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

BY

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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

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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 ArcGIS 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.
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ACRONYMS AND ABBREVIATIONS

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<th>Acronym</th>
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<tbody>
<tr>
<td>CBD</td>
<td>Convention on Biodiversity Conservation</td>
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<td>CBS</td>
<td>Central Bureau of Statistics</td>
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<td>E. P</td>
<td>Exotic Plantations</td>
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<td>FAO</td>
<td>Food and Agricultural Organisation</td>
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<td>Focus Group Discussion</td>
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<td>Indigenous Plantations</td>
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<td>IUCN</td>
<td>International Union for Conservation of Nature</td>
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<td>KI</td>
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<td>LULC</td>
<td>Land Use Land Cover Change</td>
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<td>MERECP</td>
<td>Mount Elgon Regional Ecosystem Conservation Programme</td>
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<td>NTZ</td>
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<td>NTFPs</td>
<td>Non-Timber Forest Products</td>
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<td>PRA</td>
<td>Participatory Rural Appraisal</td>
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<td>ROK</td>
<td>Republic of Kenya</td>
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<td>Statistical Packages for Social Sciences</td>
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<td>Thematic Map</td>
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<td>UNEP</td>
<td>United Nations Environment Program</td>
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<td>USA</td>
<td>United States of America</td>
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<td>UTM</td>
<td>Universal Transverse Mercator</td>
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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 km², 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 Turkel 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 km², but an expansion in global agriculture (i.e. cropland and pasture/rangeland) of 1.0 and 0.9 million km², 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 km²) of its forest in 38 years, Ghana lost 24 percent (4,000km²), and Nigeria lost 45 percent (9,570km²). 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 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 16th 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, Endeless divisions) to the east. On the Ugandan side, Mbale district is to the southeastern 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).
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 (appendix 1). 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 Chimuchewa 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 Yamane (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:

\[
n = \frac{N}{1 + Ne^2}
\]

Where
- \(n\): Sample size
- \(N\): Population size
- \(e\): Level of precision

**Table 3.1: Population and Area of Sampled Wards**

<table>
<thead>
<tr>
<th>Ward</th>
<th>Total Pop</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bungoma County</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheptais</td>
<td>28639</td>
<td>26</td>
</tr>
<tr>
<td>Chesikaki</td>
<td>23874</td>
<td>22</td>
</tr>
<tr>
<td>Chepyuk</td>
<td>25329</td>
<td>23</td>
</tr>
<tr>
<td>Kapkateny</td>
<td>28628</td>
<td>26</td>
</tr>
<tr>
<td>Kaptama</td>
<td>33402</td>
<td>30</td>
</tr>
<tr>
<td>Elgon</td>
<td>31476</td>
<td>28</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>171348</td>
<td>155</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ward</th>
<th>Total Pop</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TransNzoia County</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saboti</td>
<td>166,482</td>
<td>150</td>
</tr>
<tr>
<td>Endebeess</td>
<td>91,192</td>
<td>82</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>257,674</td>
<td>232</td>
</tr>
<tr>
<td><strong>Total Population</strong></td>
<td>429,022</td>
<td></td>
</tr>
<tr>
<td><strong>Total Sample Size</strong></td>
<td></td>
<td>387</td>
</tr>
</tbody>
</table>

(Source: KNBS 2019)
The sampled respondents included were household 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 Mapper (TM)**

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (micrometers)</th>
<th>Resolution (Meters)</th>
<th>Useful for mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, Blue</td>
<td>0.45-0.52um</td>
<td>30</td>
<td>Vegetation Mapping</td>
</tr>
<tr>
<td>2, Green</td>
<td>0.52 to 0.60um</td>
<td>30</td>
<td>Emphasizes peak vegetation, which is useful for assessing plant vigor</td>
</tr>
<tr>
<td>3, Red</td>
<td>0.63 to 0.69um</td>
<td>30</td>
<td>Discriminates vegetation on slopes</td>
</tr>
</tbody>
</table>

(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+)**

<table>
<thead>
<tr>
<th>Landsat 7</th>
<th>Wavelength (micrometers)</th>
<th>Resolution(meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 2, Blue</td>
<td>0.52-0.60</td>
<td>30</td>
</tr>
<tr>
<td>Band 3, Green</td>
<td>0.63-0.69</td>
<td>30</td>
</tr>
<tr>
<td>Band 4, Red</td>
<td>0.77-0.90</td>
<td>30</td>
</tr>
<tr>
<td>Band 5, NIR</td>
<td>1.55-1.75</td>
<td>30</td>
</tr>
</tbody>
</table>

(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≤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.
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

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

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=398km²) and 12.65% (n=235km²) 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=101.79km²) 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 practicing 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](image-url)
Further analysis on 1977 and 1986 revealed that 120.33km² (17.9%) of area under natural forest was transformed to grasslands between 1977 and 1986. About 30.61km² of natural forest was transformed into fallow land. Similarly, 10.16km² 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 138.28km² of grasslands were transformed into fallow land between 1977 and 1986. Some 93.32km² of bamboo forests was transformed into grasslands over the same period.

Similarly, 89.88km² of grasslands were changed into mixed farming over the same period. Some 27.83km² of bamboo were transformed into mixed farming between 1977 and 1986 while some 69.02km² 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](image)

Plantation forest occupied an area of about 23% (n=407.67km²). Tea farming covered some 0.1% (n=1.81km²) 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=398.94km²) in 1986 to 3.35% (n=62.39km²).
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% \((n=578.11 \text{ km}^2)\) in 1986 to 20.52\% \((n=381.77 \text{ km}^2)\) in 1999. Over the same period, grasslands declined by 10 \% from 29\% \((n=546.52 \text{ km}^2)\) in the 1986 to 19.39\% \((n=360.75\text{km}^2)\) 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.](image)

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% \( (n=570\text{km}^2) \) of the total land area. Fallow land occupied the second largest piece of land accounting for about 27.95% \( (n=520.27\text{km}^2) \) of the total land area while natural forest occupied a total of 18.1% \( (n=336.88\text{km}^2) \) of the total land. The size of land under Grasslands comprised 15.2% \( (n=282.89\text{km}^2) \) while plantation forest occupied a total of 6.47% \( (n=120.44\text{km}^2) \) (Table 4.6). Bamboo and Tea farming occupy the least size of land accounting to about 1.45% \( (n=27.12\text{km}^2) \) and 0.13% \( (n=2.42\text{km}^2) \) of land respectively (Figure 4.8).
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% \( (n=2.42\text{km}^2) \) 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).

![Age distribution of Respondents]

**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 51-60 years (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](image)

<table>
<thead>
<tr>
<th>Length of Stay (Years)</th>
<th>Frequency and Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-50</td>
<td>41.37% (n=151)</td>
</tr>
<tr>
<td>51-60</td>
<td>27.12% (n=99)</td>
</tr>
<tr>
<td>61-70</td>
<td>16.44% (n=60)</td>
</tr>
<tr>
<td>71-80</td>
<td>9.04% (n=33)</td>
</tr>
<tr>
<td>81-90</td>
<td>3.56% (n=13)</td>
</tr>
<tr>
<td>&gt;91</td>
<td>2.47% (n=9)</td>
</tr>
</tbody>
</table>

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).
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).

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.
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 Change](image_url)

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.

![Changes in crop production](image)

**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).

![Economic Drivers of Land Use Change](image_url)

**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) in 2010s (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).

![Changes in Tea and Coffee Growing](image)

**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.

![Institutional Drivers of Land Use Change](image)

**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=25.35km²) to 30.63% (n=570.76km²) between 1977 and 2019 while land under natural forests had declined from 36% (n=671.4km²) to 18.1% (n=336.9km²) 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 to 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](image_url)
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 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 overall 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).

![Abundance of Herbs in the Control Site](chart)

**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

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

*Crepis carbonaria* had some 47.5% abundance in the control site but was absent in 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

<table>
<thead>
<tr>
<th>Herb</th>
<th>Exotic Plantation (%)</th>
<th>Number</th>
<th>Control Plot (%)</th>
<th>Number</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isoglossa laxa</td>
<td>-</td>
<td>-</td>
<td>24.38</td>
<td>1950</td>
<td>-24.38</td>
</tr>
<tr>
<td>Oxalis anthelmintica</td>
<td>-</td>
<td>-</td>
<td>28.13%</td>
<td>2250</td>
<td>-28.13%</td>
</tr>
<tr>
<td>Crepis carbonaria</td>
<td>-</td>
<td>-</td>
<td>47.50%</td>
<td>3800</td>
<td>-47.50%</td>
</tr>
<tr>
<td>Galinsonga parviflora</td>
<td>34</td>
<td>6000</td>
<td>-</td>
<td>-</td>
<td>34</td>
</tr>
<tr>
<td>Cymophostemma kilimandscharicum</td>
<td>1</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Achyrospermum schimperi</td>
<td>62.5</td>
<td>11000</td>
<td>-</td>
<td>-</td>
<td>62.5</td>
</tr>
<tr>
<td>Vernonia auriculifera</td>
<td>2.8</td>
<td>500</td>
<td>-</td>
<td>-</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Further analysis of tree species in exotic plantations revealed that *Cupressus 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

<table>
<thead>
<tr>
<th>Tree Species</th>
<th>Exotic Plantation (%)</th>
<th>Number</th>
<th>Control Plot (%)</th>
<th>Number</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olea Africana</td>
<td>-</td>
<td>-</td>
<td>1.69</td>
<td>1</td>
<td>-1.69</td>
</tr>
<tr>
<td>Erythrina abyssinica</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cupressus lusitanica</td>
<td>100</td>
<td>4500</td>
<td>-</td>
<td>-</td>
<td>+91.84</td>
</tr>
<tr>
<td>Albizia gumifera</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Acacia lahai</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cedrus atlantica</td>
<td>-</td>
<td>-</td>
<td>47.46</td>
<td>28</td>
<td>-47.46</td>
</tr>
<tr>
<td>Podocarpus latifolia</td>
<td>-</td>
<td>-</td>
<td>22.03</td>
<td>13</td>
<td>-22.41</td>
</tr>
<tr>
<td>Olea europea</td>
<td>-</td>
<td>-</td>
<td>11.86</td>
<td>7</td>
<td>-11.86</td>
</tr>
<tr>
<td>Hagenia abyssinica</td>
<td>-</td>
<td>-</td>
<td>6.78</td>
<td>4</td>
<td>-6.78</td>
</tr>
<tr>
<td>Raphanea melanophloeos</td>
<td>-</td>
<td>-</td>
<td>10.17</td>
<td>6</td>
<td>-10.17</td>
</tr>
</tbody>
</table>

*Zanthoxylum gilettii* 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 gumifera, 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

<table>
<thead>
<tr>
<th>Tree Species</th>
<th>Indigenous Plantation (%)</th>
<th>Number</th>
<th>Control Plot (%)</th>
<th>Number</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zanthoxylum gilettii</td>
<td>39.47</td>
<td>1500</td>
<td>-</td>
<td>-</td>
<td>+39.47</td>
</tr>
<tr>
<td>Olea Africana</td>
<td>34.21</td>
<td>1300</td>
<td>1.69</td>
<td>1</td>
<td>+32.52</td>
</tr>
<tr>
<td>Erythrina abyssinica</td>
<td>18.4</td>
<td>700</td>
<td>-</td>
<td>-</td>
<td>+18.4</td>
</tr>
<tr>
<td>Croton macrostachys</td>
<td>2.63</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>+2.63</td>
</tr>
<tr>
<td>Albizia gummifera</td>
<td>2.63</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>+2.63</td>
</tr>
<tr>
<td>Acacia lahai</td>
<td>2.63</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>+2.63</td>
</tr>
<tr>
<td>Cedrus atlantica</td>
<td>-</td>
<td>-</td>
<td>47.46</td>
<td>28</td>
<td>-47.46</td>
</tr>
<tr>
<td>Podocarpus latifolia</td>
<td>-</td>
<td>-</td>
<td>22.03</td>
<td>13</td>
<td>-22.02</td>
</tr>
<tr>
<td>Olea europea</td>
<td>-</td>
<td>-</td>
<td>11.86</td>
<td>7</td>
<td>-11.86</td>
</tr>
<tr>
<td>Hagenia abbyssinica</td>
<td>-</td>
<td>-</td>
<td>6.78</td>
<td>4</td>
<td>-6.78</td>
</tr>
<tr>
<td>Rapanea melanophloenos</td>
<td>-</td>
<td>-</td>
<td>10.17</td>
<td>6</td>
<td>-10.17</td>
</tr>
</tbody>
</table>

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 abbyssinica* 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 abyssinica* 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 in 11 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 $\beta$ 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).

![Change in Species Abundance in Control and Urban Sites](image)

**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).

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).
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).
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.
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 4.33: Percentage number of Shrubs in Urban Settlements

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)

<table>
<thead>
<tr>
<th>Species</th>
<th>Nyayo Tea Zone (%)</th>
<th>N</th>
<th>Control Site (%)</th>
<th>N</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td>6.67</td>
<td>1</td>
<td>55.54</td>
<td>6</td>
<td>-48.3</td>
</tr>
<tr>
<td>Ferns</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>1</td>
<td>-9</td>
</tr>
<tr>
<td>Herbs</td>
<td>60</td>
<td>9</td>
<td>27</td>
<td>3</td>
<td>+33</td>
</tr>
<tr>
<td>Climbers</td>
<td>6.67</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>+6.67</td>
</tr>
<tr>
<td>Grasses</td>
<td>6.67</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>+6.67</td>
</tr>
<tr>
<td>Shrubs</td>
<td>13.3</td>
<td>2</td>
<td>9.09</td>
<td>1</td>
<td>4.21</td>
</tr>
<tr>
<td>Sedge</td>
<td>6.67</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>6.67</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>100</td>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Herb species included Achyrospermum schimperi, Conyzabonariensis, Cymphostemma kilimandscharicum, Dichondra repens, Galinsonga parviflora, Isoglossalaxa, Oxalis anthelmintica, Urtica massaica 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>
<thead>
<tr>
<th>Herb</th>
<th>NTZ (%)</th>
<th>N</th>
<th>Control Plot (%)</th>
<th>N</th>
<th>Percentage Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Urtica massaica</em></td>
<td>71.6</td>
<td>72000</td>
<td>-</td>
<td>-</td>
<td>+71.6</td>
</tr>
<tr>
<td><em>Crepis carbonaria</em></td>
<td>-</td>
<td>-</td>
<td>47.5</td>
<td>3800</td>
<td>-47.5</td>
</tr>
<tr>
<td><em>Oxalis anthelmintica</em></td>
<td>9.9</td>
<td>10000</td>
<td>28.13</td>
<td>2250</td>
<td>-18.23</td>
</tr>
<tr>
<td><em>Dichondra repens</em></td>
<td>7.4</td>
<td>7425</td>
<td>-</td>
<td>-</td>
<td>+7.4</td>
</tr>
<tr>
<td><em>Isoglossa laxa</em></td>
<td>4.8</td>
<td>4875</td>
<td>24.375</td>
<td>1950</td>
<td>-19.58</td>
</tr>
<tr>
<td><em>Vernonia auriculifera</em></td>
<td>2.7</td>
<td>2750</td>
<td>-</td>
<td>-</td>
<td>+2.7</td>
</tr>
<tr>
<td><em>Achyrospermum schimperi</em></td>
<td>2.1</td>
<td>2133</td>
<td>-</td>
<td>-</td>
<td>+2.1</td>
</tr>
<tr>
<td><em>Conyza bonariensis</em></td>
<td>1</td>
<td>1000</td>
<td>-</td>
<td>-</td>
<td>+1</td>
</tr>
<tr>
<td><em>Galinsonga parviflora</em></td>
<td>0.19</td>
<td>200</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>Cymphostemma kilimandscharicum</em></td>
<td>0.15</td>
<td>150</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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

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](image_url)
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 abyssinica* 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](image)

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 versus control site was ranked the lowest with $\beta$ 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)

![Changes in floral species groups](image)

**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.

<table>
<thead>
<tr>
<th>Herb</th>
<th>Mixed Farming Site (%)</th>
<th>Control Plot N</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Achyranthes aspera</em></td>
<td>2.93</td>
<td>867</td>
<td>2.93</td>
</tr>
<tr>
<td><em>Ageratium conyzoides</em></td>
<td>3.39</td>
<td>1000</td>
<td>3.39</td>
</tr>
<tr>
<td><em>Conyza foribunda</em></td>
<td>0.11</td>
<td>33</td>
<td>0.11</td>
</tr>
<tr>
<td><em>Crassocephalum picridifolium</em></td>
<td>1.81</td>
<td>533</td>
<td>1.81</td>
</tr>
<tr>
<td><em>Galinsonga parviflora</em></td>
<td>0.56</td>
<td>167</td>
<td>0.56</td>
</tr>
<tr>
<td><em>Justicia flava</em></td>
<td>79.91</td>
<td>23600</td>
<td>79.91</td>
</tr>
<tr>
<td><em>Leonotis nepetifolia</em></td>
<td>0.9</td>
<td>267</td>
<td>0.9</td>
</tr>
<tr>
<td><em>Phytolaccado decandra</em></td>
<td>0.34</td>
<td>100</td>
<td>0.34</td>
</tr>
<tr>
<td><em>Plectranthus comosus</em></td>
<td>1.58</td>
<td>467</td>
<td>1.58</td>
</tr>
<tr>
<td><em>Plectranthus sylvestris</em></td>
<td>4.51</td>
<td>1333</td>
<td>4.51</td>
</tr>
<tr>
<td><em>Crepis carbonaria</em></td>
<td>-</td>
<td>47.5</td>
<td>-47.5</td>
</tr>
<tr>
<td><em>Vernonia auriculifera</em></td>
<td>3.16</td>
<td>933</td>
<td>3.16</td>
</tr>
<tr>
<td><em>Vernonia smithiana</em></td>
<td>0.79</td>
<td>233</td>
<td>0.79</td>
</tr>
<tr>
<td><em>Isoglossa laxa</em></td>
<td>-</td>
<td>24.38</td>
<td>-24.38</td>
</tr>
</tbody>
</table>

*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.

<table>
<thead>
<tr>
<th>Shrub</th>
<th>Mixed Farming</th>
<th>Control Plot</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Senescio snowdenii</em></td>
<td>43.39</td>
<td>1533</td>
<td>+43.39</td>
</tr>
<tr>
<td><em>Ocimum gratissimum</em></td>
<td>11.32</td>
<td>400</td>
<td>+11.32</td>
</tr>
<tr>
<td><em>Acanthus eminens</em></td>
<td>11.32</td>
<td>400</td>
<td>+11.3</td>
</tr>
<tr>
<td><em>Sida rhombifolia</em></td>
<td>11.32</td>
<td>400</td>
<td>+11.32</td>
</tr>
<tr>
<td><em>Senna didimobotrya</em></td>
<td>6.6</td>
<td>233</td>
<td>+6.6</td>
</tr>
<tr>
<td><em>Lantana trifolium</em></td>
<td>5.66</td>
<td>200</td>
<td>+5.66</td>
</tr>
<tr>
<td><em>Mussaenda arcuata</em></td>
<td>5.66</td>
<td>200</td>
<td>+5.66</td>
</tr>
<tr>
<td><em>Rubus niveus</em></td>
<td>4.7</td>
<td>167</td>
<td>+4.7</td>
</tr>
<tr>
<td><em>Vangueria apiculata</em></td>
<td>-</td>
<td>-</td>
<td>-9.09</td>
</tr>
</tbody>
</table>

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).

![Abundance of Trees in Control Site and Mixed Farming Site](image)

**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.

<table>
<thead>
<tr>
<th>Study Sites</th>
<th>Shannon Weiner Diversity Index</th>
<th>Evenness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Site</td>
<td>2.07331</td>
<td>0.884</td>
</tr>
<tr>
<td>Indigenous Plantation forest</td>
<td>1.93962</td>
<td>0.69957</td>
</tr>
<tr>
<td>Urban Settlement</td>
<td>1.85081</td>
<td>0.66754</td>
</tr>
<tr>
<td>Nyayo Tea Zone</td>
<td>1.5324</td>
<td>0.56</td>
</tr>
<tr>
<td>Mixed Farming</td>
<td>1.43694</td>
<td>0.452114</td>
</tr>
<tr>
<td>Exotic Plantation forest</td>
<td>1.28131</td>
<td>0.61612</td>
</tr>
</tbody>
</table>
Table 4.11: The Whittaker beta diversity index of species under different land uses

<table>
<thead>
<tr>
<th>Rank</th>
<th>Study Site</th>
<th>Beta Diversity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control Site / Urban Settlement</td>
<td>0.5385</td>
</tr>
<tr>
<td>2</td>
<td>Control Site / Indigenous Plantation forest</td>
<td>0.2222</td>
</tr>
<tr>
<td>3</td>
<td>Control Site / Nyayo Tea Zone</td>
<td>0.1429</td>
</tr>
<tr>
<td>4</td>
<td>Control Site / Mixed Farming</td>
<td>0.000</td>
</tr>
<tr>
<td>5</td>
<td>Control Site / Exotic Plantation forest</td>
<td>0.000</td>
</tr>
</tbody>
</table>

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](image-url)
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.

![Mt Elgon forest Ecosystem Services](image)

**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 350 million 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](image)

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 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.
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 uugandensis* (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 uugandensis* 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).

![Trends in the Use of Wild Fruits](image)

**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 oleracea* 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](image)

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).
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).
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).
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).
This decline is 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
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.
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 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 appears 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
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).

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 by 7% 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.
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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………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………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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?

<table>
<thead>
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<th>Year</th>
<th>Crop Farming</th>
<th>Homestead</th>
<th>Animal Farming</th>
<th>Agro forestry</th>
<th>Other</th>
</tr>
</thead>
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<td>2015</td>
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</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for more food for the family</td>
</tr>
<tr>
<td>Increase in family size</td>
</tr>
<tr>
<td>Government laws and policies</td>
</tr>
<tr>
<td>Land ownership and leasing</td>
</tr>
<tr>
<td>Ready markets for products</td>
</tr>
<tr>
<td>Changes in tastes and preferences</td>
</tr>
<tr>
<td>Land Fragmentation</td>
</tr>
<tr>
<td>Need for more land for settlement</td>
</tr>
<tr>
<td>Others (specify)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acreages in 1970s</th>
<th>Acreages in 1980s</th>
<th>Acreages in 1990s</th>
<th>Acreages in 2000s</th>
<th>Acreages in 2010s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugarcane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundnuts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bambara groundnuts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finger millet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
20. What are the causes of the changes in land use on your farm?

<table>
<thead>
<tr>
<th>Reason</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Need for more food for the family</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase in family size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government laws and policies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land ownership and leasing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ready markets for products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land Fragmentation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Need for more land for settlement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Need for Wood Fuel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow peas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumpkin Leaves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable Amaranths</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pig weed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jute Mallow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunhemp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spider plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African night shade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African kale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kales</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrots</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Reason</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of cheap seeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pests and diseases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of ready market</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in tastes and preferences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of labour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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?

<table>
<thead>
<tr>
<th>Types of animals</th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
<th>2000s</th>
<th>2010s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goats</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Donkeys</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Section 4: Consequences of Land Use Changes
28. What are the observed changes in wild plant species in your farm between 1972 and 2015?

<table>
<thead>
<tr>
<th>Changes In Wild Plant Species</th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
<th>2000s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decreased</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

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

<table>
<thead>
<tr>
<th>Ecosystem Services</th>
<th>Increased</th>
<th>Decreased</th>
<th>No change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing ground for Livestock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source of Medicinal Plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source of food (game meat, fruits and indigenous vegetable)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ornamental resources (artisan work decorative plants, pet animals, fashion)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw materials (fiber, timber, wood fuel, fodder)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water (e.g., for drinking, irrigation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>recreation and tourism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spiritual experience</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education experience</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (list other benefits)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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?

<table>
<thead>
<tr>
<th>Ecosystem Services</th>
<th>Alternative Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing ground for Livestock</td>
<td></td>
</tr>
<tr>
<td>Source of Medicinal Plants</td>
<td></td>
</tr>
<tr>
<td>Source of food (game meat, fruits and indigenous vegetable)</td>
<td></td>
</tr>
<tr>
<td>Ornamental resources (artisan work decorative plants, pet animals, fashion)</td>
<td></td>
</tr>
</tbody>
</table>

**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?

<table>
<thead>
<tr>
<th>Energy Form</th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
<th>2000s</th>
<th>2010s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firewood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charcoal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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?

<table>
<thead>
<tr>
<th>Source</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a) community wood lot</td>
<td></td>
</tr>
<tr>
<td>b) trees on the farm</td>
<td></td>
</tr>
<tr>
<td>c) purchases from neighbors</td>
<td></td>
</tr>
<tr>
<td>d) Neighboring forest</td>
<td></td>
</tr>
<tr>
<td>e) others (specify)</td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Name</th>
<th>Scientific Name</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mwarobaini</td>
<td><em>Melia volkensii</em></td>
<td>88</td>
<td>24.1</td>
</tr>
<tr>
<td>2 Sakwondet</td>
<td><em>Warbugiaugandensis</em></td>
<td>46</td>
<td>12.6</td>
</tr>
<tr>
<td>3 Elgon Teak</td>
<td><em>Tectonagrandis</em></td>
<td>40</td>
<td>11.0</td>
</tr>
<tr>
<td>4 Cheptuyet</td>
<td><em>Diospyros abyssinica</em> ,(Hiern)</td>
<td>33</td>
<td>9.0</td>
</tr>
<tr>
<td>5 Moabarwa</td>
<td><em>Grewiatrichocarpa</em> ,(Horchst)</td>
<td>29</td>
<td>7.9</td>
</tr>
<tr>
<td>6 Toboswet</td>
<td><em>Croton macrostachyus</em></td>
<td>21</td>
<td>5.8</td>
</tr>
<tr>
<td>7 Rodipchepkukwa</td>
<td><em>Aloe elgonica Bullock</em></td>
<td>18</td>
<td>4.9</td>
</tr>
<tr>
<td>8 Cheptegandeet</td>
<td><em>Engleromycesgoetz , P. Hiern</em></td>
<td>15</td>
<td>4.1</td>
</tr>
<tr>
<td>9 Kokorwet</td>
<td><em>Erythrina abyssinica DC.</em></td>
<td>13</td>
<td>3.6</td>
</tr>
<tr>
<td>10 Msiembut</td>
<td><em>Entada abyssinica A.Rich</em></td>
<td>13</td>
<td>3.6</td>
</tr>
<tr>
<td>11 Tungururuuet</td>
<td><em>Flacourtiaindica</em></td>
<td>11</td>
<td>3.0</td>
</tr>
<tr>
<td>12 Chesamishiuet</td>
<td><em>Clausinaanisata , (Willd) Benth</em></td>
<td>10</td>
<td>2.7</td>
</tr>
<tr>
<td>13 Simotweet,</td>
<td><em>Spathodeacampanulata</em></td>
<td>10</td>
<td>2.7</td>
</tr>
<tr>
<td>14 Chebutiandet</td>
<td><em>Piliostigmathonningii, (Schumach)</em></td>
<td>9</td>
<td>2.5</td>
</tr>
<tr>
<td>15 Tekandeet</td>
<td><em>Bambusoideae</em></td>
<td>9</td>
<td>2.5</td>
</tr>
<tr>
<td>16 Itet</td>
<td><em>Senna didymobotrya</em></td>
<td>8</td>
<td>2.2</td>
</tr>
<tr>
<td>17 Kibumetet</td>
<td><em>Ekerbegia capensis, Sparrm</em></td>
<td>8</td>
<td>2.2</td>
</tr>
<tr>
<td>18 Metitapsorin</td>
<td><em>EchinopsangustilobusS.Moore</em></td>
<td>8</td>
<td>2.2</td>
</tr>
<tr>
<td>19 Motoniet</td>
<td><em>Clerodendrummyricoides (Horchst)</em></td>
<td>8</td>
<td>2.2</td>
</tr>
<tr>
<td>20 Saruryandet</td>
<td><em>Conyzabonariensis ,(L.) Cronq</em></td>
<td>7</td>
<td>1.9</td>
</tr>
<tr>
<td>21 Angureet</td>
<td><em>Plectranthuscomosus (Sims)</em></td>
<td>7</td>
<td>1.9</td>
</tr>
<tr>
<td>22 Korshiondet</td>
<td><em>Olea europea L. ssp africana (Mill)</em></td>
<td>7</td>
<td>1.9</td>
</tr>
<tr>
<td>23 Simborichet</td>
<td><em>Todaldiaasiatica (L)</em></td>
<td>6</td>
<td>1.6</td>
</tr>
<tr>
<td>24 Sinendet,</td>
<td><em>Markhamia lutea (Benth)</em></td>
<td>8</td>
<td>2.2</td>
</tr>
<tr>
<td>25 Sodom Apple</td>
<td><em>Solanum incanum L.</em></td>
<td>5</td>
<td>1.4</td>
</tr>
<tr>
<td>26 Legetetwet</td>
<td><em>Carissa edulis Vahl</em></td>
<td>4</td>
<td>1.1</td>
</tr>
<tr>
<td>27 Mitiviazi</td>
<td><em>Heteromorpha</em></td>
<td>4</td>
<td>1.1</td>
</tr>
<tr>
<td>28 Arumotit</td>
<td><em>Prunus africana ,(Hook.f) Kalkm</em></td>
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<td>29 Chebugaa,</td>
<td><em>Dolichoscompressus , Wilczec</em></td>
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<td>30 Ngwekwe</td>
<td><em>Tagetesminuta L</em></td>
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<td>31 Kuptoret</td>
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<td>33 Pekeriondet</td>
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<td>34 Rotiandet</td>
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<td>35</td>
<td>Sitotweet</td>
<td><em>Rapanea melanophloeos (L.)</em> Mez</td>
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<td><em>Maytenusheterophylla</em></td>
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<td><em>Teclanobilis Del.</em></td>
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<td><em>Solanum incanum L.</em></td>
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<td>Mobchabelyo</td>
<td><em>Steganotaeniaaralacea Hochst</em></td>
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<td><em>Ficus sur Forssk</em></td>
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<td>Tegeldet</td>
<td><em>Acanthus eminens</em></td>
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<td>Matabiet</td>
<td><em>Ziziphus abyssinica</em></td>
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<td><em>Vernonia auriculifera</em></td>
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<td>Chesamishiet</td>
<td><em>Clausinaanisata</em></td>
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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 Licensee and any right thereto 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 projects.
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 30015 - 00100, Nairobi, Kenya
T&L: 020 406 7000, 0713 798787, 0716 082245
Email: dg@nacostigc.go.ke, registry@nacostigc.ke
Website: www.nacostigc.go.ke

Serial No. A 22085
CONDITIONS: see back page

THIS IS TO CERTIFY THAT:

MS. NELLY NAMBARIE MASAYI
of MOI UNIVERSITY, B4-50102
Maiwara, has been permitted to conduct research in Bungoma County

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

for the period ending:
24th November, 2019

Applicant’s Signature

Permit No: NACOSTIP/18/61996/26085
Date Of Issue: 24th November, 2018
Fee Received: Ksh 2000

Director General
National Commission for Science, Technology & Innovation
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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Email: dp@nacost.go.ke
Website: www.nacost.go.ke
When replying please quote

Ref. No: NACOST/UP/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