Differences in Percentage Change in plant species between urban settlements and the control site.

Further analysis on urban settlements established that *Olea europea* was the most dominant tree species with 86.49% (n=32) dominance, followed by *Podocarpus latifolia 8.11%* (n=3). The least dominant tree species were *Olea Africana* and *Cedrus atlantica* with 2.7% (n=1) each (Figure 4.29).

In the control site, *Olea europea* recorded a major increase in abundance from 11.86% (n=7) to 86.49% (n=32) in the urban settlement marking a 74.63% increase. Similarly, 6.42 % increase in urban settlements was recorded in *Olea Africana*. However, declines were noted in some tree species. The highest decline in urban settlements was reported in *Cedrus atlantica* with a 44.76% from 47.4% (n=28) to 2.7% (n=1). *Podocarpus latifolia* had the second highest decline in urban settlements with 19.33% from 22.03% (n=13) to 2.7% (n=1) (Figure 4.30).

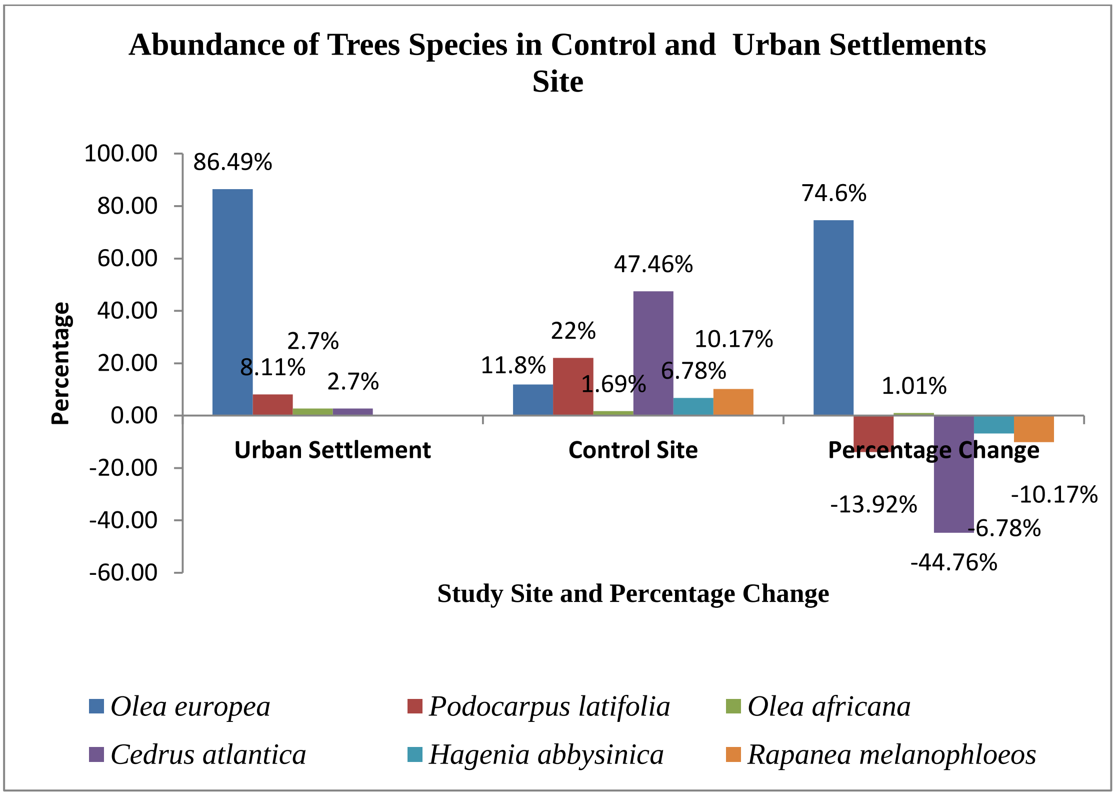

Figure 4.30: Differences in Percentage Change in Trees abundance between the Control and Urban Settlements

Further analysis of herbs revealed that *Oxalis anthelmintica* was the most common herb in urban settlements with an abundance of 57.54% (n=14,500) while *Commelina lugardii* and *Kalanchoe mitejea* were the least common herb in the sampled sites with 1.19% (n=300) (Figure 4.31).

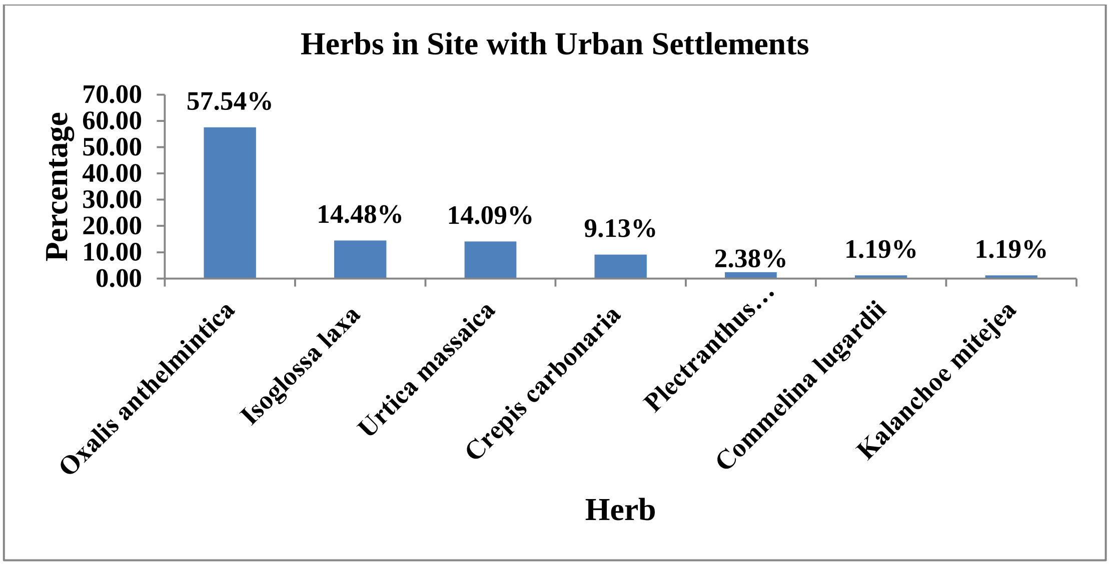

Figure 4.31: Abundance of herbs in Urban Settlements

Analysis of changes in abundance of herbs in urban settlements and the Labot control site, revealed that *Oxalis anthelmintica* had the highest increase of 29.41% from 28.13% (n=2250) to 57.54% (n=14500). *Urtica massaica* 14.09% (n =3550) was present in the urban settlement site but did not exist in the control site. Other herbs that increased in the urban settlement site included *Plectranthus comosus* (2.38% n=600), *Commelina lugardii* and *Kalanchoe mitejea* (1.19% n=300).

On the contrary *Crepis carbonaria* had the greatest decline of 38.37% from 47.5% (n=3800) to 9.13% (n=2300) followed by *Isoglossa laxa* with a 10% decline from 24.37% (n=1950) to 14.48% (n=3650) (Figure 4.32).

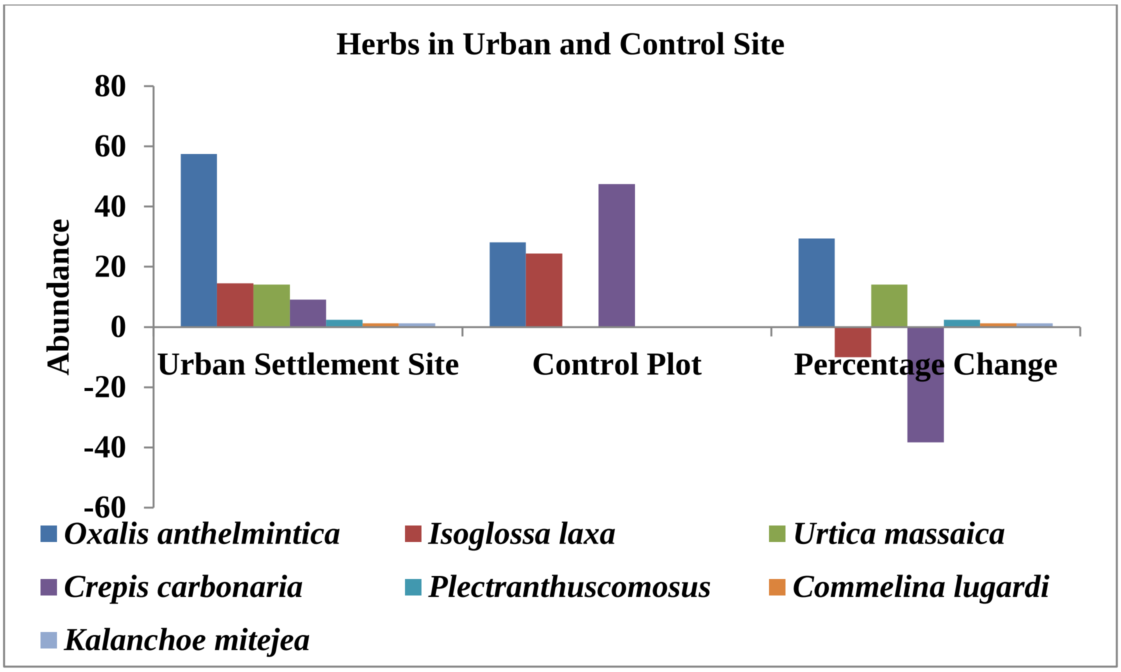

Figure 4.32: Percentage Change in Herbs between the Control and Urban Settlements

Research further revealed that *Rapanea melanophloeos* tree species and *Hagenia abbysinica* tree species were absent in the urban settlements **(**Figure 4.32). This is a clear indication that urban settlement negatively impacts diversity of tree species. Ground truthing identified 37 tree stumps in this urban settlement site that may have resulted from logging. The tree stumps were of *Cedrus atlantica and Podocarpus latifolia* species. This probably explains the reason for the decline in tree species.

Further analysis on shrubs revealed that *Clutia abbysinica* was the most common shrub in urban settlement site with a 65.52% (n=950) dominance followed by *Solanum dasyphyllum* 20.69% (n=300) and *Balanites aegyptiaca* 13.79% (n=200) (Figure 4.33). On the contrary, these shrubs were missing in the control site.

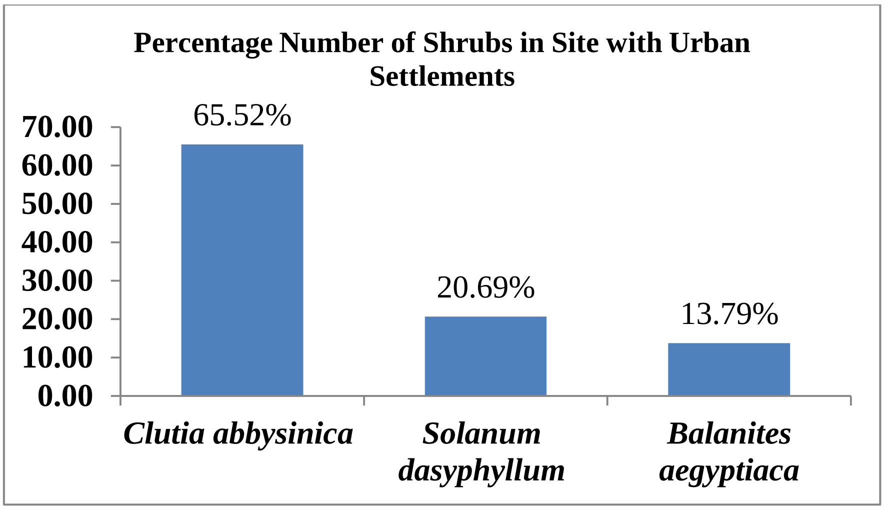

Figure 4.33: Percentage number of Shrubs in Urban Settlements

Further analysis revealed changes in diversity and abundance of shrubs found in the control site compared to those in the site under urban settlement. *Vangueria apiculata* was the only shrub that was recorded (9.09%) in the control site but was absent in the urban settlements. On the contrary, *Clutia abbysinica* accounted for (12.28%) of the herbs in urban settlements, *Solanum dasyphyllum (3.88%) and Balanites aegyptiaca (*2.59%) (Figure 4.34*).*

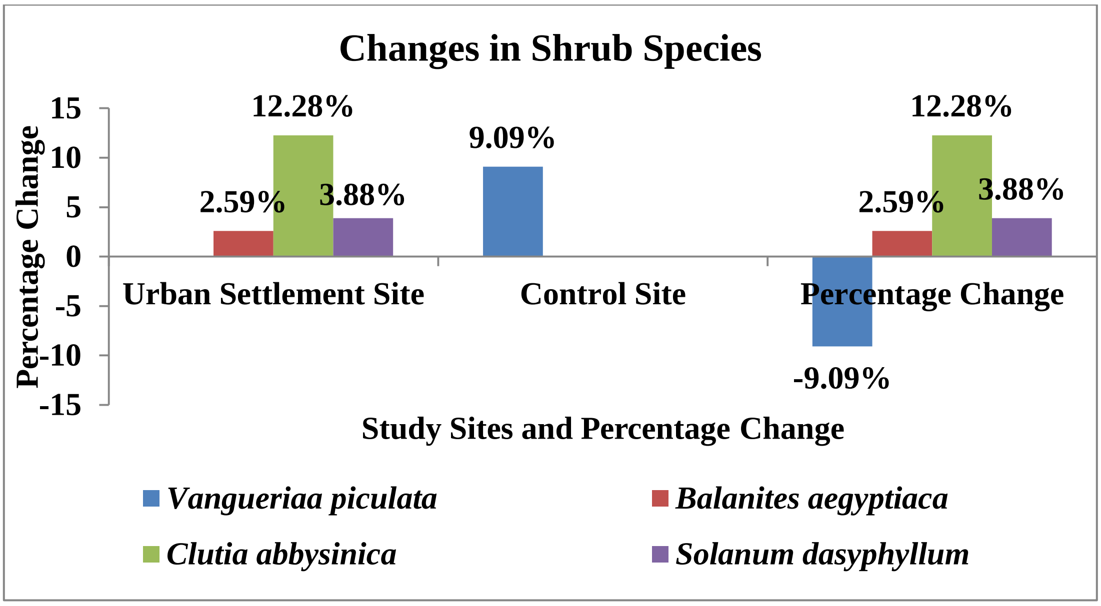

Figure 4.34: Percentage Change in Shrubs in Urban Settlement verses the Control Site.

Liporcarpa nana was the only sedge encountered in the urban settlement but was absent in the control site. The fern *Pteris catoptera* was also absent in urban settlements despite its presence in the control site.

During the last decades, the level of urban sprawl has increased worldwide and these could subsequently have an impact to plant species diversity. Forests are one of the most important habitat types in urban landscapes harbouring many native species and providing essential ecosystem services. Many studies have described the effects of urbanization on species richness and indicated that urbanization can increase or decrease species richness, depending on several variables. Some of these variables include: taxonomic group, spatial scale of analysis, and intensity of urbanization.

In Kenya, Chepkitale urban centre is located within Mt Elgon Forest of Bungoma County. Most of the urban centres in Mt Elgon region are small and only occupy a small region. This could explain the high diversity index in the plant species of this study site. Knapp *et al.*, (2008) reported similar findings that cities in Germany were hot spots of plant species richness, but included many closely related and functionally similar species, suggesting a decreased capacity in urban areas to respond to environmental challenges.

Ramona *et al.*, (2018) reported a decrease in plant species diversity with increasing degree of urbanization in Switzerland. Cameron *et al.*, (2015) reported similar results for plant species richness, but did not find any effect on plant diversity. In contrast, McKinney, (2008) found the highest number of plant species in areas with medium degree of urbanization, whereas Vallet *et al*., (2010) did not detect any difference in total species richness of plants between urban and rural woodlands.

Results on the effects of urbanization on floral diversity in Phoenix, Arizona, by Walker *et al.,* (2009) reported large decreases in local plant species diversity with urbanization. They however indicated that tree species richness is also generally elevated in urban areas relative to proximate ‘‘natural’’ habitats (Nowak, 2010). Altered environmental conditions in the urban environment, such as anthropogenic soils, pollution, and the urban heat island.

McDonnell *et al*., (1993) may also negatively or positively affect particular tree species (Searle *et al.,* 2012). Furthermore, human preferences are also likely to select for and against species (Williams *et al*., 2009; Nowak, 2010). While we see that trends of urbanization are increasing globally (UN, 2014) ecological research into the effect of urbanization on biodiversity show a negative relationship between floral diversity and urbanization.

4.5.3 Tea Farming and Floral Diversity

Results on effects of sugarcane farming on floral diversity show that floral diversity in the tea zones was lower (H=1.5324, Evenness=0.864) than in the Labot Control Site, (H=2.07331; Evenness=0.864). Whittaker beta diversity index for Nyayo Tea Zone verses control site revealed a similarity index of 0.1429. These results clearly demonstrate that tea farming significantly decreases floral diversity. Tea farming could partly explain the decline in plant species in the Mt. Elgon forest ecosystem.

4.5.3.1 Comparison of Species abundances

A species-by-species comparison between the control site and the area under tea growing reveals that, trees and ferns declined by 48.3% and 9% respectively while herbs increased by 33%, climbers and grasses 6.67%, and shrubs 4.21% in the Nyayo Tea Zone (Table 4.6).

Table 4.6: Percentage Change in Species between Control Site and Nyayo Tea Farming Zone (NTZ)

Species	Nyayo Tea Zone (%)	N	Control Site (%)	N	Percentage Change
Trees	6.67	1	55.54	6	-48.3
Ferns	0	0	9	1	-9
Herbs	60	9	27	3	+33
Climbers	6.67	1	-	-	+6.67
Grasses	6.67	1	-	-	+6.67
Shrubs	13.3	2	9.09	1	4.21
Sedge	6.67	1	-	-	6.67
TOTAL	100	15	100	11	

Herb species included *Achyrospermumschimperi*, *Conyzabonariensis*, *Cymphostemma kilimandscharicum*, *Dichondra repens*, *Galinsonga parviflora*, *Isoglossalaxa*, *Oxalis anthelmintica*, *Urticamassaica*and *Vernonia auriculifera.*

Further analysis of herbs revealed that the most abundant herb in the Nyayo Tea Zone was *Urtica massaica* with about 71.6% (n=72000) followed by *Oxalis anthelmintica* with a 9.9% (n=10000). The third most abundant herb was *Dichondra repens* with about 7.4% (n=7425) of the total herb population (Figure 4.35).

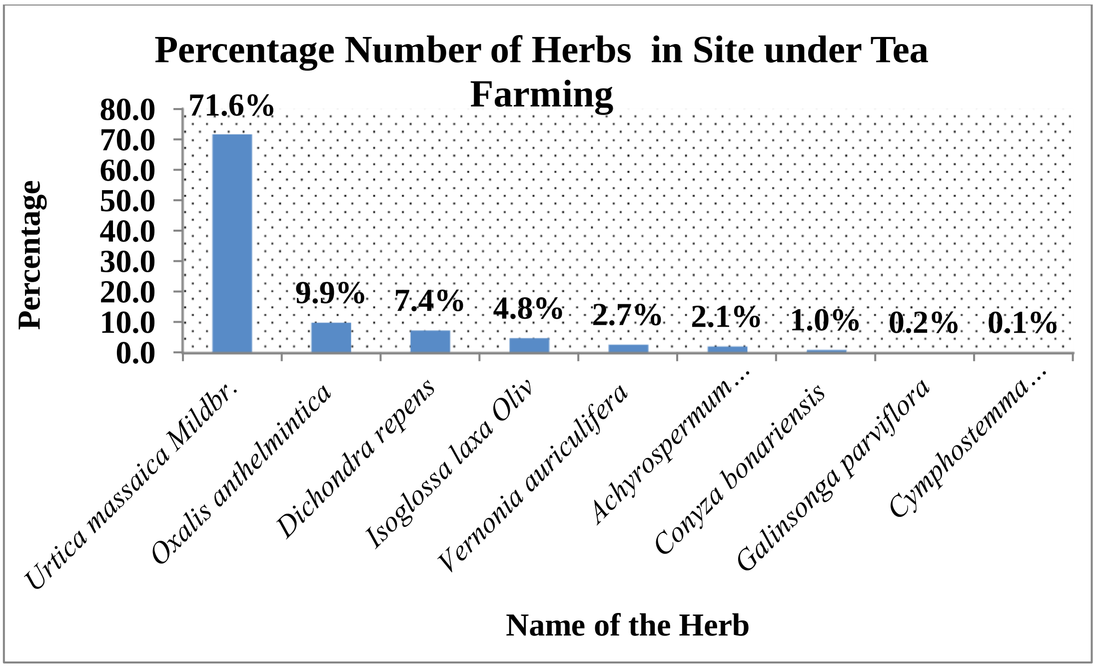

Figure 4.35: Percentage of Herbs in Tea Farming

In the control site, there were three dominant herb species *Crepis carbonaria (*47.5% n=3800)*, Oxalis anthelmintica* (28.12% n=2250 and *Isoglossa laxa* 24.37% n=1950) (Figure 4.36*).*

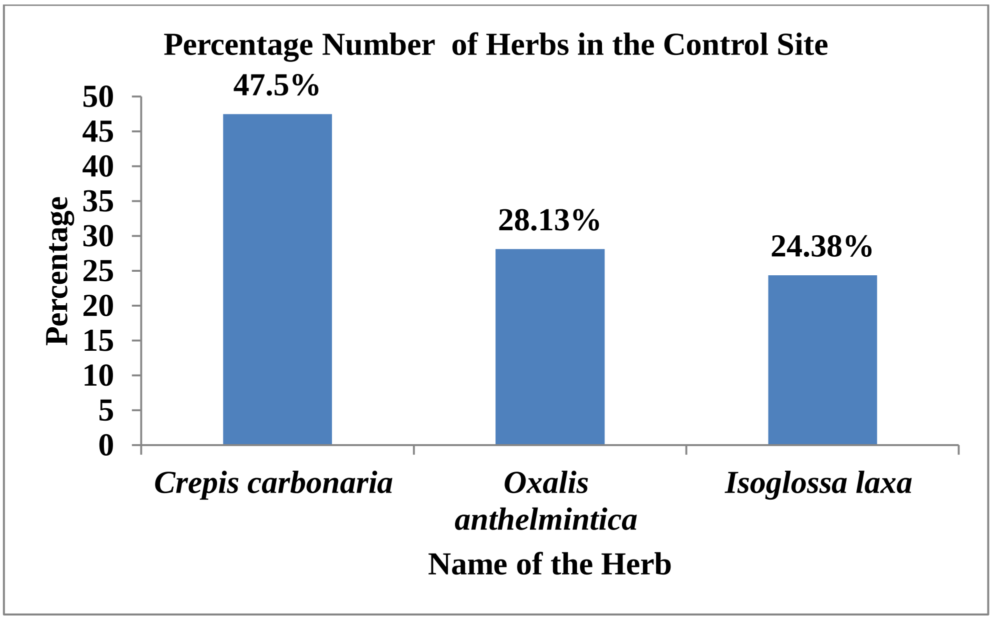

Figure 4.36: Percentage of Herbs in the Control Site

A comparison of the abundance of the herb species between the control site and the NTZ reveals that *Isoglossa laxa* experienced a 19.58% decline in its abundance in the tea farming areas compared to the control plot while *Oxalis anthelmintica* reported an 18.23 % decline (Table 4.7).

Table 4.7: Percentage Change in Herbs between Tea Farms and the control

Herb	NTZ (%)	N	Control Plot (%)	N	Percentage Change (%)
Urtica massaica	71.6	72000	-	-	+71.6
Crepis carbonaria	-	-	47.5	3800	-47.5
Oxalis anthelmintica	9.9	10000	28.13	2250	-18.23
Dichondra repens	7.4	7425	-	-	+7.4
Isoglossa laxa	4.8	4875	24.375	1950	-19.58
Vernonia auriculifera	2.7	2750	-	-	+2.7
Achyrospermum schimperi	2.1	2133	-	-	+2.1
Conyza bonariensis	1	1000	-	-	+1
Galinsonga parviflora	0.19	200	-	-	
Cymphostemma kilimandscharicum	0.15	150	-	-	-

Urtica massaica herb was absent in the control site but had 71.6% (n=72000) abundance in the tea farming site. This herb accounted for the 23.6% of the 33% increase observed in the herbs (Table 4.7).

The Nyayo Tea Zone was dominated by one exotic tree species called *Cuppressus lusitanica*, that accounted for 6.67% of the species in NTZ. On the contrary, about 55% (n=6) of the plant species in the control sites were indigenous trees (Figure 4.37).

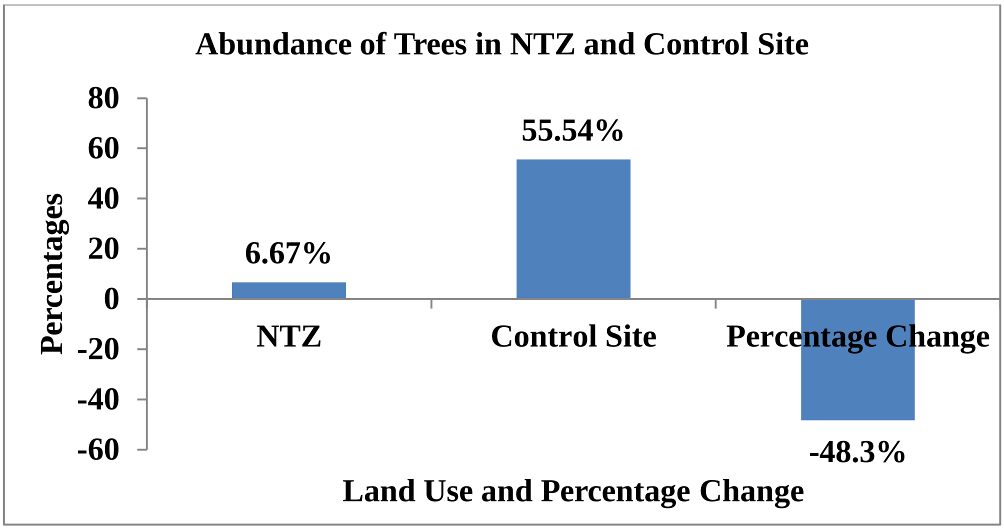

Figure 4.37: Differences in Abundance of Trees in NTZ and Control Site

The tree species that were sampled in the control site but were absent in the NTZ included *Cedrusatlantica* 47.46% (n=28), *Podocarpus latifolia* 22.41% (n=13), *Olea europea* 11.86% (n=7), *Rapanea melanophloeo*10.17% n=6, *Hagenia abbysinica* 6.78% (n=4) and *Olea Africana* 1.61% (n=1) (Figure 4.38).

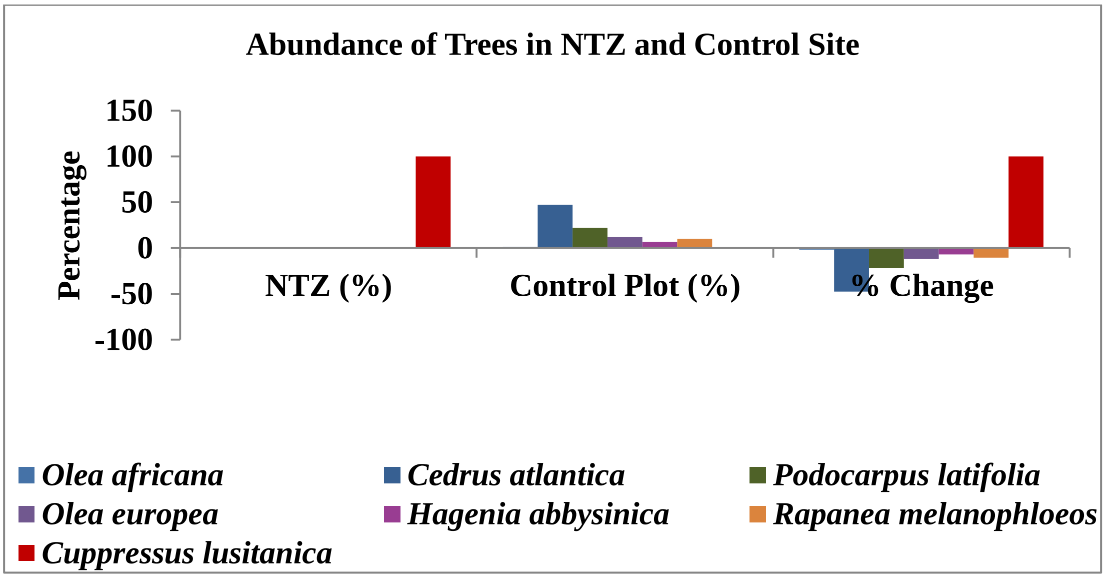

Figure 4.38: Differences in Percentage change in trees abundance between tea farms and the control site.

There were 10 stumps of indigenous tree species such as *Olea africana* in the control plots caused by natural death (Plate 4.14)

Plate 4.14: Stumps of indigenous tree in Labot Control Site

In the NTZ, there were 18 stumps of trees of indigenous tree species that appeared to have been harvested. This probably could explain the reason for the disappearance of the tree species and an indication that the region has experienced increased anthropogenic activities such as logging and deforestation.

There was an observed 4.21% increase in shrubs in the Nyayo Tea Zone 13.3% (n=2)) compared to 9.09% (n=1)) in the control site (Figure 4.39).

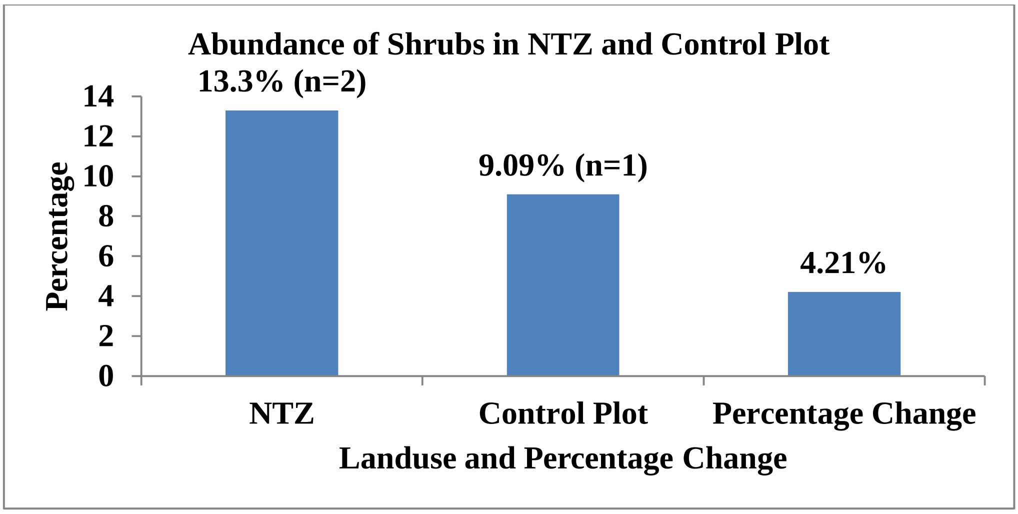

Figure 4.39: Differences in Percentage Change in Shrubs between the Control and NTZ

Further analysis of shrubs revealed that *Senna didymobotrya* was the most abundant shrub in the Nyayo Tea Zone site with 97.96% (n=2400) followed by *Dombeya torrid* with 2.04% (n=50) respectively.

Vangueria apiculata (9%) shrub was the most dominant shrub in the control site. *Senna didymobotrya* accounted for majority (4.2%) of the increase in shrubs in the Nyayo Tea Zone. *Pteris catoptera* was the dominant fern in the control site with a 9% (n=1) dominance. The dominant climber in Nyayo Tea Zone was *Stephania abysssinica* with a 6.67% (n=1) dominance.

These findings reveal that the transformation of land from natural forests to tea farming appears to increase the abundance of herbaceous vegetation, at the expense to tree species and ferns (Plate 4. 15).

Plate 4.15: Area of study with tea plantation as the major land use

The findings of this study revealed that tea farming maybe responsible for the decline in plant species diversity in the study area. These findings are in agreement with those of Selena *et al*., (2012) who provided evidence of ecological simplification with increased density of tea cultivation in Yunnan, China. Ranjan *et al.,* (2019) further confirmed that modern agriculture such as tea farming has become the single largest cause for the depression of biodiversity. Most tea plantations strictly follow monocultural practices, biodiversity assemblages in such plantations are poor compared to forest ecosystems (Lin *et al.,* 2012). Pia He and Konrad (2016) reported that expansion of rubber cultivation in the Mekong Region China led to a considerable degradation of biodiversity through the loss of natural forest area.

Varah *et al.* (2013) further indicated that modern agricultural farming methods such as tea farming focus on providing just one ecosystem service: food production, which is achieved by reducing environmental complexity and growing large areas of monocultures for better economies of scale. This lower species diversity can lead to lower functional diversity, which eventually results in reduced ecosystem functions (Mace *et al.*, 2012). Scherr and McNeely, (2007) indicated that cash crops such as coffee and tea, requiring cooler environments, force farmers of these crops to move higher up the hills, clearing new lands. In the process, montane forests important for biodiversity are likely to come under increasing threat. So far, there have been a few studies utilizing an inventory-based analysis of the relationships between land use and plant species diversity and species richness in Mt Elgon forest ecosystem.

4.5.4 Mixed Farming on Floral Diversity

There was a significant decline in the plant species diversity in mixed farming (H=1.43694; evenness 0.4521) compared with the Labot Control site (H=2.07331; evenness 0.864). This confirms that mixed farming as a land use adds to the significant decline in plant species in the Mount Elgon forest ecosystem. Whittaker beta diversity index for mixed farming verses control site was ranked the lowest with β diversity index of 0.000. These findings indicate that there were dissimilarities in plant species composition in the control site and the mixed farming site.

Species-by-species analysis revealed that the most abundant species in mixed farms were herbs with 54.55% (n=12) abundance. This was followed by shrubs with an abundance of 36.36% (n=8) while climbers and trees were the least abundant with each at 9.09% (n=2) dominance (Figure 4.40)

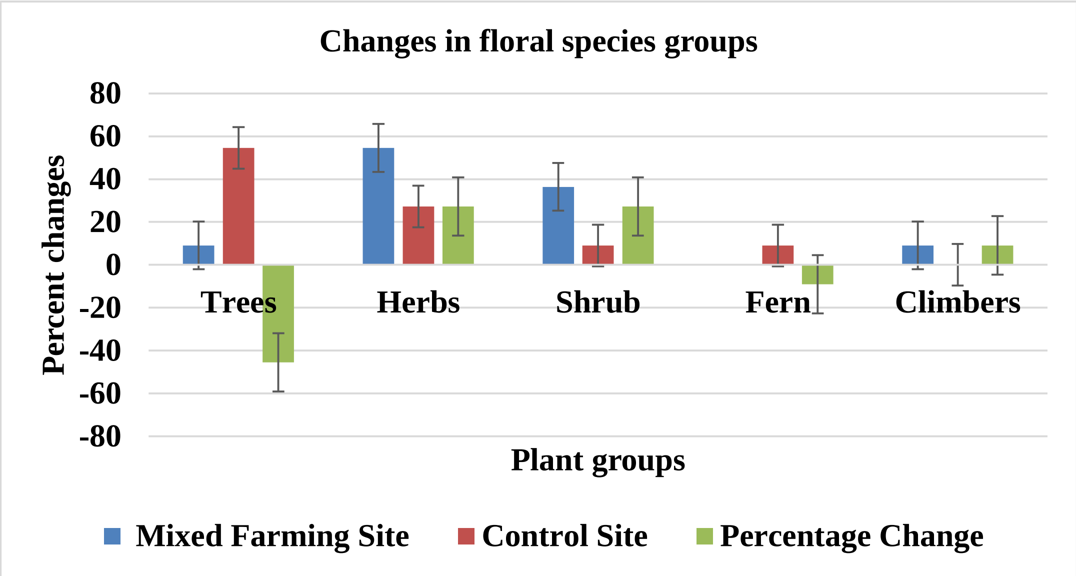

Figure 4.40: Differences in Percentage change in plant species between mixed farming and the control.

The findings of this study revealed distinct variations in plant species between the control site and mixed farming areas. For instance, there was a 45.46% decline in tree species that were found in mixed farming compared to the control site. Similarly, there was a 9.09% decline in the abundance of ferns. On the contrary, there was a 27.27 % increase in the abundance of shrubs in mixed farming. Similar increases were noted in the herbs (27.28%) and climbers 9.09% (Figure 4.40)

Further analysis of herbs revealed a significant difference in herb species in the control site and mixed farming (Table 4.8). Except for *Oxalis anthelmintica, Crepis carbonaria* and *Isoglossa laxa* majority of the herbal species were absent in the control site.

Table 4.8: Percentage Change in Herbs between Mixed Farming and the Control.

Herb	Mixed Farming Site (%)	N	Control Plot	N	Percentage Change
Achyranthes aspera	2.93	867	-	-	2.93
Ageratium conyzoides	3.39	1000	-	-	3.39
Conyza foribunda	0.11	33	-	-	0.11
Crassocephalum picridifolium	1.81	533	-	-	1.81
Galinsonga parviflora	0.56	167	-	-	0.56
Justicia flava	79.91	23600	-	-	79.91
Leonotis nepetifolia	0.9	267	-	-	0.9
Phytolaccado decandra	0.34	100	-	-	0.34
Plectranthus comosus	1.58	467	-	-	1.58
Plectranthus sylvestris	4.51	1333	-	-	4.51
Oxalis anthelmintica	-	-	28.13	2250	*-28.13*
Crepi scarbonaria	-	-	47.5	3800	-47.5
Vernonia auriculifera	3.16	933	-	-	3.16
Vernonia smithiana	0.79	233	-	-	0.79
Isoglossa laxa	-	-	24.38	1950	-24.38

Justicia flava with an abundance of 79.91% (n=23600) was the most abundant and the major contributor to the significant increase in the herbs in mixed farming areas. This herb accounted for some 21.8% of the 27.28% increase in herbs reported under mixed farming while *Plectranthus sylvestris, Ageratium conyzoides* and *Vernonia auriculifera* accounted for a 1% each for the increase. Certain species of herbs, *Crepis carbonaria* 47.5% (n=3800), *Oxalis anthelmintica* 28.13% (n=2250) and *Isoglossa laxa* 24.37% (n=1950) were present in the control site but were absent in mixed farming areas (Table 4.8)

Further analysis of shrubs revealed a significant difference between shrubs in the mixed farming sites and those in the control sites. *Senescio snowdenii* was the most abundant shrub species in the mixed farming site with a 43.39% (n=1533) abundance, while, *Sida rhombifolia*, *Ocimum gratissimum* and *Acanthus eminens* each had an 11.3% (n=400) abundance (Table 4.9). *Senescio snowdenii* was a major contributor to the increase in shrubs and accounted for 11.83% of the reported 27.27% increase. *Ocimum gratissimum*, *Sida rhombifolia* and *Acanthus eminens* each accounted to about 3.1 % of the reported increase.

Table 4.9: Percentage Change in Shrubs between the Mixed Farming and the Control Site.

Shrubs	Mixed Farming		Control Plot	Percentage Change
Senescio snowdenii	43.39	1533	-	+43.39
Ocimum gratissimum	11.32	400	-	+11.32
Acanthus eminens	11.32	400	-	+11.3
Sida rhombifolia	11.32	400	-	+11.32
Senna didimobotrya	6.6	233	-	+6.6
Lantana trifolium	5.66	200	-	+5.66
Mussaenda arcuata	5.66	200	-	+5.66
Rubusniveus	4.7	167	-	+4.7
Vangueria apiculata	-	-	9.09	-9.09

Analysis of trees species revealed that the species present in the mixed farming site differed from those in the control plot (Figure 4.42). The dominant tree species in the mixed farms was *Croton macrostachyus (*66.67%; n=67) followed by *Ficus lutea (*33.3%; n=33; Figure 4.40). The dominant tree species in the control plot was *Cedrus atlantica* (47.46%; n=28) but was absent in mixed farms and accounted for 21.6% of the decline in trees species in mixed farming. *Podocarps latifolia* accounted for 10% of the reported decline in trees in the site under mixed farming.

Declines of 11.86% and 10.17% were reported in the abundance of *Olea europea* and *Rapanea melanophloeos* respectively (Figure 4.41).

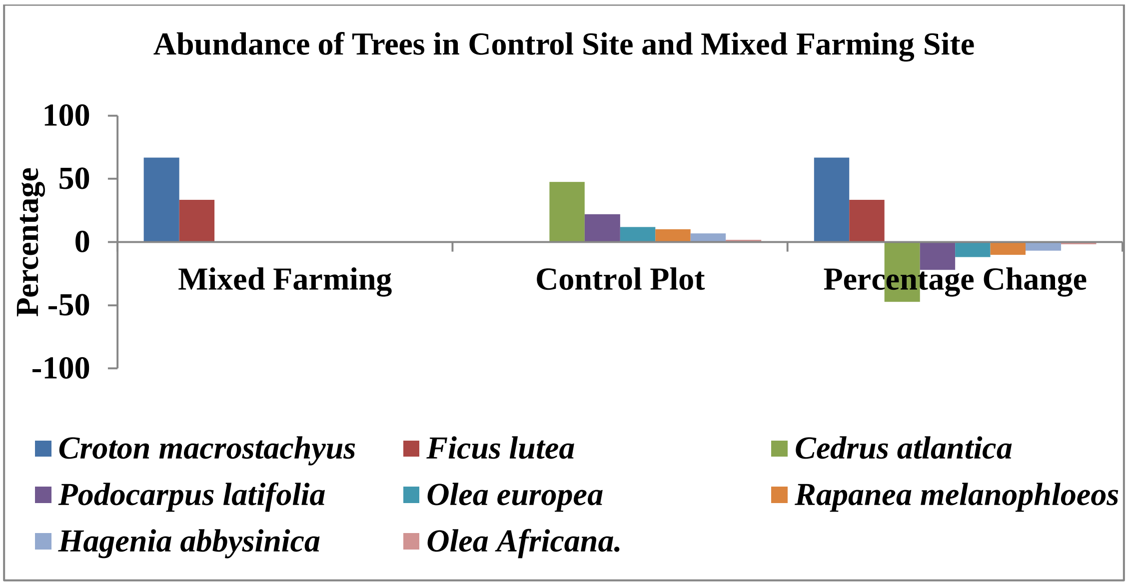

Figure 4.41: Percentage change in trees in the site under mixed farming verses the control site.

Two climbers were present in mixed farming with *Stephania abyssinica* 94.44% (n=567) and *Cymphostemma cyphopetalum*5.56% (n=33) abundance respectively (Figure 4.43). This was a remarkable increase in climbers given that they had not been recorded in the control site. *Stephania abyssinica* accounted for 8.5% of the increase in climbers that were reported in the site with mixed farming.

Mixed farming is often promoted to reduce environmental impacts of agriculture, but little is known about its effects on plant species of the adjacent region. There is little dispute that agriculture is one of the main causes of global biodiversity loss (Kleijn *et al.*, 2009) and that agricultural induced biodiversity decline is accelerated by intensification and expansion of agricultural land use (Clough *et al.*, 2011). After the conversion of natural ecosystems to agriculture, there is gradual replacement of ecological functions (e.g., nutrient mineralization, biological control of pests) by external inputs such as agrochemicals (Barrios *et al*., 2015) This trend leads to a reduction in the capacity of agroecosystems to self-regulate and brings in a greater reliance on external inputs and thus, greater vulnerability to environmental changes (Barrios *et al*., 2015). Many studies in Kenya have focused on land use change and decline in agro biodiversity (Netondo *et al.,* 2010, Mburu *et al.,* 2016, Cunneyworth, 2001, Masayi and Netondo, 2012). Very few studies have addressed the effects of mixed farming on plant species diversity and richness. This study fills this gap of knowledge.

Figure 4.42 summarizes the abundance of various species recorded in different land uses in Mt Elgon forest ecosystem. Herbs were the most dominant, with their greatest abundance being in tea farms, followed by exotic plantation forests. There were, however, least abundant in the control site. Table 4.10 show the Shannon Weiner diversity index of flora in areas under different land uses. The Shannon Weiner Diversity Index of indigenous plantations closely approached that of the control site. Table 4.11 show the beta diversity index of species in areas under different land uses. The beta diversity of control site verses the urban settlement and indigenous plantations verses control site are ranked higher in comparison to other land uses.

Table 4.10: Shannon Weiner diversity index of plant species under different land uses.

Study Sites	Shannon Weiner Diversity Index	Evenness
Control Site	2.07331	0.884
Indigenous Plantation forest	1.93962	0.69957
Urban Settlement	1.85081	0.66754
Nyayo Tea Zone	1.5324	0.56
Mixed Farming	1.43694	0.452114
Exotic Plantation forest	1.28131	0.61612

Table 4.11: The Whittaker beta diversity index of species under different land uses

Rank	**Study Site**	**Beta Diversity Index**
1	Control Site /Urban Settlement	0.5385
2	Control Site/ Indigenous Plantation forest	0.2222
3	Control Site / Nyayo Tea Zone	0.1429
4	Control Site /Mixed Farming	0.000
5	Control Site /Exotic Plantation forest	0.000

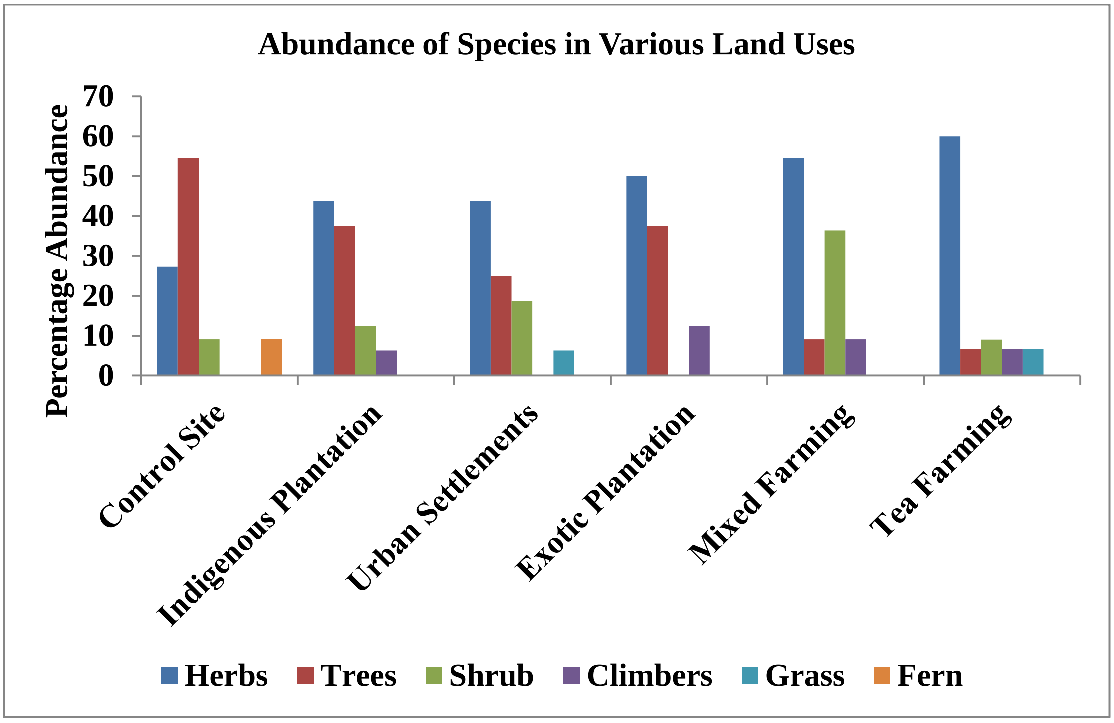

Figure 4.42: Variation in abundance of plant species under different Land uses.

The control site and the NTZ had the least abundance of shrubs with each at (9%) while mixed farming had the majority of shrubs at (36.36%). On the contrary, tree species revealed a declining trend from the control site with the majority (54.55%) to the tea farms with the least number of tree species (6.67%) (Figure 4.42). Ferns were present only in the control sites. These findings point to the fact that, land use change to tea farming and exotic plantations may have contributed to the decline of tree species and ferns in Mt Elgon region.

Results of Kruskal-Wallis test revealed that there were statistically significant differences in total number of plant species in the various study sites (H=8.288; P=0.049). Similarly, the results revealed a significant difference between specific plant communities (trees, shrubs, herbs, ferns, and climbers) in the various study sites (H=38.116; P=0.000). Chi square test of homogeneity was used to test difference in distribution of species in different location and the results revealed that the differences were insignificant.

4.6 Effects of Land Use Changes on Adjacent Community Livelihoods

This study established that majority of the households had various sources of income. Ninety-one percent 91% (n=332) indicated that their main source of income was derived from the forest, while 65.6% (n=269) reported that their primary sources of income included farming, business 11.7% (n=48), government employment 11.46% (n=47), employment in the private sector 7.8% (n=32) and charcoal burning 2.9% (n=12) (Figure 4.43). They however made it clear that despite them having other sources of income, they in one way or the other relied on the forests for livelihoods.

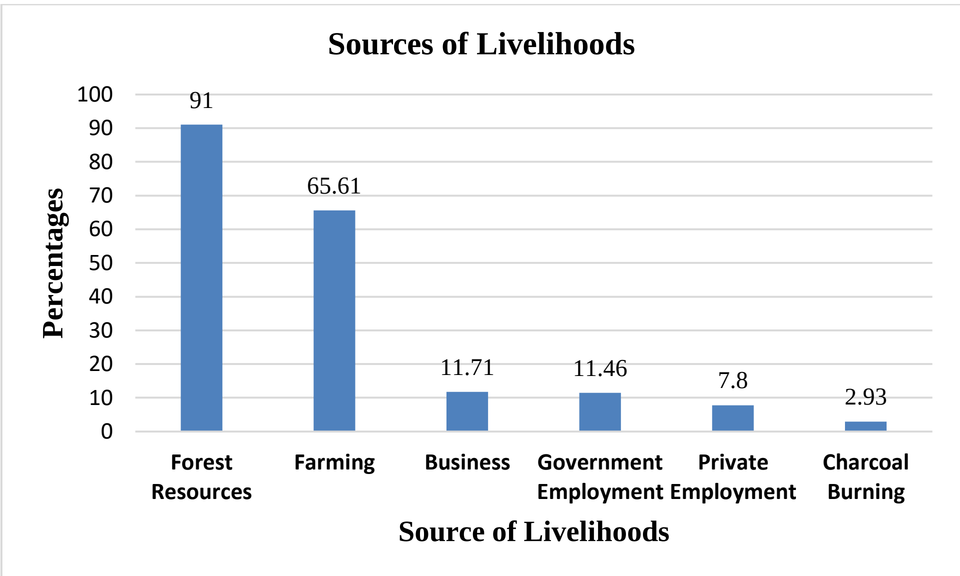

Figure 4.43: Sources of Income of the forest adjacent communities in Mt Elgon forest ecosystem

The study established that forests are widely used by majority of forest-adjacent households to provide some of their subsistence needs (Figure 4.43). Firewood was a major source of fuel energy in the area. Ninety-one 91.7% (n=330) of the households were dependent of wood fuel from the forest. Use of grasses and fodder were reported by 91% (n=328) of the households who own livestock. Some 54% (n=200) of the forest adjacent community relies on the forest for construction materials such as timber while 47% (n=171) of the households rely on the forests for herbal medicine. Herbal medicine was also reported to be very significant in the treatment of various ailments both for man and livestock in the area. Forty-three 43.8% (n=160) of the households rely on the forest for wild vegetables, game meat 41.6% (n=152), wild fruits 38.5% (n=140) and ornamental resources 24% (n=89) (Figure 4.44). Wild fruits and wild vegetables played an essential role in household nutrition while ornamental products enhanced household's beauty.

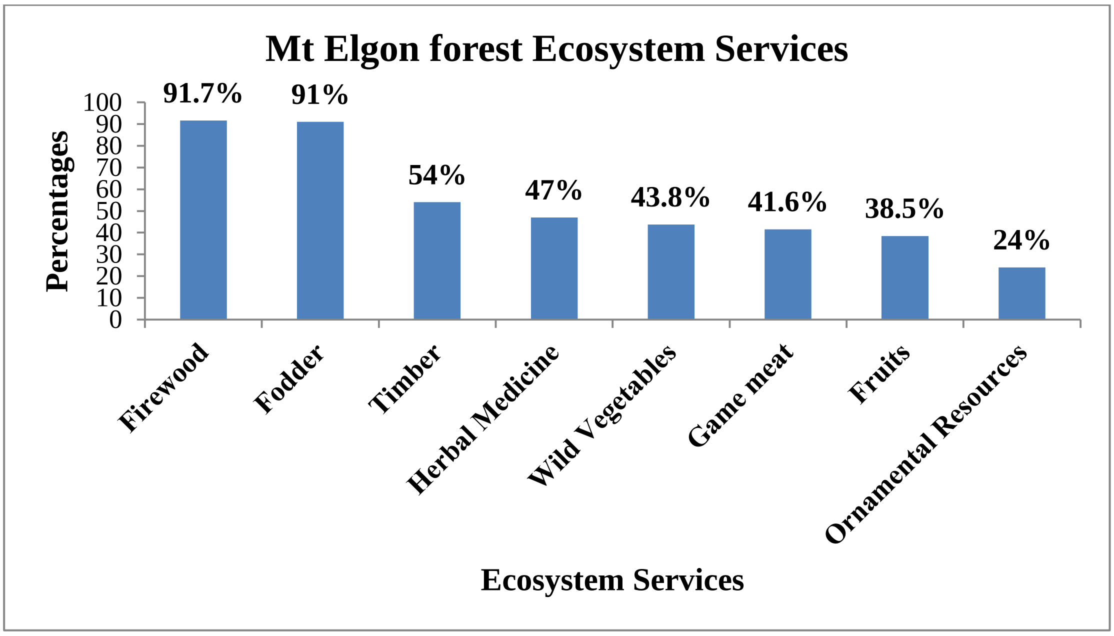

Figure 4.44: Ecosystem Services Acquired from Mt Elgon forest ecosystem

Similar findings have been reported by Langat *et al*., (2016) who found that forest adjacent communities rely on forest for various products such as fuel wood, construction materials, medicine, and food. Globally, it is estimated that between 1.095 billion and 1.745 billion people depend on forests for their livelihoods and about 200 million indigenous communities are almost fully dependent on forests (Chao, 2012). World Bank (2006) indicated that 350million people who live adjacent to dense forests depend on them for subsistence and income.

Emerton, (1992) reported that in Kenya, an estimated 71% of forest adjacent communities use the forest for firewood collection, and 32% to 44% for the provision of other wood products. The corresponding figures for use of forest products for medicinal purposes are 55% for livestock and 34% for humans, while 33% of households use the forest for honey collection, 25% for hunting, 35% for cultivation and 37% for livestock grazing. IUCN (1997) confirmed that forest products form a significant part of the households' economies in many areas, although the level and types of forest use vary both within and between communities. Forest products are used by forest adjacent communities predominantly to meet their basic subsistence needs, although they may also provide a source of cash income. In eastern Mount Kenya Forest, for example, forest products comprise an average of one tenth of the total value of household cash income (Emerton, 1993). Wunder (2014) found that overall, natural forests provide 21.1% of total household income while 6.4% is derived from non-forest environments (fallows, bush, grasslands, etc.), making the combined environmental income of 27.5%.

4.6.1 Households' dependence on the Forest

The distance from the forest significantly influenced the likelihood of relying on the forest for livelihoods. Respondents who lived closer to the forest depended more on the forest for livelihoods compared to the households that were far from the forest. About 42% (n=137) of the respondents who lived less than two kilometres relied on the forest for majority of their livelihoods compared with those who lived more than 4km away 17%(n=56) (Figure 4.45). The results show that the household dependence on the forest is inversely proportional to distance.

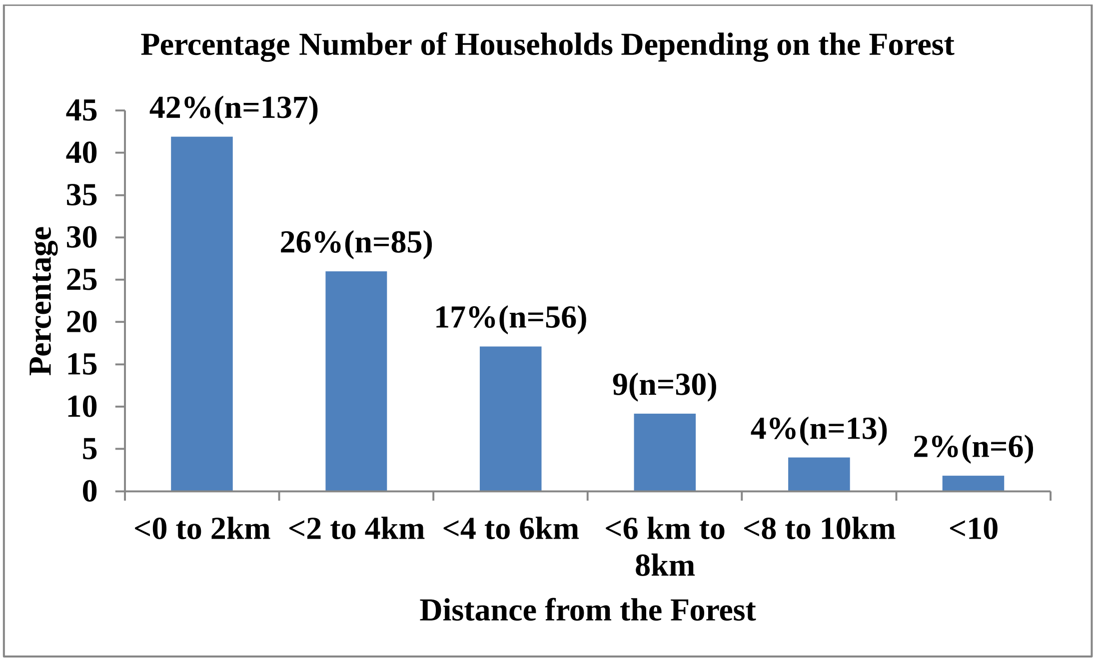

Figure 4.45: Distance Effect on Households dependence on the Mt Elgon ecosystem

In Kenya, it is estimated that 2.9 million people (530 000 households) live within 5 km of the forest edge, representing over one tenth of the population of Kenya. This forest adjacent population is unevenly distributed with nearly half living in the more fertile zones of Central Kenya, where population density is high, and with a large concentration of forests (Wass, 1995). Montane forests in Kenya, account for the highest number of forest adjacent communities with 250,000 households accounting for 47% of households living adjacent to the forest (Kenya National Census, 1989).

These findings are in agreement with those of Maua *et al*., (2018) that showed that the households living adjacent to South Nandi forest were highly dependent on the forest for non-timber forest products than those who lived far from the forest. They reported that some 90% of the household heads derived their livelihoods from the South Nandi forest. Bett *et al.,* (2020) found out that that the primary dependence upon forest products and services for household needs is concentrated among those households living within 3 km of the edge of a forest.

Bett *et al.,* 2020 further reported that interaction with the forest is inversely proportional to distance from the South West Mau forest. However, the level and range of forest use declines sharply at distances greater than 5 km. In general, communities living within 5 km of the forest boundary make most use of the forest resources (Wass, 1995). Hegde and Enters, (2000) and Guthiga, (2008) confirmed that the distance between the location of an individual and the forest affects access to the forest resources. Holmes 2007, agreeably stated that the further the communities from the forest resource, the less they interact with the forest for resources. Suda, (1992), Allhasan, (2010) and Emerton, (1993), who also reported that forest-adjacent community within 5 km buffer zone, depend on the forest for their livelihoods. Indigenous forests provide not only wood products, but a wide range of goods and services to these local users, including medicinal plants, honey, grass and fodder.

On the contrary, Bett *et al.,* (2020) had observed that there was no significant variation in their extraction of herbal medicine, seeds and honey from the forest from 1 kilometer distance to 6 kilometers away from the forest. The short distance covered to travel to the forest could attribute to the higher dependence on the Mt Elgon forests for livelihoods. On the contrary, those who are located far away have to travel for a long distance for them to get into the forest thereby increasing time taken. Those at a further distance could have to incur higher cost of transportation of forest resources like pasture, timber and fire wood. These people could opt for other means of acquiring the same within their farms or at a close range.

Mt Elgon forest ecosystem has experienced different land use changes in the recent past. The changes range from conversion of indigenous forest land to mixed farming lands, grasslands, establishment of Nyayo Tea Zone, establishment of plantation forests and establishment of protected areas. The land use changes have occurred mainly as a result of population increase and competing uses such as forests, agriculture, industry, and settlements. These land use changes appear to have impacted on the livelihoods of the forest adjacent community.

About 92.5% (n=205) of the respondents reported that the use of fodder had declined in the Elgon forest ecosystem. Ninety-two (92.1) percent (n=281) reported a decline in game meat. Wild vegetables and wild fruits were reported to have declined by 89.5% (n=273). Eighty-eight percent 88.7% (n=291) of the respondents reported a decline in herbal medicine. Similarly, 81.6% (n=253) and 80.1% (n=230) reported a decline in timber and wood fuel respectively. The use of ornamental resources was reported to have the least decline by 60.5% (n=155) (Figure 4.46). This study demonstrates that there have been significant declines in majority of these livelihoods among the Mt Elgon forest adjacent community.

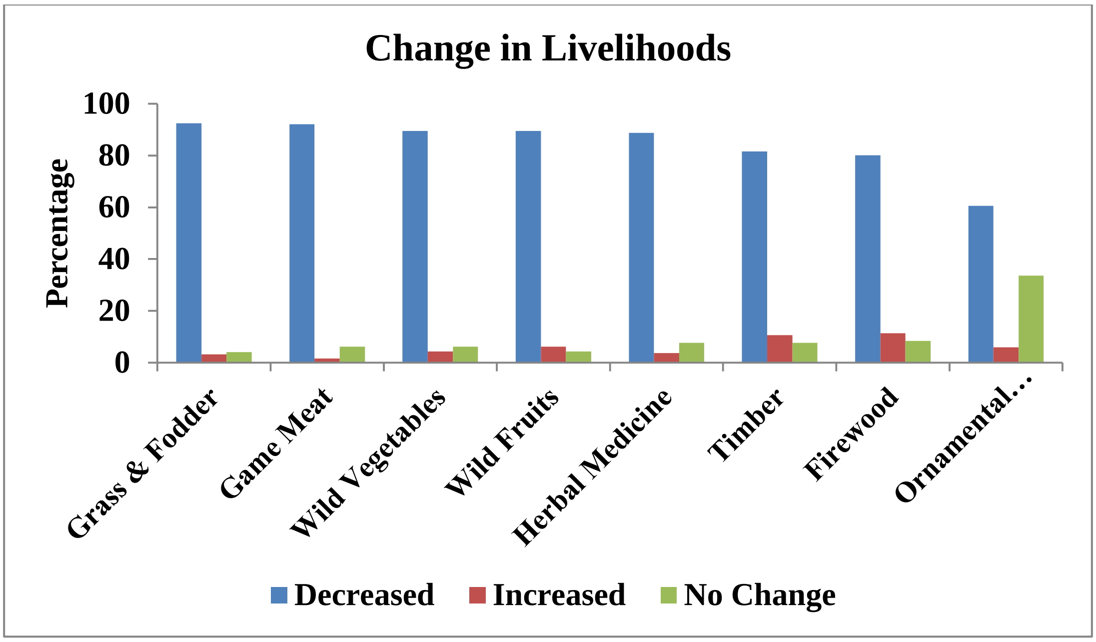

Figure 4.46: Respondents views of changes in livelihoods

Over the last 50 years (1970 to 2019), the use of herbal medicine, fodder, timber and wood fuel showed a declining trend. The highest decline was in the use of herbal medicine which showed a 28% decline from 75% (n=272) in the 1970s to 47% (n=171) in 2010s. Wild fruits had the second highest decline of 27% from 65.5% (n=237) in 1970s to 38.5% (n=140) in 2010s. The use of game meat declined by 23.9% from 65.5% (n=237) in 1970s to 41.6% (n=152) in 2010s. Grasses and fodder reported a 21% decline from 76% (n=276) in the 1970s to 55% (n=200) in 2010s. Wild vegetables declined by 16.5% from 60.3% (n=220) in 1970s to 43.8% (n=160) in 2010s. Ornamental resources reported a 14.1% decline from 38.1% (n=139) in 1970s to 24% (n=89) in 2010s. The use of forest timber declined by 13.4% from 67.4% (n=246) in 1970s to 54% (n=197) in 2010s while wood fuel had the lowest decline of 12% from 67% (n=244) in 1970s to 55% (n=201) in 2010s (Figure 4.47).

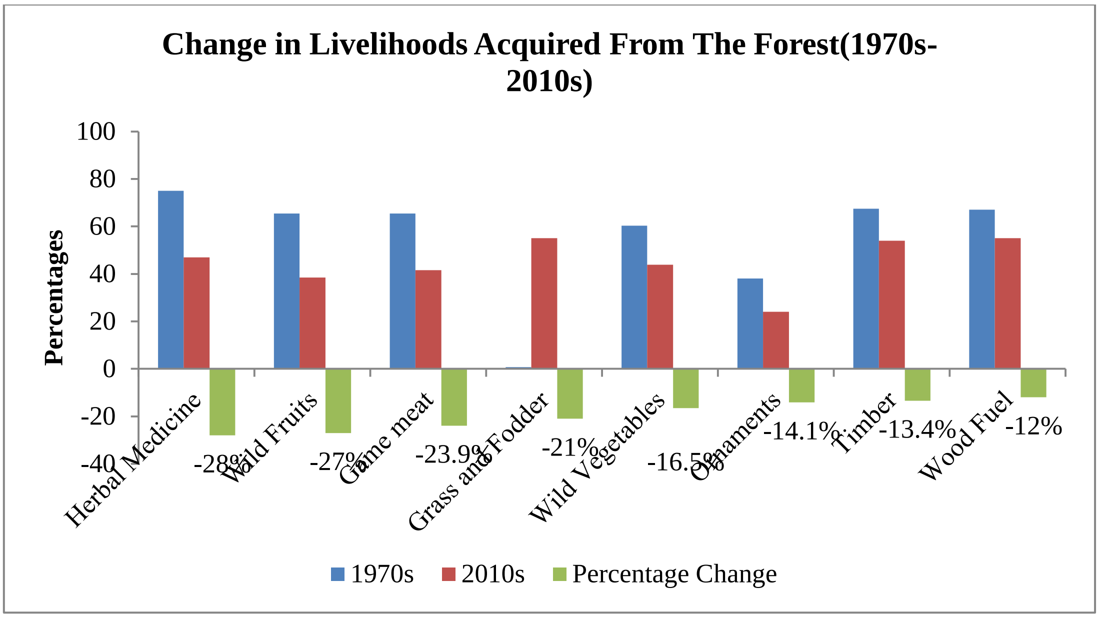

Figure 4.47: Percentage decline in livelihoods obtained from Mt Elgon forest

4.6.2 Trends in Livelihoods

Results of analysis of trends in livelihoods of the forest adjacent communities revealed that between 1970s and 1980s, the use of herbal medicine increased by 1% from 75% (n=272) to 76% (n=279). Between 1980s and 1990s, the percentage decline in use of herbal medicine was 5% from 76% (n=279) to 71% (n=260). There was a 10% decline from 71% (n=260) to 61% (n=223) between 1990s and 2000s and a further 14% decline from 61% (n=223) to 47% (n=171) between 2000s-2010s (Figure 4.48).

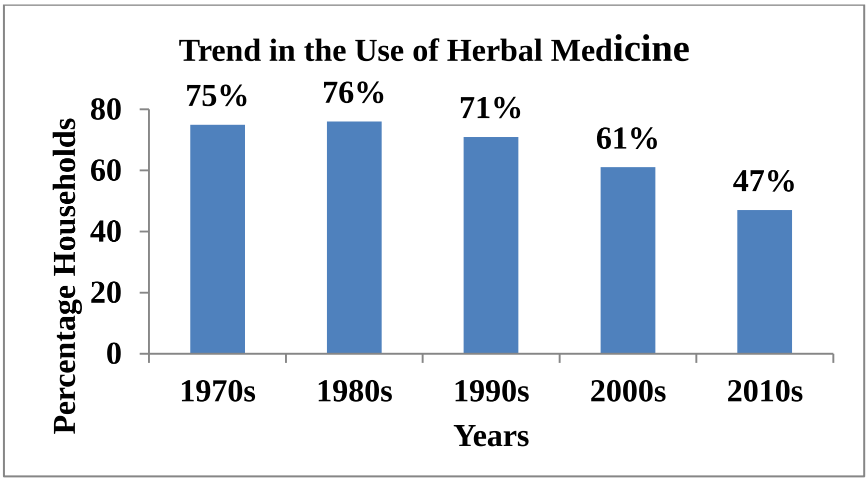

Figure 4.48: Trends in use of forest products from 1970s-2010s

Medicinal plants, *Melia volkensis* (Mwarobaine) and *Warbugia ugandensis* (Sakwondet) had greatest decline in the ecosystem as reported by 24.1% (n=88) and 12.6% (n=46) of the respondents respectively. Other herbal plant species that have declined considerably included *Diospyros abyssinica* (Cheptuyet) 9% (n=33), *Grewia trichocarp* (Moabarwa) (7.9% (n=29), *Croton macrostachyus* (Toboswet) 5.8% (n=21) and *Aloe elgonica* (Rodipchepkukwa) 4.9% (n=18) (appendix 3).

About 28.8% (n=104) of the respondents indicated that government laws and regulations could partly explain the decline in the use of herbal medicines. Government laws and regulations restrict the collection of herbal medicines from the Mt Elgon National Park. People entering the Mt Elgon National Park to collect herbal medicine need to be escorted by the park rangers for security purposes against wildlife as well as to regulate their activities.

Modernization was reported by 9% (n=33) of the respondents to be responsible for the decline in the use of herbal medicine from the forest. About 69.6% (n=254) of the respondents reported a shift to modern medicines in government hospitals. A mere 4.7% (n=17) of the respondents had opted to cultivate herbal medicines in their home gardens. Some 4% (n=15) blamed overexploitation as being responsible for the decline in the use of herbal medicine. They indicated that the over exploitation of herbal medicines has led to the reduction of specific herbal plant species and hence, reduced reliance on the forest for herbal medicines.

Kokwaro, (1976) reported that some 58 tree species are medicinally exploited nationally for their bark. For instance, *Warburgia ugandensis* has significantly declined in forests bordering Nairobi because of overexploitation of their bark, while in Kakamega *Olea capensis* is being excessively debarked for the same reason (Mutangah *et al.*, 1993). Asaha and Deakin, (2016) reported that in Cameroon, modernization has limited the use of herbal medicines by allowing the use of modern medicines to replace the use of herbs used previously.

Harvesting of wild fruits also showed a declining trend. In the 1970s, some 65.5% (n=237) respondents reported relying on wild fruits from Mt Elgon forest. In the 1980s, there was a 1.9% increase to 67.4% (n=244). In 1990s, 2000s and 2010s, the harvesting of wild fruits declined by to 57.5% (n=208), 47% (n=170) and 38.5% (n=140) respectively (Figure 4.49).

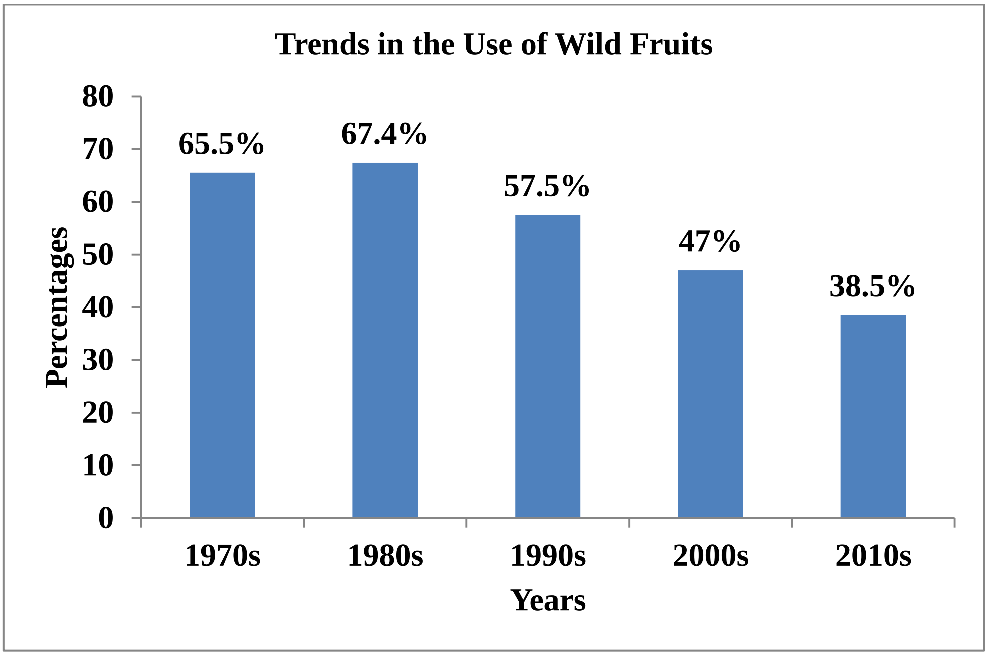

Figure 4.49: Trends in Use of Wild Fruits

Focused group discussion FGD revealed that modernization has provided alternative fruits consequently, reducing the harvesting of wild fruits from the forest.

In the 1970s, 60.3% (n=220) of the respondents relied on wild vegetables from Mt Elgon forest. The number of household increased to 65.5% (n=237) in the 1980, declined to 60.3% (n=220) in 1990s and to 47% (n=170) and 43.8% (n=160) in 2000s and 2010s respectively (figure 4.50).

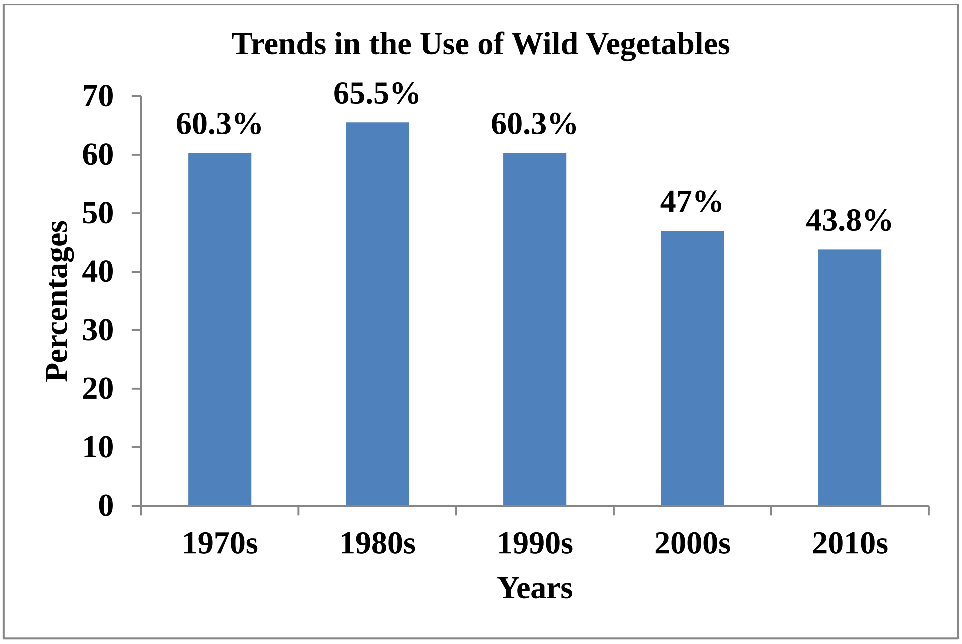

Figure 4.50: Trends in Use of Wild Vegetables

Some of the wild vegetables that have declined in the Mt Elgon forest ecosystem include *Amaranthus retroflexus* 67.7% (n=248), *Vegetable amaranth* 62.7% (n=229), *Basella alba* 49% (n=180) *Urtica dioica* 46.3% (n=169), *Solanum nigrum* 3.3% (n=12), *Brassica oleraceae 2.2% (n=8)*, *Bidens pilosa* 1.4% (n=5), young shoots of *Bambusa vulgaris 1.4% (n=5)* and forest mushrooms 0.8% (n=3) (figure 4.51).

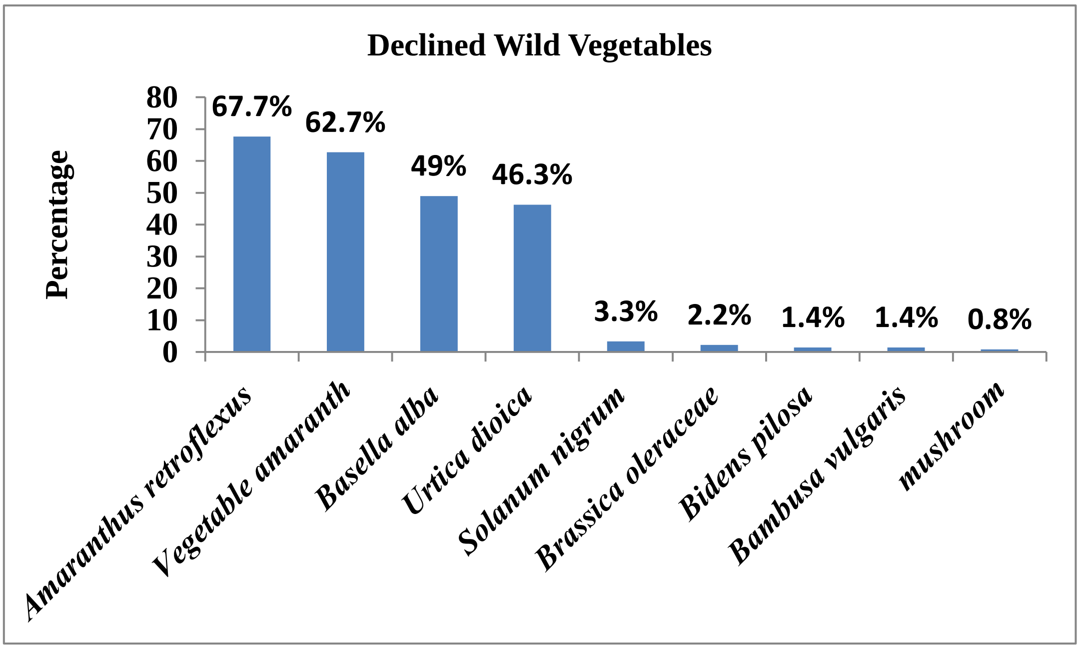

Figure 4.51: Decline in Wild Vegetable Species of Mt Elgon forest

Change in tastes and preferences was reported by 56.7% (n=276) of the respondents. About 47.9% (n=206) of the respondents indicated that wild vegetables species such as stinging nettle and pigweed lacked ready market. Only 2.7% (n=10) attributed the decline to climate change (Figure 4.52).

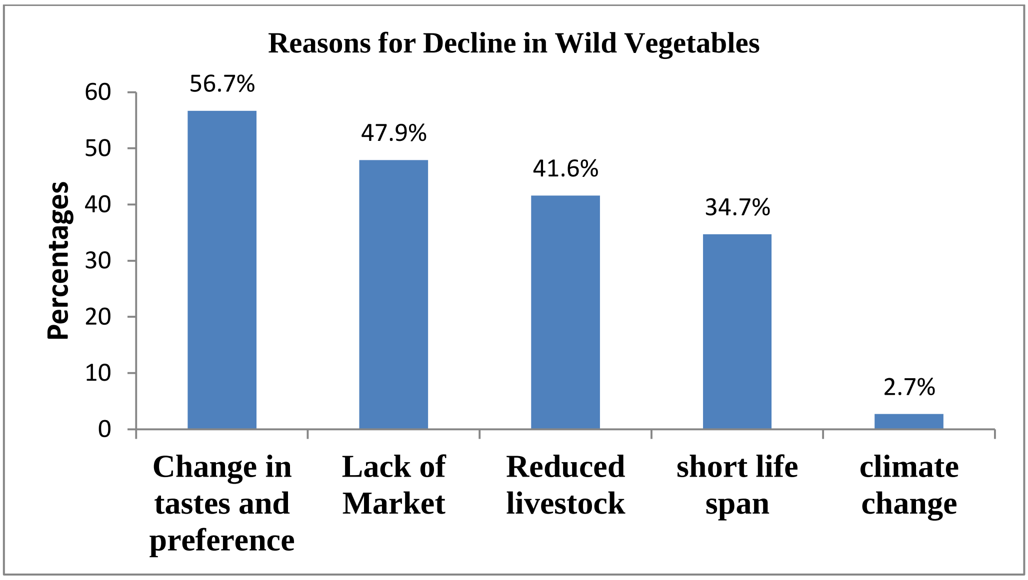

Figure 4.52: Reasons for Decline in Wild Vegetables

IUCN (1996) confirmed that forests supply non-animal foodstuffs in the form of wild fruits, vegetables, fibres, nuts and tubers. These foodstuffs constitute a regular and integral part of a household's diet, and are gathered for immediate consumption or used as drought, dry-season or emergency foods. Asaha and Deakin, (2016) indicated that the disappearance of primary forest was the main reason for the dwindling resource base of non-timber forest products (NTFPs) such as bush mango in Cameroon. This has encouraged the domestication and cultivation of these fruits.

The use of game meat increased by 1.9% from 65.5% (n=237) in the 1970s to 67.4% (n=244) in 1980s. A 9.9% decline to 57.5% (n=208) was noted in 1990s. A further 10.5% and 5.4% decline to 47% (n=170) and 41.6% (n=152) was reported in 2000s and 2010s respectively (figure 4.53).

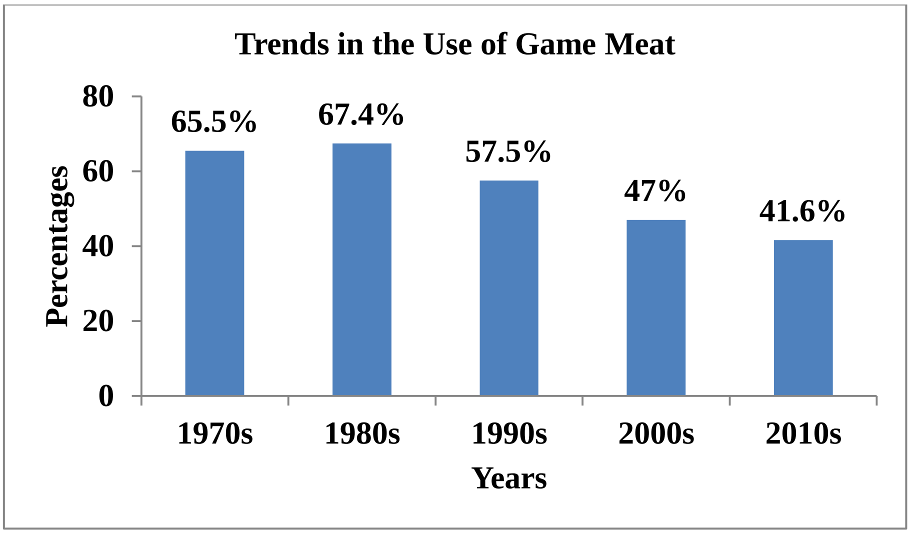

Figure 4.53: Trends in Use of Game meat

The FGD however established that majorly, only specific clans within the Ndorobos engaged in hunting of game meat (Appendix 5). The respondents attributed the decline in game meat to the introduction of agriculture, modernization (9.1%; n=33) and government laws and regulations (28%; n=104). So far no research has been reported on the drivers and trends of subsistence hunting in Mt Elgon forest ecosystem.

The findings of this study are in disagreement with those of Wass (1994) who reported that although no trend data are available, the level of forest use has increased over time due to the increasing demands placed by a growing population, urbanization, commercialization and a failure to control illegal and unsustainable use. However, findings of this study concur with those of Asaha and Deakin (2016) who reported that in Cameroon, hunting and fishing were carried out at a minimal level of less than 10% of the households. Increasing government regulations as well as dwindling numbers of wildlife were reported to contribute to the unavailability of bush meat and fish in the Cameroon.

The effects of subsistence hunting and trapping of medium-sized mammals has been much less documented (IUCN 2008). Long-term hunting and trapping on the boundaries of Trans Mara have eliminated two species of larger antelope and even the commonest two species of duikers. Very few large ungulates remain in Kakamega and hunting and trapping are no longer significant local activities (IUCN 2008).

Game meat provide an important source of food and nutrition in some areas. For instance, the Mijikenda of Arabuko Sokoke hunt up to 50 species of forest birds and animals (Mogaka, 1991). The Mau forest dwellers hunt up to 22000 of 11 species annually (Wily, 1991). However, in other regions, the incidence of hunting is decreasing because of improved policing, changing household socio-economy and the decline in numbers of the preferred species (Emerton, 1994). Forest animals additionally provide skins, hides, claws and horns for, ceremonial, medicinal and decorative use.

There was yet another decline in the use of fodder and grasses from the forest. About 76% (n=276) of the respondents were affirmative that in the 1970s, they grazed their livestock in the forest or used fodder harvested from the forest to feed their livestock. In the 1980s the number of respondents who grazed in the forest increased by 2% to 78% (n=284). In the 1990s, the number of declined by 3% to 75% (n=274). In 2000s and 2010s, the number of respondents who relied on the forest for grazing declined by 5% to 65% (n=239) and a further 5% to 55% (n=200) respectively. In total, the research established a 21% decline in use of fodder and grasses (figure 4.54).

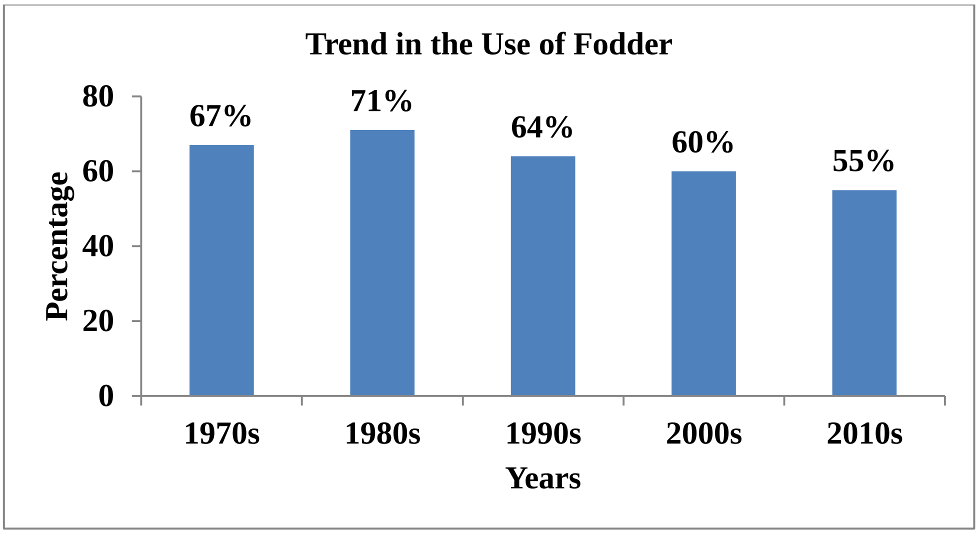

Figure 4.54: Trend in Use of Fodder between 1970s-2010s

While majority of the respondents 92.5% (n=205) indicated that grazing fields in the forest have been declining with time, analysis of Landsat imageries confirm that the size of land under grazing fields increased from 28% (n= 525.35 Km^2) to 29.37% (546.52 Km^2) between 1977 and 1986. There was, however, a 10.86% decline from 29.37% (546.52 Km^2) to 18.51% (344.71 km^2) between 1986 and 1999. A further 3.3% decline to 15.18% (n=282.89) was reported in 2019. In total, grasslands have declined by 13.05% between 1977 and 2019 (figure 4.55).

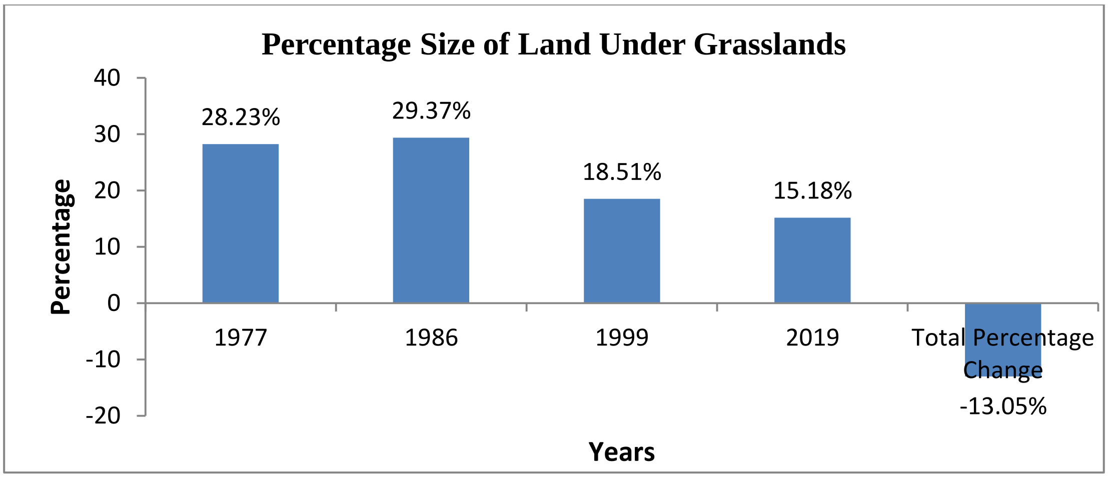

Figure 4.55: Percentage Changes in Size of Land under Grasslands

The decline in grasslands had implications on the livelihoods of the forest adjacent community. Most forest adjacent communities rely on livestock for status, meat, milk and often sell the animals so as to meet financial needs. Population increase was appearing to have been the main cause of decline in grasslands. About 32.13% (n=116) of the respondents were in agreement that population increase is responsible for the decline in grasslands. Population increase has led to the transformation of grasslands into farm lands and settlements. Climate change was reported by a mere 6.9% (n=25) of the respondents to be responsible for the decline in the grasses and fodder. They reported that the amount of rainfall in the region has been declining over time and this was attributed to change in the rainfall patterns and increase in temperature in this study area. According to Turner *et al.,* (2003) and Brady (1996), numerous stresses including increasingly severe climatic conditions, population growth and cultural changes put pressure on livelihoods in the tropics. In Uganda Nantumbwe, (2005) reported that change in land uses from forest to agriculture has led to the reduction of soil organic matter levels, impacting diversity of the Mt. Elgon slopes.

There was a slight decline in harvesting of ornamental products (figure 4.56). The number of respondents who relied on the forest for ornamental products declined slightly by 0.6% from 38.1% (n=139) in 1970s to 37.5% (n=137) in 1980s. The number declined even further by 6% to 31.5% (n=114) and 6.9% in 2000 and a further 0.6% decline to 24% (n=114) in 2010s figure 4.56).

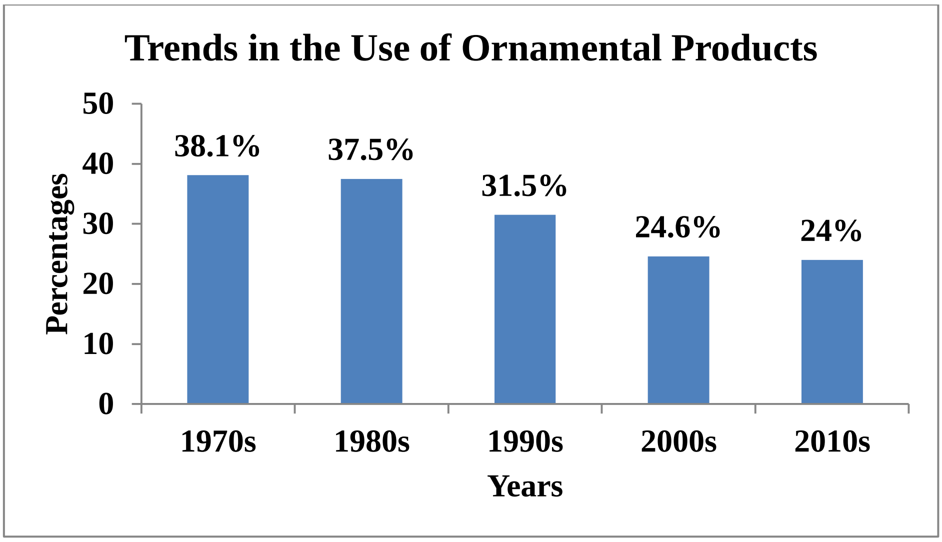

Figure 4.56: Trends in Use of Ornamental Products

About 9.1% (n=33) of the respondents attributed the decline in the acquisition of ornamental products to modernization where most forest adjacent communities can easily get imported ornaments from shops at lower costs. Other causes include government restriction on harvesting of forest products such as bamboo. The figure 4.57 shows the ornamental plant species of Mt Elgon.

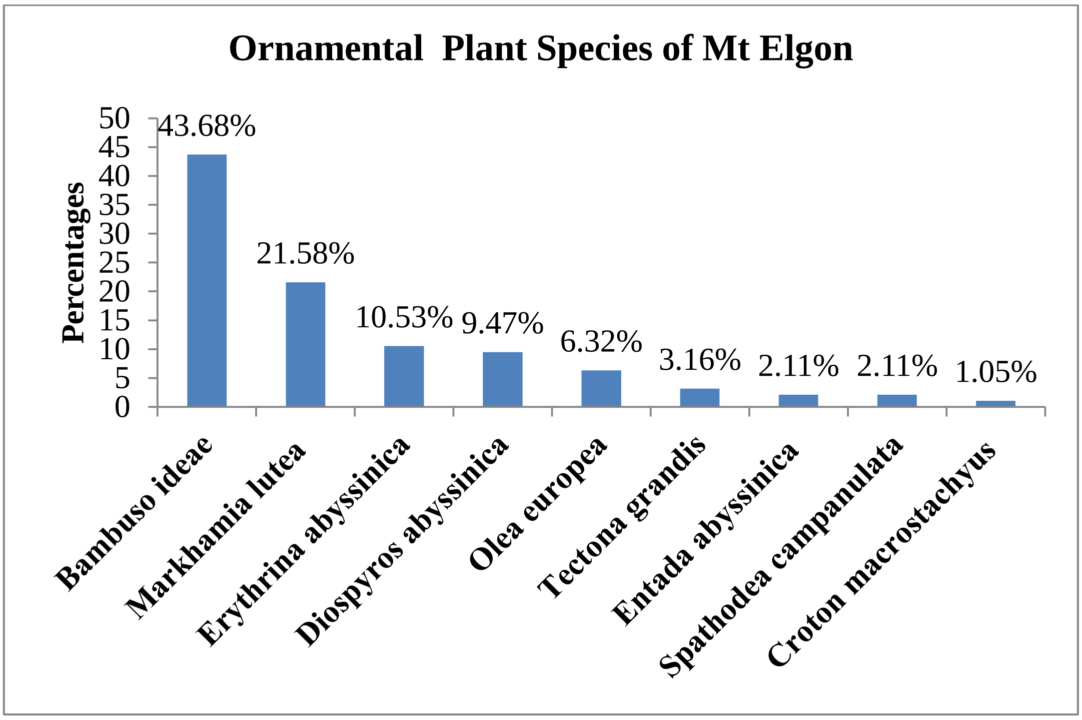

Figure 4.57: Percentage of Ornamental Plant Species of Mt Elgon

The findings of this study are in agreement with Wass (1994) who confirmed that ornamental products are also obtained from the forest. Endamana *et al.,* (2015) observed that the absence of reliable information makes it difficult to estimate the total economic contributions of forests. However, where such data are reliably available, the non-cash economic contributions of forests to household and national economies range between 3 and 5 times the formally recognized cash contributions (Agrawal *et al.,* 2013). The absence of aggregated data on the economic contributions of non-timber forest products (NTFPs) and their value are major bottlenecks in a better understanding of forest sector contributions. Systematic data on products, on different land uses and on how its benefits support livelihoods are essential in decision-making.

The use of wood fuel from the forest showed a gradual decline. In the 1970s, about 67% (n=244) of the households relied on the forest for wood fuel. However, in the 1980s, the percentage number of households relying on the forest increased by 4% to 71% (n=258). There was a 7% decline in the 1990s to 64% (n=235). In 2000s and 2010s, a further 4% and 5% decline to 60% (n=218) and 55% (n=201) was recorded respectively (figure 4.58).

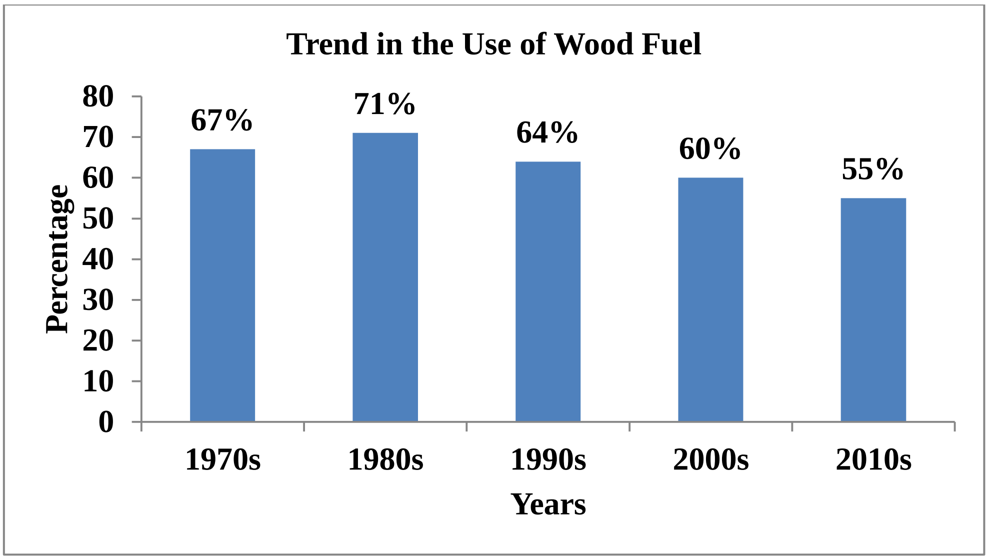

Figure 4.58: Trends in Use of wood Fuel

This decline in attributed to government policies that require a permit from the Kenya Forest Service to harvest firewood. The respondents indicated that the process of obtaining a permit is cumbersome and discourages collection of firewood from the forest. Respondents also reported that it is also illegal to burn charcoal in the forest. Field observation however revealed that the forest adjacent community still illegally burn charcoal in the forest and collect firewood without permits (plates 4.16, plate 4.17).

Plate 4.16: Illegal charcoal burning

Plate 4.17: Women carrying wood fuel Forest

Similarly, changes in sources of energy for cooking (modernization) was reported to be responsible for the decline in acquisition of wood fuel from the forest. Some households 24% (n=89%) preferred the use of gas instead of wood fuel thus reducing the reliance on the forest for wood fuel.

Households in the Mt. Elgon ecosystem indicated that they at times obtain construction materials such as timber from the forest. About 67.4% (n=244) of the respondents affirmed that in the 1970s, their timber came from the forest. However, in the 1980s, the number of households obtaining timber from the forest increased by 3.9% to 71.3% (n=262). By the 1990s, the percentage of household relying on the forests for timber declined by 6.9% to 64.4% (n=235) with a further decline of 4.4% to 60.2% (n=218) and 6.2% to 54% (n=197) in the 2000s and 2010s respectively. In total, there was a 13.6% decline in the reliance on the indigenous forest for construction material over the study period.

Government laws and policies were reported by 28% (n=104) of the respondents, to be responsible for the decline in the use of timber and wood fuel from the forest. This could partly explain the decline in wood fuel acquired from the indigenous forest. On the contrary, the government policies encourage farm forestry which provides for sufficient source of timber and wood fuel which reduces the reliance on forests for timber and wood fuel. The decline in the need for timber from the forest can also be attributed to the policy that requires one to get a permit from the Kenya Forest Service to obtain timber from the forest. Figure 4.59 summarizes trends in livelihoods between 1970s and 2010s.

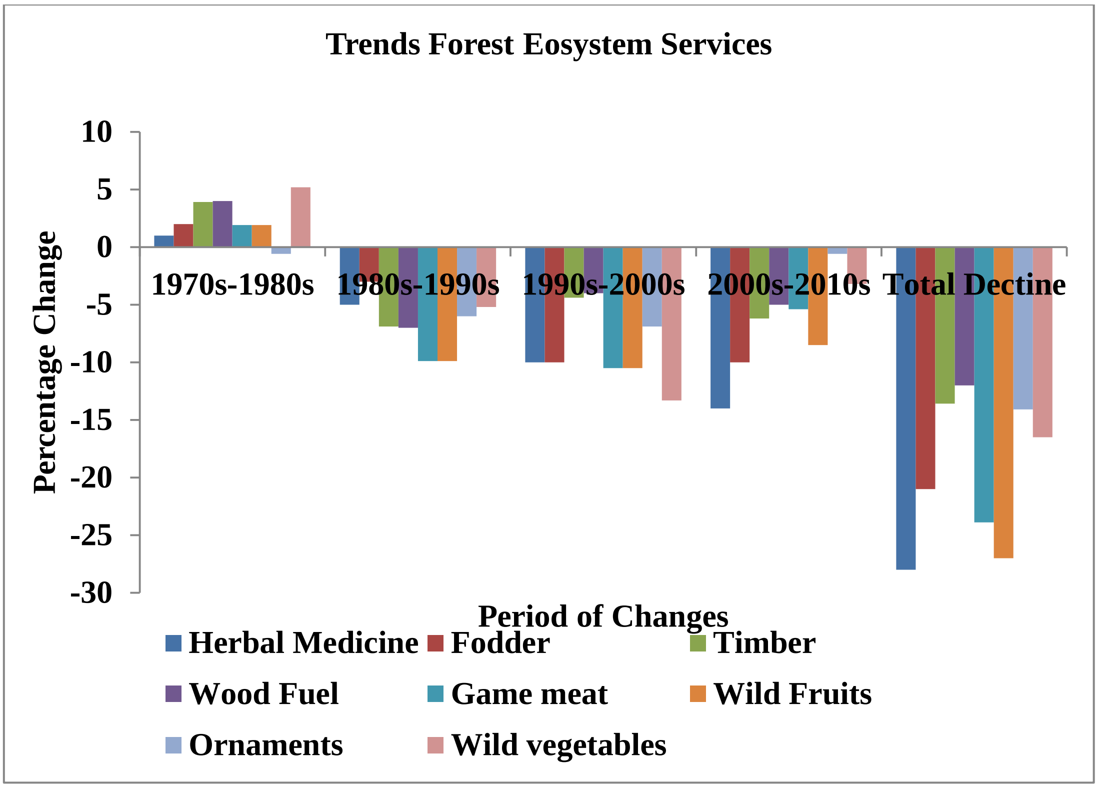

Figure 4.59: Trends in livelihoods between 1970s and 2010s

While licenses are available for domestic firewood collection (usually dead wood only), and fodder collection in all gazetted forests, many household activities are unlicensed (e.g. livestock grazing and cultivation) or take place in excess of licensed allowances (e.g. firewood collection) (Wass, 1994). In Arabuko Sokoke unlicensed domestic firewood consumption exceeds licensed collection by a factor of 2.5 (Mogaka, 1991) and in some forests, firewood and live indigenous trees are also illegally felled for timber, carving wood, charcoal production and for poles, sometimes for subsequent cash sales to meet household needs. The demand for indigenous timber is very strong which promotes illegal felling in indigenous forests. Illegal extraction of poles/posts occurs in 40% of forests, firewood, 23%, timber, 22% and charcoal in 20% of the indigenous forests. Other illegal commercial activities include bee keeping, in 25% of forests (Emerton, 1992). In Cameroon, more than 90% of timber exploitation is illegal and is conducted with no permit of any kind (Asaha and Deakin (2016).

The decline in livelihoods in Mt Elgon forest ecosystem has a led to the establishment of alternative livelihoods for the forest adjacent communities. The respondents further indicated that the decline in grazing fields had led to the community inventing alternative means of livelihood. For instance, about 38.17% (n=121) of the respondents reported that with the decline in grazing fields, they had resorted to growing Napier grass as an alternative fodder. Similarly, about 21.8% (n=69) of the respondents reported that they grazed their livestock on the limited grasses available in the forest. Some 14.82% (n=47) relied on buying fodder while 10.41% (n=33) grazed their livestock solely in the homestead (figure 4.60).

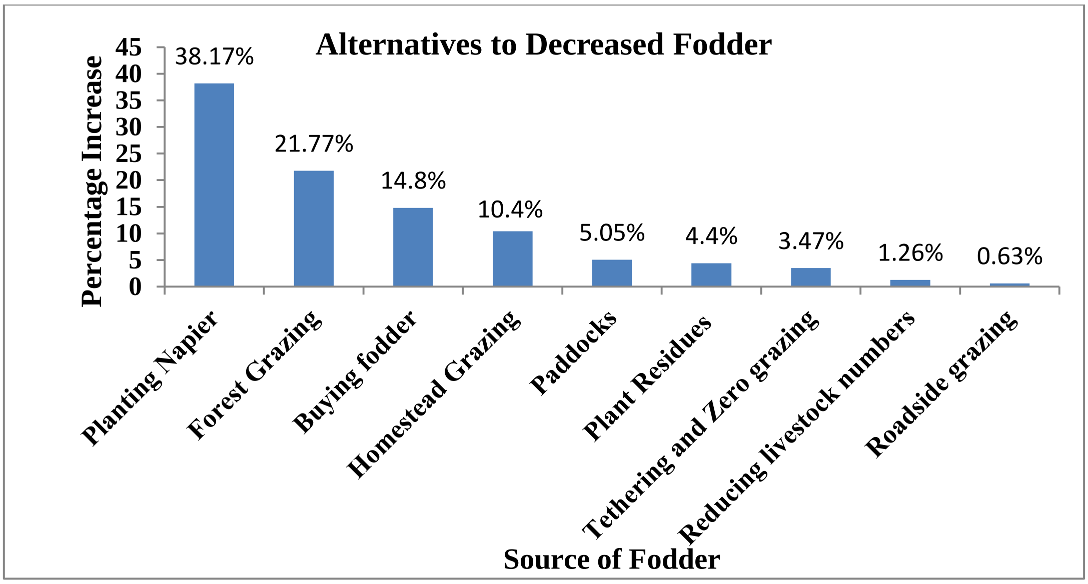

Figure 4.60: Alternative means of feeding animals

From the results, it is clear that the decline in fodder from the forest ecosystem appear to have had great impacts on the livelihoods of the forest adjacent communities. Reducing the number of livestock may have greatly impacted the livelihoods of the local community, since majority of them rely on animal farming as a source of livelihoods.

With the decline in timber acquired from the natural forests, the respondents had resorted to the use of farm forestry as an alternative source of timber. About 32% (n=117), of the respondents engaged in farm forestry in the 1970s. In the 1980s, this number increased by 3% to 35% (n=128) and in the 1990s, 2000s and 2010s, the number further increased by 5%, 3% and 11% respectively (figure 4.61). These findings translate into a 22% increase in households engaging in farm forestry over the entire study period (Plate 4.18).

Plate 4.18: On farm forestry

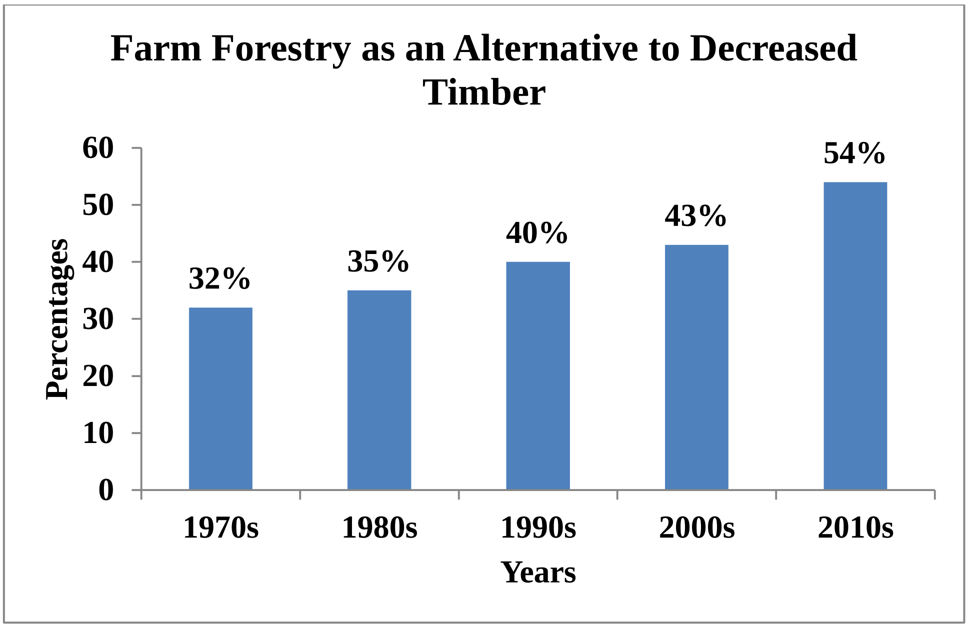

Figure 4.61: Changes in Farm forestry as an alternative to decreased timber

With the decline in wood fuel, alternative sources of energy came on board that included kerosene, plant residues, electricity, solar and gas (figure 4.62).

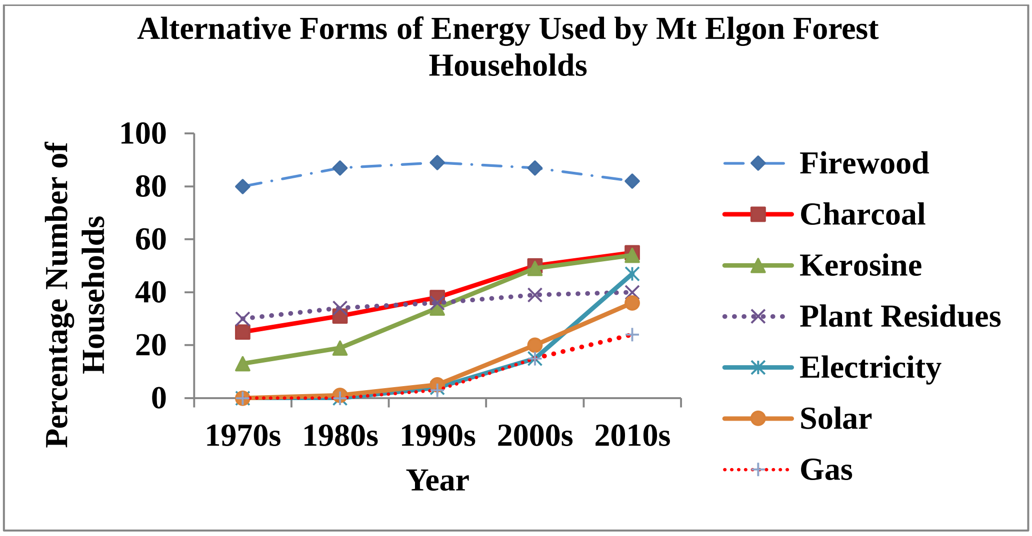

Figure 4.62: Alternative forms of energy

Firewood was the most popular form of energy used in Mt Elgon region. About 80% (n=291) of the respondents used firewood in 1970s. In the 1980s, the number increased by7% to 87% (n=317). The number increased further by 2% to 89% (n=326) in 1990s.

A 2% and 5% decline was reported in 2000s and 2010s to 87% (n=317) and 82% (n=300) respectively.

The use of charcoal was the second most popular form of energy. In the 1970s, 25% (n=91) of the respondents relied on charcoal fuel in the 1970s. This increased by 6% in the 1980s, 7% in 1990s, 12% in 2000s and 5% in 2010s. The use of charcoal has been increasing as a result of the increase in farm forestry in the region. In addition, charcoal tends to have a ready market in the neighbouring urban areas. Consequently, the use of charcoal has increased by 30% between 1970s and 2010s.

Kerosene reported a remarkable increase in the number of households using it. There has been a 41% increase in the use of kerosene in the region, 47% increase in the use of electricity and a 37% increase in the use of gas (figure 4.62)

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the study findings outlined in chapter four, conclusions and recommendations of the study on land use changes and their effects on Mt Elgon forest ecosystem. The chapter is organized into three sections. The first section presents a summary which includes discussions related to the research objectives. The second section focuses on conclusions derived from the summary. Lastly recommendations are drawn from the findings and finally, suggestions for further research.

5.2. Summary of Findings

The size of land under natural forest has experienced the highest decline by 18% (n=334.48km^2) from between 1977 and 2019. Bamboo forests declined by 15.19% over the same period. Grasslands declined by 13.05%, but, mixed farming increased by 29.27% and fallow land increased by 10.25% over the same period. Similarly, plantation forests increased to 120km^2(6.47%), while land under tea plantation had a slight increase to 2.42km^2(0.13%) between 1977 and 2019 respectively.

Various drivers were recognized as responsible for the changes in land uses in Mt Elgon forest and the adjacent region. Demographic factors were the most important driver of land use change with (76.7%; n=280). Socio cultural factors were the second driver (74.05%; n=270). These factors included preferential cultivation of crops, collection of honey and collection of herbal medicines. Institutional factors were ranked third (58.08%; n=212). The change to plantation forest was necessitated by changes in government policies that advocated for the introduction of plantation forest as a means of protecting the Mt Elgon forest from encroachment. Other institutional factors included land fragmentation, land excisions, land ownership and leasing and legal logging. Economic factors were ranked fourth (50.95%; n=186). Economic factors included ready market and increased profits from selling of forest products, food crops and cash crops such as tea and coffee.

Ranking of plant species diversity and evenness indices in areas under different land uses of Mt Elgon forest ecosystem revealed that the highest species diversity and evenness was in the control site. The second highest site in species diversity was indigenous plantation forests. This was then followed by urban settlements, tea farming and mixed farming. Exotic plantation forest site had the least species diversity index.

Herbs were the most dominant species in Mt Elgon forest ecosystem, with their greatest abundance being in areas adjacent to NTZ farms, followed by mixed farms and exotic plantation forests, urban settlements and indigenous plantations There were, however, least abundant in the control site.

Tree species were the most abundant in the control site followed by Indigenous planted forests while urban settlements mixed farming and NTZ had a lower abundance respectively. Shrubs were most abundant in the site adjacent to mixed farms. Urban settlements had a high shrub abundance while indigenous plantations and the control site had the lowest abundance of shrubs.

Climbers were most abundant in exotic plantations followed by site adjacent to mixed farming. Climbers however had a low abundance in NTZ and indigenous forests respectively. They were however absent in the control site. Ferns were abundant in the control sites. These findings point to the fact that, land use change to tea farming and exotic plantations may have contributed to the decline of tree species in Mt Elgon ecosystem.

Results of Kruskal-Wallis test revealed a statistically significant differences in total number of plant species in the various study sites (H=8.288; p=0.049). Similarly, the results revealed a significant difference between specific plant communities (trees, shrubs, herbs, ferns, and climbers) in the study area (H=38.116; p=0.000). Chi square test of homogeneity was used to test difference in distribution of species communities in different location and the results revealed that the differences were insignificant.

Results of multiple comparisons for specific land uses revealed significant differences between plant species that were recorded in the exotic plantation forest and the NTZ site verses the control site. There was a significant difference between floral diversity in the control and NTZ. There was also a significant difference between floral diversity in the control site and Exotic Plantations. However, the results for comparison between the control site and urban settlements, mixed farming and indigenous plantations were not significant.

Majority of the livelihoods of Mt Elgon forest adjacent communities were derived from the forest. Most of these livelihoods showed an increasing trend between the 1970s and 1980s. However, between 1980s and 2010s, most livelihoods declined. The highest decline was in herbal medicine followed by the use of wild fruits, game meat, fodder and wild vegetable respectively. Ornamental products, timber and wood fuel recorded the least decline in their use. Field observation revealed that harvesting of honey from the Mt Elgon forest was one of the livelihoods of the forest adjacent communities.

The main factors responsible for the decline in the livelihoods of the Mt Elgon adjacent community included the transformation of the natural forest into mixed farms. Government policies was reported to have been responsible for the changes in livelihoods. Government policies that prohibit unlicensed collections of forests products were responsible for a decline in the use of timber, wild fruits, wild vegetables, wood fuel, game meat and herbal medicines. On the contrary, government policies that favour on-farm forestry was responsible for a lower decline in the acquisition of timber and wood fuel from the forest. Other factors responsible for the decline in forest livelihoods included modernization and climate change.

5.3 Conclusion

From the findings, the study concludes that, the Mt Elgon forest ecosystem has experienced major changes in land uses that have had a great effect on biodiversity and livelihoods of the forest adjacent community. The study concludes that Mt Elgon forest ecosystem has experienced major land uses between the 1977 and 2019. These changes include decrease in natural forests, bamboo forests and grasslands.

There has also been an increase in mixed farming, plantation forest, tea farming and fallow land. This study concludes that demographic factors are key drivers for the decline in the size of land under indigenous forests, bamboo forests and grasslands while socio-cultural factors drive the decrease in grasslands. Institutional factors and economic factors are the main drivers of increase in planted forests and mixed farming.

Land use changes have had great effects on floral diversity of Mt Elgon forest ecosystem. Land use changes from natural forests to monocultural tea farming, mixed farming, urban settlement and planted forest has led to a decline in tree species and an increase in herbaceous species. The findings further revealed that exotic plantations and Nyayo Tea Zone have the greatest effects on floral diversity of Mt Elgon forest ecosystem. Contrary, indigenous plantation had an insignificant effect on plant species diversity and abundance. The study therefore concludes that planting indigenous forests can restore floral diversity in Mt Elgon forest ecosystem while planting of exotic plantations and tea farming could lead to the highest decline in floral diversity.

It is apparent that land use change from natural forests to mixed farming has led to a decline in majority of the livelihoods acquired from Mt Elgon forest. Other factors that impacted the livelihoods of the forest adjacent community include modernization and climate change. The most affected livelihood is the use of herbal medicine while the least affected is the use of timber and wood fuel. Government policies that encourage farm forestry have played a crucial role in reducing the acquisition of wood fuel and timber from the forest. Asaha and Deakin (2016) confirmed that the disappearance of primary forest and modernization are the main causes of the dwindling resource base of Non timber forest products (NTFPs) such as bush mango and herbal medicines in Cameroon.

5.4 Recommendations

Based on the findings of the study, the study recommends that

a) More indigenous plantations forest be used in restoring floral diversity of the Mt Elgon forest ecosystem. This is because the Shannon Weiner diversity index and Whittaker beta diversity index closely approach that of the control site.
b) The government stops the use of exotic plantation as a means of restoring biodiversity
c) There is need for establishment of traditional laws by the local administration and local community representatives to ensure the proper management and use of forest resources.

d) The local community be educated on the role of forest products such as herbal medicine in health and nutrition.

e) Involvement of stakeholders, decision makers at the local, regional, and national level in forest management.

5.5 Contributions of this Study to Research

1. The study has contributed to the body of knowledge by highlighting changes in land use that have taken place between 1977 and 2019 within Mt Elgon forest Ecosystem.
2. The study highlights the land uses that have adverse effects on floral diversity of the Mt Elgon forest Ecosystem. It identifies the specific species that are most affected and thus endangered. Most research in this area had focused on the role of climate change and land conflicts in the Mt Elgon region. This research has unearthed information that is crucial in the conservation of floral diversity of Mt Elgon forest Ecosystem.
3. The study quantifies the livelihoods that have been affected by land use change in Mt Elgon region. No research has focused on livelihoods such as wild plant species and wild fruits in the study area. These livelihoods maybe termed as "forgotten" and yet they play a critical role of meeting the nutritional needs of the local community.

5.6 Areas for Further Research

1. The study suggests that further research be carried out on effects of land use change on faunal diversity.
2. The study also suggests that a research be carried out on the role of forest flora and fauna on nutrition of the forest adjacent communities.

REFERENCES

Abate, S. (2011). Evaluating the Land Use and Land Cover Dynamics in Borenaworeda of South Wollo Highlands, Ethiopia. *Journal of Sustainable Development in Africa*, 13, 87-107.

Agrawal, A., Cashore, B., Hardin, R., Shepherd, G., Benson, C., and Miller, D. (2013). Economic contributions of forests. Paper prepared for the United Nations Forum on Forests, tenth session. Istanbul, Turkey.

Ahlcrona, E. (1986). Monitoring the Impact of Climate and Man on Land Transformation: Study in Arid and Semi-Arid Environment in Central Sudan. Lunds Universitets Naturgeografiska Institution No.66

Akotsi, E., & Gachanja, M. (2004) Changes in Forest Cover in Kenya's Five ''Water Towers'' 2000-2003. DRSRS (Department of Resource Surveys and Remote Sensing) & KFWG (Kenya Forests Working Group), Nairobi.

Aladjadjiyan, A. (2012). *Physical Factors for Plant Growth Stimulation Improve Food Quality*. Agricultural University, Plovdiv, Bulgaria

Alam, M.S., & Masum K.M. (2005). Status of Homestead Biodiversity in the Offshore Island of Bangladesh. *Res J Agr Biol Sci.* 1(3): 246-253

Albinus M., Makalle, P., Obando, J., & Bamutaze, Y. (2008). Effects of land use practices on livelihoods in the transboundary sub-catchments of the Lake Victoria Basin. *African Journal of Environmental Science and Technology* Vol. 2 (10). pp. 309-317, October, 2008 Available online at http://www.academicjournals.org/AJest

Alhassan, A. M. (2010). Analysis of primary stakeholders participation in forest resources management: the case of the Krokosua hills forest reserve, Ghana, Master of Science Thesis, Kwame Nkuruma university: Ghana

Alig, R., & Platinga, A. (2004). Future forestland area: Impacts from population growth and other factors that affect land values. *Journal of forestry*102 (8):19-24

Allnutt, T. F., Asner, G. P., Golden, C. D., and Powell, G. V. N. (2013). Mapping recent deforestation and forest disturbance in Northeastern Madagascar. *Tropical Conservation Science*, 2013, 1–15.

Amsalu, A. (2006). Caring for the land: Best practices in soil and water conservation in Beressa watershed, highlands of Ethiopia. Thesis Wageningen UR ISBN: 908504443-X

Arnoldo, C. H. (2000). The underlying causes of forest decline. Centre for International forestry research. Occasional Paper No. 30. ISSN 0854-9818.

Asaha, S., & Deakin, L. (2016) Land-use change and its influence on rural livelihoods, food security and biodiversity conservation in the Southwest Region of Cameroon. Center for International Forestry Research.

ASDS (2010). Agricultural Sector Development Strategy (2010-2020)

Barlow, J., Gardner, T. A., Araujo, I. S., Avila-Pires, T.C., Bonaldo, A. B., Costa, J.E., Esposito, M. C., Ferreira, L.V., Hawes, J., Hernandez, M.I.M., Hoogmoed, M.S., Leite R.N., Lo-Man-Hung, N.F., Malcolm J. R., Martins MB., Mestre, L.A. M., Miranda-Santos, R., Nunes-Gutjahr A.L., Overal W.L., Parry, L., Peters, S.L., Ribeiro-Junior M.A., daSilva M.N.F., da Silva Motta, C., & Peres, C.A. (2007). Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. *Proc. Natl. Acad. Sci. USA* 104:18555–18560

Barrios, E., Shepherd, K., & Sinclair, F. (2015). Soil health and agricultural sustainability: the role of soil biota. In: FAO, editor. Agroecology for food security and nutrition. Rome (Italy): Proceedings of the FAO International Symposium; p. 104–122.

Bello, I. K., & Arowosegbe, O.S. (2014). Factors Affecting Land-Use Change on Property Values in Nigeria. *Journal of Research in Economics and International Finance* (JREIF) (ISSN: 2315-5671) Vol. 3(4) pp. 79 - 82, DOI: http:/dx.doi.org/10.14303/jrief.2014.038. Available online http://www.interesjournals.org/jreif

Benin, S., & Pender, J. (2001). Impacts of land redistribution on land management and productivity in the Ethiopian highlands. *Land Degradation & Development,* 12:555- 568.

Berihun, M. L., Tsunekawa, A., Haregeweyn, A., Meshesha, D. T., Adgo, E., Tsubo, M., Masunaga, T., Fenta, A. L., Sultan, D., & Yibeltal, M. (2019). Exploring land use/land cover changes, drivers and their implications in contrasting agro-ecological environments of Ethiopia. *Land Use Policy*, 87, 104052. https://doi.org/10.1016/j.landu sepol.2019.104052.

Bertalanffy (1901-1972). Ludwig von Bertalanffy 1901-1972." *American Journal of Psychiatry,* 130(11), p. 1292. Production Systems. W.H Freeman, San Francisco.

Bett K. N., Mwasi B., & Esho, L. (2020). Influence of Distance in Forest Utilization and Its Interaction with Neighbouring Communities of South West Mau, Kenya, Konoin Sub-County. *African Journal of Education, Science and Technology*, March, 2020, Vol 5, No. 4

Bezuayehu, T., & Geert, S. (2008). Hydropower-induced land use change in Fincha'a watershed, western Ethiopia: analysis and impacts. *Mountain Research and Developmen*t. Vol 28 No.1:72-80

Bičík, I., Kupková, L., Jeleček, L., Kabrda, J., Štych, P., Janoušek, Z., & Winklerová, J. (2015). *Land Use Changes in the Czech Republic 1845–2010, Socio-Economic Driving Forces*; Springer: Basel, Switzerland

BirdLife International (2013). Deforestation in the Mau Forest, Kenya, is impacting wildlife and people. Downloaded from http://www.birdlife.org on 22/06/2021

Birdlife International. (2012). Ecosystem profile: Eastern Afromontane biodiversity hotspot. USA: Critical Ecosystem Partnership Fund, Conservation International

Boateng R. Y., Marek, M.V., Mikuláš, H., & Kluvankova, T. (2021). Perceived Injustices in Forest Policy Interventions are Causes of Forest Resources Degradation and Loss in Ghana: A Review. Scientific Research Publishing. *Open Journal of Forestry*, 2021, 11, 171-191 https://www.scirp.org/journal/ojf

Boserup, E. (1988). *Population Growth as a Stimulant to Agricultural Development*; Springer: Berlin/Heidelberg, Germany; pp. 61–75.

Brady, N. C. (1996). Alternatives to slash-and-burn: A global imperative. Agriculture, *Ecosystem and Environment*, 58, 3–11

Briassoulis, H. (2000). Land use land cover and soil sciences: Vol 1 Factors influencing Land use land cover change. Encyclopedia of Life Support System. University of the Aegean Mytilini, Lesvos Greece http://www.eolss.net/Eolss-sampleAllChapter.aspx

Cameron, G.N., Culley, T.M., Kolbe, S.E., Miller. A.I., & Matter, S.F. (2015). Effects of urbanization on herbaceous forest vegetation: the relative impacts of soil, geography, forest composition, human access, and an invasive shrub. *Urban Ecosyst*. 2015; 18: 1051±1069. https://doi.org/10.1007/s11252-015-0472-6M.

Cavanagh, C. J. (2012). Anthropocene Conservation: Governing Environmental Change, Biodiversity and Local Resistance at Mt. Elgon Uganda. Master Thesis. Noragric, UMB.

CBD (2010). Convention on Biological Diversity. Mountain Biodiversity United Nations decades on biodiversity. Living in harmony with nature. Available at https://www.cbd.int/undb/media/factsheets/undb-factsheet-mountains-en.pdf. Accessed on 14 April 2015.

CBS (2004). Economic Survey. Ministry of Planning and National Development, Nairobi.

Chao, S. (2012) Forest People: Numbers across the World, Forest Peoples Program, Moreton-in-Marsh, UK, 2012.

Cheesman, O. D. (2006). *Environmental impact of sugar production*. Cambridge MA. Cabi Publishers Brazil.

Cheruto, M.C., Kauti, M.K., Kisangau, P.D., & Kariuki, P. (2016). Assessment of Land Use and Land Cover Change Using GIS and Remote Sensing Techniques: A Case Study of Makueni County, *Kenya. J Remote Sensing & GIS* 5: 175.

Clough, Y., Barkmann J., Juhrbandt J., Kessler M., Cherico T W., Alam A, Damayanti B, Cicuzza D., Darras K., Dadang D. P., Stefan E., Ramadhanil P., Schmidt C., Christian H. S., Seidel D., Ingolf S.D., Stenchly K., Vidal S., Weist M., Arno C W., &Teja Tscharntke (2011). Combining high biodiversity with high yields in tropical agroforests. Proceedings of the National. *Academy of Sciences* May 2011, 108 (20) 8311 8316; DOI: 10.1073/pnas.1016799108

Convention on Biological Diversity (2010). Mountain Biodiversity United.

Cooke, P., Köhlin, G., & Hyde, W. (2008). Fuelwood, forests and community management – evidence from household studies. *Environment and Development Economics*, 13(1), 103-135. doi:10.1017/S1355770X0700397X

Corey J. A. B. (2011). Little left to lose: deforestation and forest degradation in Australia since European colonization. *Journal of Plant Ecology* Volume 5, Issue1 Pp.109-120.

Costanza R., de Groot R., Sutton P., van der Ploeg S., Anderson SJ., Kubiszewski I., Farber S., & Turner, R.K. (2014) Changes in the global value of ecosystem services. *Glob Environ Chang* 26:152–158

Davenport, T., Howard, P., & Dickenson, C., (1996). Mount Elgon Biodiversity Report. of Uganda Forest Department, P.O. Box 1752, Kampala, Uganda.

Earth Policy Institute (2012). Providing Plan for the Future, Eco Economy Indicators, Forest Cover. Available at http://www.earth-policy.org/indicators/C56/forests_2012. Accessed in February 2015

Eckert, S., Ratsimba, H. R., Rakotondrasoa, L. O., Rajoelison, L. G., & Ehrensperger, A. (2011). Deforestation and forest degradation monitoring and assessment of biomass and carbon stock of lowland rainforest in the Analanjirofo region. Madagascar. *Forest Ecology and Management*, 262, 1996–2007.

Ekesa B. N. (2009). Agricultural biodiversity for food and nutrient security: The Kenyan perspective. *International Journal of Biodiversity and Conservation* Vol. 1(7) pp. 208-214. Available online http://www.academicjournals.org/ijbc

Ellis F. (2000). *Rural Livelihoods and Diversity in Developing countries*. Oxford University Press. UK

EMCA (1999). Environment Management and Coordination Act. Kenya Emerton, L. (1992). The Role of Natural Forests in the Kenyan National Economy. KIFCON, Nairobi.

Emerton L. (1994). Summary of the current National Value of Use of Kenya's Indigenous Forest to Adjacent household, Kenya Indigenous Forest Conservation Programme, Forest Department

Emerton, L. (1993). The value of Kenya's indigenous forests to adjacent households. Nairobi: Forest Department.

Endamana, E., Akwah, N. G., Angu, K., & Shepherd, G. (2015). The Linkage Between Forest Resources, The Livelihoods of Rural Households and Possible Contributions to Sustainable Development Goals in The Developing Countries of the Central African Region. XIV WORLD FORESTRY CONGRESS, Durban, South Africa, 7-11 September 2015

Eni, D. D., & Ukpong, B. J. (2014). The Impact of Population Growth on Residential Land use in Calabar, Cross River State. Research on Humanities and Social Science ISSN (Paper) 2224-5766 ISSN (Online) 2225-0484 (Online)Vol.4, No.14, 2014.

FAO (1993). Guidelines for Land Use Planning. Rome: Food and Agricultural Organization of the UN. Rome

FAO (2004). What is agro biodiversity. Rome: Food and Agricultural Organization of the UN. Rome. Http://www.oecd.org/dataoecd/44/18/40713249.pdf. Accessed on 15 February 2015.

FAO (2007). Food and Agriculture Organization of the United Nations Rome, State of the Worlds Forest. Available at http://www.fao.org/3/a-a0773e.pdf

FAO (2009). Vital Forest Graphics. The United Nations Environment Programme, The Food and Agriculture Organization of the United Nations and The United Nations Forum on Forests Secretariat.

FAO (2010). Food and Agricultural Organization of the United Nation. Global Forest Assessment; FAO: Rome, Italy, 2010

FAO (2012). State of the World´s Forests 2012. Rome. (available at www.fao.org/docrep/016/i3010e/i3010e00.htm).

FAO (2016). Food and Agriculture Organization of the United Nations. State of the Worlds Forests. Land Use Challenges and Opportunities. Rome

FAO (2016). State of the World´s Forests 2012. Rome.

FAO. (2015). Global forest resources assessment 2015. Rome (available at www.fao.org/forest-resources-assessment/en)

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F. S., Coe, M. T., Daily, G.C., & Gibbs, H. K (2005). Global Consequences of Land Use Change. *Science*, 309, 570–574

Forest Act (2005). Kenya Forest Act 2005

Garrett, R D., Koha, I., Lambin E.F., le Polain de Warouxe, C.D., Kastensf, J.H., & Browng J.C. (2018). Intensification in agriculture-forest frontiers: Land use responses to development and conservation policies in Brazil. *Global Environmental Change journal.* Available at www.elsevier.com/locate/gloenvcha

Gautam, A. K. (2008). Climate Change Impact on Nepalese Agriculture and Strategies for Adaptation. Paper presented in NAPA workshop organized by LI-BIRD and Diversity International. 23 December 2009 (Mimeo, LI-BIRD).

Geist, H.J., & Lambin, E.F. (2002). Proximate causes and underlying driving forces of tropical deforestation. *BioSciences,* 52, 143–150.

Gerber, N., Nkonya, E., & von Braun, J. (2014). Land Degradation, Poverty and Marginality. *Marginality*. PP181

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., & Foley, J. A. (2009). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. Proceedings of the National Academy of Sciences of the United States of America, 2010(107), 16732–16737

Githae, E.W., Chuah-Petiot, M., Mworia, J.K., & Odee, D.W. (2007) A botanical inventory and diversity of Mt. Marsabit forest, a sub-humid montane forest in the arid lands of northern Kenya. *Afr. J. Ecol*. 46, 39–45. Governance in Kenya: A paper prepared for the East African Community, led regional process in the framework of the ministerial declaration, Yaoundé, Cameroon Oct 16 2003 on the Africa Forest Law Enforcement and Governance (AFLEG)

GOK (2015). Government of Kenya. Fifth National Report to the Conference of Parties to the Convention on Biological Diversity

Gunlycke, N., & Tuomaala, A. (2011). Detecting forest degradation in Marakwet district, Kenya, using remote sensing and GIS. Lund, Sweden.

Guthiga, P.M. (2008). "Economic Assessment of Different Management Approaches of Kakamega Forest in Kenya: Cost-benefit and Local Community Satisfaction Analysis" (PhD Thesis).

Gutierrez, B. L., Almeyda, Z. A.M., Almeyda, Z. S.L., Quispe, G. C.A., Bohlman, S., & Avellan, A. E. (2019) An island of wildlife in a human-dominated landscape: The last fragment of primary forest on the Osa Peninsula's Golfo Dulce coastline, Costa Rica. *PLoS ONE* 14(3): e0214390. https://doi.org/10.1371/journal.pone.0214390

Hansen, A.J., DeFries, R.S., & Turner, W. (2012) Land Use Change and Biodiversity. In: Gutman G. et al. (eds) *Land Change Science. Remote Sensing and Digital Image Processing,* vol 6. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-2562-4_16

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O., & Townshend, J. R. (2013). High-resolution global maps of 21st-century forest cover change. *Science,* 342, 850-3.

Hardin, G. (1968). The tragedy of the commons. *Science,* 162(3859), 1243-1248.

Hegde, R., & Enters, T. (2000) Forest products and household economy: A case study from Mudumalai Wildlife Sanctuary, Southern India. *Environmental Conservation* 27(3): 250–259.

Hemmati, M., & Röhr U (2009). Engendering the climate-change negotiations: experiences challenges, and steps forward. *Gender Dev* 17(1):19–32

Holmes, T. N. (2007). Contribution of Participatory Forest Management (PFM) Intervention to the Socio-economic Development in the Southern Cape Forests: A Retrospective Approach. Masters of Philosophy Thesis (Social Science Methods). University of Stellenbosch, South Africa

Hosea, M. M., Padia, L., Stefan, J., Sopan, D. P., Morag, A. M., & Karl, H. F. (2017). Characterizing the intensity and dynamics of land-use change in the Mara river basin. East Africa. *Forests*, *9*(1), 8.

Howard, P. C. (1991). Nature Conservation in Uganda Tropical Reserves. Forest Department/Ministry of Environment Protection Uganda. http/ www.unep.org/geo/geo3/ Accessed 15th January 2007

Indigenous Information Network (2008). Protected areas in Kenya. The case of Mt Elgon in North West Kenya. A review of Kenya's Implementation of the CBD of Work on Protected Areas.

Israel, G.D. (2013). Determining Sample Size. Institute of Food and Agricultural Sciences (IFAS), University of Florida, PEOD-6, 1-5.

IUCN (1995). Uganda Nationally Threatened Taxa listed at WCMC: conservation listing of plants. The World Conservation Monitoring Centre, Cambridge.

IUCN (1996). The Economic Value of Non-Timber Forest Products in South East Asia. Netherlands Committee for IUCN. Amsterdam

IUCN (1997). Non-timber Forest Products: Value, use and management issues in Africa, including examples from Latin America. Forest Conservation Program. The World Conservation Union. European Union.

IUCN (2007) International Union for the Conservation of Nature. Pro-poor and pro-conservation policies and operational procedures in the Mount Elgon ecosystem. MERECP Programme. Nairobi, Kenya: EARO.

IUCN (2008). Arborvitae. The IUCN Forest Conservation Programme Newsletter Issue 37 2008

IUCN, Gland, Switzerland and Cambridge, UK.158 pp.

IUFRO (2005). Interconnecting Science Forests and People. Contribution of Biodiversity to Ecosystem Services in Managed Forest.

Jensen, J. (1996). *Introductory Digital Image Processing: A Remote Sensing Perspective*. 2nd ed. Prentice Hall, Saddle River, NJ.

Joerg P A., Mimler M., & Heiko R. W. (2007). Faust Socio-Environmental. Impacts of Land Use and Land Cover Change at a Tropical Forest Frontier http://www.mssanz.org.au/MODSIM07/papers/5_s45/Socio-environmental_s45_Priess_.pdf

Johnson, A. K. L., McDonald, G. T., Shrubsole, D. A., and Walker, D. H. (1997). Sharing the land—the sugar industry as part of the wider landscape. In *Intensive Sugarcane Production: Meeting the Challenges Beyond* 2000 (B. A. Keating and J. R. Wilson, Eds.), pp. 361–380. CAB International, Wallingford.

Johnson, A.K. (2000). *Land cover changes and its environmental significance in the Herbert River Catchment North East Queensland*. Routledge publishers, Babinda, Queensland.

Kaboggoza J, J., Petursson G., & Vedeld P. (2006). *Transboundary biodiversity management challenges; The case of Mt. Elgon, Uganda and Kenya*

Kamwi, J. M., Chirwa, P. W. C., Manda, S. O. M., Graz, F. P., & Kätsch, C. (2015). Livelihoods, land use and land cover change in the Zambezi region (pp. 1–24). Windhoek, Namibia: Population and Environment.

Kanianska, R. (2016). Agriculture and Its Impact on Land-Use, Environment, and Ecosystem Services, Landscape Ecology - The Influences of Land Use and Anthropogenic Impacts of Landscape Creation, Amjad Almusaed, IntechOpen, DOI: 10.5772/63719. Available from: https://www.intechopen.com/books/landscape-ecology-the-influences-of-land-use-and-anthropogenic-impacts-of-landscape-creation/agriculture-and-its-impact-on-land-use-environment-and-ecosystem-services

Kanianska, R., Kizekov´ M Nov´ A.J aˇ cek, & Zeman, M. (2014). "Land-use and land-cover changes in rural areas during different political systems: a case study of Slovakia from," *Land Use Policy*, vol. 36,pp. 554–566

Karina, W., Fuchs, R., Rounsevell, M., & Herold, M. (2021). Global land use changes are four times greater than previously estimated. *Nat Commun* 12**,** 2501 (2021). `https://doi.org/10.1038/s41467-021-22702-2.

Kashian, D. M., Barnes, B. V., & Walker, W. S. (2003). Ecological species groups of landform level ecosystems dominated by jack pine in northern Lower Michigan, USA. *Plant Ecol.,* 166 (1), 75-91

Kees, K. G., & Navin, R. (2010). Land use changes during the past 300 years. Land use, land cover and soil sciences. *Encyclopedia of Life Support Systems (Eolss),* I, 1–23.

Kideghesho J. R. (2015). Realities on Deforestation in Tanzania Trends, Drivers, Implications and the Way Forward, Precious Forests - Precious Earth, Miodrag Zlatic, IntechOpen, DOI: 10.5772/61002. Available from: https://www.intechopen.com/books/precious-forests-precious-earth/realities-on-deforestation-in-tanzania-trends-drivers-implications-and-the-way-forward

Kiragu, S. W. (2002) Community Participation in Forest Resources Management in Mt. Elgon Forest and its environs. A thesis for Masters of Philosophy in Environmental Studies; Moi University

Kironchi, G., & Mbuvi, J. P. (1996). Effects of deforestation on soil fertility on the northwestern slopes of Mt Kenya. *ITC Journal.*

Kisiwa, A., Langat, K., Gatama, S., Kiprop, S., Cheboiwo J., and Kagombe J., (2013). Community Perception of Ecosystem Services and Management Implications of Three Forests in Western Part of Kenya. *E. Afri. Agri. For. J* (Pg. 80 -90 Special Issue)

Klaus, D. (2003). Land Policies for Growth and Poverty Reduction. A World Bank Policy Research Report. Washington, Dc

Kleijn D., Kohler F.A., Ba´ldi, P., Bata´ry, E. D., Concepcio´n, Y., Clough, M., Dı´az, D., Gabriel, A., Holzschuh, E., Knop, A., Kova´cs, E. J. P., Marshall, T., Tscharntke and Verhulst J (2008). On the relationship between farmland biodiversity and land-use intensity in Europe. *Proc. R. Soc. B* (2009) 276, 903–909 doi:10.1098/rspb.2008.1509.

Knapp, S., Kuhn, I., Schweiger, O., and Klotz S. (2008). Challenging urban species diversity: contrasting phylogenetic patterns across plant functional groups in Germany. *Ecol. Lett* 11:1054 64.

KNBS (2019). Kenya National Bureau of Statistics. Nairobi Kenya

KNBS, (2010). Kenya Population and Housing Census 2009. Nairobi. ISBN.

Kokwaro, J.O. (1976). *Medicinal plants of East Africa*. East African Literature Bureau, Nairobi

Kuemmerle, T., Christian L., Karlheinz E., Stephan E., Martin R. J., Daniel Müller., C.P., Julia S., Pieter J V., Peter H V., & Anette R. (2016). Hotspots of land use change in Europe. Environmental Research Letters. *Environ. Res. Lett.* 11 064020. Available at http://iopscience.iop.org/1748-9326/11/6/064020

KWS (2014). Mount Elgon National Park- Kenya: "Untamed wilderness, secluded splendour". Available at http://www.kws.go.ke/content/mount-elgon-national-park. The Conservation of Ecosystems and Species. Groom Helm, New York.

KWTA (2017). Kenya Water Towers Agency. Coordinated Environmental Protection. Policy Brief, Mt Elgon Water Towers.

Lambin, E. F., & Geist J.H., (2007). Causes of land use land cover change. The encyclopedia of the Earth.

Lambin, E. F., & Geist, H.J. (2008). Land-use and land-cover change: local processes and global impacts, Springer Science & Business Media.

Lambin, E. F., & Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. Proceedings of the National Academy of Sciences of the United

Lambin, E.F., & Geist, H.J. (2001). Global land-use and land-cover change: what have we learned so far? Global change newsletter, Land-use/Cover change

Lambin, E.F., & Geist, H.J. (2003); Lepers, E. Dynamics of Land Use and Land Cover Change in Tropical Regions. *Annu. Rev. Environ. Resourc.* 2003, 28, 205–241.

Langat, D.K., Maranga, E.K., Aboud, A.A., & Cheboiwo J.K (2016). Role of Forest Resources to Local Livelihoods: The Case of East Mau Forest Ecosystem, Kenya. *International Journal of Forestry Research*. Volume 2016, Article ID 4537354. Available at http://dx.doi.org/10.1155/2016/4537354

Lillesand, T.M., & R.W. Kiefer, (2000). *Remote Sensing and Image Interpretation.* John Willy & Sons, New York, Chi-chester.

Lillesand, T.M., Kiefer, R.W., & Chipman, J.W. (2004). *Remote Sensing and Image Interpretation.* Fifth Edition. CRC/Lewis Press, Boca Raton, Florida.

Lin, N., Nam, T.T., & Perera, J. (2012). Response of birds to different management types of tea cultivation in a forest-agriculture landscape, SW China. Proceedings of the Advanced Field course in Ecology and Conservation—XTBG 2012, Yunnan, China. 12–20

Liu, J., Daily, G.C., Ehrich, P.R., & Luck, G.W. (2003). Effects of household dynamics on resource consumption and biodiversity. *Nature* 421, 530–533

Lung, T., & Schaab, G (2009). A comparative assessment of land cover dynamics of three protected forest areas in tropical eastern Africa, *Environ. Mon. Assess* (2010), Vol.161, pp.531-548.

Lybbert J.T., & Sumner, A.D. (2012) Agricultural technologies for climate change in developing countries: policy options for innovation and technology diffusion. *Food Policy* 37(1):114–123. doi:10.1016/j.foodpol.2011.11.001

Mace, G.M., Norris, K., & Fitter, A.H. (2012). Biodiversity and ecosystem services: A multilayered relationship. *Trends. Ecol. Evol.* 2012, 27, 19–26

Maitima, J. M., Olson, J. M., Mugatha, S. M., Mugisha, S., & Mutie, I. T. (2010). Land Use Changes, Impacts and Options for Sustaining Productivity and Livelihoods in the Basin of Lake Victoria. *Journal of Sustainable Development in Africa* (Volume 12, No.3,). Clarion University of Pennsylvania, Clarion, Pennsylvania

Makenzi, P.M. (2016). Integrity of Mt. Elgon as a Biosphere Reserve, Water Tower and a Proposed Trans-boundary Biosphere Reserve. Presented to the "Mountains WorKESop" at the 4WCBRs March 14-17, 2016, Lima. Peru. Millennium Ecosystem Assessment

Makino, S., Goto, H., Hasegawa, M., Okabe, K., Tanaka, H., Inoue, T., & Okochi I. (2007). Degradation of longicornbeetle (Coleoptera, Cerambycidae, Disteniidae) fauna caused by conversion from broad-leaved to man-made conifer stands of Cryptomeria japonica (Taxodiaceae) in central Japan. *Ecol Res* 22:372–381

Malthus, T. (1960). *First Essay on Populatio.* Modern Library: New York, NY, USA,

Margono, B.A., Turubanova, S., Zhuravleva, I., Potapov, P., Tyukavina, A., Baccini A, Goetz, S., & Hansen M.C. (2012) Mapping and monitoring deforestation and forest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990–2010. Environ Res Lett 7(3):034010

Masau J., Sang J., Gathenya J., & Luedeling, E. (2014) Hydrological Response to Climate Change in Mt Elgon Water Sheds. *Journal of Hydrology: Regional Studies*. 3:235

Masayi, N., & Netondo, G.W. (2012). Effects of Sugarcane Farming on Diversity of Vegetable Crops in Mumias Division, Western Kenya *(International Journal of Biodiversity and Conservation,* Vol. 4(13), pp.515-524).

Masek, J.G., Lindsay F.E., & Goward, S.N. (2000) Dynamics of urban growth in the Washington DC metropolitan area, 1973-1996, from Landsat observations. *International Journal of Remote Sensing* 21(18): 3473-3486

Masika, (2009). Annual reports and Financial Statements. Kenya Red Cross

Mathu, W. (2007). Kenya wildlife service forest law enforcement and governance in Kenya: A paper prepared for the East African Community, led regional process in the framework of the ministerial declaration. Yaoundé, Cameroon Oct 16 2003 on the. Africa Forest Law Enforcement and Governance (AFLEG).

Matthews, S., O'Connor, R., & Plantinga A.J (2002) Quantifying the impacts on biodiversity of policies for carbon sequestration in forests. *Ecol Econ* 40:71–87.

Mazel, F., Guilhaumon, F., Mouquet N., Devictor V., Gravel, D., Renaud, J., Cianciaruso, M.V., Loyola, R.D., Diniz-Filho, J.A., Mouillot, D., & Thuiller, W. (2014). Multifaceted diversity–area relationships reveal global hotspots of mammalian species, trait and lineage diversity Glob. *Ecol. Biogeogr*., 23 (2014), pp. 836-847

Mbonile, M. J., Sokoni, C.H., Mkindi, A., & Mwanukuzi, P. (2016). Mapping Poverty, Vulnerability and Resource Rights in Tanzania. *Journal of the Geographical Association of Tanzania*, volume 37, p. 1 - 24

McDonnell, M J., Pickett, S. T. A., & Pouyat, R.V. (1993). The application of the ecological gradient paradigm to the study of urban effects. In: McDonnell MJ and STAP, editor. *Humans as components of ecosystems: subtle human effects and the ecology of populated areas*. New York: Springer, pp. 175–189.

McGinnis, M. V. (1999). Special Symposium on Watershed Policy. *Policy Studies Journal* 27 (in press).

McGovern, S., Evans, C.D., Dennis, P., Walmsley, C., & McDonald, M.A. (2011). Identifying drivers of species compositional change in a semi-natural upland grassland over a 40-year period. *J Veg Sci* 2011, 22: 346– 356

McKinney, (2008). Effects of urbanization on species richness: a review of plants and animals, *Urban Ecosystems*, vol. 11, no.2, pp. 161–176.

MEA (Millennium Ecosystem Assessment), (2005). *Ecosystems and Human Well-being: Synthesis.* Island Press, Washington, DC.

MEICDP (1999). Mount Elgon Integrated Conservation and Development Project. Plan of Operations.

MEICDP (2001). Aerial photography and land cover mapping of Mt Elgon: Technical rep Mt. Elgon integrated conservation and development project

MENR (1994). Kenya Forestry Master Plan. Ministry of Environment and Natural Resources, Nairobi, Kenya

Millar J., & Roots J. (2012). Changes in Australian agriculture and land use: implications for future food security, *International Journal of Agricultural Sustainability*, 10:1, 25-39, DOI: 10.1080/14735903.2012.646731

Misana, S.B., & Nyaki, F.R.(1993). Population and Deforestation. In United Nations (ed). *Population, Environment and Development.* University of Dar es Salaam, United Nations.41-60pp.

Mishra, V. (2002). "Population Growth and Intensification of land Use in India", *International Journal of Population Geography*, Vol. 8, pp. 365-383.

Mitra, A., Chandan, S., & Marie-AngeVeganzones-Varoudakis (2011). *Total factor productivity and technical efficiency of Indian manufacturing: the role of infrastructure and information & communication technology.* CERDI, Etudes et Documents

Mogaka, H.R. (1991). Local Utilization of Arabuko-Sokoke Forest Reserve. KIFCON, Nairobi

Mohanty, S. (2009). *Population Growth, Changes in Land Use and Environmental Degradation in India*. Research Scholar, IIPS.

Mugenda, O.M., & Mugenda, A. G. (1999). *Research Methods. Quantitative and Qualitative Approach.* African Centre for Technology Studies (ACTS). Nairobi, Kenya

Mugenda, O.M., & Mugenda, A. G. (2003). *Research Methods*, *Quantitative and Qualitative Approaches*. ACT, Nairobi

Muhweezi A. B., Sikoyo, G. M., & Chemonges, M. (2007). Introducing a Transboundary Ecosystem Management Approach in the Mount Elgon Region. *Mountain Research and Development 27*(3):215-219. DOI: 10.1659/0276-4741(2007)27[215:IATEMA]2.0.CO;2

Müller, D., & Zeller, M. (2004). Agricultural Intensification, Population Growth and Forest Cover Change: Evidence from Spatially Explicit Land Use Modeling in the Central Highlands of Vietnam; Springer: Berlin/Heidelberg, Germany, pp. 495–519

Mungo, C.W.P. (2003). The Implications of Land Use Change on Forests and Biodiversity: A Case of the "Half MileStrip" on Mount Kilimanjaro, Tanzania. LUCID pp: 56.

Mutangah, J.G., Mwangangi O.M., & Mwaura P.K. (1992). Kakamega Forests: a Vegetation Survey. KIFCON/NMK, Nairobi.

Mwangi, E., Cerutti, P., and Nasi, R. (2018). State of the forests of Eastern Africa, EUR 29251 EN. Publications Office of the European Union. Available at http://apps.rcmrd.org/ofesa/images/ofesa/reports/The_Current_State_of_Eastern_Africa_Forest.pdf. ISBN 978- 92- 79- 86634- 0, https://doi.org/10.2760/88556 8,JRC11 1239.

Myhren. S. (2007). Rural Livelihood and Forest Management in Mount Elgon, Kenya. Msc. Degree in Development Studies Noragric, Norwegian University of Life Science.

Nachmias F., & Chava, L.G. (2002). *Research Methods in Social Sciences.* NY Publishers, New York.

Nahuelhual, L., Donoso, P., Lara, A., Nuñez, D., Oyarzun, C., & Neira, E. (2007). Valuing ecosystem services of Chilean temperate rainforests. *Environment, Development and Sustainability*, 9(4), 481-499

Nangware K M., Lianxi S., & Lyimo J. (2019). Land Use Change Trends and their Driving Forces in the Kilombero Valley Floodplain, Southeastern Tanzania. *Sustainability* 2019, 11, 505; doi:10.3390/su11020505

Nantumbwe, C.M. (2005). *Temporal land use and soil property interrelationships in Wanale and Manafwa catchments of Mt. Elgon*. Makerere University, Kampala, Uganda.

Netondo, G.W., Fuchaka, W., Maina, L., Naisiko, T., Masayi, N., & Ngaira, J. K. (2010). Agro biodiversity endangered by sugarcane farming in Mumias and Nzoia Sugar belts of Western Kenya. *African Journal of Environmental Science and Technology* Vol. 4:437-445).

Nield, R., Mugo, E., & Mwathe, K. (1999). Review of the management of the forest resources of Mt. Elgon Ecosystems, Kenya. Prepared for: The National Project Steering Committee of Mt. Elgon Integrated Conservation and Development Project (MEICDP). Nairobi, Kenya.

Nkonya, E., Gerber, N., von Braun, J., & De Pinto, A., (2011). "Economics of land degradation: The costs of action versus inaction," Issue briefs 68, International Food Policy Research Institute (IFPRI).

Norul A. S., & Mizarul, R. (2011). Comparison of Plant Diversity of Natural Forest and Plantations of Rema-Kalenga Wildlife Sanctuary of Bangladesh. *Journal of Forest Science*. Vol. 27, No. 3, pp. 127~134

Noss, R.F. (1995). U.S. Department of the Interior, Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation. Biological Report 28. Washington, DC

Nowak, D.J. (2010). Urban biodiversity and climate change. In: Muller N., P.W, J.G. K, editors. *Urban biodiversity and design*. New Jersey: Wiley-Blackwell Publishing inc. pp. 101–117.

Nwosu, E. J. (2014). The Nigerian Challenge in Environmental Sustainability: Forest Economics and the Need for Conservation. *Mechanism of Economic Regulation*, 2014, No 2.

Nzeh, C. E.P. (2012). *Economic Analysis of Deforestation in Enugu State, Department of Agricultural Economics.* University of Nigeria

O'Ktingati, A., & Kessy, J.F. (1991). The farming systems of Mount Kilimanjaro. In Newmark, W.D. (ed), *The Conservation of Mount Kilimanjaro.* IUCN, Gland, Switzerland and Cambridge, UK.71-80 pp

Obare, L., & Wangwe, J.B. (1998). Underlying Causes of Deforestation and Forest Degradation in Kenya. World Forest Movement. http://www.wrm.org.uy/deforestation/Africa/Kenya.html

Ochuoga, O. (2002). Agriculture Environment Health. 28. Nairobi: Picasso Productions; 2002. Biosafety News Biotechnology

Odada, E. O., Olago, D. O., & Olaka, L. A. (2020). An East African perspective of the Anthropocene. *Scientific African*, 10, e00553. https://doi. org/10.1016/j.sciaf.2020.e00553.

Olang L. O., & Kundu, P.M. (2011). Land Degradation of the Mau Forest Complex in Eastern Africa: A Review for Management and Restoration Planning. Kenyatta University Institutional Repository

Oldfield E. E., Mark A. B., & Stephen, A. (2019). Wood Global meta-analysis of the relationship between soil organic matter and crop yields. *SOIL*, 5, 15–32, 2019 https://doi.org/10.5194/soil-5-15-2019

Olson, J. M., Misana, S., Campbell, D., J Mbonile, M., & Mugisha, S. (2004). The Spatial Patterns and Roots Causes of Land use Changes in East Africa. LUCID Project Working Paper No. 47. Nairobi Kenya International Livestock Research Institute [http://www.lucidafrica.Org

Olupot, W., & Chapman, C. A. (2006). Human Encroachment and Vegetation Change in Isolated Forest Reserves, the Case of Bwindi Impenetrable National Park in Uganda.http://chapmanresearch.mcgill.ca/Pdf/206_Olupot%20%20Chapman.pdf

Ongong'a, I.A., & Sweta, L. (2014). Land cover and land use mapping and change detection of Mau Complex in Kenya using geospatial technology. *Int. J. Sci. Res.* 2014, *3*, 767–778.

Ongugo, P., & Mwangi, E.N. (1996). Common property and Forest Resource Management in Kenya. Paper presented to the East African Symposium on Common Property Management, Uganda International Conference Centre. 26th-28th March 1996.

Ongugo, P. O., & Njuguna, J. W. (2004). Effects of Decentralization Policies on Forest Management: Experience from Seven Forests in Kenya. Draft Paper. IFRI Collaborating Research Centre, Kenya Forestry Research Institute (KEFRI). Nairobi, Kenya.

Ongugo, P. O., Langat, D., Oeba V.O., Kimondo, JM., Owuor B., Njuguna, J., Okwaro, G., & Russell, A.J.M. (2014). A review of Kenya's national policies relevant to climate change adaptation and mitigation: Insights from Mount Elgon. Working Paper 155. Bogor, Indonesia: CIFOR.

Ongugo, P., Kimani, S.M., & Okwaro, G., (2001). Forests, Communities and Urban Markets: Can They Co-Exist in A Devolved Structure?

Ongugo, P., Njuguna, J., Obonyo E., & Sigu, G., (2005) Kenya IFRI Collaborative Research Centre Livelihoods, Natural Resource Entitlements and Protected Areas: The Case of Mt. Elgon Forest in Kenya.

Oso, W.K., & Onen, D (2005). *A General Guide to Writing Research Proposal and Report*. Option Press and Publishers. Kisumu, Kenya

Peach, B. H. (2011). Gender, climate change and REDD + in the Congo Basin forests of Central Africa. *Int For Rev* 13(2):163–176.

Pejchar, L., Holl, K.D., & Lockwood, J. L. (2005). Hawaiian honeycreeper home range size varies with habitat: implications for native *Acacia koa* forestry. Ecol. Appl. 15:1053–1061

Pereira, H.M., Navarro, L.M., & Martins, I.S. (2012). Global biodiversity change: the bad, the good, and the unknown. *Annu Rev Environ Resoucr*, **37**: 25– 50.

Petursson, J.G, Vedeld, P., & Kaboggoza, J. (2011). Transboundary Biodiversity Management: Institutions Local Stakeholders, and Protected Areas: A Case Study from Mt. Elgon, Uganda and Kenya. Society & Natural Resources. *An International Journal* 24 (12) pp. 1304-1321 Available at https://doi.org/10.1080/08941920.2010.5403 10

Pia, H., & Konrad (2016). Effects of rubber cultivation on biodiversity in the Mekong Region. Available at: http://www.cabi.org/cabreviews

Population Action International, (2011). Why Population Matters to Biodiversity. Health Families, Healthy Planet

Ramona, L. M., Braschler, B., Hans-Peter, R., & Baur B., (2018). Diverse effects of degree of urbanization and forest size on species richness and functional diversity of plants, and ground surface-active ants and spiders. University of Basel, Basel, Switzerland.

Ranjan, B., & Antara, S. (2019). Biodiversity Monitoring Study to Assess the Impact of a Comprehensive Organic Farming Practice namely Inhana Rational Farming (IRF) Technology on the Ecological Components of India.

Reij, C. V., Tappan, G., & Smale, M. (2009). Agro Environmental transformation in the Sahel: Another kind of “Green Revolution. International Food Policy Research Institute. Sustainable Solutions for ending hunger and Poverty

Renner, M. (2017). Alienation in Agriculture: How the Shamba System Promotes the Degradation of Kenyan Montane Forests. *Aisthesis.* Volume 8, 2017

Rowcroft, P. (2005). Gaining Ground: The Socio-Economic Driving Forces Behind Decisions Regarding Land Use and Land Use Change; An Overview, Working Paper 16: Vientiane, Loas,

Rudel, T.K., Defries, R., Asner, G.P., & Laurance, W.F. (2009). Changing drivers of deforestation and new opportunities for conservation. *Conserv. Biol* 23(6):1396–1405

Russell, A.J.M., Waiswa, D., Owuor, B., Ongugo, P.O., Bomuhangi, A., Banana, A.Y., & Kimondo, J. (2017). Trends in forest conditions and implications for resilience to climate change under differing forest governance regimes: The case of Mount Elgon, East Africa. Working Paper 225. Bogor, Indonesia: CIFOR.

Sassen, M., Sheil, D., Giller, K E., & Braak C J. (2013). Complex contexts and dynamic drivers: Understanding four decades of forest loss and recovery in an East African protected area. *Biological Conservation* 159:257–68.

Sayer, A.J., Harcourt C. S., & Collins, N.M. (1992). *The Conservation atlas of tropical forests.* Africa .288 p. Macmillan Publishers Ltd., United Kingdom.

Scherr S. J., & McNeely, J.A. (2007). Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'Eco agriculture' landscapes. *Philos Trans R Soc Lond B Biol Sci*. 2008 Feb 12; 363(1491): 477–494.

Schneider, F., Feurer, M., Lundsgaard-Hansen, L. M., Win, M., Cing, D. N., Nydegger, K., Oberlack, C., Nwe, N. T., Zähringer, J. G., Aung, M. T., & Messerli, P. (2020). Sustainable development under competing claims on land: Three pathways between land-use changes, ecosystem services and human well-being. *The European Journal of Development Research*, 32(2), 316–337. https://doi.org/10.1057/ s41287-020-00268-x

Scott, P. (1998). From conflict to Collaboration: People and Forests at Mt. Elgon, Uganda.

Searle, S.Y., Turnbull, M.H., Boelman, N.T., Schuster, W.S.F., Yakir, D., & Griffin, K. L. (2012). Urban environment of New York City promotes growth in northern red oak seedlings. *Tree Physiol* 32:389–400.

Selena, A., Charles, M. P., Long, C., Meyer, R., Uchenna, U., Amy, L., Edward, K., & John R. S. (2012). Biodiversity and phytochemical quality in indigenous and state-supported tea management systems of Yunnan, China. *Conservation Letters* 6 (2013) 28–36

Simiyu, R. R. (2008). Militarization of resource conflict. The case of Land Based Conflict in Mt. Elgon Region of Western Kenya. Netherland, Institute for Security Studies

Singh, A., & Masuku, M. (2014). Sampling Techniques & Determination of Sample Size in Applied Statistics Research: An Overview. Ijecm.co.uk, II (11), 1-22.

Smith, P., Bustamante, M., Ahammad, H., Clark, H., Dong, H., Elsiddig, E. A., Haberl, H., Harper, R., House, J., & Jafari, M. (2014). Agriculture, forestry and other land use (AFOLU). In *Climate change*. Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press.

Soini, E. (2006). Past and present land tenure and incentives for land management in the five districts surrounding Mount Elgon (Kapchorwa, Sironko and Mbale in Uganda, and Trans-Nzoia and Mt. Elgon in Kenya). Mount Elgon Regional Ecosystem Conservation Programme (MERECP). Final Draft. IUCN

Stefanescu, C., Carnicer, J., & Peñuelas J (2011). Determinants of species richness in generalist and specialist Mediterranean butterflies: the negative synergistic forces of climate and habitat change. *Ecography* 2011, 34: 353– 363.

Stefanescu, C., Carnicer, J., & Peñuelas, J. (2011). Determinants of species richness in generalist and specialist Mediterranean butterflies: the negative synergistic forces of climate and habitat change. *Ecography* 2011, 34: 353– 363.

Stephens S. S., & Wagner M.R. (2007). Forest plantations and biodiversity: a fresh perspective. J for 105:307–313

Streiner, D. L. (2005). Finding Our Way: An Introduction to Path Analysis. In *Research Methods in Psychiatry.* Vol. 50, No.2, February, 2005

Suda, C. (1992). Literature review on the use of indigenous forests in Kenya. Nairobi: Kenya Indigenous Forest Conservation Project/Institute of African Studies, University of Nairobi.

Sunderland, T. C. (2011). Food security: why is biodiversity important? *International Forestry Review*, 13(3), 265-274

Svein, T., Bååtvik, John, R.S., Kaboggoza, Kabutha, C., & Vedeld P. (2002). Mt. Elgon Regional Ecosystem Conservation Programme (MERECP) Appraisal Report. Noragric Report. NLH. As, Norway

Taubenbock, H., Wegmann, M., Roth, A., Mehl, H., & Dech, S. (2009). Urbanization in India – Spatiotemporal analysis using remote sensing data. Computers, Environment and Urban Systems, 33, 179–188.

TEEB (2009). The Economics of Ecosystems and Biodiversity for National and International policy makers. www.teebweb.org/ForPolicymakers/tabid/1019/language/en-US/Default.aspx

Thomas, D. S., & Middleton, N. J. (1994). *Desertification: exploding the myth*, John & Sons Ltd

Turner, B.L., Skole, D., Sanderson, S., Ficher, D., Fresco L., & Leemans, R. (1995). Land use and land cover change. The international Geosphere-Biosphere program and the human dimension of Global environmental change program, Stockholm and Geneva.

Turner, B. (1995). Changes in land use and land cover: *A global perspective*: 3-10. Cambridge University Press.

Turner, B. L., Lambin, E.F., & Anette, R. (2007). "The Emergence of Land Change Science for Global Environmental Change and Sustainability." Proceedings of the National Academy of Sciences of the United States of America *10*4.52 (2007): 20666–20671.

Turner, B.L., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., & Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences of the United States of America. 2003;100:8074–8079

Turner, BL., Moss, R.H., & Skole, D. (1993). "Relating land use and global land-cover change: a proposal for an IGBP-HDP core project. A report from the IGBP/HDP Working Group on Land-Use/Land-Cover Change," Global Change Report, Royal Swedish Academy of Sciences, Stockholm, Sweden, 1993.

Uganda Wildlife Authority, (2011). Report on Kapsekek Land Re Allocation at Amnang Parish, Bukwo District.

UN (2014). United Nations, Department of Economic and Social Affairs Population Division. World urbanization prospects [Internet]. New York: United Nations; 2014.

UNEP (2001). An assessment of the status of the world's remaining forest.

UNEP (2002). Global Environmental Outlook 3. London.

UNEP (2008). "Kenya: Atlas of Our Changing Environment." Environmental Change Hotspots. Mau Forest Complex. Deforestation in the Mau Forest Complex. Kenya

UNEP (2009). "Kenya: Atlas of Our Changing Environment." Division of Early Warning and Assessment (DEWA) United Nations Environment Programme (UNEP), Kenya.

UNEP (2011) United Nations Environmental Program. Livelihood Security Climate Change, Migration and Conflict in the Sahel. UNESCO, Paris.

Vallet, J., Beaujouan, V., Pithon, J., Roze, Â. F., & Daniel, H. (2010). The effects of urban or rural landscape context and distance from the edge on native woodland plant communities. *Biodivers, Conserv*. 2010; 19: 3375 3392. https://doi.org/10.1007/s10531-010-9901-2

van Heist, M. (1994). Land Unit Map of Mount Elgon National Park. IUCN technical

Vandeplank, J, E., (1984). Asymptotic behaviour of model plant disease, Epidemics

Vangen, C. (2009). Evicted in The Name of Nature. The Process of Eviction and its Impact on the Local Rural Livelihoods in Mt Elgon National Park, Uganda. Master Thesis. UMB.

Varah, A., Jones, H., Smith, J., & Potts, S.G. (2013). Enhanced biodiversity and pollination in UK agroforestry systems. *J. Sci. Food Agric*. 2013, 93, 2073–2075

Vedeld, P., Van R. A., Sundnes, F., & Jorgensen, I.T. (2005). Final appraisal of the Mt. Elgon Regional Ecosystem Conservation Programme (MERECP). Noragic Rapport No. 25. As, Norway: Department of International Environment and Development Studies (Noragric), Norwegian University of Life Sciences (UMB).

Veldkamp, A., & Fresco, L.O. (1996). CLUE-CR: an integrated multi-scale model to simulate land use change scenarios in Costa Rica. *Ecological Modelling* 91: 231-248

Villamor, G.B., Desrianti, F., & Akiefnawati, R. (2013) Gender influences decisions to change land use practices in the tropical forest margins of Jambi, Indonesia. *Mitig Adapt Strategy Global Change* 19, 733–755 (2014). https://doi.org/10.1007/s11027-013-9478-7

Vitonset, D.M., Harris, C.D., & Bulog E.W. (2007). Human Domination of Health's Ecosystems. *Science*, 27: 494-499

Walker, J. S., Grimm, N. B., Briggs, J.M., Gries, C., & Dugan, L. (2009). Effects of urbanization on plant species diversity in central Arizona. *Front Ecol. Environ* 7:465–70.

Wass, P. (1994). Kenya's indigenous forests: status, management and conservation. IUCN, Nairobi, Kenya.

Wass, P. (1995). Kenya's Indigenous Forests: Status, management and conservation. IUCN, Gland, Switzerland and Cambridge, UK.

Waswa, F., Mcharo, M., & Netondo, G. (2009). Enhancing household food and income Security through crop diversification in the Nzoia and Mumias Sugar belts in Kenya. *Journal of Applied Biosciences* 23: 1406 – 1415

Waweru, P. K. (1974). The basis of politics in Trans-Nzoia 1963-1973 [BA dissertation]. Nairobi, Kenya: Department of Government, University of Nairobi.

Weber, R., Faust, H., Schippers, B., Mamar, S. Sutarto, E., and W. Kreisel (2007). Migration and Ethnicity as Cultural Impact Factors on Land Use Change in the Rainforest Margins of Central Sulawesi, Indonesia. In: Tscharntke, T., Leuschner, C., Guhardja, E. & M. Zeller (eds.): *The Stability of Tropical Rainforest Margins: Linking Ecological, Economic and Social Constraints of Land Use and Conservation*. Springer, Berlin, London, New York, 392-417.

Weldemariam, S.G. (2018*). Application of DPSIR Framework for Assessment of Land Degradation: A Review*. Crimson Publishers.

Williams, N., Schwartz, M., Vesk, P,McCarthy, M., Hahs, A., Clemants, S., Corlett, R.,Duncan, R., Norton, B., and Hompson, K. (2009). A conceptual framework for predicting the effects of urban environments on floras. *J Ecol* 97:4–9.

Wily, L. (1991) Hunting in the Mau. KIFCON, Nairobi

Witcomb, M., & Dorward, P. (2009). An assessment of the benefits and limitations of the shamba agroforestry system in Kenya and of management and policy requirements for its successful and sustainable reintroduction. *Agroforestry Systems*, 75(3), 261-274.

Wood, A., Stedman, T., Edwards, P., & Mang J., (2000). *The root cause of biodiversity Loss.* Earth Scan Publications Ltd, UK. 36-57

Wood, E.C., Tappan, G.G., & Hadj, A. (2004). Understanding the drivers of agricultural land use change in central Senegal. *J. Arid Environ.* 2004, 59, 565–582

World Bank (2006), Global Issues for Global Citizens: An Introduction to Key Development, Challenges, Edited by V.K. Bhargava, The World Bank Report, Washington, DC, USA, 2006.

Wunder, S., (2000). Big Island, Green forests and Back packers. Land use and development options on IIHA Grande, RIO de Janeiro State, Brazil. Centre for development research, Denmark.

Wunder, S., Angelsen, A., & Belcher B. (2014). Forests, Livelihoods, and Conservation: Broadening the Empirical Base. *World Development* Vol. 64, pp. S1–S11, 2014. http://dx.doi.org/10.1016/j.worlddev.2014.03.007

WWF (2017) World Wide Fund for Nature (2017) Farming: Habitat conversion & loss. Xiaomei Y. and Ronqing L.Q. Y, (1999). Change Detection Based on Remote Sensing Information Model and its Application to Coastal Line of Yellow River Delta – Earth Observation Center, NASDA, China

Yamane, T. (1967). *Statistics, An Introductory Analysis*, 2nd Ed., New York: Harper and Row.

Yongliang, S. H., Rusong, W., LingyunFANa, C., Jingsheng L. I., Dongfeng Y. D. (2010). Procedia Environmental Sciences 2 (2010) 175–184

Young, R.H., & Young, M. P. (2010). *The links between biodiversity, ecosystem service and human well-being. Ecosystem Ecology*: A New Synthesis Publisher: Cambridge University Press

Young, S., & Swiacki. L.N. (2006). Surveying the Forest Biodiversity of Evansburg State Park: Plant Community Classification and Species Diversity Assessment. *Int J Bot.* 2(3): 293-299.

Yunfeng, H., Batunacun, L., & Dafang, Z. (2019). Assessment of Land-Use and Land Cover Change in Guangxi, China. Scientific reports. https://doi.org/10.1038/s41598-019-38487-w

Zaehringer, J. G., Flurina, S., Andreas, H., & Peter, M. (2019). Coproducing knowledge for sustainable development in telecoupled land systems. *Telecoupling, Palgrave Studies in Natural Resource Management,* 7, 357–381. https://doi.org/10.1007/978-3-030-11105-2_19

Zaehringer, J., Eckert, S., & Messerli, P. (2015). Revealing regional deforestation dynamics in north-eastern Madagascar-insights from multi-temporal land cover change analysis. *Land*, 4(2), 454–474. https://doi.org/10.3390/land4020454

Zondag, B., & Borsboom, J. (2009) Driving forces of land-use change. In: Paper prepared for the 49th ERSA conference, Lodz, August 2009

Zubair A.O. (2006). Change detection in land use and land cover Using remote sensing data and GIS: A case study of Ilorin and its environs in Kwara State. M.Sc. thesis. University of Ibadan, Ibadan

APPENDICES

Appendix 1: Questionnaire

Project Title: Impacts of Land Use Changes on the Mt. Elgon Forest ecosystem, Kenya

Section 1: Respondents Identification

1. Name…………………………………… Date……………………
2. Division…..……. Location………………. sub-location……...village……..
3. Distance from Forest Reserve…………………………………………….
4. Season of Interview--

Section 2: Respondents Demographic and Socio-economical Characteristics

5. Gender of the respondent…………………Age…………….
6. Were you born in this area…………………………….
7. Period lived in the area……………………………..
8. Ethnicity…………………………………...
9. Level of Education………………………...
10. Major Sources of Income………………………...
11. Average monthly income……………………….
12. Occupation--

Section 3: Nature of and Causes of Land Use Changes

13. Which of the following best describe how your piece of land looked like at the time you settled here? (a) Thickly forested (b) Moderately forested (c) Slightly forested (d) Other (specify...
....
....

14.Since you came here what changes have you noticed in the size of the forest…………………………………………………………..…………………….
….………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
………………………………………………………………………………..………

15: In your opinion, what is the cause of these observed changes in the forest?

Cause	
Government Laws and policies	
Increase in Population	
Land Fragmentation	
Need for industrial materials	
Land ownership and leasing	
Insecurity	
Urbanization	

Need for Charcoal Fuel	
Other	

16. How many acres of land do you have? ....

17. What is the size of your land under the following uses in the specified years on your farm?

Year	Crop Farming	Homestead	Animal Farming	Agro forestry	Other
1970s					
1980s					
1990s					
2000s					
2010s					
2015					

18. What are the causes of the changes observed in the size of land allocated to different land uses on your farm?

Causes	
Need for more food for the family	
Increase in family size	
Government laws and policies	
Land ownership and leasing	
Ready markets for products	
Changes in tastes and preferences	
Land Fragmentation	
Need for more land for settlement	
Others (specify)	

19. How would you rate the acreages of the following crops on your farm in the times indicated?

Crop	Acreages in 1970s	Acreages in 1980s	Acreages in 1990s	Acreages in 2000s	Acreages in 2010s
Maize					
Sugarcane					
Potatoes					
Groundnuts					
Vegetables					
Bambara groundnuts					
Millet					
Finger millet					

Cassavas					
Simsim					
Others					

20. What are the causes of the changes in land use on your farm?

Need for more food for the family	
Increase in family size	
Government laws and policies	
Land ownership and leasing	
Ready markets for products	
Land Fragmentation	
Need for more land for settlement	
Need for Wood Fuel	

21. Indicate in the table below the kind of traditional vegetables you have been growing in the times indicated

Indigenous Vegetable	**1960s**	**1970s**	**1980s**	**1990s**	**2000+**	**2010s**
Cow peas						
Pumpkin Leaves						
Vegetable Amaranths						
Pig weed						
Jute Mallow						
Sunhemp						
Spider plant						
African night shade						
African kale						
Kales						
Cabbage						
Carrots						
Tomatoes						
Onions						

22. What specific reasons do you think are responsible for the observed changes in the diversity of vegetables on your farm?

Reason	
Availability of cheap seeds	
Pests and diseases	
Availability of ready market	
Change in tastes and preferences	
Lack of labour	

23. Do you practice animal farming? a) Yes b) No
24. If yes how long have you been in the practice? ....
25. What type of animals did you rear in these times?

Types of animals	1970s	1980s	1990s	2000s	2010s
Cattle					
Sheep					
Goats					
Chicken					
Donkeys					
Others					

Section 4: Consequences of Land Use Changes

28. What are the observed changes in wild plant species in your farm between 1972 and 2015?

Changes In Wild Plant Species	1970s	1980s	1990s	2000s
Increased				
Decreased				
No Change				

29. List the wild plant species that have been increasing in the region between 1970s and 2015……………………………………………………………………………….
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………..

30. List the plant species that have been declining in the region between 1970s and 2015……………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………..

Mt Elgon Forest Ecosystem

29. Has Mt Elgon forest ecosystem been of benefit to you (a) Yes (b) No?

30. What are the benefits that you get from Mt Elgon Forest in the following period?

Benefit	1970s	1980s	1990s	2000s
Grazing ground for Livestock				
Source of Medicinal Plants				
Source of food (game meat, fruits and indigenous vegetable)				
Ornamental resources (artisan work decorative plants, pet animals, fashion)				
Raw materials (fiber, timber, wood fuel, fodder)				
Water (e.g., for drinking, irrigation				
recreation and tourism				
Spiritual experience				
Education experience				
Other (list other benefits)				

31. Are there any changes in the availability of these benefits between 1970s and 2015? (a) Yes (b) No

32. Indicate whether the ecosystem service has increased or decreased between 1972-2019

Ecosystem Services	**Increased**	**Decreased**	**No change**
Grazing ground for Livestock			
Source of Medicinal Plants			
Source of food (game meat, fruits and indigenous vegetable)			
Ornamental resources (artisan work decorative plants, pet animals, fashion)			
Raw materials Fiber, Timber, Wood fuel, Fodder			
Water (e.g., for drinking, irrigation)			
Recreation and tourism			
Spiritual experience			
Education experience			
Other (list other benefits)			

33. List some of the medicinal plants that have declined in the region---------------------
----

---..

34….List some of the plants used for ornamental purpose in the region-------------------
----

----

35. Give reason for the increase or decrease in this benefits.--------------------------------
----

36: For the ecosystem services that declined, what is the alternative way of acquiring these services?

Ecosystem Services	**Alternative Source**
Grazing ground for Livestock	
Source of Medicinal Plants	
Source of food (game meat, fruits and indigenous vegetable)	
Ornamental resources (artisan work decorative plants, pet animals, fashion)	
Raw materials Fiber timber, wood fuel fodder)	
Water (e.g. for drinking, irrigation	
recreation and tourism	
Spiritual experience	
Education experience	
Other (list other benefits)	

34. What is the main form of energy that you have been using for different purposes like cooking, space heating, and others for the stated periods?

Energy Form	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**
Firewood					
Charcoal					

Plant Residues					
Kerosine					
Gas					
Electricity					
Solar Panel					
Other					

35). If wood fuel and /or charcoal are the main source of energy, what is the main source of fuel wood that you depend most on?

Source	
a) community wood lot	
b) trees on the farm	
c) purchases from neighbors	
d) Neighboring forest	
e) others (specify)	

Appendix 2: Structured Interview

Project Title: Impacts of Land Use Changes on the Mt. Elgon Forest ecosystem, Kenya

Section 1: Respondents Identification

1. Name…………………………………… Date……………………
2. Gender of the respondent
3. Period lived in the area
4. Occupation
    a) Agricultural Officer
    b) County environmental officer
    c) NEMA Official
    d) KEFRI official
    e) KWS official
    f) Chief
    g) Assistant Chief
    h) Traditional medical Practitioners

5.What changes have you noticed in the size of the natural?
6. What changes have you noticed in the size of the plantation forest?
7. What are the causes of changes in the plantation forests?
8. What are the causes of these observed changes in the natural forests?
9. Have you noticed any changes in the number of livestock owned by the communities?
10. What changes have you observed and what are the causes of the observed changes in numbers of livestock
11. Are there any noticeable changes in crop farming in this region?
12. What are the causes of the observed changes in crop farming?
13. What are some of the benefits of the Mt Elgon forest to the adjacent community?
14. Is there any process in the acquisition of these benefits?
15. Are there any changes in the availability of these forest products between 1970s to 2010s?
16. What are the causes of the changes in the acquisition of the mentioned forest products?
20. Give reason for the increase or decrease in this benefits
22. How much money is changed when acquiring these benefits from the forest?
23. What are some of the medicinal plants that have declined in the region?
24. What are some of the ornamental plants that have declined in the region?
25. What are some of the wild vegetables that have declined in the region?
26. What are some of the wild fruits that have declined in the region?
27. In your opinion, is the Shamba System successful in the management and Conservation of the Mt Elgon Forest?
24. What are some of the challenges facing the effectiveness of the conservation of Mt Elgon forest?

Appendix 3: Medicinal Plants of Mt Elgon

	Name	***Scientific Name***	**Frequency**	**%**
1	Mwarobaini	*Melia volkensii*	88	24.1
2	Sakwondet	*Warbugiaugandensis*	46	12.6
3	Elgon Teak	*Tectonagrandis*	40	11.0
4	Cheptuyet	*Diospyros abyssinica ,(Hiern)*	33	9.0
5	Moabarwa	*Grewiatrichocarpa ,(Horchst)*	29	7.9
6	Toboswet	*Croton macrostachyus*	21	5.8
7	Rodipchepkukwa	*Aloe elgonica Bullock*	18	4.9
8	Cheptegandeet,	*Engleromycesgoetzi ,P. Hiern*	15	4.1
9	Kokorwet	*Erythrina abyssinica DC.*	13	3.6
10	Msiembut	*Entada abyssinica ,A.Rich*	13	3.6
11	Tungururuet	*Flacourtiaindica*	11	3.0
12	Chesamishiet	*Clausinaanisata ,(Willd) Benth*	10	2.7
13	Simotweet,	*Spathodeacampanulata*	10	2.7
14	Chebutiandet	*Piliostigmathonningii, (Schumach)*	9	2.5
15	Tekandeet (Bamboo)	*Bambusoideae*	9	2.5
16	Itet	*Senna didymobotrya*	8	2.2
17	Kibumetet	*Ekerbegia capensis, Sparrm*	8	2.2
18	Metitapsorin	*EchinopsangustilobusS.Moore*	8	2.2
19	Motoniet	*Clerodendrummyricoides (Horchst)*	8	2.2
20	Saruryandet	*Conyzabonariensis ,(L.) Cronq*	7	1.9
21	Angureet	*Plectranthuscomosus (Sims)*	7	1.9
22	Korshiondet	*Olea europea L. ssp africana (Mill)*	7	1.9
23	Simborichet	*Toddaliaasiatica (L*	6	1.6
24	Sinendet,	*Markhamia lutea (Benth)*	8	2.2
25	Sodom Apple	*Solanum incanum L.*	5	1.4
26	Legetetwet	*Carissa edulis Vahl*	4	1.1
27	Mitiviazi	*Heteromorpha*	4	1.1
28	Arumotit	*Prunus africana ,(Hook.f) Kalkm*	4	1.1
29	Chebugaa,	*Dolichoscompressus , Wilczec*	3	0.8
30	Ngwekwe	*Tagetesminuta L*	3	0.8
31	Kuptoret	*Pteridiumaquilinium*	3	0.8
32	Lamaywet	*Syzigiumcordatum*	2	0.5
33	Pekeriondet	*Olea capensis L.*	2	0.5
34	Rotiandet	*Spathodeacompanulata P.*	1	0.3

35	Sitotweet	*Rapanea ,melanophloeos (L.) Mez*	1	0.3
36	Chepkatait	*Maytenusheterophylla*	1	0.3
37	Kwiriondet	*Tecleanobilis Del.*	1	0.3
38	Labotwet	*Solanum incanum L.*	1	0.3
39	Lambachwet	*Brideliamicrantha*	1	0.3
40	Mobchabelyo	*Steganotaeniaaraliacea Hochst*	1	0.3
41	Mogoiwet	*Ficus sur Forssk*	1	0.3
42	Tegeldet	*Acanthus eminens*	1	0.3
43	Matabiet	*Ziziphus abyssinica*	1	0.3
44	Tabongwe't	*Vernonia auriculifera*	1	0.3
45	Chesamishiet	*Clausinaanisata*	1	0.3

Appendix 4: Research Permit

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS

1. The License is valid for the proposed research, location and specified period.
2. The License and any rights thereunder are non-transferable.
3. The Licensee shall inform the County Governor before commencement of the research.
4. Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
5. The License does not give authority to transfer research materials.
6. NACOSTI may monitor and evaluate the licensed research project.
7. The Licensee shall submit one hard copy and upload a soft copy of their final report within one year of completion of the research.
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice.

National Commission for Science, Technology and innovation
P.O. Box 30623 - 00100, Nairobi, Kenya
TEL: 020 400 7000, 0713 788787, 0735 404245
Email: dg@nacosti.go.ke, registry@nacosti.go.ke
Website: www.nacosti.go.ke

REPUBLIC OF KENYA

National Commission for Science, Technology and Innovation

RESEARCH LICENSE

Serial No.A 22005

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MS. NELLY NAMBANDE MASAYI
of MOI UNIVERSITY, 84-50102
Malava,has been permitted to conduct research in *Bungoma County*

on the topic: *IMPACTS OF LAND USE CHANGES ON THE MT. ELGON FOREST ECOSYSTEM, KENYA*

for the period ending:
24th November,2019

Permit No : NACOSTI/P/18/61996/26085
Date Of Issue : 24th November,2018
Fee Recieved :Ksh 2000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471, 2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/18/61996/26085**

Date: **24th November, 2018**

Nelly Nambande Masayi
Moi University
P.O Box 3900-30100
ELDORET

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Impacts of land use changes on the Mt. Elgon Forest Ecosystem, Kenya"*** I am pleased to inform you that you have been authorized to undertake research in **Bungoma County** for the period ending **24th November, 2019.**

You are advised to report to **the County Commissioner and the County Director of Education, Bungoma County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Bungoma County.

The County Director of Education
Bungoma County.

Appendix 5: Focus Group Discussion