FOREST COVER CHANGE AND ECOSYSTEM SERVICES OF KATIMOK FOREST RESERVE, BARINGO COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfillment for the Requirements of the Award of Master of Science Degree in Environmental Science of Egerton University

EGERTON UNIVERSITY

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DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not been presented for a degree in any other university or any other award.

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Recommendation

This thesis has been submitted for examination with our recommendations as the university supervisors.

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DEDICATION

To my husband Philip Gikonyo and to my daughter Maryanne Wangui

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ABSTRACT

Katimok Forest Reserve in Baringo County is an ecosystem that contributes immensely to the livelihoods of the communities living adjacent to it. Despite the several direct and indirect benefits that the forest offers to the surrounding communities, the ecosystem is increasingly threatened by deforestation, conversion to agricultural land, overgrazing and logging. This study was conducted to assess the effects of forest cover change on the ecosystem services in Katimok Forest Reserve with the purposes of highlighting the importance of the ecosystem to the community's livelihood thereby, leading to sustainable utilization and management of this ecosystem. To quantify the changes, Landsat satellite images for the years 1985, 2001, and 2015 were used. Temperature and rainfall data were used to assess any changes in climate in the study area since1985 to 2015. Social survey research design was employed for this study. Household questionnaires, focus group discussions and field observations were used to assess the land use and land cover changes that have taken place within the period of study, and also determine the impacts that the changes have had on the ability of the forest to effectively provide ecosystem services. Land cover maps were prepared using supervised classification method and post classification technique was used to detect the changes in forest cover. Descriptive and inferential statistics were used to analyze the social data and climatic data. The study findings indicated a decline in forest cover at the rate of 0.04% per year. The study also revealed three major land uses within the forest: dense forest, open forestland and built-up area. There was a significant association (x^2 = 151.072, n = 80, df = 16, p<.05), between forest cover and ecosystem services. Therefore, a decrease in forest cover and changes in land use correspond to the sharp decline in ecosystem services that the forest provides (r = .515, n =100, p < .005). The results from the climate data shows a slight increase in temperature trend from 1985-2012 with mean annual temperature range of + or -1.44561. Similarly, the rainfall data shows an increasing trend, though not significantly. The study indicates that the observed forest degradation is as a result of observed anthropogenic activities, such as logging, infrastructural developments and expansion of agricultural activities, in and around the forest. It is therefore, important that the relevant forest resource management agencies formulate sustainable resource utilization options/strategies for the local communities to curb degradation of this life-supporting ecosystem.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND ACRONYMS

AFF African Forest Forum

BCG Baringo County Government

CIFOR Center for International Forestry Research

CFA Community Forest Association

ETM Enhanced Thematic Mapper

FAO Food and Agriculture Organization

FOSA Forest Outlook Studies in Africa

GIS Geographic Information System

IPCC Intergovernmental Panel on Climate Change

KFMP Kenya Forestry Master Plan

KFS Kenya Forest Service

KOD Kenya Open Data

KWS Kenya Wildlife Service

MEA Millennium Ecosystem Assessment

NRC Natural Resource Canada

OFRI Oregon Forest Resources Institute

PELIS Plantation Establishment Livelihood Improvement Scheme

PEN Poverty Environment Network

REDD Reducing Emissions from Deforestation and Forest Degradation

TEEB The Economics of Ecosystems and Biodiversity

TM Thematic Mapper

UNDP United Nations Development Programme

UN-REDD United Nations Reducing Emissions from Deforestation and Forest Degradation

WWF World Wide Fund for Nature

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Forests are among the major world ecosystems whose value lies in the goods and services they provide for the maintenance of both human and environmental welfare. Healthy ecosystems provide goods and services that are essential for human health and livelihoods, commonly known as Ecosystem Services (Costanza et al., 1997; MEA, 2005). Forests sustain major life support systems on earth and are essential for the development of social and economic sectors of many countries. This is because forests provide employment opportunities for the population, raw materials for industries and fuel wood, herbal medicine and timber for basic needs (UN-REDD Report, 2012).The rural poor in most developing countries depend on these forest resources for their livelihood (Bauhus et al., 2010). The wellbeing of a forest adjacent community greatly depends upon the services provided by the ecosystem. The continued flow of these services is dependent upon the human activities which can either increase or decrease the benefits derived from the ecosystem consequently impacting on their livelihood.

The world's forests are estimated to cover about thirty four million square kilometers or roughly 27% of the earth surface (Daily, 2012). In Africa, forests cover approximately 21.4% of the total land area which, represent 674 million hectares. Eastern Africa's forests constitute about 13% of the total land area and Kenya, which is termed as the richest in terms of forest cover in the region has a forests cover of about 6.07% of the land area (FAO, 2008).

Global impacts of human-induced land conversions affect a wide range of services that ecosystems provide to answer health, social, cultural and economic needs. Human activities affect forest cover directly through activities such as harvesting of timber and clearing for settlement and agriculture. According to MEA (2005), humans can transform ecosystems in ways that can improve or reduce the benefits derived by the community. When a forest is converted into an agricultural land, crop productivity improves hence ensuring the supply of food but the functioning of other services such as climate regulation, soil erosion control, pollution control and other services which are important for human welfare are disrupted. In the long run, the value of services lost through conversion of the ecosystem exceeds the short term benefits obtained from the economic activity of crop production (MEA, 2005).

Social and economic forces also have important indirect impacts by encouraging policies and courses of action that can initiate chains of activities leading to degradation and ultimate decline in ecosystem services (Bravo, 2008). Despite review of Kenyan forest policies to conserve and manage forests through sustainable utilization, the forests are still undergoing significant negative change. In Kenya, many forests are under pressure owing to increasing human populations and as a result, these forests have been encroached. Clearing of forested areas for agriculture and settlement are seen in most forests while in others the population impinge upon the forests for their products such as timber and charcoal (KFS, 2014). These human activities threaten forest ecosystems and lead to eventual decline or even loss of services that the ecosystem provides (Bauhus et al., 2010).

Katimok Forest is situated in the semi-arid areas of Baringo County, an area susceptible to environmental and climate change and high rates of food insecurity. Dependence on ecosystem for provision of goods and services in this area is highest owing to the community's limited alternative livelihood options due to aridity of the environment that negatively impacts on household production activities. Overdependence on the forest and unsustainable utilization of the forest resources translates to considerable deterioration in terms of the ecosystem services and forest cover. Therefore, there is need to embrace sustainable forest resource utilization to safeguard the ecosystem against degradation, and thus a reliable source of goods and services for various user-groups. This study was conceived on the premise that the current resource extraction approaches are unsustainable and thus compromising the ability of future generations in accessing the same resources and services. Thus, this study aimed at studying the effects of forest cover changes on the provision of ecosystem services by analyzing forest cover changes that have occurred in Katimok Forest Reserve over the last few decades, and the impacts it has had on the forest's ability to provide ecosystem services.

1.2 Statement of the Problem

The effects of the dynamics of forest cover on the ecosystem services they provide to the surrounding communities has not been adequately understood and appreciated by many. As a result, many forest ecosystems have been subjected to human induced degradation, rendering them quite ineffective in the provision of crucial ecosystem services for the local communities.

For instance, there have been increased floods in the lowland areas of Baringo that are in part associated with forest destruction on the hilly sides and along river courses. There has also been accelerated soil erosion occurring in the hilly and sloppy areas of Baringo, and this has in turn led to siltation of dams and lakes, for example Lake Kamnarok, and decrease in river flows due in part to destruction of forests in the source areas. In addition, food insecurity has been witnessed in Baringo and Elgeiyo Marakwet, a neighboring county, owing to poor rains and frequent and prolonged droughts. All these impacts are relatively associated with forest cover change resulting from unsustainable utilization of the forest resources, which evidently impact on the ecosystem's ability to provide the services.

1.3 Research Objectives

1.3.1 Broad Objective

To detect changes in land use and land cover and document their impacts on the ecosystem services and trend of climate change, in Katimok Forest Reserve in Baringo County, Kenya.

1.3.2 Specific Objectives

1. To assess the forest cover change of Katimok Forest Reserve from 1984 to 2015
2. To determine the impacts of the forest cover change on ecosystem services of Katimok Forest Reserve
3. To assess the changes in local climate in terms of temperature and rainfall trends between the years 1985 and 2015
4. To establish the local community's perception of the relationship between forest cover changes and ecosystem services

1.4 Research Questions

1. How has the Katimok forest cover changed since the year 1984 to 2015?
2. How have the changes impacted on the ecosystem services of Katimok Forest?
3. How has been the trend of local climate in terms of temperature and rainfall between the years 1985 to 2015 in Katimok and its environs?
4. From the local community's perception, is there a relationship between forest cover changes and the ecosystem services they provide?

1.5 Justification and Significance

Forest ecosystems provide significant economic, social, cultural and environmental benefits to the society. These benefits include provision of herbal medicines, fibres, fruits, fodder, air and water purification, climate regulation, employment, recreation, and religious values as well as sustenance of livelihoods. In Kenya, the forests are an essential component of the livelihoods of the forest adjacent communities as they, to varying degrees, depend on forest ecosystem services. Their standards of living therefore, closely depend on the quality and quantity of the forest owing to the ecosystem's significant contribution on their wellbeing. However, natural forests in Kenya have been degraded and thus negatively impacting on local livelihoods. Forest regulatory services are also negatively affected leading to declines in water quantity and quality, increased surface runoff and soil erosion among other consequences. Katimok Forest in Baringo County is one of such natural forests that have undergone degradation owing to unsustainable utilization. It is, therefore, necessary to study forest cover changes over time as well as its effects on ecosystem services to the community. Findings from this study will be used by forest resource managers and other stakeholders in making decisions that promote sustainable utilization and conservation of the forest.

There is also insufficient research and information regarding the forest cover and ecosystem services of Katimok Forest Reserve, therefore, by assessing the change in forests cover, this study has attracted the attention of decision-makers that will use the study findings to make informed decisions concerning the management of the forest. Furthermore, sustaining human welfare and ecosystems require information about the use, dependence and vulnerability of a forest resource. Sustainable conservation of forests means that the ecosystem will be able to effectively provide provisioning services such as food, raw materials, fresh water and medicinal resources for the communities, hence reducing poverty and hunger. It also implies that the forest will efficiently perform its regulation services such as climate regulation, erosion control, pollution control and water regulation. Such an assessment is therefore significant as it contributes toward the realization of the Sustainable Development Goals 1, 2, 6 and 13 which aim at eradicating poverty, minimizing high incidences of hunger and malnutrition, thus promoting human welfare, ensuring clean water and sanitation, and combating climate change respectively. The study findings will aid in the realization of the vision for environment, under the social pillar of the Kenya's Vision 2030.

1.6 Assumptions/Delimitation

This study assumed that the human induced impacts on forest cover and ecosystem services were from the community. It also assumed that Katimok forest is managed as a natural forest and not 100% under plantation management. Another assumption was that the communities would be able to share information willingly. The study assumed that KFS and Katimok forest station would avail records with all the needed data. Further, the study assumed that timeline satellite images would be available for the period under investigation.

1.7 Scope of the Study

The proposed study was carried out for five months. The study was confined to Katimok Forest, Baringo County, and the local population living around the forest; at least 5km from the forest. The study employed social and ecological survey, ex post facto research designs to gather both secondary and primary data. The respondents for the household surveys were those people who have lived in the area for more than 30 years. The ecosystem services included provisioning, regulatory and cultural forest ecosystem services. Impacts of forest cover changes considered were those related to anthropogenic activities and how those impacts related to the forest ecosystem services. Household questionnaires and FGDs were used to establish the local community's awareness and perception of the relationship between forest cover changes and forest ecosystems services.

1.8 Definition of Terms

Ecosystems – a dynamic complex of living and non-living environment interacting together as a functional unit. Ecosystems constitute the natural resources of this world including the forests

Ecosystem function- functions of all ecosystems including provisional, regulatory, cultural, and supporting functions

Ecosystem services- the set of ecosystem functions by specific ecosystems which can be useful to humans. They are the benefits that people obtain from the ecosystems e.g. regulation services such as climate regulation and water purification

Forest ecosystem Provisioning services- material products obtained from the forest ecosystems like food, fuel wood, timber etc.

Forest ecosystem regulatory services- benefits obtained from regulation of forest ecosystem processes such as climate regulation and water purification

Forest ecosystem Cultural services- social benefits that people obtain from the forest ecosystems like recreation, spiritual enrichment and aesthetic experiences

Remote Sensing- the use of aerial sensor technologies to detect and classify objects on Earth by means of propagated signals e.g. electromagnetic radiation

Geographic Information System- a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface

Forest density- number of plants per hectare including trees and shrubs

Methodological triangulation-the use of more than one method to gather information/data such as interviews, observations, questionnaires, and documents

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The expanse of a forest gives the first indication of the relative significance of forest ecosystems in a nation. Estimates of forest cover change overtime provide an indication of the demand for forest ecosystem services. Forest ecosystems are continuously changing as a result of both natural and anthropogenic threats. Measuring change in forest cover is one of the indicators for monitoring progress toward the achievement of Sustainable Development Goal fifteen: *"Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss"*. This chapter presents an account of other research works and documentations on studies relating to the relationship of forest cover change and its ecosystem services. It aims to link the study with other related research projects so as to justify and identify knowledge gaps that exist.

2.2 Forest Cover Change and Its Impacts on Ecosystem Services

According to TEEB (2010), forests are estimated to cover about a third of the earth's surface and contains over half of the terrestrial species. These forests and their products play a critical role in the improvement of lives of the local communities (Daily, 2001). In its Poverty Environment Network (PEN) research, the Center for International Forestry Research (CIFOR) reveals that forests play a major contribution to the livelihoods of communities globally (CIFOR, 2014). World Bank (2013), estimates that approximately 350 million people in forest adjacent communities rely on forests for their livelihoods and 60 million of these are entirely reliant on the forest ecosystems. However, the worldwide conversion of forests into farmlands and other related uses are threatening the capacity of these ecosystems to support livelihoods globally (FAO, 2000).

According to UNEP's green economy report, an additional investment of $40 billion per year could raise the value added in the forest industry by $600 billion by 2050, improving the well-being of billions of the world's poorest people (UNEP, 2013).Forests play a crucial role in the economic and environmental health of the planet and their value is gradually being realized (Smail, 2010). The tropical forests cover 6% of the earth's land surface and receive almost half of the world's rainfall on land (OFRI, 2013). This makes them extremely significant for their watershed services e.g. water purification and erosion control. Additionally, tropical forests contain more vegetation than any other biome in the world and for this reason they play an essential function in mitigating global warming and thereby directly and/or indirectly influencing global climate. In general, tropical forests are ranked higher in the provision of ecosystem services as compared to other forests (Ninan, 2012).

Of the total world forest cover, Africa's forests constitute 17%. This is approximately 650 million ha. Forests in Africa make up about 22% of the continents total land area and their extent varies from region to region (Boon, 2009). African forests are of great value to the African communities through the provision of the various ecosystem services. A research conducted in Madagascar indicated that the value of the forest ecosystem services to the local populations was approximately 200,000 US dollars over a decade (Kremen, 2005). Similarly, 16% to 20% of Ghana's populations directly depended on forest ecosystem services for their livelihoods. Forests are therefore an important source of livelihood for most African communities and a decrease in forest cover means a reduction in the communities' ability to meet their day to day needs. Deforestation and forest degradation are affecting the forest cover negatively and in turn, this affects the abundance of the forest ecosystem services. Table 1 shows changes in forest cover over time in different sub-regions of Africa.

Table 1: Forest Cover Trend in Africa Sub-Regions

Change in forested land 1990-2000 by sub-region: Africa							
Sub-region	**Area (1000 ha)**			**Annual Change (1000 ha)**		**Annual Change Rate (%)**	
	1990	**2000**	**2010**	**1990-2000**	**2000-2010**	**1990-2000**	***2000-2010***
Central Africa	268 214	261 455	254 854	-676	-660	-0.25	-0.26
Eastern Africa	88 865	81 027	73 197	-784	-783	-0.92	-1.01
Northern Africa	85 123	79 224	78 814	-590	-41	-1.72	-0.05
Southern Africa	215 447	204 879	194 320	-1 057	-10 56	-0.50	-0.53
Western Africa	91 589	81 979	73 234	-961	-875	-1.10	-1.12
Africa	749 238	708 564	674 419	-4 067	-3 414	-0.56	-0.49
World	**4,168,399**	**4,085,063**	**4,032,905**	**-8 334**	**-5 216**	**-0.2**	**-0.13**

Source: FAO, 2011

2.3 Benefits of Forest Ecosystems to Communities

Rural communities largely depend on the flow of ecosystem services for their economic and socio-cultural needs. In Indonesia, forests in Ruteng have been conserved for their ecosystem services mainly drought mitigation and soil conservation. In 1993, the Indonesian government established Ruteng Park on 32,000 hectares primarily to prevent further deforestation and initiate reforestation programmes and soil conservation hence enhancing watershed protection. By conserving the forests, the government would mitigate cases of droughts since forests conserve the soil, reduce soil erosion and protect watersheds (FAO, 2000).

In Beijing, forests are the most important ecosystems as they provide a lot of services to the surrounding communities. Among the services are water supply, soil conservation, air purification, soil formation, recreation, employment and education. Forests serve many purposes both as a habitat and in enhancing the conservation of the natural environment. They also provide both direct and indirect benefits to the society (NRC, 2013). Forest ecosystems support diverse life forms of flora and fauna that provide services of critical importance to the surrounding communities (Newmark, 2002).

A Nordic workshop on ‘ecosystem services in forests’ identified three major ecosystem services in the Nordic nations namely carbon sequestration, biodiversity and recreation. The workshop recognized that 60% of all known species reside in the forests. They also recognized that forests act as carbon sinks hence they play a key role in preventing climate change (Nordic Workshop, 2012).

According to the Convention on Biological Diversity, Kenya and Tanzania are the most endowed countries in Africa in terms of biological diversity. Although both countries have ratified the international convention, there is need to ensure that the local populace who are ultimately responsible for the degradation or conservation of the ecosystems receive benefits for conserving biodiversity. Also, there is need to address the issue of land ownership and promote indigenous knowledge for sustainable consumption and utilization of the ecosystem services (Bond, 2009).

In Tanzania, many forest products such as wild green leafy plants are important for the local populace especially women as they sell them to buy other household items. This is especially the case in the Usambara Mountains of Tanzania where elderly women, divorcees, widows and young women exclusively depend upon these edible green leafy plants for their income. Among other products extracted from the forests by the residents of the Eastern Arc Forests are mushrooms, wild fruits from indigenous plant species, and cooking fats extracted from native trees fruits such as *Allanblackia stuhlmannii* and *Trichilia roka* (Newmark, 2002).

In Kenya, some of the ecosystem services commonly used includes timber, herbs, fruits, fodder, poles, honey and mushrooms (Kaye-Zwiebei & King, 2014; Mbuvi, 2009; Kahuki & Muniu, 2004). In rural Kenya, about 80% of the local population meets their health care needs through herbal medicines. This is mainly due to inadequate supply of conventional medicine, and inability to afford the high costs of treatment in established health care facilities. A good example of such a medicinal plant is *Prunus africana* whose bark has a large cash value as a remedy against prostate disorders (Kahuki & Muniu, 2004).

Fodder has also been adopted by many small-scale farmers for their livestock. About 71% of the energy consumed in Kenya comes from wood fuel mainly as firewood for cooking and heating in rural areas and as charcoal in most households in urban areas. The Kenya Forestry

Master Plan (1994) estimates the demand for wood fuel to increase systematically to 30.1 million tons by the year 2020. The annual demand for poles and posts is projected to grow at 2.4% from 1.4 to 2.7 million m^3 between 2000 and 2020. These will be consumed by the construction industry and as transmission poles by Kenya Power & Lighting Company and Kenya Posts and Telecommunications Corporation (Mbugua, 2000).

In the Arabuko Sokoke Forests, the residents living within the forest proximity regularly hunt and trap wild game. It is estimated that over 1277 inhabitants hunted and trapped wild animals yearly in the Arabuko Sokoke forest (Newmark, 2002). Owing to these human activities, forest species are rapidly declining in the Eastern Arc Forests and the forests capacity to act as water sequester has been inhibited hence more streams and rivers have dried. The people of eastern arc mountains also depend on the forests for medicinal plants, fuel wood, dyes, building materials, and household items such as baskets, chairs, mortars, wooden spoons, ropes, arrows, bows and beehives. The indirect benefits derived from the forest include tourism soil and water conservation, climate regulation, education and research. In addition, the Eastern Arc Forests are the catchment areas for all the major rivers and hydroelectric plants in Tanzania. Currently, the major threats facing the eastern arc forests are forest degradation and fragmentation, over exploitation of forest products, deforestation and introduction of exotic species (Newmark, 2002).Another ecosystem that significantly contributes to the livelihoods of the communities living around it is Katimok Forest Reserve in Baringo County. However, little is documented on the benefits of Katimok forest to the local communities in terms of ecosystem services that it provides such as honey, clean water, mushrooms, wild fruits and building materials among other benefits.

2.4 Drivers of Forest Cover Change

Forests are of major importance to human societies, contributing several crucial ecosystem services (Gamfeldt, *et al*., 2013). The capacity of this ecosystem to provide various services is determined by different direct and indirect drivers that can operate at the local or global levels. The well-being of people living around forests is dependent on forest ecosystem services (Stedman *et al.,* 2011). The Millennium Ecosystem Assessment findings was that human actions are depleting Earth’s natural capital, putting such strain on the environment that the ability of the planet’s ecosystems to sustain future generations can no longer be taken for granted (OFRI, 2013). Such factors that may contribute to the degradation of forest ecosystems by surrounding communities include overgrazing, excessive logging, demand for fuel wood and charcoal, demand for agricultural land and human-induced fires. The changes in ecosystem and their services in turn affect human well-being (MEA, 2005).

In Africa, where there is high rates of poverty and population growth coupled with low agricultural production, expansion of agricultural lands remains the main cause of deforestation (Geist & Lambin, 2002). Kenya has a total of about 1.64 million ha of gazetted forestland and about 100,000 ha of trust lands (Matiru, 1999). The country's closed canopy forests are concentrated in the moist central highlands where the human population and agricultural production are also pervasive (Wass 2000). In the semi-arid region, closed canopy forests are mainly found on isolated hills and along riverbeds. Forest degradation and destruction in Kenya has been on the rise. It is estimated that between the years 1995 and 1999, an entire 44,502.77 hectares of forest land were formally degazetted and cleared (Matiru 1999). Between 1972 and 1980, natural forests shrank at an average rate of two per cent per annum (Doute*et al.* 1981), and later at an average of 3700-5000 ha per year (Wass 1995).

According to Harrison (2010), the main drivers behind the degradation of forest ecosystems are pressures from the growing human population and rising rates of consumption. Kinyanjui & Karachi (2013) observed that between 1990s and early 2000, huge sections of the Mau Forest Complex were excised to resettle the forest dwelling communities, communities from other counties and the landless rural poor. They noted that Eastern Mau was reduced from 65,000 to 25,000 hectares. In general, the outcome of increased population densities appears to depend on economic opportunities available to rural people, agricultural and cropping systems, and access to markets for timber and non-timber products, as well as for other forms of production (Mythili & Shylajan, 2009).

A report by the UN-REDD Programme (2012) discovered that the Montane Forests of Kenya popularly referred to as the “water towers” contribute significantly to the country’s GDP. The forests provide both direct and indirect services including the regulatory services which serve as an insurance value to various chief economic sectors. However, these forests are constantly under degradation through logging, charcoal production, conversion into agricultural land and other illegal human activities. The report asserts that the degradation of these forests is an indication that the forests have been undervalued and thus there is need for better management through innovative policy instruments such as Reducing Emissions from Deforestation and Forest Degradation (REDD).

While the loss of forest cover through agricultural expansion and clearing for settlement as well as overexploitation of forest resources is thought largely to be the outcome of a rapid population growth and high rates of poverty, there are other more serious underlying issues such as poor government policies, corruption, inadequate information and lack of education and property rights (Geist & Lambin, 2002).Weak institutional capacity and poor enforcement of forest laws have also been identified by Ochieng (2013) as major underlying drivers of forest cover change in Kenya. Poor governance and corruption are making it easy to flout forest conservation and protection policies and legislation. But by its nature, Ochieng (2013) notes that, this cause of deforestation is very difficult to document and quantify. As international agencies pay more attention to good governance, transparency and accountability, there is growing recognition that corruption facilitates illegal deforestation and that a significant proportion of deforestation occurs illegally despite laws designed to protect forests (Ochieng, 2013).

Shackleton *et al*. (2008) cite that, in arid and semi-arid areas, climate change, and particularly change in rainfall patterns, is a key driver of forest ecosystems change. In their view, fluctuations and variations in rainfall patterns disrupt the normal functioning of the ecosystem hence the delivery of a range of forest ecosystem services. While this is the case, they further argue that climate change can be aggravated by human induced activities and this increases the frequency of extreme events such as high temperatures thereby high evapo-transpiration and overall decline in rainfall resulting to loss of forest plant diversity(Shackleton *et al.*, 2008).

The various regions of Kenya and the world as a whole generally experience the same drivers of degradation, but on closer examination, the underlying drivers differ in nature and even intensity. Human’s ability to coexist with the ecosystems and sustainably utilize them has an influence on the peoples living conditions. An underlying cause for the deterioration of the ecosystems services is that the values of these services have not been taken into account in decision making. The international study on the economics of ecosystems and biodiversity (TEEB, 2010), has pointed out that increasing information and raising awareness on the importance of ecosystem services is of great importance to the local communities and decision makers. However, there is little information regarding the driving forces of forest cover change in Katimok Forest Reserve even though the forest cover has been shifting over the years.

2.5 Land Use Changes and Climate Change

Land use is one of the major factors through which humans influence the environment. According to Intergovernmental Panel on Climate Change (IPCC) report on land use, land use change and forestry (LULUCF), when humans modify the environment through land use, certain environmental impacts such as; soil erosion, flooding, drought, leaching of nutrients, emission of carbon dioxide and methane gases, and microclimate change among other consequences occur. Overall, the world's forest ecosystems are estimated to store approximately 638 billion tons of carbon, which is more than the amount of carbon in the entire atmosphere (IPCC, 2000). Therefore, alteration of forests into agricultural land, grazing lands and settlements can affect climate on various scales ranging from micro to macro scale. This is because forests absorb carbon dioxide from the atmosphere and store some of the carbon throughout their lifetime. When a forest is cleared, its ability to store carbon is reduced and hence the carbon they had sequestered is emitted into the atmosphere causing global warming. Carbon dioxide, methane, and nitrous oxide are greenhouse gases, which contribute to global warming (Stiebert *et. al*., 2002).

As scientists continue to research on global warming, climate change has been found to be the most pressing environmental concern facing the current generation. Furthermore, it has also been established that major global challenges facing the human population such as, population increase, hunger, poverty and forest destruction, are associated with and all are factors contributing to climate change. This is because all these factors intertwined in that population growth leads to food shortages thus aggravating poverty. The population then turns to forests as a livelihood option, and overeliance on the forest resources degrades the ecosystem. When the forestsare degraded their ability to sequester carbon is drastically reduced resulting in global warming and consequently climate change (World Bank, 2016). Presently, forest ecosystems are estimated to contribute roughly one-sixth of global carbon emissions when degraded due to land use changes. However, when managed sustainably, they can absorb substantial amount of carbon emitted globally into their biomass and store them infinitely (FAO, 2012).

According to FAO (2006), there are several parameters that point to change in local climate such as distribution and abundance of flora and fauna. Change in climate affects forest cover and species composition mainly through rise in annual temperatures, fluctuating rainfall patterns and, recurrent and extreme weather events. Different plant species flourish in distinct ecological zones, and this essentially depends on temperature and rainfall patterns. Therefore, as climate changes, these climatic aspects are affected and different plant species are forced to shift to different ecological zones that suit them. Kirilenko & Sedjo (2007)also indicate that, fluctuations in rainfall trends can decrease the general growth of plants while rise in temperatures can prolong planting seasons, and this may allow for planting and harvesting of crops more than once in one season, as well as extension of farm lands towards the higher elevations.

Moreover, changes in temperature and rainfall can escalate risks of insect infestation and disease outbreaks, harmful to forests biodiversity. Changes in temperature and rainfall trends may also lead to extreme weather events such as floods and drought, and these events can cause significant amounts of damage to the overall health of forest ecosystems (Kirilenko & Sedjo, 2007). The Kenya's Climate Change Action Plan highlights that an increase in temperature may deprive the floras of water as a result of water shortage and this may lead to the emergence of drought resistant species in the locality. This particularly alters the ecosystem services of moist forests as the plants that are unable to bear the increasing temperatures may die out leading to loss of biodiversity. Faunas that rely on such particular plant species will go away to other habitats or become extinct as well. Consequently, this may have a significant impact on the tourism sector -a sector that contributes largely to the Kenyan economy (Stiebert *et.al.*, 2002).

In Kenya, approximately 14 million tons of carbon dioxide is released annually mainly as a result of changing the forests into other land uses. However, Kenya is now working toward achieving and maintaining a forest cover of 10% of the country's land area. This has been well articulated in Article 69 of the country's Constitution. Healthy forests absorb tremendous amounts of carbon dioxide, which is essential for human and environmental health. Forest cover change due to conversion to various land uses such as agriculture, logging and settlement has reduced the capacity of the forests to act as carbon sinks. Nevertheless, Kenya has developed a national REDD+ strategy, an international initiative aimed at reducing deforestation consequently increasing the absorption of carbon from the atmosphere. REDD+ offers financial incentives to developing nations that create and implement strategies to sustainably utilize and manage their forest ecosystems (Global Canopy Programme, 2016). Little has been documented on the trend of climate change and its effects on the forest cover of Katimok Forest Reserve.

Likewise, there is limited information concerning the impacts of Katimok forest cover change on the local climate, specifically rainfall and temperature aspects.

2.6 Legal Framework on Forest Management and Resource Exploitation

The management of the natural forests and that of the forest resource in Kenya is governed by the Forest Act of 2005 which is implemented mainly by the Kenya Forest Service, since most forested lands fall under its jurisdiction as gazetted forest reserves (KFS, 2014). The Kenya Wildlife Service (KWS) has management responsibility for all indigenous forests falling within national parks, national reserves and game sanctuaries. The Forest Act 2005, established in 2007, is an Act of Parliament that provides for the establishment, development and sustainable management, including conservation and rational utilization of forest resources for the socio - economic development of the country (FAO, 2008).

The Act recognizes the importance of forests for its ecosystem services such as soil and ground water regulation, absorption of greenhouse gases, moderation of climate change and protection of water catchments. Some key elements of the Act are; involvement of adjacent forest communities and other stakeholders in forest conservation and management through the formation of Community Forest Associations (CFAs), an ecosystems approach to forest management planning, and provision of appropriate incentives to promote sustainable use and management of forest resources (KFS, 2014).

Other policies and legislations that support the Forest Act of 2005 include The National Energy Policy which ensures that the relevant ministries, NGOs and other organizations address environmental problems associated with the supply and use of energy like charcoal and fuel wood (Ndiritu, 2009). National Environmental Policy, 2012, provides an overall strategy for all natural resources sectors, including forestry, and provides a focal point for coordination and harmonization of activities between sectors. Another policy that supports forest conservation is the Kenya Wildlife Policy, 2011. This policy addresses resource use conflicts, expansion of arable land and grazing in the parks. It recognizes that land adjudication and vegetation clearing is the biggest problem in the group ranches where most of the wildlife is found. Economic policies recognize the important role that forests play in the provision of energy, construction wood and environmental functions (Ndiritu, 2009).

In general, current indications suggest a more supportive policy environment for sustainable forest management. However, the challenge lies in the implementation of these policies. Economic development strategies and lax implementation of forest protection regulations are the principal pressures on forest resources. In order to achieve sustainable forest management, the government needs to involve communities more and more in policy making, as well as in implementing forest management strategies.

2.7Theoretical/Conceptual Framework

The theoretical approach for this study was developed based on the Drivers, Pressures, State, Impact and Response (DPSIR) framework, an approach that aims to understand the interactions between the people and their surroundings (Agu, 2007). This framework was chosen for this study as it is suitable for describing the associations between the roots causes and consequences of environmental problems such as forest cover change. The framework has five components that influence each other and in order to understand it better, it is important to focus on the links between these elements. According to this framework, the driving forces exert pressure on the forest and as a result, the state of the ecosystem is altered such as change in forest cover. This leads to impacts on the health of the ecosystem hence inhibiting effective provision of ecosystem services. The negative impacts eventually necessitate the society to come up with responses, such as law enforcement and formation of CFA’s, to curb the situation. In this study, forest cover (state) is the independent variable, and change in forest cover will affect the provision of ecosystem services (dependent variable) hence certain impacts such as soil erosion and loss of biodiversity will be felt. In addition, intervening variables such as poverty, education level, climate change, cultural beliefs, government policies, population growth and lack of information also take part in contributing to the effects that forest cover change has on the availability of ecosystem services. This study investigated the relationship between forest cover change, which is the independent variable, and the provision of forest ecosystem services; the dependent variable. Intervening variables were also taken into consideration as they influence both the dependent and independent variables.

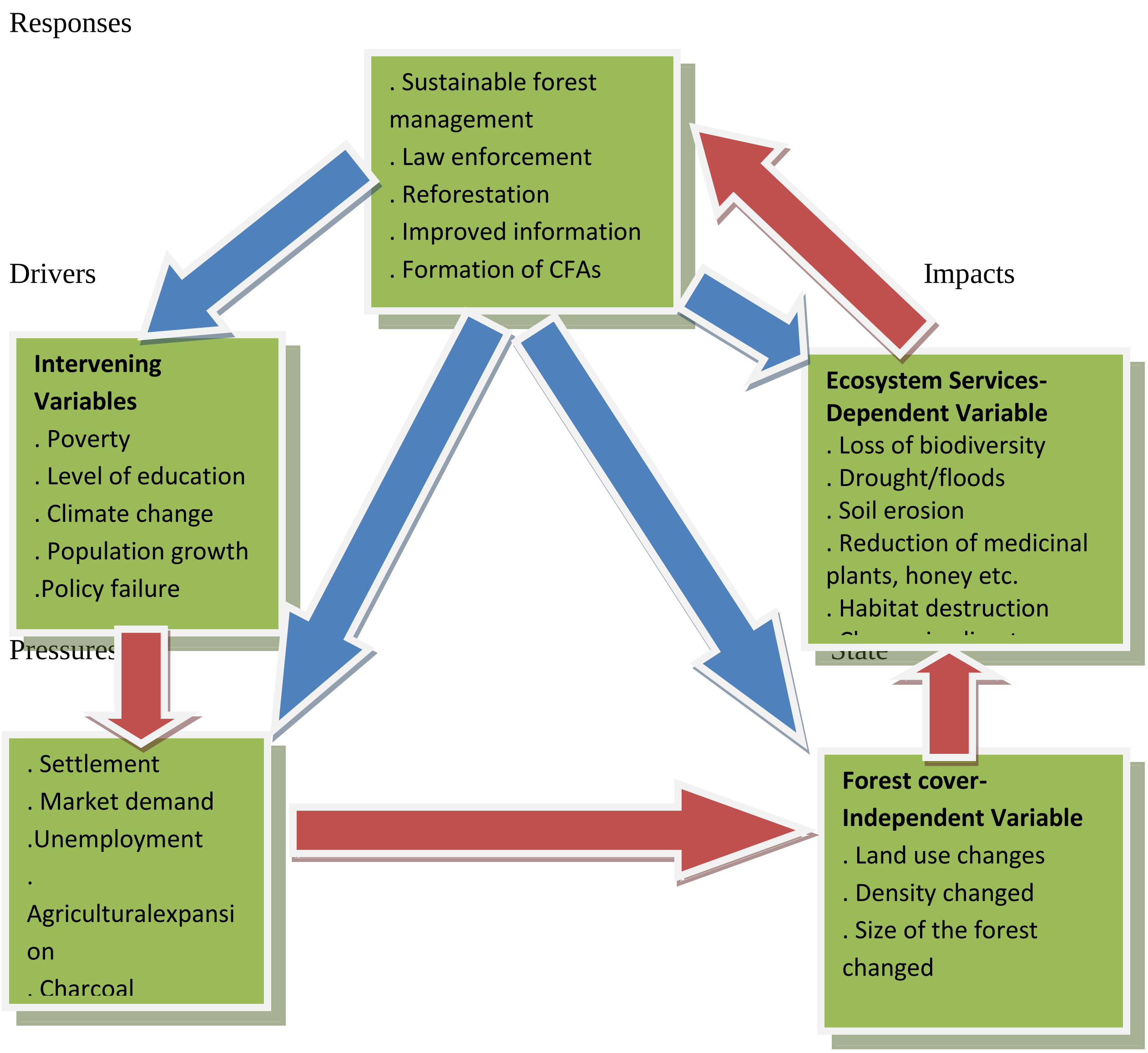

Figure 1: Conceptual Framework (Source: Author)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Introduction

This chapter has a detailed description of the study area, giving the geographic, demographic and socio-economic characteristics of the population adjacent to the study area. The research designs that were employed, sampling size and sampling procedure, methods of data collection and statistical analysis tools are subsequently discussed in detail.

3.2Description of Study Area

3.2.1 Geographical Setting

Katimok Forest Reserve, Gazetted 1949, is a forest in Baringo County, Kenya. It lies at an altitude of 2162 meters and between Latitude of 0°35'55.82" and Longitude: 35°47'26.52" (KOD, 2014). The forest is under the management of Baringo County Government and protected by the Kenya Forest Service. It is the largest block of the current Kabarnet Forest which consists of thirteen blocks as shown in Table 2. It covers a total area of 19.5659 Km^2.

Table 2: Kabarnet Forest Blocks

Block	**Size (ha)**
Katimok Forest	1 956.59
Saimo Forest	750.9
Tarambas Hill Forest	483.8
Morop Forest	212.6
Kimeto Forest	210.4
Mosegem Forest	202.7
Sokta Hill Forest	163.9
Pemwai Forest	117.7
Chebartigon Forest	103.3
Ketwan Forest	46.6
Cherial Forest	42.5
Kabiok Forest	14.2
Tutwoin Forest	12.1

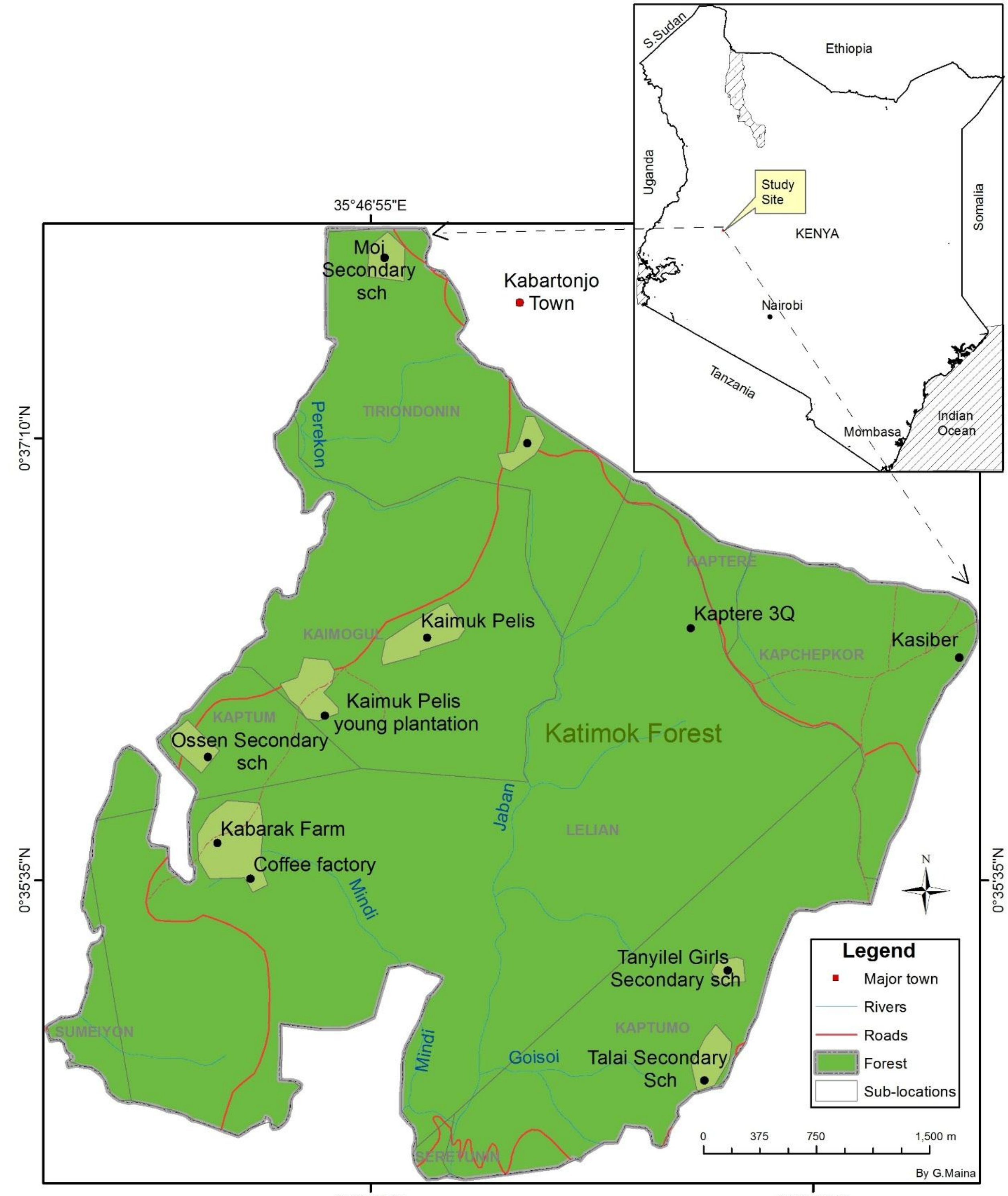

Figure 2: Map of study area (Katimok Forest Reserve)

3.2.2 Flora and Fauna

A larger portion of the forest is composed of indigenous trees including *Syzygium guineense,Olea Africana*, *Prunus Africana*, *Vitex keniaensis* and the endangered *Osyris tenuifolia*, among other tree species. Exotic plantations, such as *Eucalyptus saligna, Cupressus lucitanica, Pinus patula* and *Grevillea robusta*, also make up the forest and they were established as early as 1970s on lands which became vacant after the eviction of illegal settlers. The forest is also home to wild animals and birds which include; *Colobus angolensis*, *Papio anubis*, *Lepus capensis*, *Coturnix coturnix*, *Numida meleagris* and *Madoqua kirkii* among others.

3.2.3 Climate and Socio-economic Activities

Agriculture is the backbone of the community living adjacent to Katimok Forest. This is especially because the soils and the climate of the region are conducive for crop and livestock production. The area receives an annual rainfall of about 1000-1500mm and temperatures ranging from a minimum of 10^0C and a maximum of 30^0C. This coupled with fertile soils make the forest surrounding populations practice production of different varieties of crops such as maize, sorghum, millet and beans among other crops. In addition, rearing of goats, sheep, cattle, and bee keeping are other common economic activities in the area. (Baringo County Government, 2014).Furthermore, the poverty level of the area is at 58.5% and as such, the communities surrounding the forest are largely dependent on the forests ecosystem services such as honey, wild fruits, construction material, fuel wood, agricultural land, water, traditional ceremonies and fodder among other benefits, for their livelihood. There are four major streams flowing through the forest and they are Goisoi, Mindi, Jaban and Perekon streams.

3.2.4 Population

The forest is surrounded by Ossen, Kapchemungot, Kabarbet and Kaimugul sub-locations, which according to the 2009 population census, have household populations of 693, 205,159 and 399 respectively. The population density is 50 persons per Sq. Km with an annual growth rate of about 2.6 %. The age distribution is 0-14 years (48.4 %), 15-64 years (48.2 %), and 65 and above years (3.3 %), (Kahuthu, Muchoki, & Nyaga, 2005).

3.3 Research Design

The study employed a social survey design with the aim of gathering information on the ecosystem, its services and the local community, from the selected sample. In addition, information concerning the current status of the ecosystem as well as describing the relationships between and among variables under study was obtained. This research design was appropriate for this study as the data and findings obtained from the sample population were representative of the population.

3.4 Sample Size and Sampling Procedure

The sampling frame was a list of households adjacent to the forest. The study used a combination of stratified random sampling and simple random sampling in selecting the required number of household respondents to participate in the study. This was achieved through identification of strata of interest based on their administrative locations and proximity to the forest. The strata were Ossen, Kapchemungot, Kabarbet and Kaimugul sub-locations with household populations of 693, 205,159 and 399 respectively. Proportionate sampling was then used to draw 48, 14, 11 and 27 households from Ossen, Kapchemungot, Kabarbet and Kaimugul strata respectively totaling to 100 households.

3.5 Data Collection Methods

3.5.1 Primary Data

Primary data was obtained from the field by employing both qualitative and quantitative data collection techniques. The study used the methodological triangulation technique in order to build a valid and reliable data collection plan. The instruments administered for collecting data from the field were;

a) Household survey
b) Focus group discussions
c) Observations

3.5.1.1 Household Survey

A structured questionnaire was administered to the heads of households that had been selected into the study. The questionnaire mainly served to assess the provisioning, regulatory and cultural ecosystem services provided by the forest to the community. This was done by assessing the different uses of the different ecosystem services by the households. The questionnaires were administered in conformity with the sample size.

3.5.1.2 Focus Group Discussions

Focus group discussion (FGD) instrument was developed and administered to the staff from the Kenya Forest Service, members of Community Forest Associations, and local village representatives of the area. A topic guide to aid the discussion was developed beforehand and brainstorming was used to explore each topic. FGDs were conducted with the purpose of getting additional information or information which may have not been clearly captured through questionnaires.

3.5.1.3 Observation

To get a clear picture of the status of the forest and its ecosystem services, an observation checklist was used to gather information. The condition of the forest (health, growth etc.), flora and fauna species, and land use types were recorded. Similarly, the pressures on the forest e.g. felling of trees, livestock grazing, firewood collection etc. were also recorded. For more detailed information, photographs were taken. Observation gave a clear condition of the forest hence enabling an understanding of the relationship between the people and the use of the forest's ecosystem services.

3.5.2 Secondary Data

3.5.2.1 Temperature and Rainfall Data

Data regarding the rainfall patterns was obtained from the Katimok forest weather station, and that of temperature patterns was obtained from the Kenya Meteorological Department. The data of both temperature and rainfall were from the years 1985 to 2015 which enabled analysis of how these climate attributes have been changing over the last three decades.

3.5.2.2 GIS and Remote Sensing Data Acquisition

The datasets that were used in this study included, satellite images, and GPS ground control points. All pre-processing and processing activities were done using Idrisi Kilimanjaro Selva and ERDAS IMAGINE image processing software. Satellite images of the study area taken by Landsat Thematic Mapper ™ sensor for the years 1985, and Enhanced Thematic Mapper for 2001 and 2015 were used. The images acquired were for the dry season to minimize errors that might arise from seasonal differences, and near anniversary dates were chosen for consistency within the time periods.

3.6 Image Pre-processing

Pre-processing of satellite images is essential so as to remove data acquisition errors. The most common operations applied to an image during the pre-processing stage include geometric correction, radiometric correction, mosaicking and sub-setting. The images acquired did not need any radiometric and geometric corrections as they were already rectified.

3.7 Ground Truth Points

For ground-truthing, each land use type was noted and GPS used to capture the coordinates of the land use types at each point. These ground control points were used as training samples for supervised classification and also for accuracy assessment.

3.8 Land Cover Classification

A supervised classification of the satellite imagery was used to produce Land use land cover classes. The following land use types were generated from the classification as described in Table 3.

Table 3: Land Use Description

Land cover type	**Description**
Dense Forest	These are lands that have a compact stock of trees capable of producing timber and other wood products
Open forest land	Composed of lands with scattered patches of trees, farmlands, and lands with small trees, grasses and shrubs
Built up area	Areas composed of infrastructure mostly rural villages, schools, hospitals and roads

Maximum likelihood classification technique was performed using the spectral bands 2, 3 and 4 in each satellite image. Feature extraction, selection of training data and selection of suitable classification approaches was carried out in order to generate land cover classes of the study area.

3.9 Accuracy Assessment

This was done by comparing samples of pixels from the classification results and the ground truth data collected with GPS in the field. The overall accuracy was calculated by dividing the number of correct pixels for a particular class with the overall number of reference pixels for the class.

3.10 Methods of Data Analysis

Data collected from various sources was entered into different software for analysis. Social data was entered into SPSS, climatic data into Microsoft Excel and GPS ground truth data into ArcGis 10.1, Idrisi Kilimanjaro and ERDAS IMAGINE. The process of data analysis involved cleaning the questionnaires for errors and coding quantitative data from the household interviews. Descriptive statistics were used for both climatic and social data, to make cross tabulations, frequency tables, pie charts, histograms, bar graphs and to calculate percentages and means. To determine whether the statistics were significant or not, Chi-square test of independence and Fishers Exact tests were performed.

For digital image processing, false color composites were created using bands 2, 3 and 4 for each of the images. The images were then geo-referenced in UTM projection WGS84 reference ellipsoid. Both supervised and unsupervised classification methods were used to classify the images, but owing to the high accuracy of supervised classification, the change detection base map was prepared using supervised classification.

Post classification comparison method was used for change detection. In this method, images of different dates were first classified and labeled individually then the classified images were then compared and changed areas extracted. Classification accuracy was assessed by an error matrix. Arc GIS 10.2,Idrisi Kilimanjaro and ERDAS IMAGINE software's were used to process the data.

3.11 Rate of Land Cover Change

The rate of Katimok Forest cover change since 1985 to 2015 was computed using the formula by FAO 1995

$q= [(A2/A1)^{1/(t2-t1)}]-1$

Where

q= deforestation rate (% lost areal year)

A1= Initial forest area

A2= final forest area

t1-t2= interval in year during which change in land cover is being assessed

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Social Data

4.1.1 General Description of the Respondents

Out of the sampled respondent 62% were male and 38% female. Their education levels varied with 42.7% having up to tertiary level of education, 31.8% secondary education, 14.5% primary education and1.8% of them having informal education as shown in Figure 3.

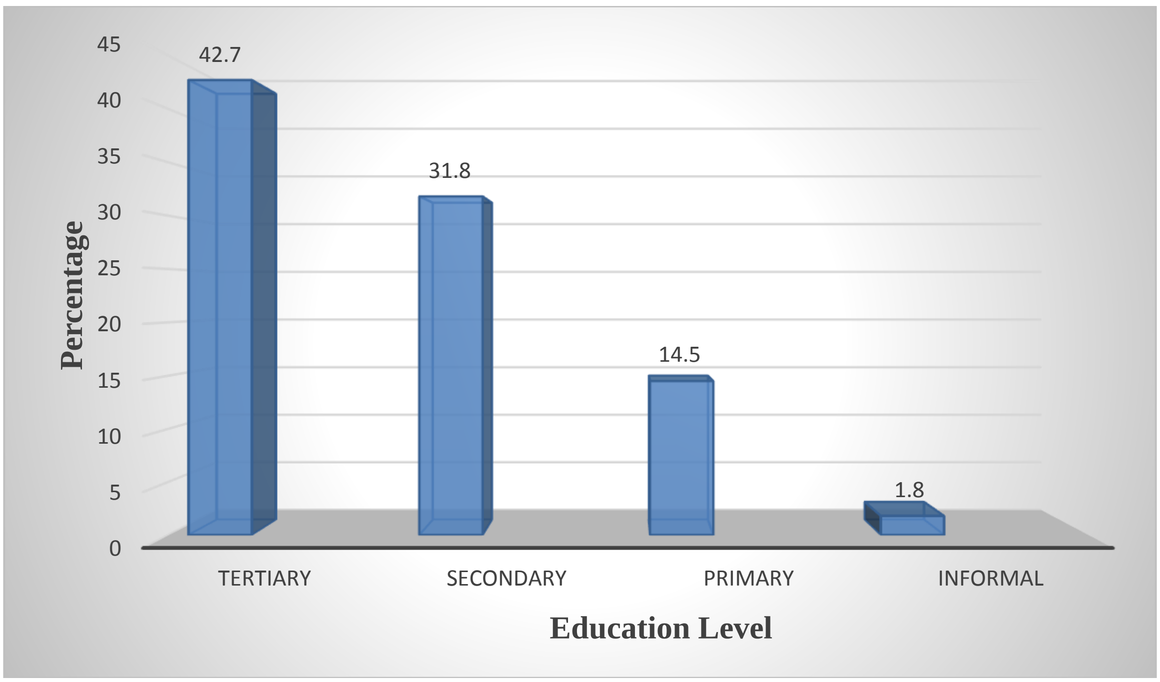

Figure 3: Respondents Level of Education

4.1.2 Sources of Livelihood

The major sources of income for the inhabitants were agriculture, off-farm activities and products from the forest with 37.3% of the respondents getting household income from sale of crops, 40.9% from off-farm activities, 8.2% from livestock and 4.5% from sale of forest products (Figure 4). The large number of income from off-farm activities could be attributed to the fact that most of the respondents were educated up to tertiary level and so they have salaried jobs or have their own businesses. Those who have informal and primary education level could be the ones who entirely depend on the forest as they have few or no other sources of income.

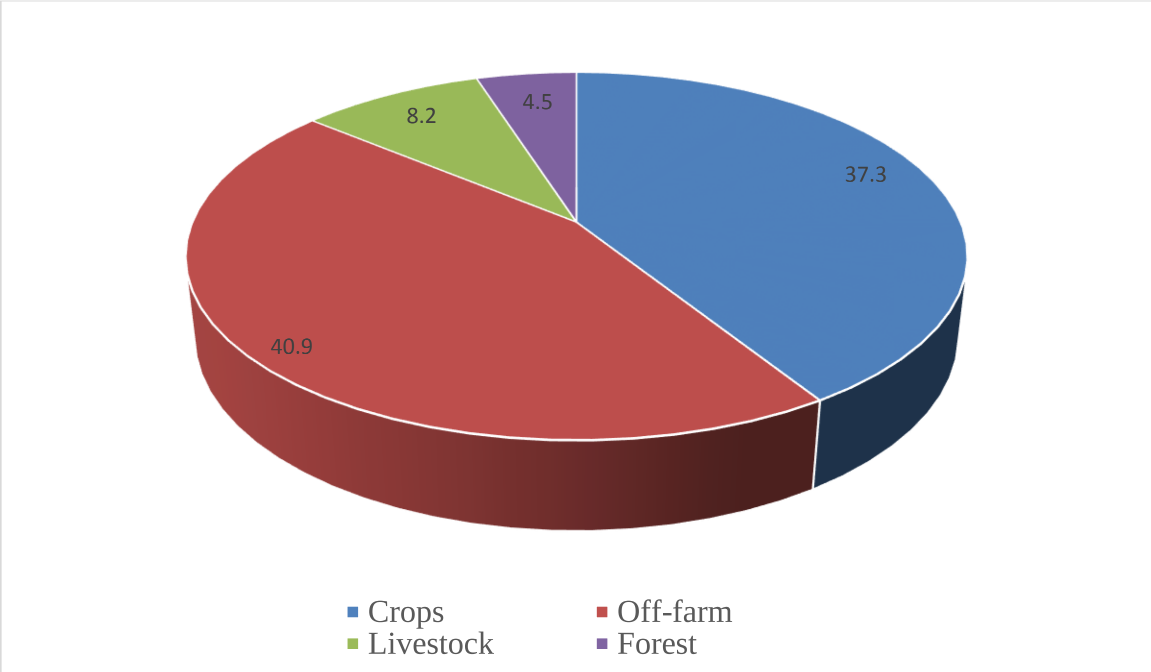

Figure 4: Sources of Livelihoods for Household

The major ecosystem goods and services identified by the respondents included provision of fruits 80%, source of water 90%, fuel wood 94.5%, and timber 83.6%. The results indicate that majority (45.5%) of the respondents moderately depend on forest ecosystem for their livelihood. This implies that they have other sources of income for survival. However, only 16.4 % greatly depend on the forest ecosystem for their survival. Although this number may seem small, it may have a great impact that leads to forest degradation possibly due to high extraction of products from the forest. 29.1% that least rely on the ecosystem services for their livelihood (Figure 5) is probably due to diverse sources of income as indicated from the high income from off-farm sources. High percentage of the household income from off-farm activities is a reflection of high number of members of the community with tertiary education hence engaged either in self-employment activities or salaried jobs. However, a small number of residents entirely rely on the forest ecosystem services as a source of income for their households. These are the people who may be involved in activities such as logging and sale of timber, building posts, firewood extraction and production of charcoal (Figure 6).

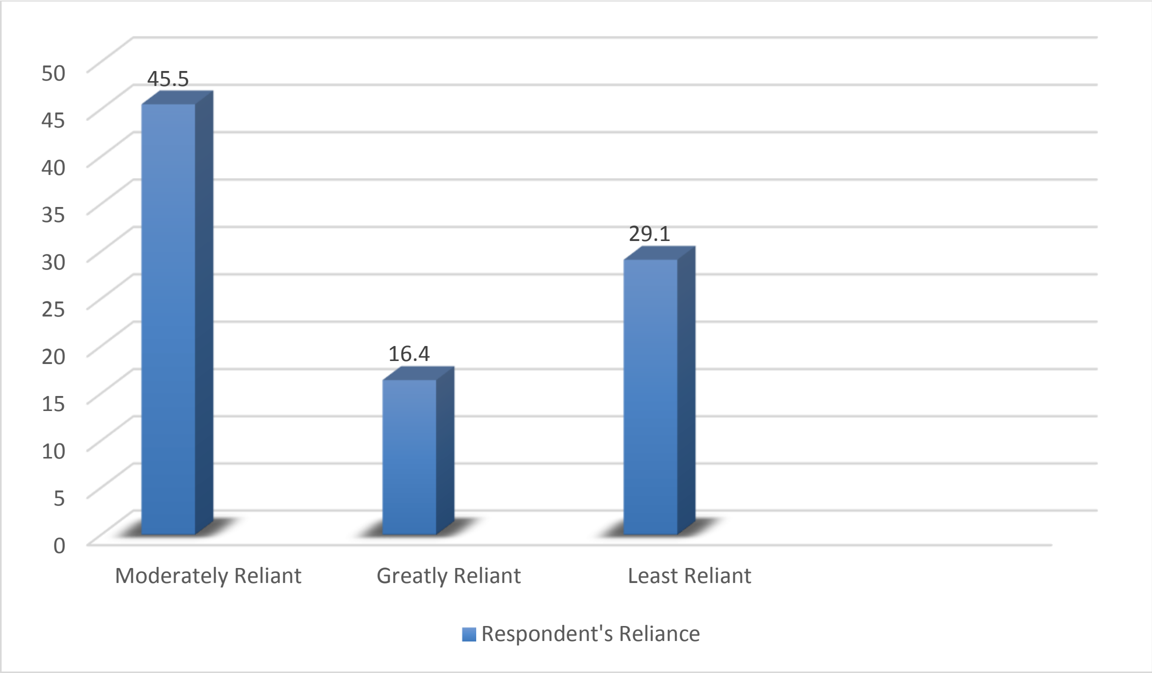

Figure 5: Extent of Reliance on Ecosystem Services for Livelihood

The respondents' reliance on these ecosystem services varies for different households and also depending on the ecosystem service. The Fishers Exact test results indicate that there is a significant association ($p = 0.000$, $\alpha = .05$) between household size and reliance on the ecosystem services. Larger household sizes tend to rely more on ecosystem services for income than smaller households who mostly obtain the ecosystem services for domestic uses. This is because economic consumption in larger households is higher than in smaller households hence, they use the ecosystem services as a supplement for their income. These findings are consistent with observations made by Lakerveld et al. (2015). These researchers cite that household size is a demographic factor that influences how a family utilizes the ecosystem services, for example, need for fuel wood and timber for construction. The services that give the most income according to the respondents are timber at 41.7%, charcoal 20.8%, poles 19.4%, and honey 4.2% (Figure 6). High harvesting of timber and poles (62.1 %) for sale may contribute to degradation of forest ecosystem, hence loss of biodiversity that will affect other forest products such as honey that constitute a major source of income for forest adjacent community.

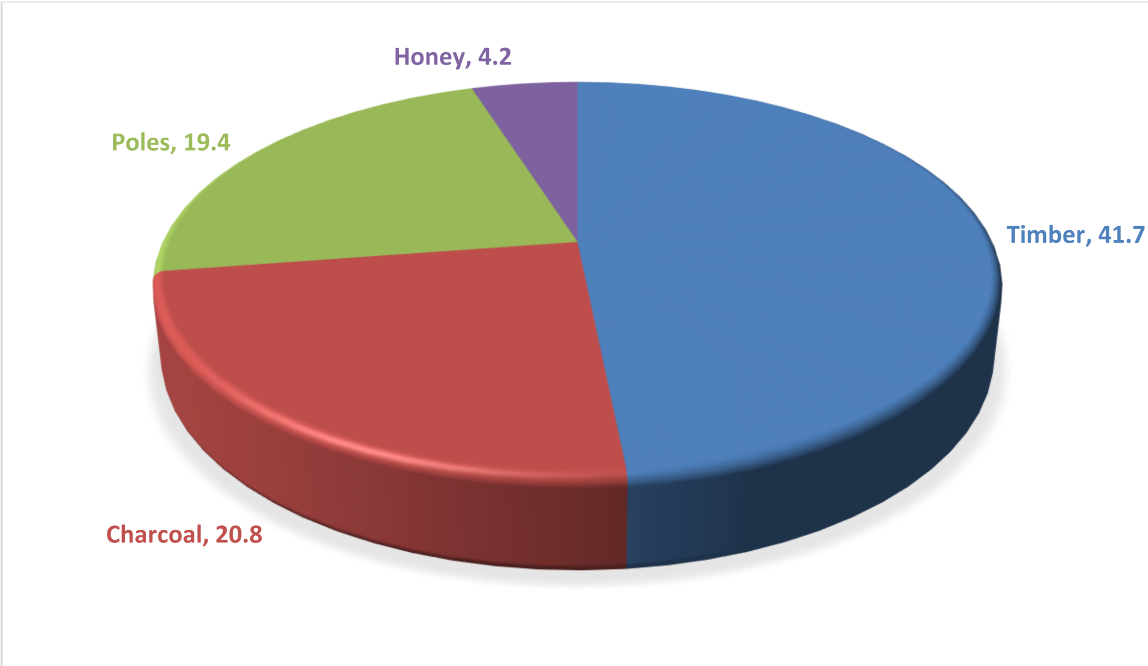

Figure 6: Income Generating Ecosystem Services

4.1.3 Local Community's Perception of the Relationship between Forest Cover and Ecosystem Services

Most of the respondents are aware of the effects of their derivation of ecosystem services on the forest cover. There is a significant association between this awareness and their education level (X^2 = 124.196, df = 12, p<.05; Figure 4.5). Those who are educated tend to be more aware on the effects of their derivation of ecosystem services on the forest cover as compared to those who have little or no education. These findings are in agreement with those of Martinez (1998), who cites that social factors such as education level influence the rate of deforestation. Geist and Lambini (2002), in their research also agree that education level isimportant in forest ecosystem conservation since knowledge on the ecological functions of a forest enhances sustainable utilization of forest resources. Education shapes the behavior of an individual causing forest destruction.

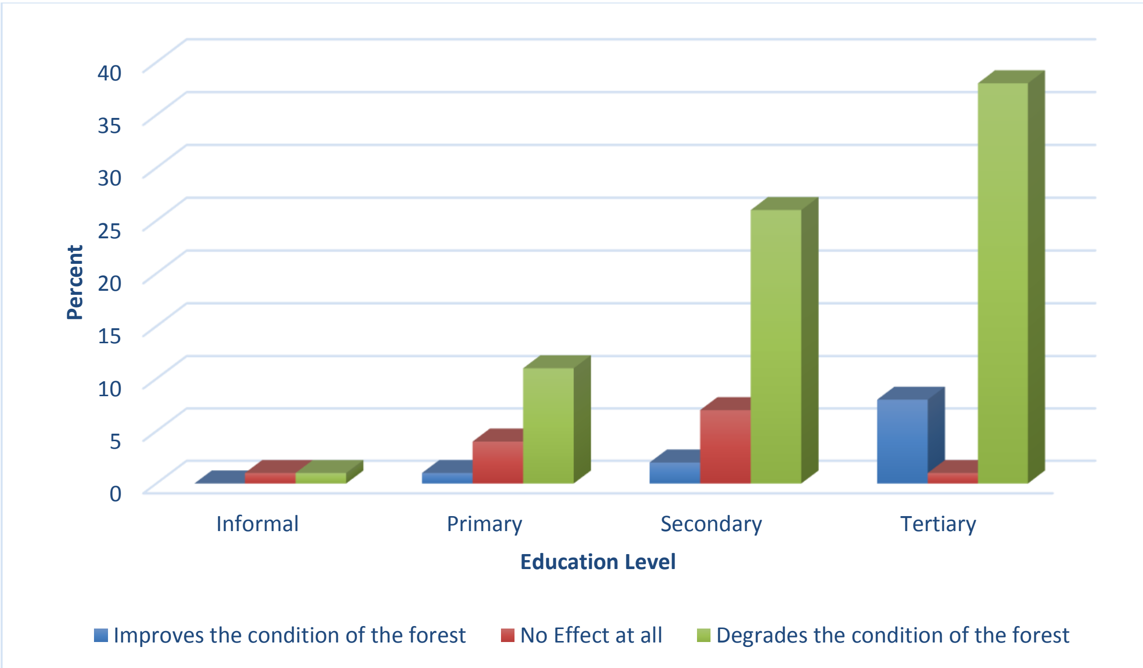

Figure 7: Level of Awareness on Effects of Anthropogenic Activities on the Forest

Based on the focus group discussion, the participants agreed that there is a strong relationship between forest cover and ecosystem services. As the forest cover decreases the ecosystem services also reduce. The Pearson's Chi-Square test results of the household survey also concur with what the FGD participants had indicated. The tests reveal that there is a strong relationship (X^2 = 151.702, df = 16, p<.05) between forest cover change and how the ecosystem services have changed overtime. According to the research conducted by WWF (2016), forest degradation not only reduces the forest cover but also the ecosystem services that the forest provides, and eventually the livelihoods of the people that depend on it.

4.2 Forest Cover and Land Use Change

4.2.1 Land Cover Mapping

The Landsat TM image 1984, Landsat ETM+ images 2001 and 2015 were used to make the land use maps of 1984, 2000 and 2015 respectively. The images were classified using both supervised and unsupervised techniques, but as the accuracy of supervised images were higher compared to unsupervised images, they were used to prepare land use cover maps. The classified images were then converted into vector ESRI shapefiles to give the land use land cover maps of the study area for the different years.

4.2.2 Forest Cover and Land Use 1984

According to the land use land cover map of the year 1984 (Figures 8 and 9), the results show that the dense forest occupies 91.4% of the total land area and is hence the major land use type. This is followed by open forest land 8.3% and built-up areas 0.3%. The summary of the land use areas is given in Table 4.

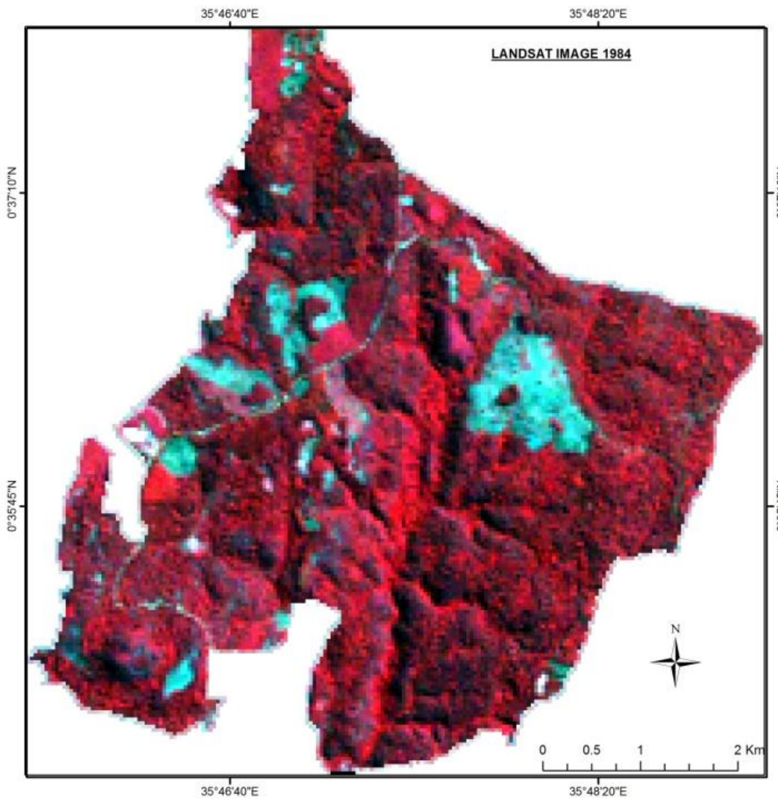

Figure 8: Supervised Classification of the 1984 Satellite Image

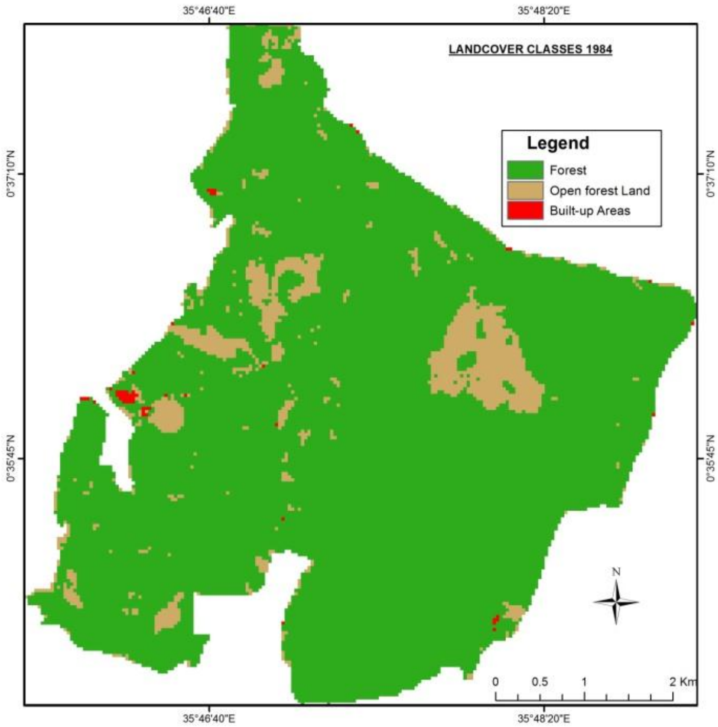

Figure 9: Land Use Land Cover Map of the Year 1984

Table 4: Land Use Land Cover Areas 1984

Class Type	1984(AreaSq Km)	1984 (%)
Dense Forest	*18.81*	*91.4%*
Open forest land	*1.71*	*8.3%*
Built-up areas	*0.05*	*0.3%*
TOTAL	**20.57**	

Figure 10 shows an illustration of the lad use types areas in Katimok forest during 1984. From the graph, Dense Forest occupies the largest area followed by Open Forest then Built-Up Area.

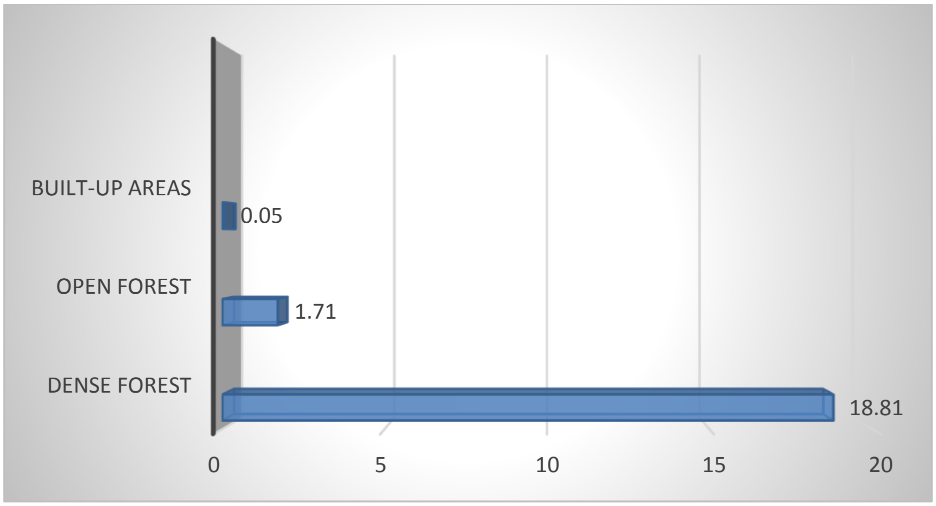

Figure 10: Land use cover 1984

4.2.4 Forest Cover and Land Use 2001

According to the results of the image classification (Figures 11 and 12), dense forest still remains the major land use type covering 86.5% of the total land area. Open forest land had increased by 4.3% and now covers 12.6% of the total land area. Similarly built-up area has increased by 0.6%. The results are as shown in Table 5;

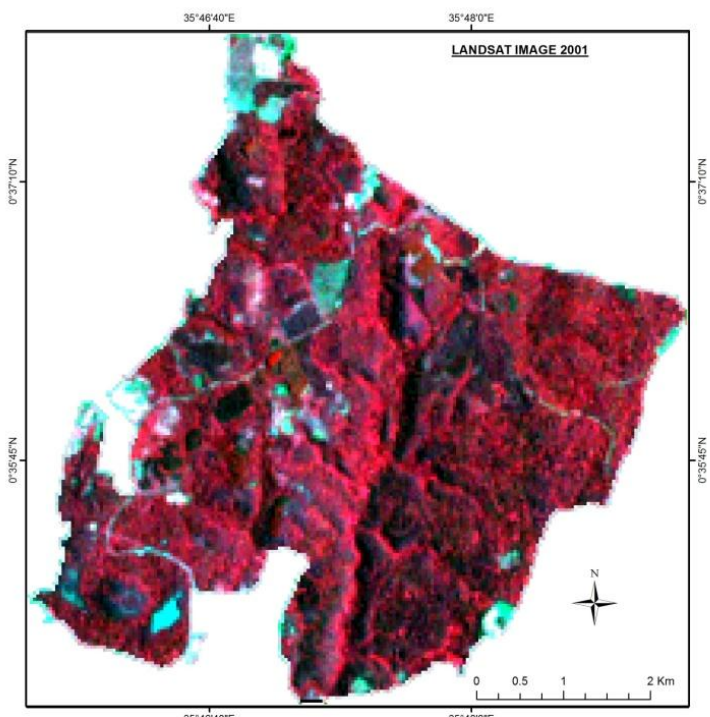

Figure 11: Supervised Classification of the 2001 Satellite Image

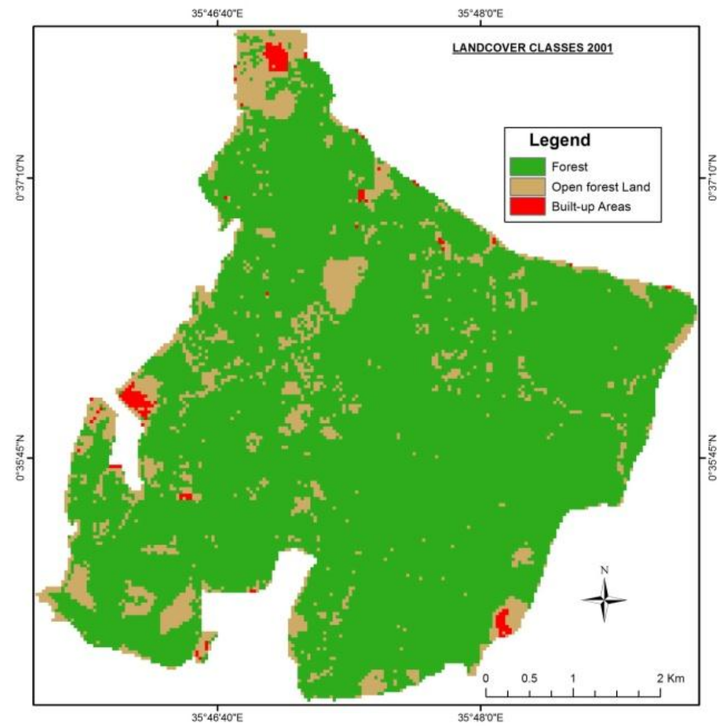

Figure 12: Land Use Land Cover Map 2001

The comparison of the 1984 and 2001 land use land cover maps indicate a decrease in dense forest land and an increase in open forest land and built up areas. The dense forest has reduced by 4.9% and this compensates for an increase in open forest land and built up area by 4.3% and 0.6% respectively. The reduction in forest cover could be attributed to the logging, overgrazing, settlement and conversion of the dense forest into agricultural land. This observation concurs with those of Giliba et al. (2011), who concluded that human activities such as illegal logging, fodder use, agriculture and honey harvesting are among the causes of forest cover change.

Table 5: Land Use Cover Table Area 1984-2001

Class Type	1984(AreaSq Km)	1984 (%)	2001(AreaSqkm)	2001 (%)	ΔHa	Change %
Dense Forest	*18.81*	*91.4*	*17.80*	86.5	-1.01	-4.9
Open forest land	*1.71*	*8.3*	*2.60*	12.6	0.89	4.3
Built-up areas	*0.05*	*0.3*	*0.17*	0.9	0.12	0.6
TOTAL	**20.57**		**20.57**			

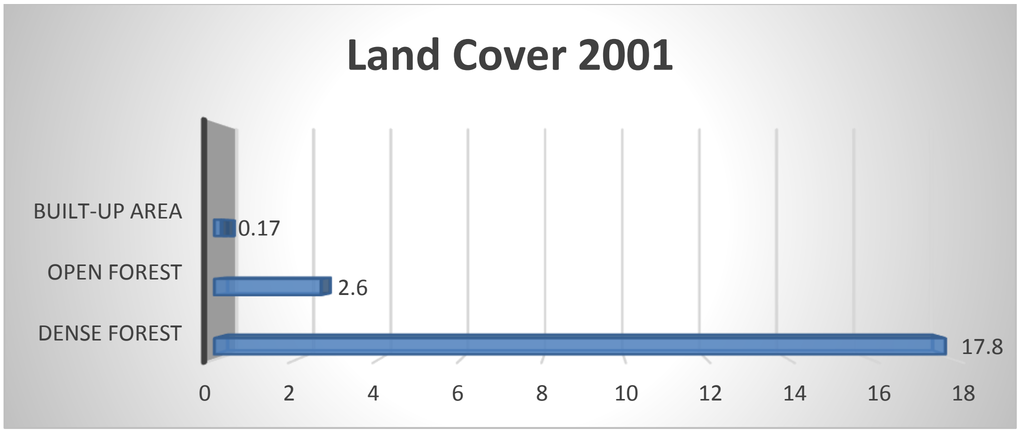

Figure 13: Land Use Cover 2001

4.2.4 Forest Cover and Land Use 2015

The 2015 land use map indicates that the dense forest has now slightly increased up to 18.59 Km^2 of the total land area, and it still remains the major land use type. This increase in dense forest land has resulted in a decline in open forest land as well as built-up area to 9.1% and 0.5% respectively. The changes above can be attributed to the eviction of the illegal settlers from the forest, in 1988 during the KANU regime, which led to a decrease in the built-up area as observed in the land use map. Afforestation was carried out in the lands that were left vacant after the eviction and this led to an increase in the dense forest land and a decline in open forest land as indicated in the land use map (Figure 15).

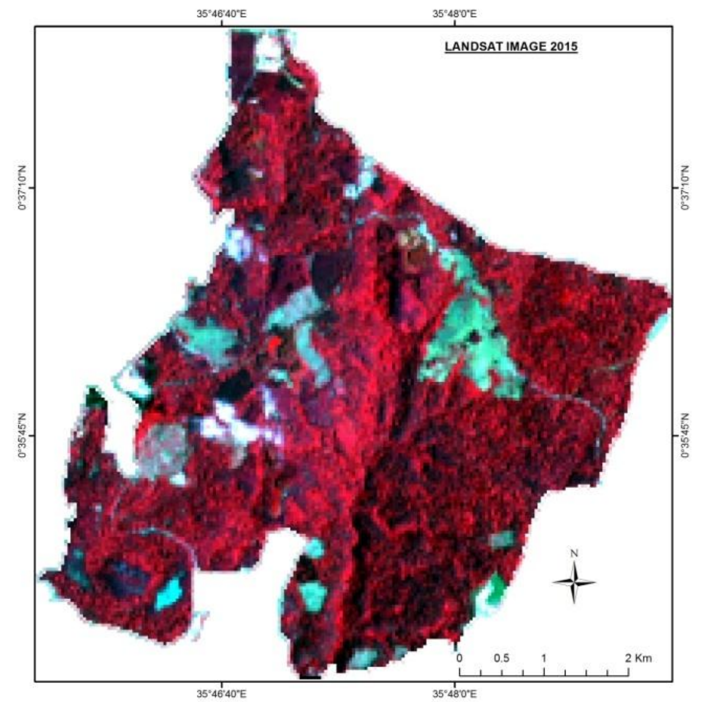

Figure 14: Supervised Classification of the 2015 Satellite Image

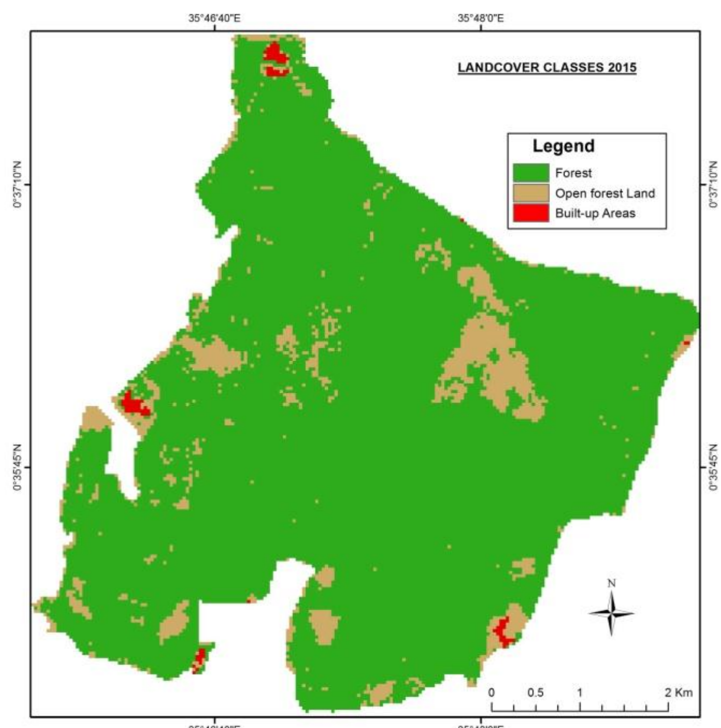

Figure 15: Land Use Land Cover Map 2015

Table 6: Land Use Land Cover Change Areas 2001-2015

Class Type	2001(AreaSqkm)	2001 (%)	2015(AreaSqkm)	2015 (%)	ΔHa	Change %
Dense Forest	*17.80*	*86.5*	*18.59*	90.4	0.79	3.9
Open forest land	*2.60*	*12.6*	*1.87*	9.1	-0.73	-3.5
Built-up areas	*0.17*	*0.9*	*0.11*	0.5	-0.06	-0.4
TOTAL	**20.57**		**20.57**			

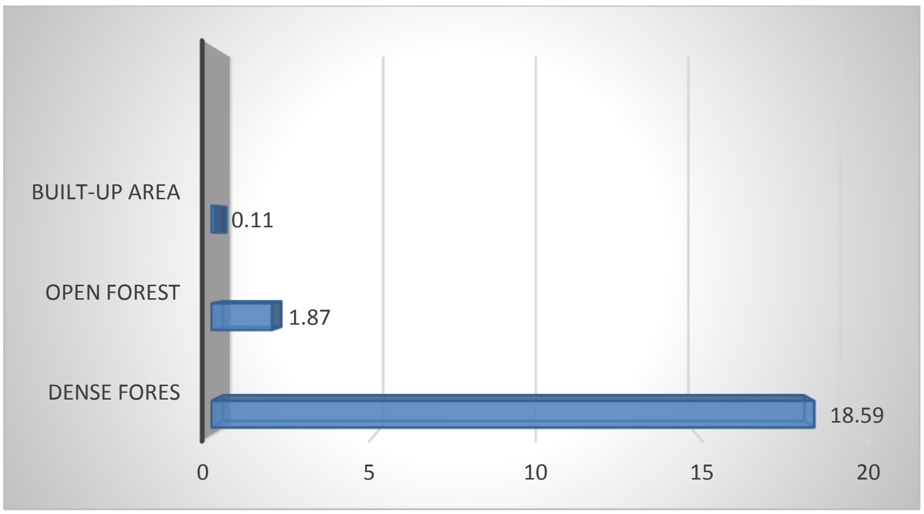

Figure 16: Land use cover 2015

4.2.5 Rate of Forest Cover Change

In order to estimate the rate of forest cover change between 1984 and 2015, the following formula by FAO, 1995 was used.

q= [(A2/A1)^1/(t2-t1)]-1

Where

q= deforestation rate (% lost areal year)

A1= Initial forest area

A2= final forest area

t1-t2= interval in year during which change in land cover is being assessed

Therefore q=[(18.59/18.81)^1/31]-1

q=[0.988^0.03]-1

q=0.04

The rate of forest cover change between 1984 and 2015 is thus 0.04 %. This implies that the rate of forest conversion has slowed down since 1984. Figure 17 shows that between the years 1984 and 2001, there was a negative forest cover trend and between the years 2001 and 2015, the trend in forest cover was positive. This means that there was reforestation in between the years 2001-2015 resulting in an increase in forest cover.

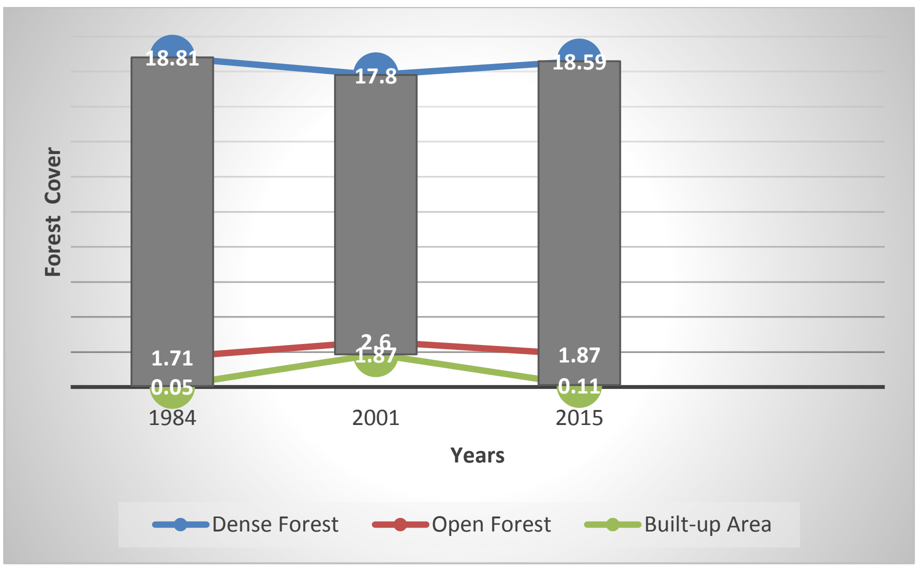

Figure 17: Trend of Forest Cover Change 1984-2015

4.3 Forest Cover Change and Its Driving Forces

At independence, Kenya's forest cover stood at 11% (Stiebert et al., 2002), but it has reduced to 7%. The causes of this reduction in forest cover are diverse and constitute both direct and indirect drivers. Some of the main causes of forest cover change as indicated by Geist and Lambini (2002) are conversion into agricultural land, unsustainable charcoal production, demand for fuel wood and logging. Degazzettement of forest lands, corruption and ineffective enforcement capacity are other underlying causes of forest cover reduction (Stiebert *et al*., 2002). These studies are in agreement with the findings of this study. Based upon the household survey and the FGDs conducted, it was found that most respondents believed that the forest cover has decreased as compared to the past years. 62.7% of the respondents cite a decrease, 11.8% cite a major decrease, 10.9% cite an increase, and the rest 3.9% cite a major increase in forest cover since 1985.

Based on the Focus Group Discussions held, it is evident that the forest cover has changed in terms of size and density. According to the FGDs, the size of the forest has greatly reduced since 1985. This is attributed to many factors such as the encroachment of the boundaries by sawmills, individual encroachment by local leaders, clearing of the forests to pave way for the establishment of health facilities, schools and administration centers. These encroachments, led to the degazettment of the forest in 1989 to enable the institutions and the persons legally own the forestland. The density of the forest, as gathered from the discussion, has also reduced. This is mainly due to illegal and legal logging of exotic trees, overgrazing, firewood collection, charcoal production and poaching of indigenous trees such as the sandalwood. Some of these activities were observed in the forest. There has also been the establishment of the Plantation Establishment and Livelihood Improvement Scheme (PELIS) system which allows the community to farm on the forestland as they tend to young trees until they reach a certain growth level.

Plate 4.1: A Picture showing finger millet within the forest cultivated under the PELIS programme (Source: Author)

All these human activities have greatly reduced the forest cover as well as the ecosystem services that the forest used to supply. These findings are consistent with those ofStiebert*et al.* (2002) who observed that forest degradation impacts on the livelihoods of the forest adjacent communities through reduction of ecosystem services such as biomass and water among other services.

4.5 Importance of the Forest to the Community

The forest is the livelihood of the community as gathered from the FGDs and household survey. They obtain socioeconomic as well as cultural benefits from the forest. The forest is a catchment area and the community gets water from the rivers and streams that flow through the forest such as *Sokom, Endao* and *Kampi Samaki* Rivers. The forest is also important to the community as they rely on it for herbal medicine derived especially from the indigenous plants such as *Garcinia johnstonii* (Muikutwe). According to the FGD, the participants also indicated that during the dry season when there is shortage of grass for their livestock, the community relies on the forest for fodder with some of the species like *Trichocladus ellipticus* acting as alternative feed for their livestock.

Table 7: Tree Species Found in the Forest

Local name	**Scientific Name**	**Common Name**	**Uses**
Tarakwo	*Junipreus procera*	African pencil cedar	Construction material
Auwe	*Polycius kikuyuensis*	Parasol tree	Timber
Arariet	*Ekebergia capensis*	Cape ash	Medicinal for dysentery
Benet	*Podocarpus falcatus*	Yellowwood/podo	Making furniture
Boroa	*Dombeya goetzenii*		Medicinal for indigestion
Kolutwet	*Albizia amara*	Bitter albizia	Fruit and medicinal
Kamilet	*Combretum molle*	Velvet bushwillow	Medicinal for stomach ache and headache
Sosionte	*Phoenix reclinata*	Wild date palm	Fruit
	Vitex keniensis	Meru oak	Fruits, medicinal
Bunus	*Eucalyptus saligna*	Sydney blue gum	Building and construction
Yemit	*Olea africana*	Wild olive	Fruits and oil
Soket	*Warbuginia ugandesis*	Uganda greenheart	Fruit and medicinal for general body pains
Sesia	*Acacia tortilis*	Umbrella thorn acacia	Making furniture
Leketwa	*Carissa edulis*	Simple-spinednum-num	Fruits, Medicine for malaria and pain
Kunyukwe	*Prunus Africana*	Red stinkwood	Medicinal for stomach ache, malaria, fever
Kuryonte	*Teclea nobilis*	Small-fruited teclea	Fruit tree, timber
Samut	*Cordia Africana*	Sudan teak	Beehives and furniture
Se	*Albizia gummifera*	Peacock flower	Firewood, charcoal
Septa	*Podocarpus latifolius*	Real yellowood	Fruits, making furniture
Ortulet	*Croton megalocarpus*	Croton	Construction material, fuel wood, charcoal
Nerkwo	*Garcinia livingstonei*	African mangosteen	Fruit tree
Lomoiwe	*Syzygium guineense*	Water berry	Fruits, construction material
Koloswo	*Trichocladus ellipticus*	White witch-haze	Fodder, medicine for upset stomach
Tegat	*Bambusa vulgaris*	Bamboo	Construction
Sinendet	*Ficus sycomorus*	Sycamore	Fruits, ceremonial
Kures	*Euphorbia candelabrum*	Candelabra tree	Medicinal for leukemia, tumor, HIV infections

The forest also plays a significant role in fulfilling cultural and spiritual practices of the community. Some cultural benefits of the forest that the participants indicated are that the forest is a ceremonial ground and circumcisions are done inside the forest. The community also has some designated sacred sites within the forest that are used for prayers; both traditional and modern Christianity. The Governor's Camp is a historical place and a tourist attraction in the forest. Other places of cultural importance are *kebenonin, tuiyobei*, and *kapchumba* where there is a cave. There are also plant species with some cultural significance to the community and they include sycamore, *Warburgia ugandensis, Acocanthera schimperi, and Euclea divinorum.* These plant species are not available in their farms and hence the forest is an important source of these species. The forest is also a source of fuel wood which is a readily available form of energy for the community. Moreover, the forest is an ideal place for placing beehives and as such, it is important for bee farmers.

Plate 4.2: Picture showing Sheep grazing within the Forest (Source: Author)

Other important benefits that the community derive from the forest include fodder (Plate 4.2), honey from stingless bee, mushrooms, soil, tree seedlings, farming, fresh air, climate regulation, habitat for wild animals, recreation, construction material and wild fruits, such as, *Syzygium guineense*, among other benefits. All these benefits that the community derive from the forest as indicated in the FGDs conducted and field observations, agree with the findings of Shackelton et al. (2001). According to these researchers, communities utilize a wide array of ecosystem services such as medicine, food, construction material and cultural purposes to meet their livelihood needs. Millennium Ecosystem Assessment (2003) findings are also consistent with the current study findings in which different communities value different ecosystems according to the values they attach and obtain from them. Our current study findings further note that, there are various ecosystem services obtained from the forest and they range from bush meat, water, firewood, wild fruits as well as spiritual and cultural value.

4.6 Impacts of Forest Cover Change on Ecosystem Services

The changes in land use and forest cover of Katimok forest have had some effects on the ecosystem services that the forest provides. The results from the household questionnaires indicate that there is a strong positive correlation between forest cover change and reduction in ecosystem services which was statistically significant ($r = .515$, $n = 100$, $p < .005$). Some of the examples given in the FGDs include the loss of medicinal plants such as *mesketwo* that cures headaches, *soset* for stomachache, *kelembetwe* that purifies water, and *meriebei*. Some of the regulation services of the forest have been hindered such as soil erosion prevention, which is now a common phenomenon during heavy rains. Flooding downstream is now also observed especially in the Endao and Kampi Samaki.

According to the FGD, there has also been a reduction in water levels and quantity, and also in water points owing to siltation which eventually lead to the drying up of some rivers. The rivers have also become seasonal. This may be attributed to the change in land use which reduces the forest cover thereby affecting the ability of the forest to act as a catchment area. A study conducted by the Center for Watershed Protection (2008) established that a reduction in forest cover affects the ability of the forest to regulate the quality, quantity and flow of water. Their findings are in agreement with the results of this study. The reduction in forest cover has also led to human-wildlife conflicts since their habitat have been destroyed. The forest has become open and the animals which used to come out only at night can now be seen even during the day, as they have nowhere to hide. Some animals such as the Colobus monkey, antelopes, serval cat, and some bird species such as the guinea fowls, kites, hawks and eagles have also disappeared and can no longer be found in the forest. Special flowering plants for bees e.g. *songucha* have also disappeared, and so the bees go away in search of nectar. In general, there has been a reduction in the abundance of the ecosystem services and in some cases the services have become extinct.

Table 8: Animal and bird species found in the forest

Local Name	Common Name	Scientific Name	Distribution/Range
Terkekyat	Helmeted guineafowl	*Numida meleagris*	Native range covering much of Africa
Kipkosiret	Bushy tailed mongoose	*Bdeogale crassicauda*	Woodlands and moist savannahs
Boinet	Grants gazelle	*Nanger granti*	Somali-Maasai biome, Kenya/Somali coast
Taiwa	Common quail	*Coturnix coturnix*	Diverse range, Least concern
Cheroriot	Red forest duiker	*Cephalophus natalensis*	Evergreen and tropical forest biomes
Moset	Olive baboon	*Papio anubis*	Savanna and evergreen forest biomes
Kiplengwet	Cape hare	*Lepus capensis*	Large range including shrub-land, grassland and semi-desert biomes
kiptaraarit	Serval cat	*Leptailurus serval*	Native to Africa; wide range
Kipsichit	Tawny eagle	*Aquila rapax*	Afro-tropical regions
Chereret	Vervet monkey	*Chlorocebus pygerythrus*	Largely distributed across Sub-Saharan Africa

However, citing a reduction of some of the ecosystem services, they also indicate that there has been an increase in agricultural production as well as forest products such as timber and other building materials as a result of land use change. Logging increases the supply of timber and also the availability of bare land on which the community are allowed to farm on as they tend to young tree seedlings (the PELIS system). This concurs with what Lawler, et al. (2014)had established that land use change increases the production of food crops and timber among other products but at the expense of a decline in other ecosystem services. Devisscher (2009),also agrees that changes in land use as well as systems of production affects the abundance of ecosystem services.

Plate 4.3: A Picture showing River Siltation as an Impact of Forest Cover Change

The situation of the river as shown on plate 4.3 can be attributed to reduction in forest cover which has caused erosion and thus siltation of the river. The findings are consistent with those from FAO (2011), which indicate that, forests play an important role in regulating the water supply, minimizing the effects of flooding and preventing soil erosion.

4.7 Change in Local Climate

Climate is a phenomenon with many variables such as humidity, temperature, rainfall, among many other measurements that can be used to describe climate. In this study, temperature and rainfall data are used as indicators of local climate change since 1985 to 2015.The findings are illustrated in line and bar graphs.

4.7.1 Rainfall Trend

Regarding the rainfall trend, majority (77.1%) of the interviewed households had experienced a decrease, 8.6% an increase and the rest 14.3% had no idea. Unfortunately, the rainfall data obtained from the forest's meteorological station indicates an increasing trend, in the annual rainfall, although not significantly as shown in Figure 18. However, the data shows fluctuating rainfall pattern with the lowest rainfall recorded in 1991 and 2009 and the highest peak observed in 2010 and 2012. It is worth noting that, the area has been receiving fluctuating rainfall amounts. This observation concurs with the UNDP climate change profile for Kenya report which notes that there are no significant variation in rainfall amounts received in various parts of Kenya since 1960 (Lizcano et al., 2008). The FGD respondents of this study are also of the opinion that the rainfall amounts have become unpredictable during the recent decades. The dry periods have become longer and frequent causing shrinkage of rivers and when it does rain, it is severe, bringing about floods and erosion.

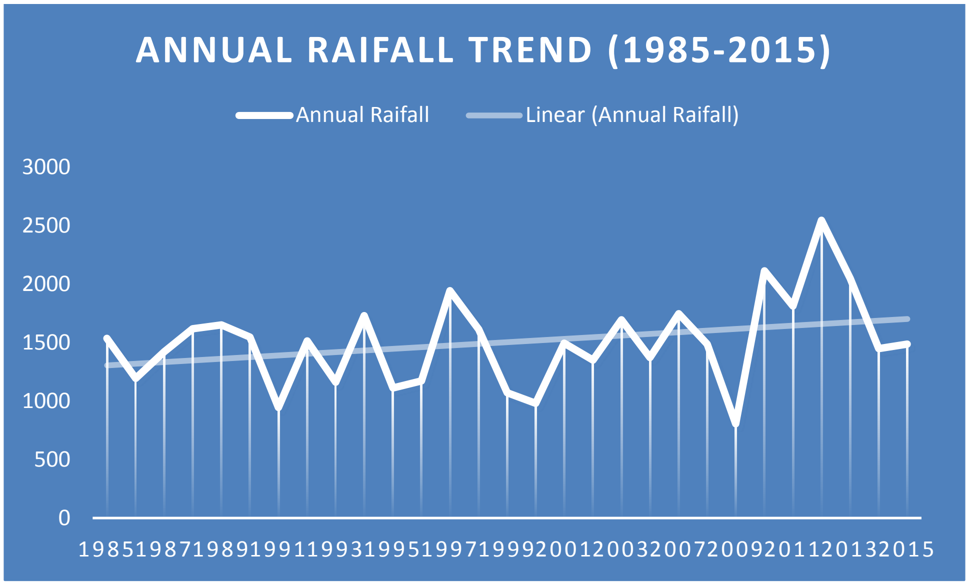

Figure 18: Katimok Forest Annual Rainfall Trend

Figure 19 shows the seasonal rainfall cycle of the study area calculated from rainfall data 1985-2015. In this graph, two wettest months are observed, July with a mean seasonal rainfall of 207.64 mm followed closely by April with a mean seasonal rainfall of 207.28mm. In Kenya, there are two wet seasons, long rains season (March-June) and short rains (October-December). This graph indicates that there is a change in climate since July and August which are supposed to record lower rainfalls are peaking. According to the household survey, majority of the respondents (83.6%) indicated that the seasonality had become unpredictable. Similarly, the FGDs participants were of the same opinion, noting that this phenomenon had completely altered their cropping cycle. These findings are in concurrence with the UNDP climate change profile for Kenya report which notes that the onset, duration and amount of rainfalls vary from year to year (Lizcano et al., 2008).

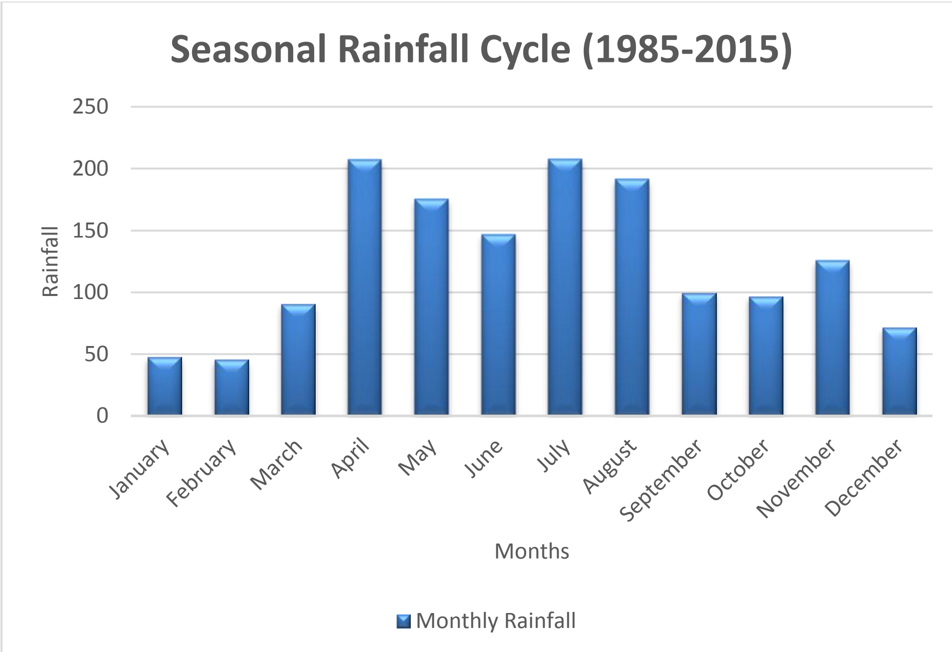

Figure 19: Katimok Forest Seasonal Rainfall Cycle (1985-2015)

Figure 20 shows the long rains season (March-June) rainfall amounts for the different years. The patterns are seen to be inconsistent and the trends decreasing over time. This shows that there is change in climate since the rainfall amounts should be consistent for the different months rather that varying. This would have resulted in an unchanging trend over the years. Moreover, the decreasing trend means that the wet season is now receiving low rainfall amounts hence change in seasonality.

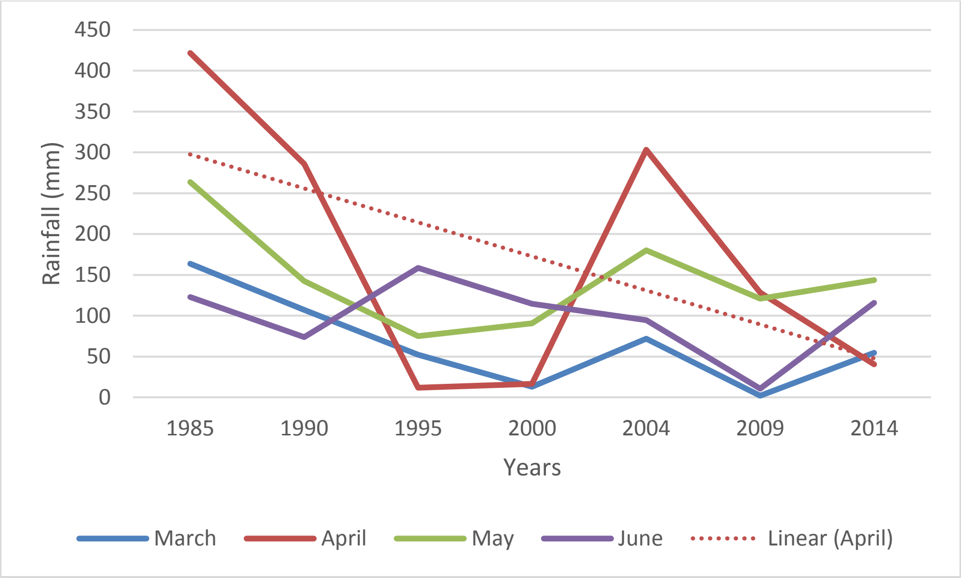

Figure 20: Katimok Forest Long Rains Wet Season Trend for Selected Years

Similarly, the short rains period (Figure 21) indicates a fluctuating pattern for the different years. First, it shows an increasing trend which means that there is a gradual increase in rainfall amounts during the short rains season. Again, the pattern is not consistent for the different time periods.

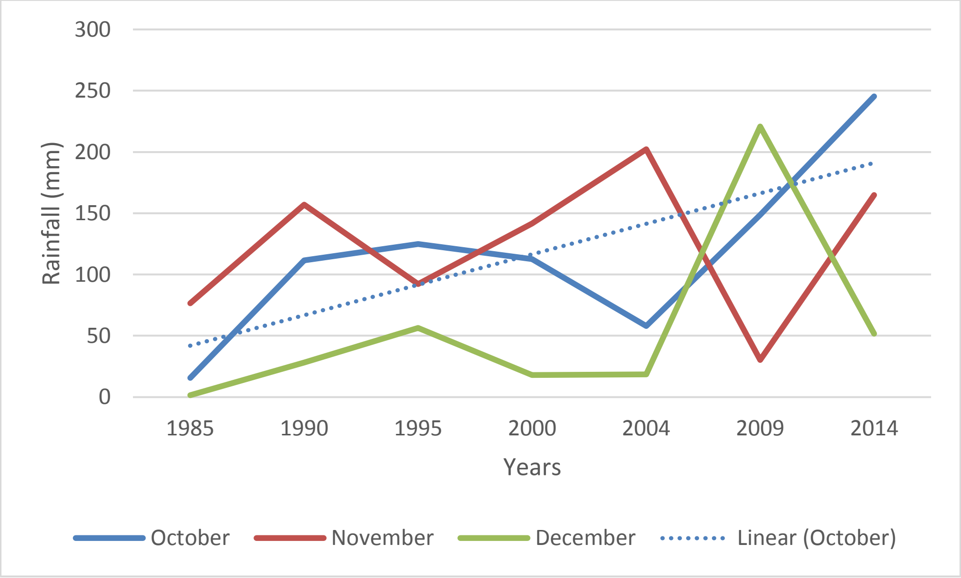

Figure 21: Katimok Forest Short Rains Wet Season Trend for Selected Years

A comparison of the graphs of long rains and short rains wet season as shown in Figures 22 and 23 depicts a clear difference between the two seasons. A slight decline in rainfall during the long rainy season and a rainfall increase during the short rainy season is observed. This is an indication of a changing climate. The respondents of the study indicated that the rainfall patterns had become erratic and there had been a change in seasonality which affects the time of planting and harvesting of their crops. These findings corresponds with those of Lykens &Liebmann (2012), which also indicated that the trends of rainfall in the Rift Valley region showed a small decrease in the long rains and an increase during the short rains season.

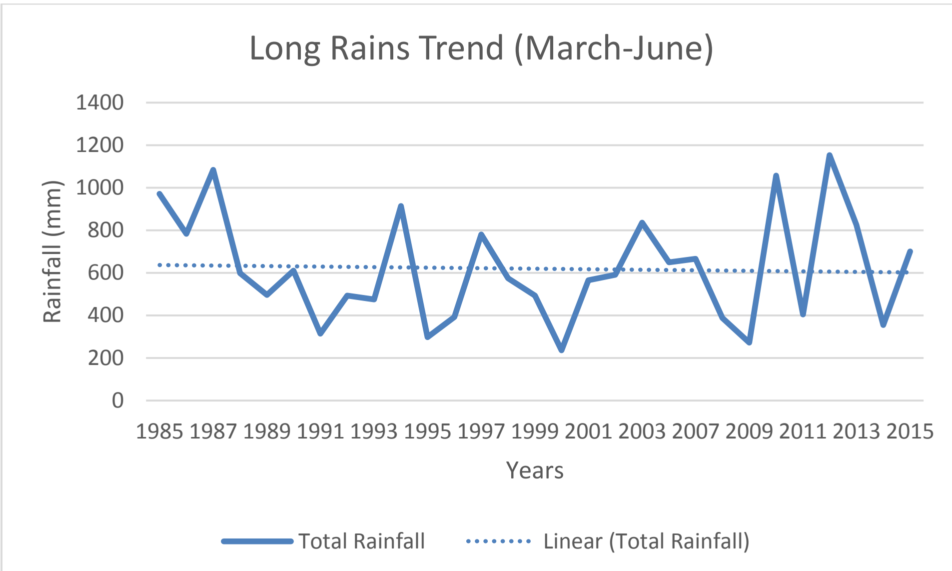

Figure 22: Katimok Forest Long Rains Trend (1985-2015)

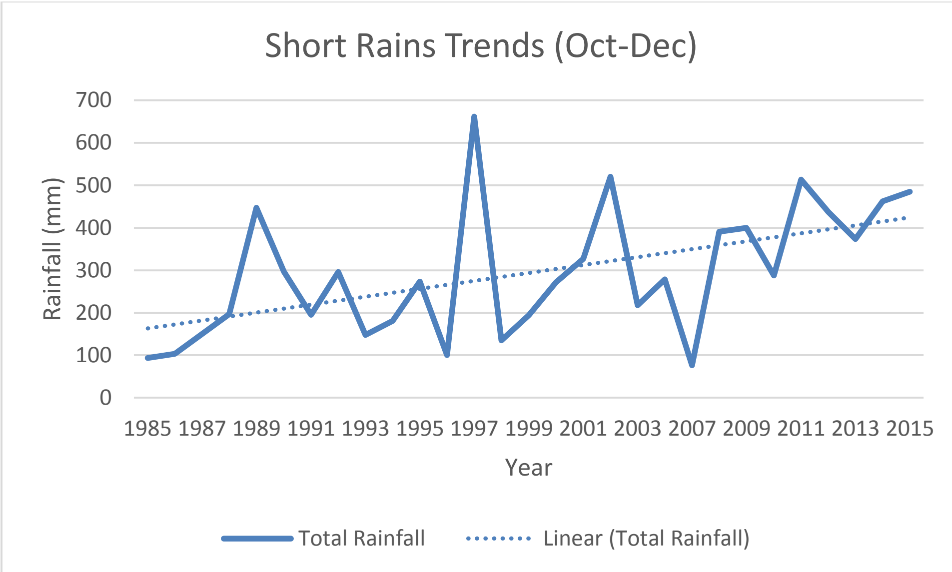

Figure 23: Katimok Forest Short Rains Trend (1985-2015)

4.7.2 Temperature Trend

The temperature data obtained from the World Bank Climate Change Knowledge Portal indicates a rising trend of temperatures as shown in Figure 24. This increase in temperature is an indicator of climate change (warming). This is consistent with what was gathered in the FGDs as the respondents indicated that the temperatures had increased in the area. Majority (76.9%) of the household respondents also reported to have experienced increasing temperatures in the last few decades. According to Figure 24, the highest temperatures were recorded 2009 with annual average temperatures of 25.59 degrees Celsius, and the lowest temperatures were recorded in 1989 with an average annual temperatures of 24.14 degrees Celsius.

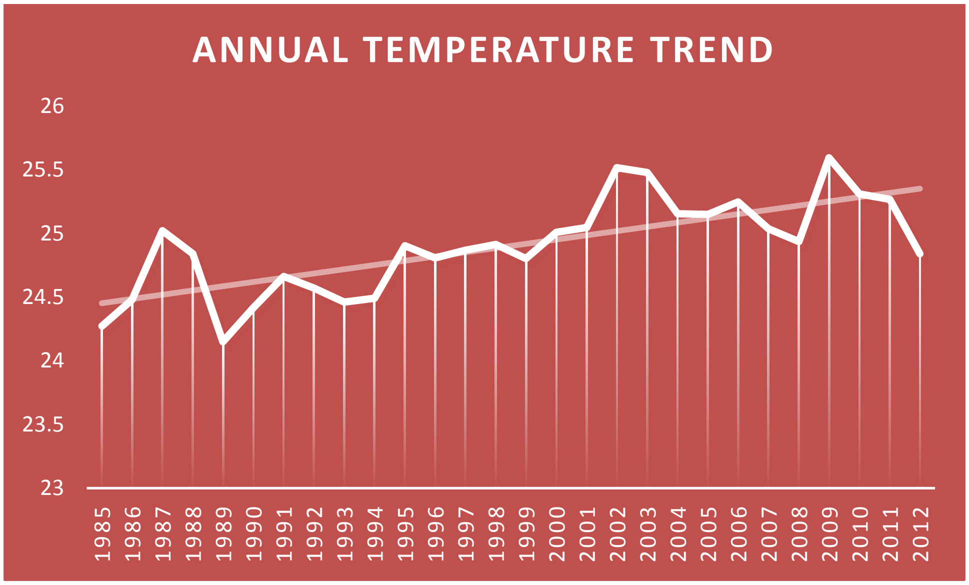

Figure 24: Katimok Forest Annual Temperature Trend (1985-2012)

The annual temperature range of change in the maximum and minimum mean annual temperature is +-1.44561.This concurs with the findings of UNDP Climate Change Profile for Kenya which also note that the mean annual temperatures in Kenya have risen by about 1.0^{0}C. The change in average temperatures between the years 1989 and 2009 gives a clear picture of the warming trend in the area.

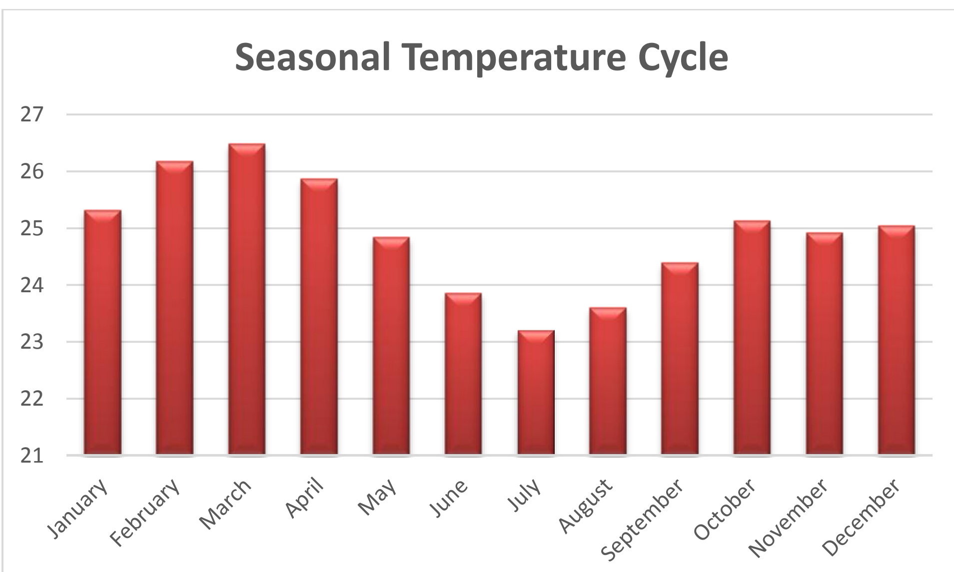

Figure 25: Katimok Forest Seasonal Temperature Cycle (1985-2012)

Figure 25 shows the seasonal temperature cycle of the study area calculated from the average monthly temperature data 1985- 2012. In this graph, it is observed that February, March and April are the hottest months while June, July and August are the coolest months. It is also observed that there is little temperature variations between these hottest and coolest months with the range between March (26.48^0C) and July (23.2^0C), which are the hottest and coolest months respectively, being 3.28 degrees Celsius. These findings are in agreement with those of the UNDPs Climate Change Profile for Kenya which note that temperatures in Kenya have slight fluctuations throughout the year but drop in the coolest months of June, July, August and September (Lizcano Et al., 2008).

4.7.3 Traditional Climate Change Indicators

Local knowledge has long been used by communities to predict climate change based on its impacts on the ecosystems. The results of the sampled respondents indicate that there has been a change in climate over the last 30 years, more so in terms of temperature, rainfall and seasonality. Most respondents noted that there has been a change in seasonality, in that it has become unpredictable. The temperatures have also risen according to 45% of the respondents and the rainfall has become inconsistent according to 56% of the respondents. Some of the local indicators that the community uses to determine change in climate are described below.

4.7.3.2 ***Invasive Species***

Change in climate can alter vital components of natural systems such as rainfall, temperature, and land cover and this can facilitate the spread of invasive species. According to the focus group discussions, there has been a shift in ecological zones and tree species that used to grow in the lowlands are now found in the highland areas, for example *Balanites aegyptiaca*, *Acacia tortilis and Euphorbia candelabrum*.

4.7.1.1 Spread of Diseases

Climate change and shift in ecological conditions has supported the spread of diseases such as malaria and Rift Valley Fever. The FGD participants noted that malaria was not common in the area as there were no mosquitoes to transmit the disease, but nowadays mosquitoes have invaded the area and this is an indicator that climate has changed. The participants also noted that there was re- emergence of Rift Valley Fever, a disease that is attributed to unusually long rains indicating a change in climate.

4.7.3.3 Change in Planting and Harvesting Seasons

The FGD participants observed that, in the olden times, planting seasons used to be the same every year usually at the beginning of long rains. March to April. They used to follow a particular pattern, but nowadays planting and harvesting seasons have become unpredictable.

4.7.4.4 Mist and Fog Spells

Based on the FGDs, the participants indicated that mist and fog spells which used to be so common especially during the rainy and cold seasons have become rare these days, and when they appear, they are at unusual times. This is clearly an indicator of climate change.

4.8 Forest Management Interventions

The Kenya Forest Service raises tree seedlings in their tree nurseries (Plate 4.4) and plants them in degraded areas. They also sell the trees to the local people to go and plant them in their farms. This reduces the reliance on the forest in terms of fuel wood and timber since the community has the trees available in the farms. Some of the trees raised in the nursery are;

Table 9: Trees raised in Katimok Forest Nursery

Names	**Description**
Eucalyptus saligna	Tall forest tree with height 30-55m
Cupressus lusitanica	Evergreen conifer tree; ovoid crown; up to 40m tall
Green ash	Deciduous tree, medium in size. Grows up to 12-25m
Podocarpus falcatus	Evergreen conifer; grows up to 45m in height
Prunus africana	Evergreen tree native to Sub-Saharan Africa
Grevillea robusta	Fast growing evergreen tree; 18-35m in height
Olea hoschiteteri	Evergreen tree; varies from 2-15m in height
Croton megalocarpus	Drought resistant tree;upto36m high
Warbugia ugandesis	Evergreen insect resistant tree
Casuarina equisetifolia	Slender evergreen tree with grey-green twigs; 6-35m tall
Pinus patula	30m tall tree that is moderately drought resistant
Vitex keniensis	Straight trunk tree that is endemic to Kenya

Plate 4.4: A Tree Seedling Nursery at Katimok Forest KFS Station

The community forest associations (CFAs) also engagein theprotection of the forest by offering surveillance and reporting to KFS any illegal activity as well as wildfires that might occur in the forest. Some of the areas have also been fenced off under the PELIS system to keep off any animals that might enter the forest. The forest is manned by KFS forest rangers that can arrest any illegal loggers and grazers in the forest. The rangers are allowed to detain any livestock found illegally grazing in the forest.

4.9 Challenges faced in the Management of the Forest

There are many challenges that hinder the sustainable management of the forest as gathered from the FGDs. One of the challenges is that the community lacks information and awareness on the significance of trees and the value of conservation, so they take part in encroaching the forest. Furthermore, there is no restriction in entering the forest, unlike in the past where people had to seek permission to enter the forest. This encourages illegal practices such as logging and poaching within the forest. Carandang et al. (2013) in their research found out that lack of knowledge and awareness on the benefits of protecting the forest is a socio-cultural factor that indirectly causes forest degradation. They also add that laxity on enforcement of the laws further fuels the rise in illegal forest activities.

According to the FGD, grazing of livestock in the forest has not been controlled as before, where the community used to sit and agree on certain water points and certain boundaries. Fodder would be cut and taken to the animals in the field and goats were not allowed to browse in the forest. Open grazing in forests adversely affects the growing stock as well as the capacity of the forest to regenerate leading to degradation (Nayak, Kohli, & Sharma, Undated).

Another concern was that the residents are threatened and victimized whenever they report illegal poaching. There is no action taken on the offenders and so people do not care anymore about reporting, so they end up poaching as well. What is more, there are only eight officers managing the entire thirteen blocks of Kabarnet Forests and few staff to monitor a vast expanse of forest. Poor remuneration of KFS officers has also contributed to less effort in management of the forest, thus they also poach and/or receive bribes from illegal loggers. These findings are in agreement with those of (Contreras-Hermosilla, 2000) who found out that some forest management authorities often abuse the public powers bestowed on them to unlawfully make themselves rich. He further states that, this conduct is especially true for those officials who are poorly paid as they start making prejudiced decisions against those activities that do not attract bribes hence continued illegal logging.

The participants also mention that commercialization of tree products has made the community look at trees in terms of commercial values and this has led to illegal logging. There is ready market for timber, poles and other building materials hence they practice illegal logging to earn a living. Goll, Li, & McKay (2014) in theirresearch also indicated that market demand for forest products is one of the root causes of forest degradation.

Moreover, the FGD participants stated that there is corruption among the forest authorities and those trading in forest products, mostly timber. The authorities are offered handsome bribes to give licenses to some few known individuals. Besides, those licensed persons do not even hail from the community. Therefore, the community feels sidelined as they are not given licenses so that they can also obtain the forest products legally. This makes them practice illegal logging and other forms of forest degradation.This is consistent with the findings of Carandang et al. (2013) who established that corruption is one of the rampant institutional weaknesses that has hindered effective enforcement of forestry laws. In addition, theyargue that this corruption allows illegal logging to continue as the forest authorities are bribed to issue permits.

Another concern raised in the FGD was that the last batch of the illegal settlers was forcefully evicted in 1988. During this eviction, houses were burnt and property destroyed. For that reason, there is still resentment as evicted persons were not compensated, so they feel neglected and they take part in illegal logging to make up for their lost property. According to FAO when illegal forest settlers are forcefully evicted, they retaliate in form of participating in unlawful forest activities such as illegal logging, and this results in rapid decline of forest resources. Therefore, FAO recommends the resettlement of illegal settlers so as to economically empower the local communities as well as promote forest conservation (FAO, undated).

Lastly, the FGD results indicates that the community forest associations (CFAs) lack the capacity to make and enforce rules as well as financial resources to carry out their activities. This is consistent with the findings of Chomba et al. (2015) who indicated that the CFAs had no power to even make the basic rules concerning forest management, for example, making decisions regarding the fees to charge the forest users. They also cannot enforce these rules as this mandate is entirely vested on the KFS officers. On top of that, Chomba et al. adds that the CFAs has no external source of funding but majorly depend on their membership contributions to finance their activities.

CHAPTER 5

CONCLUSION AND RECCOMMENDATIONS

5.1 Conclusions

Forest cover change due to human activities that has led to deforestation anddegradation is an environmental concern in Katimok area. The results from this study have indicated that there has been a decline in forest cover since 1985 at a rate of 0.04% per annum. Two major anthropogenic activities that have resulted in the decline of Katimok forest cover are conversion to agricultural land and logging. Areas that were once covered with dense forest lands in the early 1980s have been turned into farmlands and build-up areas. The degazzettment of the forest in 1989 to allow for human settlement, infrastructural development, such as construction of hospitals and schools in the former forest land reduced forest land from its original size.

From the results, it is also clear that the climate of the area has changed. There has been a slight increase of temperatures as indicated in the results, and this has led to shrinkage of rivers. The results also show that the rainfall patterns have become erratic. Sometimes it rains too much causing floods and at other times there is no rain at all. This unpredictability in the rainfall patterns has affected the cropping cycles of the farmers leading to losses. Change in climate has also been manifested by the change in the planting seasons, the appearance of invasive species and the emergence of diseases associated with extreme weather conditions.

Regarding the perception of the community on the effects of their activities on the ecosystem, the results indicate that a larger percentage of them seem to be aware of their actions on the ecosystem. Majority of those who are aware are educated while those who are not aware have little or no education. Therefore, according to the household survey results, their level of awareness on the effects of their activities on the forest ecosystem is largely dependent on their level of education.

All in all, the trend in ecosystem services has been declining as gathered from the findings of this study. There has been loss of certain medicinal plants, reduction in the water levels and water points, decrease in mushroom and honey and even disappearance of some wild animal and bird species. All these impacts arise from the community's unsustainable utilization of the forest and forest resources.

5.2 Recommendations

To sustainably utilize and manage the forest ecosystem, the following feasible recommendations are made based on the findings and conclusions drawn from this study

1. The forest cover change that has occurred is as a result of overexploitation of forest resources, therefore, economic empowerment of the communities surrounding the forest needs to be carried out so that the residents can explore other avenues of income generation
2. To curb further negative changes in forest cover and ecosystem services, it is important to sensitize the community on the consequences of destroying the forest and instill a sense of responsibility in them so that they can be in the forefront in forest conservation activities
3. To minimize the impacts of forest cover change on ecosystem services, important plant species of socio-cultural and economic significance to the community should be conserved to ensure their continual utilization amongst the communities.
4. To mitigate changes in local climate and achieve a positive trend in forest cover, the communities should be encouraged to plant trees on their farmlands (10%), especially gravellier and croton which grow fast, and where possible establish private forests to avoid overdependence on forest resources.
5. More research needs to be carried out in order to understand the different effects of climate change at the local level and its adaptation mechanisms

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APPENDICES

APPENDIX 1: HOUSEHOLD QUESTIONNAIRE

I am an MSC student at Egerton University, department of Environmental Science. I am conducting a research on Forest cover changes and their impacts on ecosystem services in Katimok Forest Reserve in Baringo County. This household survey is therefore for this purpose, and the findings will be used purely for academic purpose and for enhancing community awareness in forest management. You are kindly requested to provide honest answers regarding the local forest status and the various services obtained from the forest. Your responses will be held in confidentiality and used only for the above mentioned purposes. Thank you in advance for your cooperation.

SECTION A: DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS OF THE HOUSEHOLD

Survey Date…………………..

Respondents Personal Detail

1. Location…………………, Sub-location…………………, Village……………………...
2. Respondent Name (optional)…………………………………………………………….

For the following questions tick appropriately

3. Respondents' gender: A. Male [ ] B. Female [ ]
4. Respondents' age bracket: A. 18-34 [ ] B. 35-49 [ ] C. 50-64 [ ] D. 65+ [ ]
5. Role in the family A. Father [ ] B. Mother [ ] C. Child [ ] D. Visitor [ ] E. Employee [ ]
6. Are you originally from this Village? A. Yes [ ] B. No [ ]
7. How long have you been living in this Village? A. 30 years [ ] B. 20-29 years [ ] C. 10-19 years [ ] D. < 10 years [ ]
8. Respondents' level of education A. None [ ] B. Primary [ ] C. Secondary [ ] D. College/University [ ]
9. Number of people in the household A. 1-5 [ ] B. 6-10 [ ] C. More than 10 [ ]

10. Principal occupation of the respondent A. Professional job [ ]B. Casual work[ ] C. Farming [ ]D. Other [] specify…….
11. Major source of income A. On-farm (crop) [ ] B. On farm (livestock) [ ] C. Off-farm [] D. Forest dependent [ ]

SECTION B: HOUSEHOLD QUESTIONNAIRE

1. Forests provide a number of ecosystem services, as listed in the table below, that are of benefit to local communities. In this question you are requested to tick the ecosystem services that you obtain from Katimok Forest as well as its benefits.

Ecosystem Service	Benefit Obtained	Use of the service (for sale, domestic use or both)	
Provision of foods	Fruits (specify) Honey Wild meat Water Other (Specify)		
Provision of raw materials	Fuel wood Fibre Fodder Construction materials Genetic resources Medicinal products (name) Timber Poles Charcoal		

	Other (Specify)		

2. Where do you graze your livestock? (If any)

   A. In my farm [ ]   B. In the forest [ ]   C. Any other place (Specify) [ ]

3. Do you get income from the forest?

   A. Yes [ ]   B. No [ ]

4. If yes, what service gives you the most income?

   A. Timber [ ]   B. Charcoal [ ]   C. Honey [ ]   D. Construction material [ ]

   E. Other (specify) [ ]

5. To what extent do you rely on these services for your livelihood?

   A. Greatly reliant   B. Moderately reliant   C. Least reliant   D. Not reliant at all

6. What effects does your derivation of these ecosystem services have on the forest

   A. Degrades the forest [ ]   B. Improves the condition of the forest [ ]   C. No effect at all [ ]

7. How long have you lived in the environs?

   A. 1-5 years [ ]   B. 6-15 years [ ]   C. 15-30 years [ ]   D. More than 30 years [ ]

8. If the forest was converted, what would you like it to be?

   A. Agricultural land [ ] B. Grazing land [ ]   C. Settlement land [ ]   D. any other (specify)

9. How would you benefit from the forest if it was conserved?

   A. It improves the ecosystem services that I get [ ]   B. It preserves the cultural values [ ]

   C. It promotes forest sustainability [ ]   D. It has no benefit for me [ ]

10. If the forests were to be extinct today, how would you describe your livelihood?

    A. Improve [ ]   B. Remain the same [ ]   C. Reduce [ ]

11. How would you term the forest’s contribution to your livelihood?

A. Greatly improves my livelihood [ ]   B. Moderately contributes to my livelihood [ ]

C. Least contributes to my livelihood [ ]   C. No contribution to my livelihood [ ]

12. How would you describe the climate of the area since 1985?

A. Has changed positively [ ] B. Has change negatively [ ] C. Has not changed at all [ ]

13. How would you describe the forest cover since 1985 to date?

A. Increased [ ] B. Decreased [ ] C. Remained the same [ ]

14. In your opinion, does the change in climate relate to forest cover?

A. Yes [ ] B. No [ ]

15. If yes, how has the forest cover influenced the local climate?

16. What is your perception on ecosystem services and forest cover?

17. What is your perception on forest cover and climate change?

18. In your opinion, has the forest cover changed?

19. If yes, how?

A. Increased [ ] B. Decreased [ ]

20. What cultural benefits does the forest provide?

A. Traditional ceremonies B. Spiritual ceremonies C. Recreation D. Education

21. Are there any tree species that are highly valued by the community?

A. Yes [ ]   B. No [ ]

22. If yes, which ones?

23. What is the significance of the tree?

24. Rank the ecosystem services in order of importance

APPENDIX 2: INTERVIEW SCHEDULE FOR FGD

1. What activities related to forest protection and conservation do the local people engage in?
2. What environmental changes have you noticed in the area in the last ten years?
3. What are the main challenges facing the conservation of the forest in the area?
4. Are there any traditional festivals in your community that are conducted and relates to the forest or materials derived from it?
5. Are there any places or trees in the forest that the community consider sacred/historical?
6. What is the significance of the tree/place to the community?

7. How has been the Climate change in the area?
8. Does PELIS help in conserving the forest or the community more
9. What are the limitations of the PELIS system

APPENDIX 3: FIELD OBSERVATION CHECKLIST

1. State/condition of the forest
2. List of provisioning, regulation and cultural ecosystem services offered by the forest as observed
3. Settlements adjacent to the forest
4. Ecological features of the forest
5. Dominant plant species
6. Dominant animal species
7. Current threats to the forest
8. Ongoing activities within and around the forest
9. Current conservation efforts within the forest
10. Major land use type within and around the forest

APPENDIX 4: CONDITION OF THE FOREST AS OBSERVED

Plate 1: A Picture showing Focus Group Discussion

Plate 2: A picture showing tree density in the forest

Plate 3: A picture showing farmlands in the forest

Plate 4: A picture showing deforestation

Plate 5: A picture showing a school within the forest

Plate 6: A picture showing beehives within the forest