LAND USE CHANGES, CAUSES AND EFFECTS IN IMENTI FOREST MERU COUNTY, KENYA

BY

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DECLARATION

Declaration by the Candidate

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

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To the God Almighty for his guidance, and to my family and society in general for according me an opportunity to pursue education to this level.

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ABSTRACT

Forests provide functions and services that support livelihoods and ecosystem processes. However, despite of many interventions to sustainably manage forests, they are continually turned into other land uses undermining their capacity to effectively function resulting in many negative impacts. The ineffectiveness of these interventions could be associated with inadequate local information on land use changes and variation of their causes from one geographical place to another. Thus, this study was undertaken to evaluate changes in land use in Imenti forest, identify their causes and effects. The study employed the theory of tragedy of the commons to understand the problem. A combination of longitudinal and cross sectional designs was adopted. Multi stage stratified random sampling was used to select questionnaire participants. Questionnaires were supplemented with key informants interviews and photographs. Analyses were done in arc GIS 10.1 and excel spreadsheet 2013. The results showed that the area under indigenous forest, plantation forest and grassland decreased from 32.3%, 30.0% and 16.2% to 26.4%, 25.8% and 10.7 % and lastly to 20.2%, 20.8% and 7.5% in year 1986, 2001 and 2016 respectively. During the same period the area under agriculture and bare/built up area classes increased from 15.7% and 5.7% to 29.8% and 7.3% and then to 42.6% and 8.9%. All land use classes changed at a fluctuating rate except grassland. The distribution of change in each land use class varied from time to time and indigenous forest was mainly losing to plantation forest and active agriculture while plantation forest was mainly losing to agriculture. Farmland expansion, population increase, demand for forest products and grazing land, access to road and expansion of urban centers, insecure land tenure, inadequate participation in off farm activities and ineffective management of Imenti forest were found to be the causes of land use change in this area. On other hand loss of biodiversity, decline in soil fertility, rainfall fluctuation and increase in temperature were effects of land use change. The study concluded that a lot of unpleasant land use changes driven by a variety of causes have taken place and their effects are being experienced. Lastly the study recommended for: more studies on land use change in this area, population control, participation in other off farm activities apart from those related to agriculture and/or forests, speedy issuance of title deed, and promotion of reforestation and afforestation activities.

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OPERATIONAL DEFINITIONS

Land use: land use is the purpose for which humans exploit the land cover, while land cover refers to the physical and biological cover over the surface of the Earth, including water, vegetation, bare soil, and or artificial structures (Ellis and Pontius, 2007, p. 1). From the above definition, it can be inferred that land cover influence the type of land use and land use influence type of land cover found in that particular place. Therefore, in this study, the term land use was used inclusive of land cover.

Land use change in a layman language means an increase or decrease in the areal extent of a given type of land use. However, in broader terms land use change means either conversion or modification (Turner *et al*., 1995, p. 22). Conversion is the change from one land use category to another. On other hand modification entails alterations within one land use category. However, in this study land use modification was not investigated into.

Deforestation: is complete removal of trees and the conversion from forest into other land uses such as agriculture, mining among others (Hosonuma *et al.,* 2012, p. 13).

Sustainable Forest management: it is management of forests in a way that will maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations (FAO, 2015a, p. 23)

Causes: are drivers of land use change which can be natural or human. This study limited itself to human induced drivers of land use change due to the fact that natural factors take a long period to be manifested.

Effects: these refer to impacts of land use on the environment. The effects may be positive or negative. However, the study considered only the negative effects

ABBREVIATIONS AND ACRONYMS

ETM+	: Enhanced Thematic Mapper Plus
FAO	: Food and Agriculture Organization
GHGs	: Green House Gases
GIS	: Geographic Information System
GoK	: Government of Kenya
ILRI	: International Livestock Research Institute
KFS	: Kenya Forest Service
KFWG	: Kenya Forest working Group
KIFCON	: Kenya Indigenous Forest Conservation Programme
KLA	: Kenya Land Alliance
KNBS	: Kenya National Bureau of Statistics
LULC	: Land Use Land Cover
MCG	: Meru County Government
MEA	: Millennium Ecosystem Assessment
NEMA	: National Environment Management Authority
OLI/TIRS	: Operational Land Imager and Thermal Infrared Sensor
RS	: Remote Sensing
SEI	: Stockholm Environment Institute
TM	: Thematic Mapper
UNEP	: United Nations Environment Programme
USD	: United State Dollars
USGS	: United State Geological Survey
WHO	: World Health Organization
WWO	: World Weather Online

CHAPTER ONE

INTRODUCTION

This chapter starts by presenting the background to the study, followed by a statement of the problem, research objectives, research questions, and significance of the study. The chapter also goes on to state the scope and limitation of the study, and lastly, it closes by giving a description of the study area.

1.1 Background to the Study

Globally, forests provide functions and services that support livelihood and ecosystem processes. For instance, they provide shelter, habitat, fuel, food, fodder, fiber, timber, medicines, security and employment. In addition, they regulate freshwater supplies, store carbon and recycle nutrients among others (United Nations Environment Programme [UNEP], 2012). However, despite the aforementioned importance, forests are slowly being turned into other land uses. This undermines their capacity to effectively function which results in many negative impacts.

Over the years, the world has experienced an unprecedented loss of its forests, particularly in the Tropics. However, during the period of 2010 to 2015, globally forest was being converted to other land uses at a rate of 3.3 million hectares (ha) per annum compared to 7.3 million ha in 1990-2000 (Food and Agriculture Organization [FAO], 2015a, p.16). Although the above figures indicate a decline in the global rate of deforestation, the current global forest cover of only 3,999 million ha (FAO, 2015a; MacDicken, 2015; Keenan *et al*., 2015), is far less when compared to the approximated original forest cover of 6,000 million ha (Bryant, Nielsen, & Tangley, 1997). This implies that the deforestation rate is still high and alarming.

In Africa, little is known about rates of forest conversion due to insufficient studies on processes of deforestation (Lung & Schaab, 2010). However, according to FAO (2010a, p. 229), Africa lost around 3.4 million ha of forests per year during the period of 2005-2010. This left about 21.4 % of the land area or 674 million ha under forest cover. Further, the same report indicated that the annual rate of forest loss in Kenya, Tanzania and Uganda was 0.4%, 1.2%, and 2.7% respectively. In addition deforestation Kenya water towers is estimated to have amounted to 50,000 ha during the period of 2000 and 2010 (FAO, 2010b).

However, in recognition of the fast disappearance of forests, interventions to sustainably manage or conserve forests such as government-owned protected areas, private conservation parks, community participation in the management of forests among others have been implemented over the time (Nagendra, 2007, p. 15218). In addition, there has been a call for substantive studies on land use changes in international forums like the 1972 Stockholm Conference on the Human Environment, and the 1992 United Nations widely Conference on Environment and Development (Fan, Weng, & Wang, 2007). Although a recognized problem, the rate and extent of deforestation varies across continental, national, regional and local boundaries (FAO, 2005). Therefore, as Adams (2009) noted, research and policy development on deforestation should be location specific.

Studies such as that of Geist and Lambin (2002), Nagendra (2007), Mwavu and Witkowski (2008), and Government of Kenya ([GoK], 2013a) among others reported varying causes of land use change. For instance, Geist and Lambin revealed that agricultural expansion, wood extraction, infrastructural expansion, were some the causes of land use change in Africa while Nagendra showed that tenure regimes, monitoring and user group size as the causes of land use change in Nepal. These variations echo Rudel, De Fries, Asner, and Laurance (2009, p. 1401) that "the causes of land use change vary from one geographical location to another and from time to time". Thus, the findings of one study in a particular forest should not be generalized to other forests. Instead, the location specific causes in each forest should be investigated.

In Kenya, many reforms have been designed and implemented in an endeavor to conserve and or sustainably manage forest resources. For instance, there has been the establishment of; forest department, Shamba system, forest policy of 1957, forest act of 1968, Nyayo Corporation Tea zones among others (Imo, Ogweno, Senelwa, Ochieng, & Balozi, 2009). In addition Despite the above reforms the area under forest cover is said to have declined from approximately 30% in the year 1895 (Klopp, 2012) to 6.01% in 2000 (Kenya Forest Service [KFS, 2013]).

Although there has been a reversed trend in the area under forest, that is the area under forest cover in Kenya is said to have increased from 6.01% in the year 2000 to 6.99% in 2010 (KFS, 2013; FAO, 2015a). The 6.99 % is still below the 10% constitutional requirement (GoK, 2014, p. 1). In addition, FAO (2010b, p. 9) reported a general decline in natural and public planted forests and an increase in private and community forests. This implies that deforestation is still on and it is likely to continue threatening the remaining forests if no well-informed measures are put into place.

Imenti forest is of valuable importance to the adjacent community and to the entire economy of Kenya in general. The forest supports the livelihood of adjacent people, acts as a migratory corridor for animals from Mt Kenya to Meru National Park, in addition to being sub-catchment of tributaries draining into Tana drainage system where the highest proportion of country's hydro electricity comes from (Kenya Indigenous Forest Conservation Programme [KIFCON], 1994; Gathaara, 1999).

However, this forest has experienced vast destruction (Gathaara, 1999; Vanleeuwe, Woodley, Lambrechts, & Gachanja, 2003) in the past and still, this destruction continues unabatedly.

This persistent destruction of Imenti forest in spite of many reforms in place aimed at conservation or sustainable management of forest in Kenya suggests that these reforms are insufficient. Thus an evaluation of how land uses have been changing in the Imenti forest over the past three decades, and an identification their causes, as well as their effects, is vital in updating the existing information upon which new useful intervention policy aimed at reversing or curbing this situation can be based.

1.2 Statement of the Problem

Imenti forest is of valuable importance to the adjacent community and to the entire economy of Kenya in general. However, despite its immense importance, Imenti forest has experienced vast destruction in the past (Gathaara, 1999; Vanleeuwe *et al*., 2003). In addition, this destruction continues unabatedly despite of many interventions aimed at sustainable management and or conservation of forest in Kenya.

The continued destruction of this water tower suggests that; there is inadequate detailed and accurate local information about forest cover changes in Imenti forest, and the presumptions regarding the causes of land use change in this study area may be inaccurate or incomplete. The above are some of the prerequisites for sustainable ecosystem management (Coppin, Jonckeere, Nackaerts, Muys, & Lambin, 2004; Odada, Ochola, & Olago, 2009a). It is against these backdrops that this study was carried out to update the existing information upon which formulation of effective policies for sustainable management of Imenti forest and other land uses can be based.

1.3 Objectives of the Study

1.3.1 General objective

The general objective of this study was to evaluate how land uses have been changing in the Imenti forest from 1986-2016, identify their causes and effects, with an aim of updating the existing knowledge upon which past forest policy have been formulated.

1.3.2 Specific objectives

Specific objectives of the study were:

1. To assess how land use has been changing in Imenti forest from 1986 to 2016.
2. To identify the causes of land use changes in Imenti forest.
3. To determine the effects of land use change in Imenti forest.

1.4 Research Questions

This research attempted to answer the following questions:

1. What is the extent, rate, and distribution of land use change in Imenti forest from 1986-2016?
2. What are the causes of land use change in Imenti forest?
3. What are the effects of land use change in Imenti forest?

1.5 Significance of the Study

Forests and their associated species are of great economic, scientific, educational, aesthetic and environmental conservation importance to our country. However, external pressure on these forests, especially Imenti forest weakens their capacity to effectively function. This in the long run has resulted in prolonged drought and frequent floods in some parts of the country. This research study was therefore expected to contribute critical information to all stakeholders who have their own interest to minimize or avoid the adverse impacts of land use change in this area.

In Africa there is the unavailability of adequate, accurate and up to date resource information due to insufficient studies focusing on deforestation (Lung & Schaab, 2010). This trend is reflected in Kenya, where there exist many outdated and varying forest cover estimates (Kenya Forest Working Group [KFWG], 2005, as cited in Ndegwa, 2005). In addition, most these forest estimates are mainly national figures and though important in evaluating long-term trends, they may not reflect the local conditions. Thus the determination of the extent, rate and distribution of land use changes in this study was hoped to be of paramount importance in creating an understanding of the changes of local forest and other land uses among forest stakeholders upon which the design of locally innovative and sustainable forest management interventions would be based.

The persistent destruction of Imenti forest suggests that the presumptions regarding the causes of deforestation upon which the policies in place have been based may be inaccurate or incomplete. The formulation of new effective policies requires up to date information on causes of land use change (Odada *et al*., 2009a). Thus the need for assessing the causes of land use change in this study to update the existing knowledge upon which the formulation of alternative effective policies could be based.

Land use change or deforestation in particular, is a location specific issue (Adams, 2009). Therefore, this study was further hoped to serve as a good basis for the researchers and scholars who may have a strong desire to carry out a research on this or related topics in this study area or elsewhere.

1.6 Scope and Limitation of the Study

The study covered Imenti forest and the adjacent areas within 3.5 kilometers (km) around the forest boundary. The total spatial area of the study was 466km^2. The analysis of imageries covered a duration of 30 years from 1986 to 2016 with three-time series covering, 1986, 2001 and 2016. Further, a cross-sectional survey to identify the causes and effects of land use change was limited to only five sub locations.

Like any other research, this study also experienced some challenges. First, the study targeted to acquire four images at an interval of 10 years from 1986-2016. However, this was not possible due to lack of cloud-free same season images. Thus how the study ended up with three images at an interval of 15 years. Further, some of the respondents were absent during the field visit, so the researcher had to reschedule the field time and pay tolerance to get them.

1.7 Description of the Study Area

1.7.1 Geographical location

The study area is located in the eastern province of Kenya in Meru County, approximately 225km northeast of Nairobi. The largest proportion of Imenti forest lie in Imenti North constituency and only small proportions of it are found in Imenti central and Tigania west constituencies of Meru County (Meru County Government [MCG], 2013; Kenya National Bureau of Statistics [KNBS], 2009). According to the Universal Transverse Mercator projection, this study area falls within zone 37North and approximately between the latitude 0° 08’ south to 0° 10’ north and the longitude 37°30’ and 37°50’ east (Figure 1.1).

1.7.2 Geology and soils

The study area is generally covered with volcanic igneous rock and pyroclastic unconsolidated materials of Pleistocene geological period towards mountain area (Baker, 1967). The southern and eastern part of the study area is underlain mainly by basalts from the Mt. Kenya volcanic series. The northern part of the study area is composed of the Nyambene lava volcanic, which are low lying and with particularly shallow and rocky soils.

Some areas of Imenti Forest are dispersed with tuffs and ashes near craters and vents. Ashes and fine agglomerates are well exposed south and west of the Kathita River, and these are overlain by well bedded sandy and pisolitic ashes (Baker, 1967). Generally, the soils of this area are red, deep consisting of moderately to highly fertile loams mostly of volcanic origin. These soils include nitisols, andosols, andic and chromo-luvic, andic and nitochromic cambisols (Olago, 1995).

1.7.3 Topography and drainage

The study area falls within an altitude 1120 to 1800 m above sea level. The slope of the study area falls gently from the west side to northern and eastern side. The area is also characterized by several hills and valleys in the northern and eastern part of the study area.

The drainage of the area is characterized by Crater Lake and tributaries and streams such the Kaonde, Kinyaritha, Kagene, gachioma which drains into Kathita River, a tributary of the Tana River drainage system (KIFCON, 1994). However, there are also swamps, boreholes, and springs in this area.

1.7.4 Climate

The climate of this region can be described as cool and warm. The mean annual temperature of this area has been estimated to range from 18-22ºC, with the coldest and hottest months being July (12.4°C) and February (24.5°C) respectively (Olago, 1995; GoK, 2000). The area also experiences a relative humidity of 68% and the north east and south east wind, which blows at a speed of 4 meters per hour.

The area is characterized with bimodal rainfall, with long rains occurring during March to May and short rains during October to December. The rainfall in the study area varies from 380 to 2500mm. The areas around Meru town experiences the highest amount of rainfall (900-2500) mm due to its highest elevation, while northern and eastern part of the study area receives less rainfall of 380 to 1000 mm due to the shadowing effects of Mt Kenya and Nyambene hills respectively (KFS, 2010).

1.7.5 Biodiversity

Imenti forest is rich with a variety of both indigenous and exotic trees. On its western side (towards Mt. Kenya), the forest is dominated by tree species such as camphor (*Ocotea usambarensis*), red stink wood (*Pygeum africanum*), podo (*Podocarpus latifolius*) and Cypress (*Cupressus lusitanica*). On the eastern side (lower part) the forest is characterized by tree species such as Elgon Olive (*Olea capensis*), velvet bush willow (*Combretum molle*), white stinkwood (*Celtis africana*) and Abyssinian coral (*Erythrina abyssinca*) (Beentje, 1991, as cited in Gaathara, 1999; Nzokia, 1991).

The surface of Lake Nkunga is covered by vegetation like water lillies (*Nyamphaea)*, sedges *(Cyperaceae*) and ferns (*Pteriodophyta*) (Ficken *et al*., 1998). In addition, the lake is rich in fish (tilapias) as well as bird population like the crested crane, the little eaglet, the crested eagle, and various species of ducks. Imenti forest also hosts large herds of resident and migratory elephants, which frequent the area during the dry season. Other wild animals found in this forest include monkeys, baboons, buffaloes, hyenas, birds, reptiles, and insects (Gathaara, 1999).

1.7.6. Human and economic aspects

The people living around Imenti forest are mainly Imenti dialect speaking people who form a sub-tribe of the Ameru people of Kenya. However, the area is also occupied by a small proportion of Tigania dialect speaking of Ameru although in isolation. According to KNBS (2009), Meru County had a population growth rate of 2.1 percent. In addition, the same report indicate that Imenti north, Tigania west, and Imenti central constituencies where the study area lies had a total population density of 509, 298 and 351 people per square km respectively by the year 2009.

Due to its close proximity to Meru town and the expanding universities such as Kenya Methodist University and Meru University, people from other parts of Kenya have settled in the area. The highest proportions of these people include the Agikuyu, Aembu, Agusii, and Akamba communities. However, there are also some proportions of Borana, Somali, Asian and a few Caucasian whites in this region. The land use around Imenti forest is characterized mainly by small-scale farming of beans, potatoes, maize, livestock keeping, coffee, groundnuts, wheat, barley, tobacco and pyrethrum.

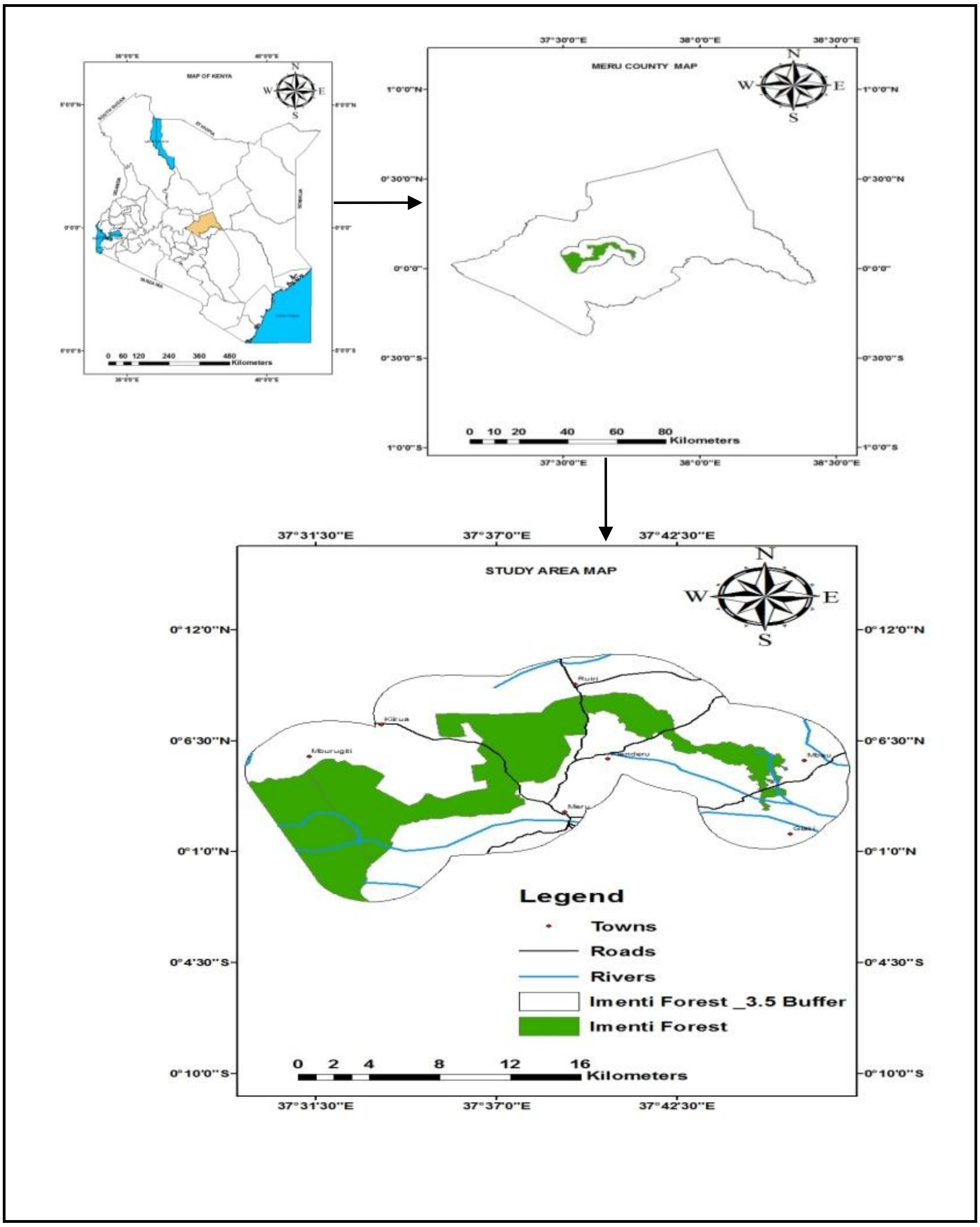


Figure 1.1: Study area map
Source: Modified from ILRI (2007) & KIFCON (1994)

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews the related literature gathered from textbooks, journals, reports and theses. It aimed at identifying the gaps to be filled and the contribution to the general body of knowledge.

2.1 Forest Cover Change

Studies have estimated and proven that forests covered a large portion of the Earth's land area several years ago. For instance Bryant *et al*. (1997) estimated that the original global land area under forest was approximately six billion hectares. However, this global forest area has been deforested, degraded and reduced to only 4 billion ha, or 31% of the global land area (FAO, 2015a; MacDicken, 2015; Keenan *et al*., 2015).

In addition, these studies continued to claim that 44% of this global forest cover is found in the tropical countries, 26% in the temperate countries, 22% in the boreal countries and 8% in sub-tropical countries. That notwithstanding the above studies went on to report that the global deforestation rate declined from 7.3million ha per annum in the period of 1990-2000, to 4.6 million ha in 2000-2005, then to 3.4 million ha between 2005-2010 and lastly to 3.3 million ha per annum between 2010-2015 (FAO, 2015a; MacDicken, 2015; Keenan *et al*., 2015).

However, the global statistics on the rate and extent of deforestation are extrapolations from local, national, and continental findings, thus they vary among continents, countries, regional and local boundaries (FAO, 2005). As such these global estimates on the extent of deforestation may be misleading due to underestimation or overestimation and general changes of parameters and internal variations within the different locations (Keenan *et al*., 2015). This supports Adams (2009) viewpoint that research and policy development on deforestation should be location specific.

In Africa, less is known about rates of forest conversion due to insufficient studies on processes of deforestation (Lung & Schaab, 2010). However, according to FAO (2010a, p. 229), Africa lost the second largest amount of forest after South America during the period of 2005-2010. That is, the continent lost around 3.4 million ha of forests per year during this period. This left about 21.4 % of the land area or 674 million ha under forest cover. Further, the same report indicated that the annual rate of forest loss in Kenya, Tanzania and Uganda was 0.4%, 1.2%, and 2.7% respectively.

Forest clearing in Kenya can be backdated to 1897 when European settlers cleared forests to provide room for commercial farming and supply fuel wood for Uganda-railway construction (Mwangi, 1998). The process continued even after independence some purely for public interest like to build public utilities like schools and hospitals and also to settle landless (Mathu, 2007). However, the late 1990s and early 2000s had several politically motivated excisions of forested area. For example, Mathu reported that in the year 2001, a total of 67,000 ha were cleared in Mau and Mt Elgon without undergoing the process envisaged in Environment Management and Coordination Act of 1999.

In addition, the creation of the Nyayo Tea corporation in 1986 to buffer people from the forest and create employment in Mount Kenya, Mount Elgon, West and East Mau, Trans Mara, Tinderet, North and South Nandi, Kakamega, Kipkabus, Uplands, Kikuyu escarpment and the Aberdares also resulted in a total of 11,000 ha of forest land converted into tea plantations as people extended the tea zone strip up to about 25 kilometers (Mathu, 2007).

In 1895, Kenyan forest covered 30% of the land area (Klopp, 2012). However, the forest estimates for the year 2005 and 2010 indicates that forest covered 6.84% and 6.99% of the total land area (KFS, 2013; FAO, 2015b). Although the above estimates suggest a reversed trend in forest cover, the 6.99% is still below the constitutional requirement (GoK, 2014, p. 1) and the recommended threshold by the United Nations (FAO, 2010b).

Moreover the positive trend in forest cover could be as a result of an offset of the decline in natural and public planted forests and increase in communal and private forests (FAO, 2010b, p. 9). Further, these forest estimates are national figures and though useful in evaluating long term trends, they may not reflect the local conditions. Thus the need for mapping the local forests like Imenti forest so as to inform policymakers on their extent, rate and the distribution of their change.

2.1.1 Use of Remote sensing and GIS in land use change studies

Remote sensing (RS) is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand, Kiefer, & Chipman, 2008). On the other hand, Geographic Information Systems (GIS) is a computer data system capable of capturing, storing, analyzing, and displaying geographically referenced information (United State Geological Survey [USGS], 2007).

Several satellite imageries are available such as Landsat series, Spot, Aster, Ikonos, Quick Bird, Geoeye, amongst others. However, the Landsat series archive is available at no cost to the scientific community (Chander, Markham, & Helder, 2009), this provides a wealth of information for identifying and monitoring changes in man-made and physical environments (El Bastawesy, 2013, as cited in Kumar, Babu, & Reddy, 2017). Integration of RS and GIS in the evaluation of changes in forest cover or land use, in general, has achieved a lot of success in the recent decades.

Pandit (2011) demonstrated the utility of GIS and RS in monitoring the status of the forest by investigating forest cover change of laljhadi forest in Nepal over the spatial and temporal scale. The result of change detection revealed a decrease in forest coverage from 63.73% to 35.9% during the period of 1996 to 2010 which compensated for an increase in bush area from 1.37% to 29% during the same study period. Further, the study also recommended the need for updating national land use data that the study stated that it could be done through increased and intensified use of RS and GIS in monitoring natural resources, especially forest for better results and frequent updates.

In southwestern Nigeria a study by Oyinloye and Oloukoi (2013), assessed the competition between land use and land cover and highlighted the ensuing environmental impacts using multi-temporal Landsat data sets acquired between 1972 and 2002. The data sets were processed and analyzed using ILWIS version 3.3 Software. The study found that land use types were rapidly colonizing the forest reserve land cover type. In addition, the projections made indicated that there would be no forest outside the forest reserves in the area if no measure is taken to check or control the land use practices within the next two to three decades.

In Ethiopia a study by Hailemariam *et al*. (2016), utilized GIS and RS to show that forest had lost most of its area to other land use classes (123,751 ha) while farmland class had gained from other LULC classes (292,294 ha) during the period of 1985 to 2015. Similarly a study by Houessou, Teka, Imorou, Lykke, & Sinsin, 2013 in “W” Biosphere Reserve in West Africa used GIS and RS to revealed that Probability transition matrices for woodland and savanna vegetation to be changed into cropland outside the reserve were high (>0.6) in the southern part and moderate probabilities (0.3 to 0.5) in the northern part of reserve.

Mwavu and Witkowski (2008) in Bugondo forest analyzed changes in land use and land cover around the Budongo Forest Reserve from multi-temporal Landsat images of 1988 and 2002 with a view to understand the dynamics of land use and land cover changes, especially deforestation and associated agricultural developments from 1988 to 2002. The study established that during the study period of 1988-2002, areas of forests/woodlands outside the forest decreased by 8.2%, while areas under sugarcane plantations and subsistence agriculture increased substantially by over 17 folds. The study also recommended that "future studies should consider more recent changes and also attempt to assess the changes within the interior of the forest at a finer scale of resolution as it faced increased selective timber and pole harvesting" (p. 619).

Ayuyo and Sweta (2014) aimed at creating a geospatial tool for land cover and land use (LULC) change detection in the Mau forest complex that could be used in decision making. Through analysis of Multispectral Landsat imageries for 1973, 1986, 2000 and 2010 using ENVI 4.8 software, the study was able to successfully reveal that changes in land use and land cover had occurred in all the 22 blocks of Mau forest complex and resulted in the reduction of forest cover. In addition, this study was able to vividly show that conversion of forest land to agricultural land was the main cause of deforestation in the Mau complex.

Gathaara (1999) undertook an aerial survey of Mt. Kenya, Imenti and Ngare Ndare forest to provide a rapid systematic assessment and monitoring baseline information on these forests. Although the study clearly illustrates that these forests were under extreme threats emanating from charcoal production, extensive illegal logging of indigenous tree species, and abuse of the Shamba system. This study visually interpreted the aerial photographs collected to identify deforestation areas and later these areas were confirmed through a field survey. Land cover mapping using traditional aerial photography is expensive, time consuming, and is not easily translated into a geographical information system. Further, interpretation of aerial photographs is very difficult especially when the study area is large (Zubair, 2006).

Vanleeuwe *et al*. (2003) on other hand conducted a study on Mt Kenya forests to assess its damage from 2000-2002. This study used a visual interpretation of Landsat Thematic Mapper (TM), and Enhanced Thematic Mapper (ETM+) images, and aerial photography. However the visual interpretation of satellite images and aerial photography can be very subjective and thus difficult to replicate, and its success depends on the experience of the analyst (Coppin *et al*., 2004).

Ndegwa (2005) conducted a study in Mt Kenya forests to establish baseline conditions for the forest resources for 1976 and to assess how this has changed through 2002. The study concluded that satellite RS provided a quicker and more efficient method of forest change monitoring compared to the traditional mapping using aerial photographs. More so this study underlined the importance of post classification comparison technique as a good change detection method that provided from-to information and minimized the problem of normalizing for atmospheric and sensor differences between two dates.

However, the above study by Ndegwa recommended the need for more studies utilizing satellite RS in monitoring forests in Kenya so as to update existing maps and provide a more accurate and efficient method to detect changes. In addition, this study recommended future research on causes and effect of forest cover change. The present study was undertaken to fill this gap by using 1986 TM, 2001 ETM+ and 2016 Operational Land Imager and Thermal Infrared Sensor (OLI/TIRS) land sat imageries and arc GIS 10.1 software to evaluate changes in land use in Imenti forest and later identify their causes and effects.

2.2. Causes of Land Use Change.

Land use or land cover change may occur as a result of natural processes such as climatic variations, volcanic eruptions, changes in river channels or the sea level among others. However, most of the present and the recent past land use or land cover changes are due to human actions such as the use of land for production or settlement (Turner *et al.*, 1995, p. 27). This is probably due to the increasing human footprints on the Earth's surface.

Considerable research has been conducted to identify the causes of land use or land cover changes, for instance a study by Geist and Lambin (2002) on the proximate and underlying driving forces of tropical deforestation based on 9 out of 152 case studies in Africa revealed that agricultural expansion, wood extraction, and infrastructure extension were the proximate causes of deforestation. In addition, Geist and Lambin also established that these proximate factors were driven by the following underlying factors:

(i) Economic factors these entailed commercialization and development of timber markets; product price increases, especially of cash crops; low domestic costs for land, labor, fuel, and timber; the requirement to generate foreign exchange earnings at the national level; and frontier colonization in the form of either poverty or capital driven deforestation.

(ii) Institutional factors included formal pro-deforestation measures such as policies on land use and economic development related to colonization, transportation or subsidies for land based activities; land tenure arrangements and policy failures such as corruption and mismanagement of the forestry sector; insecure ownership, quasi-open access conditions, maladjusted customary rights and legalization of land titles.

(iii) Technological factors such as agro-technological change and poor technological applications in the wood sector

(iv) Cultural and sociopolitical causes, for example, attitudes of public, unconcerned about forest environments

(v) Demographic factors which included in-migration of colonizing settlers into sparsely populated forest areas resulting in higher population densities.

In Nepal, a study by Pandit (2011) on the lalhjadi forest area corridor of kanchanpur district reported that the causes of forest cover change were; encroachment by flood victims, open grazing of cattle in the critical area of the forest, expansion of cultivated land in forest and population increase. Further, a study by Nagendra (2007) on drivers of forest cover changes in Nepal found that tenure regimes, monitoring and user group size per unit of forest area were significantly associated with forest cover change. Further, Nagendra study revealed that lack of monitoring was associated with deforestation while different levels of monitoring resulted in differing levels of reforestation. Nonetheless, the study also found that management of social conflict, adoption of new technologies to reduce pressure on the forest, and involvement of users in forest maintenance activities influenced forest cover change.

In Ethiopia, Hailemariam, Soromessa, and Teketay (2016) study in Bale mountain Eco region found that the major factors of land use land cover change were population growth and cropland expansion. More also the study reported government policy (conversion of grazing lands to farmland), weak institutional arrangements and law enforcement as other factors that contributed to land use land cover change in Bale mountain. Elsewhere in Gelana sub water catchment, Ethiopia a study by Miheretu and Yimer (2017) found land use and land cover changes in this study area were driven by population growth and its associated growing demand for cultivated and rural settlement and forest for extraction of fuel and construction materials.

In Lake Victoria Basin, a study by Lung and Schaab (2010) that assessed land cover change and its drivers around three protected areas, Kakamega-Nandi forests in Kenya, Mabira, and Budongo forests in Uganda, revealed that population pressure was the major driver of deforestation. In Uganda, a study by Twongyirwe *et al*. (2011) in Bwindi impenetrable forest found that land use land cover change was as a result of land use pressure due to population growth, change in socioeconomic conditions and institutional arrangements.

In Tanzania, a study by Makunga and Misana (2017) in Masito Ugalla Ecosystem found that agricultural expansion, wood extraction and expansion of the settlement area as the proximate causes of deforestation and forest degradation. In addition, the study revealed that the drivers behind the aforementioned causes were population growth, poverty, poor levels of education, lack of employment, corruption, and embezzlement of public funds by politicians and senior government officials and high demand for fuel wood. Nonetheless, the study also found that biophysical factors such as unplanned fires and civil strife events also caused deforestation and forest degradation in this study area.

Elsewhere on the slopes of Mt Kilimanjaro, Tanzania, a study by Misana, Sokoni, and Mbonile (2012) found that the land use and land cover changes were driven by factors such as demographic, government policies, economic, socio-cultural factors including the land tenure system, institutional factors, technological change and infrastructure development.

In Kenya, according to Kenya Land Alliance ([KLA],2003) land use land cover changes are as a result of population growth, agricultural potential, knowledge and practices, food security, stifling indigenous skills, misapplication of modern technological innovations, poor environmental regulation and natural and man-made disasters.

Yet the results of the regional workshops conducted by GoK (2013a) showed that agricultural expansion and harvesting or extraction of wood for charcoal or firewood are the most dominant direct drivers of forest cover loss in Kenya. In Nandi hills forest, Kenya the causes of deforestation and forest degradation were found to be heavy exploitation as a result of escalating demand for timber and fuel wood, land for cropping and grazing according to the study by Tanui and Saina (2015). While in Western and Southern slope of Mt Kenya, Kenya, the study by Bett (2005) revealed that human wildlife conflict, poverty, encroachment, lack of tangible returns, environmental degradation, market, land subdivision, lack of credit facilities, lack of technical experts and water scarcity as causes for deforestation and forest degradation.

From the above reviewed studies, it is clear that the human causes of Land Use Land cover Change reported falls into either proximate or underlying categories identified by Geist and Lambin (2002) model. Further, the above studies reinforce Rudel *et al*. (2009, p. 1401) observation that the causes of land use change differ from time to time and from one geographical location to another. So, despite the existing literature on drivers of land use land cover change, the question on what are the causes of land use land cover change in a particular geographic location say "y" still remains a black box. To address this question requires the acquisition of location specific information for fine-tuning existing knowledge (Odada *et al*., 2009b), necessary for developing useful policy interventions to reverse location specific deforestation (Nagendra, 2007). That the need for identifying the causes of land use change this study.

2.3. Effects of Land use change

Land use changes can have profound impacts on climate, soil, water, biodiversity and human well being among others (Lambin, Geist, & Lepers, 2003). Some of these impacts have been felt globally, making the issue of land use land cover change a key item on the agenda of several global environmental forums in the last few decades. For instance, the scientific research community called for substantive studies on land use change during the 1972 Stockholm Conference on the Human Environment, the 1992 United Nations Conference on Environment and Development (Fan *et al*., 2007).

At the same time, there has been signing of international agreements which touches on conservation and management of natural resources. For example, the 1971 Ramsar Convention, the 1992 Convention on Biological Diversity, and the 1992 United Nations Framework Convention on Climate Change, among others. Therefore, the problem of land use land cover change has been widely recognized and considerable commitments to have been devoted to address them.

2.3.1. Effects on climate change

Vegetation, especially forests are known as the major sinks and sequester for carbons. Deforestation and forest degradation activities like urbanization, infrastructural expansion, extensification and intensification of agricultural activities, among others release Green House Gases (GHGs) such carbon dioxide, carbon monoxide, methane, and nitrous oxide (Ellis & Pontius, 2007) to the atmosphere. These GHGs traps heat energy within the atmosphere, causing an increase in Earth's average surface temperatures.

Land use change also is known to affect the fraction of solar energy (shortwave radiation) reflected from the Earth back into space and the incoming solar energy (through cloud formation and the amount aerosols in the atmosphere). In addition, land use change affects the flow of wind and water vapor, and absorption of solar energy, thus influencing local and global climate (Chomitz, Buys, Luca, Thomas, & Wertz-Kanounnikoff, 2007).

The changing climate impacts society and ecosystems in a variety of ways. Evidence indicates that climate change can alter rainfall, influence crop yields, affect human health, cause changes to forests and other ecosystems, and even impact energy supply. For instance, in Kenya, the 1997/98 El Niño floods affected approximately 1.0 million people and resulted in an economic loss of USD 0.8 to USD1.2 billion due to damage to infrastructure, public health impacts and crop losses (Stockholm Environment Institute[SEI], 2009, p.ii). In addition, the drought of 1998-2000 has been estimated to have economic costs of United State Dollar (USD) 2.8 billion from the loss of crops and livestock, forest fires, damage to fisheries, reduced hydro-power generation, reduced industrial production and reduced water supply (SEI, 2009).

2.3.2. Effects on Soil and Water resource

Plant canopy and litter shield soil against intense sun's rays and torrential rains. The loss of vegetation, therefore, exposes soil to the agents of erosion such as animal, wind and water thus facilitating soil erosion. For instance, the study by Miheretu and Yimer (2017), observed that land use land cover change in Gelana sub catchment resulted in soil erosion, which was manifested through the formation of deep and wide gully erosion that extended from upper to lower parts of the watershed and in the cultivated land. In addition, land use conversions have been also reported to result in soil carbon losses and carbon dioxide emissions. This is due to changes in quality and quantity of biomass carbon inputs, accelerated decomposition of soil organic matter, leaching of dissolved carbon and loss of particulates through mechanical clearing, water, and wind (Powlson *et al*., 2011).

Further, forest and its associated biodiversity are indispensable in soil nutrients maintenance. As the leaves, flowers, and branches fall to the ground or as roots die, the numerous soil-dwelling animals and bacteria act on them, transforming the forest litter into organic matter, which is a reliable supply of soil fertility (Gabler, Petersen, &Trapasso , 2007). The conversion of land cover, for example, forests, grasslands, shrublands among others, to arable lands causes depletion of soil organic matter which results in reduced soil biodiversity, low crop yield and cover, and weak soil structure (Scherr & Sthapit, 2009). In addition, intensive subsistence farming or removal of crop residues from farms either through burning or use for domestic purposes depletes soil nutrients. The depletion of soil nutrients intensifies soil acidic levels, triggers soil erosion, and reduces crop yields (FAO, 2001).

According to Turner *et al*. (1995), land cover type can affect both rates of water infiltration and the amount of surface runoff (Ground and surface water). Vegetation filter and hold water for infiltration, therefore insufficient vegetation will result in reduced infiltration and increased surface runoff. This affects the quality and the availability of water for domestic, industrial, agriculture, recreation and other environmental activities leading to water pollution and water use conflicts (KLA, 2003) among others.

Deforestation and forest degradation reduces the ability of the watersheds to sustain and regulate water flows from rivers and streams. Too much water can result in downstream flooding, many of which have caused severe damages in many parts of the world. For example, the Pakistan 2010 and the Australia 2013 floods (Oyinloye & Oloukoi, 2013), the Budalangi floods (along River Nzoia) in western Kenya arising from the Cherangani Hills (GoK, 2013b) and the Tana River floods due to poor land use practices in the Mount Kenya and Aberdares catchment areas (National Environment Management Authority [NEMA], 2007).

2.3.3. Effects on biodiversity

Forests, especially those in the tropics are known as a storehouse of biodiversity. In support of this, Myers, Mittermeier, R., Mittermeier, C., Gustavo, da Fonseca and Jennifer Kent (2000) argues that tropical forests support about two-thirds of all species and contain 65% of the world's ten thousand (10,000) endangered species. Myers and others continued to add that deforestation, forest fragmentation and degradation destroy the biodiversity as a whole and habitat for migratory species including the endangered species.

Biodiversity plays a fundamental role in the functioning of the ecosystem by increasing its flexibility and resilience (Millennium ecosystem Assessment [MEA], 2005). Therefore the loss biodiversity, in turn, affects the functioning of these ecosystems which poses a risk to all people and sectors which depend on them wholly or partially. For instance, Kareri (2012) observed that the destruction of Kenya water towers was manifested in the drying up of rivers and streams. In addition, the study by Ochola, Eitel, and Olago (2010) in Kilifi, Kenya, reported a massive deforestation of mangrove forests as a result of Salt Mining activities led to the migration of native avian species making them unavailable to those who relied on them for livelihoods.

Moreover, according to the World Health Organization (WHO) report of 1999, 80% of the world population depends on herbal medicine for primary health care needs. However, studies like that of Owour and Kisangau (2006) indicates an increasing difficulty in finding some popular species of medicinal plants. The main sources for these traditional medicines are mainly forest ecosystem. The continued loss of these ecosystems, therefore, will continue to influence the health of the poor who are financially constrained and are not be able to buy modern medicine.

The above effects of land use change are disastrous and widely felt. However, to minimize or avoid the afore reviewed effects calls for a clear understanding of the effect of land use change at the local level (source). The researcher suggests this basing on Adams (2009) acknowledgment that deforestation or land use change in general is a location specific issue. The above acknowledgment and the recommendation to investigate the effects of forest cover change on ecology provided by Ndegwa (2005, p.

78) necessitated the need for determining the effects of land use change in the current study.

2.4. Theoretical Framework

This research was guided by the Garrett Hardin 1968 theory of the tragedy of the common. Hardin posited that the users of a commons are caught in a process that eventually leads to the destruction of the common resource upon which they depend on. This is because each individual continues to use the resource until the expected costs of utilization equal to the expected benefits. Since each individual does not consider the costs imposed on others, the accumulated individual decisions result in the destruction of the common.

Hardin concluded that for sustainable use, the commons could be privatized or kept as public property to which rights to entry and use could be allocated. Hardin's theory has been highly discredited on basis that the tragedy had nothing to do with intrinsic characteristics of the commons (Okoth-Ogendo, 2002). However, his theory captures a lot of elements that characterize a tragedy (Kareri, 2016).

Thus in this study, it was postulated the residents around Imenti forest in their own self interest gain have degraded and still continue to degrade this common resource (Imenti forest) through their unsustainable activities such as overexploitation for timber, poles, charcoal making and fuel wood, unregulated grazing and clearance of the forest for agriculture and settlement among others. The underlying driver of these activities is because Imenti forest is a resource that belongs to everybody (common) or none, so even if "they" don't use the resource, "someone else" will use it. This in long run has brought ruin to some or all residents through the negative impacts associated with the destruction of this forest.

2.5. Conceptual Framework

A conceptual framework describes the relationship between the main concepts of a study. It is arranged in a logical structure to aid provide a picture or visual display of how ideas in a study relate to one another (Grant & Osanloo, 2014). Accordingly, the conceptual framework below (Figure 2.1) shows that land use change could be as a result of factors such as population growth, economic development, lack off-farm activities, lack of land tenure security, agricultural expansion and intensification and increased demand for; fuel wood, grazing land, and building materials. The land use change in turn results in negative environmental effects such as the decline in soil fertility, rainfall fluctuation, increased temperature and loss of biodiversity.

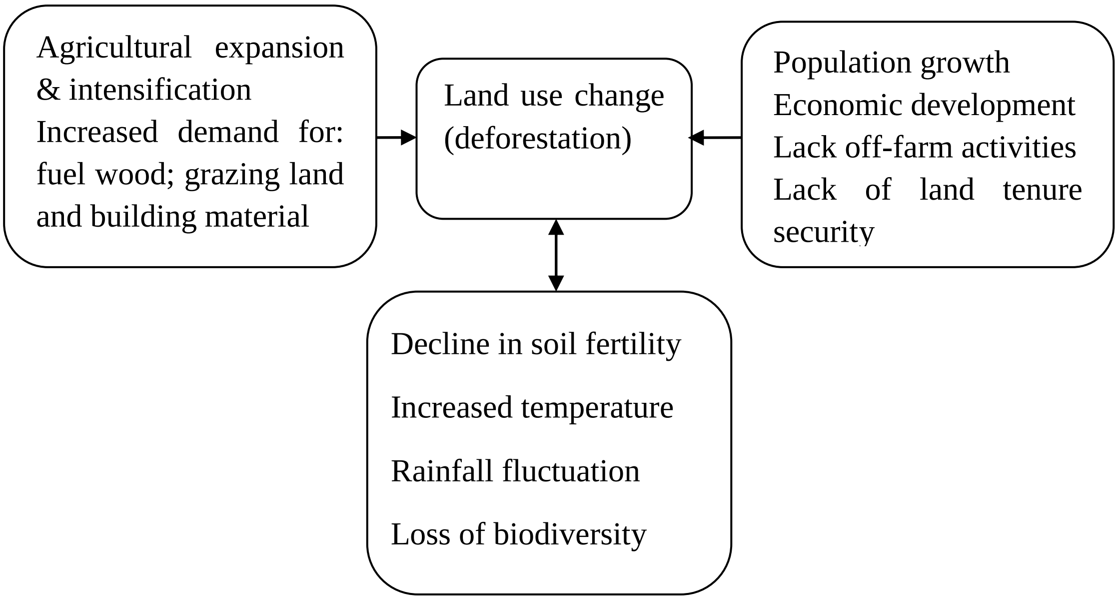


Figure 2.1: Conceptual framework
Source: Adopted from Geist and Lambin 2002; Lambin *et al*., 2003

CHAPTER THREE

METHODOLOGY

3.0. Introduction

This chapter discusses the procedures adopted while conducting this research. It starts by giving the study design, target population, sample size, and sampling procedure. Then the chapter continues to state the data sources. Lastly, the chapter ends by noting data analysis procedure and the ethical issues observed while undertaking the research.

3.1. Research Design

Research design is a blueprint or plan on how one aim to obtain answers to research questions (Welman & Kruger 2001). This study sought to evaluate land use changes in Imenti forest, identify their causes and effects. In order to obtain the appropriate evidence, the study employed both longitudinal and cross-sectional designs. Longitudinal study gathers data on a factor over time while cross-sectional study involves collecting data from a sample of the population at one specific time (Bryman, 2008).

The main aim of longitudinal study is to analyze change over time (Valkenburg & Peter 2009), therefore it was employed based on satellite images to capture how land use had changed in Imenti forest during the period of 1986, 2001 and 2016 respectively. On the other hand cross-sectional design is mostly limited to descriptions of the status quo (Bryman, 2008) and thus it was used to collect evidence to best describe the causes and effects of land use change in the study area.

3.2. Target Population, Sampling and Sample Size

The target population constituted all the residents within 3.5 km buffer around Imenti forest. The multistage stratified random sampling was used to select questionnaire participants. In the first selection, the Imenti north constituency was purposely selected because of the existence of a large portion of Imenti forest within its territory (MCG, 2013; KNBS, 2009). Then the Upper Igoki, Nkabune, Munithu, Thuura, and Giaki sub locations were further purposely selected due to their close proximity to Imenti forest. The total number of households in each selected sub locations was obtained from KNBS 2009 and prepared as in Table 3.1 colum1 and 2 below.

Using Yamane's 1967 formula $n = \frac{N}{1+N(e^2)}$ where N was the total number of households (7045) and level of precision (e) was 7% at 95% confidence level, the sample size for the study was found to be 198. This sample size was then distributed to the selected sub locations proportional to the number of households as in Table 3.1 column 3 and 4.

Table 3.1: Number of households/sample size per the selected sub locations

Name	Total number of households	Proportion	n per sub location
Upper Igoki	2687	0.38	76
Nkabune	727	0.10	20
Munithu	1614	0.23	45
Thuura	1115	0.16	31
Giaki	902	0.13	25
Total	7045	1.00	198

Finally, a total of 198 households were randomly selected from the respective sub locations using the local list of households provided by the chief and in each household, the head was interviewed. More so, a total six key informants were purposively selected for interview schedule to gather in depth information on land use change, their causes and effects in this area.

3.3. Sources of Data

3.3.1. Primary sources of data

3.3.1.1. Questionnaire

After a literature review, open questionnaires were prepared to obtain the information on land use changes, their causes and effects. They were re-evaluated by supervisors and pilot tested in September 2016 with a sample of 15 household heads within 3.5 km buffer around Imenti forest. Thereafter they were amended into closed and open ended questionnaires from which every respondent was expected to respond to as the researcher or research assistant marked the answer (s).

3.3.1.2. Interview schedule

Six key informants were purposely selected on the basis of their expertise and interviewed to obtain detailed information on the changes in land use, causes and their effects in this area. These informants were three elderly people, two forest officers, and the agricultural officer of the area.

3.3.1.3. Camera

In the field, the camera was used to take photographs to capture salient information about the study. The photographs were later used in the text to support the discussion and to better describe some facts about the study.

3.3.2 Sources of secondary data

3.3.2.1 Satellite imagery

Three land sat satellite images were used in this study all with a spatial resolution of 30 meters. These were the TM for 1986; ETM+ for 2001 and OLI/TIRS for 2016 as shown in Table 3.2 and Figure 3.1 below. These imageries were chosen because they were cloud free and were acquired during the dry season, which is ideal for differentiating between vegetated and non-vegetated land use classes.

Table 3.2: Land sat images that were used in the study

Data type	Date of acquisition	Spatial resolution (m)	Path and Row	Source
1986 Landsat 5 TM	2/25/1986	30	168p 060r	USGS database (http://glovis.usgs.gov/)
2001 Landsat7 ETM+	2/21/2001			
2016Landsat8 OLI/TIRS	2/20/2016			

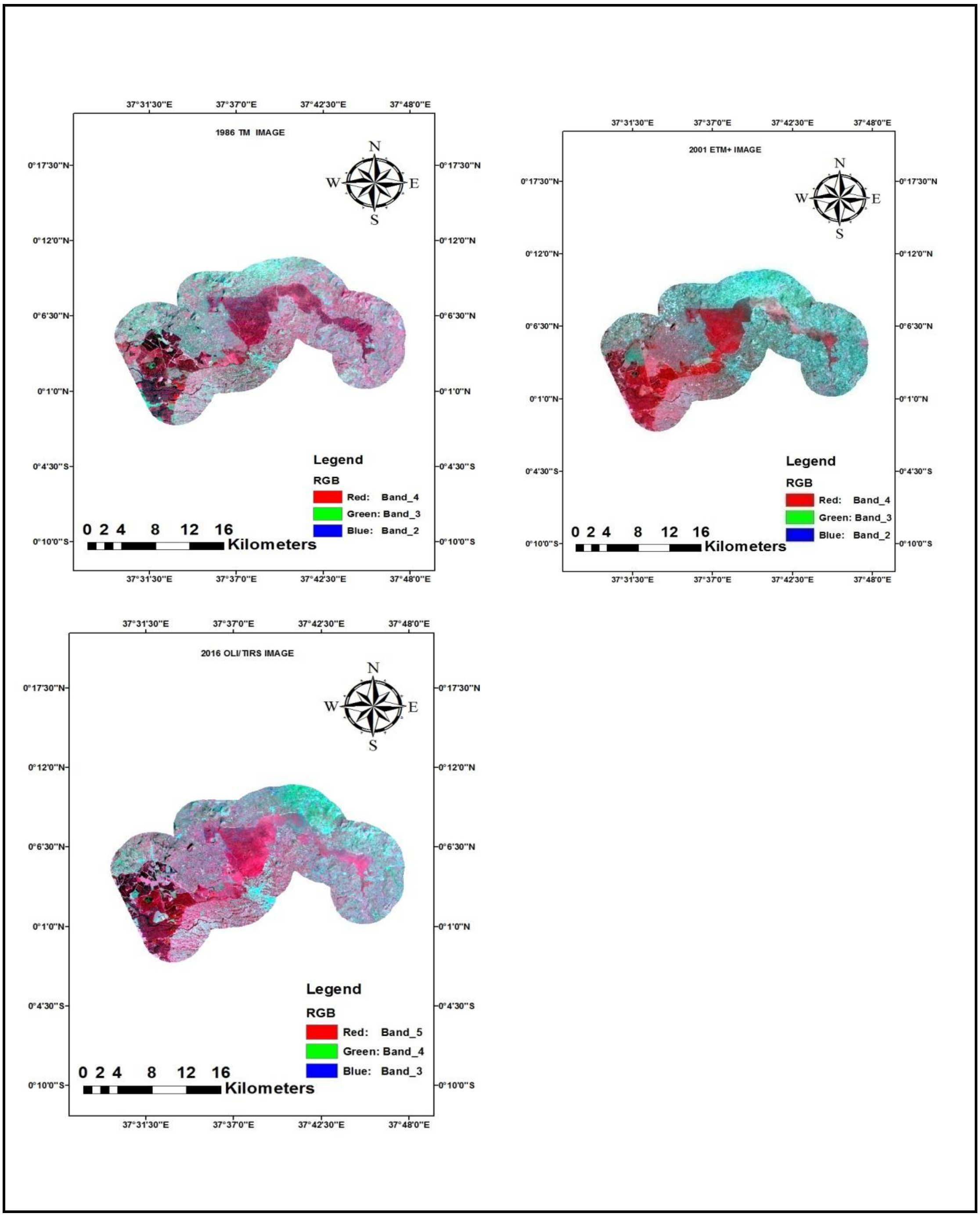


Figure 3.1: Landsat images used in the study

Source: Modified from USGS (2016)

3.3.2.2. Topographic and Google Earth images

The 1997 topographic maps (at a scale of 1:50,000) by the survey of Kenya and Google Earth images were also used in this study as a source of ancillary data for image classification and accuracy assessments.

3.3.2.3. Others

Various secondary data were also used. These included; books and articles that provided information on similar studies done elsewhere, Population data from International Livestock Research Institute (ILRI) and KNBS and climatic data from world weather online (WWO) that provided data on the rainfall and temperature patterns for the study area.

3.4 Data Analysis

3.4.1. Analysis of land sat imageries

3.4.1.1. Pre classification

1986, 2001 and 2016 landsat images were already geo referenced so there was no need for geo referencing them. Using the Imenti forest boundary shape file by KIFCON, 3.5 km buffer was created around the forest boundary. The buffer was then used to extract the study area from images. Visual interpretation of the image was done using both false and true color composite where color, texture, pattern, and shape were key characteristics that were being sought to aid in differentiating various different land use classes.

3.4.1.2. Image Classification

Before image classification, land use descriptions for the study area were made based on Frimpong (2011) with some modifications as in Table 3.3 below. The modification was based on information obtained during field reconnaissance that was carried out in September 2016 and on the additional information from the 1997 topographic map.

Table 3.3: Description of land use classes

Land use class	Descriptions
Indigenous forest	Densely forested areas with natural plant species
Plantation forest	Densely forested with exotic tree species
Grassland	Areas covered with grass and small shrubs dominated by grass
Agriculture	An area used for cultivation of food crops
Bare/built up area	Included bare ground and built up areas such as urban centers and roads

Source: Modified from Frimpong 2011

Then the supervised classification was used since it allows the researcher to be in control in defining the land use types in the image, thus minimizes errors and gives uniform classes (Jensen, 2005; Al-doski, Mansor1, & Shafri, 2013). This involved digitizing different land use in each image based on Table 3.3 above. After digitizing training sites in each image, the signature files were saved. Then the maximum likelihood classifier algorithm and signature file for each image were run one at a time to produce land use maps for 1986, 2001 and 2016.

3.4.1.3. Accuracy assessment

After classification, accuracy assessment was undertaken to evaluate the correctness of the classified maps. Basing on Congalton (1991) rule of thumb, 50 points were located into each land use class from the unclassified false color composite images of 1986, 2001 and 2016 to create a classification accuracy assessment reference dataset (Lung & Schaab, 2010). Then the 250 (50*5) reference points were imported into Google Earth.

The historical imagery time slider in Google Earth was used to select imagery that corresponded to 1986, 2001 and 2016 imageries. A sub-sample of the 250 points was interpreted as indigenous forest, planted forest, grassland, and agriculture and bare/built up area to create another reference dataset. The confusion matrix for each map was produced and used to calculate user, producer, and overall accuracies in addition to kappa statistics using Congalton and Green (2009) formula below.

User's accuracy$i = \frac{n_{ii}}{c_i}$

Producer's accuracy$i = \frac{n_{ii}}{G_i}$

Overall accuracy= $\frac{\Sigma_{i=1}^{k} n_{ii}}{n}$

Kappa statistics $\frac{n\Sigma_{i=1}^{k} n_{ii} - \Sigma_{i=1}^{k}(G_i\, C_i)}{n^2 - \Sigma_{i=1}^{k}(G_i\, C_i)}$

Where i is the class number, n is the total number of the classified pixels that are being compared to ground truth, n_{ii} is the number of pixels belonging to the ground truth class i, that have also been classified with a class i, C_i is the total number of the classified pixels belonging to class i and G_i is the total number of ground truth pixels belonging to class i

3.4.1.4. Rate of land use change

After accuracy assessment the rate of each land use class was calculated according to Peng *et al.* (2008) procedures, that is

Rate of change $= \frac{\left\{\frac{(u_1-u)}{u}\right\}}{t} * 100$

Where u_1 =is the recent year land use

u = is the initial year land use

t= is the interval year between initial and recent year.

3.4.1.5. Land use Change detection

The purpose of change detection was to obtain spatial and quantitative information about periodic conversions of one land use to another. Among other methods for change detection such as principal component analysis, image differencing and ratioing, post classification comparison change detection technique selected as it: 1) minimizes the problems associated with multi temporal images that were recorded under different atmospheric and environmental conditions (Singh, 1989). 2) Provides from-to change information (Coppin *et al*., 2004). The comparisons were for the 1986 TM and 2001 ETM+, 2001 ETM+ and 2016 OLI/TIRS and 1986 TM and 2016 OLI/TIRS.

3.4.2 Analysis of primary data

The data from the questionnaires was coded and entered into excel spreadsheet version 2013 for descriptive analysis. The analysis generated totals, frequencies, and percentages which were presented using Tables and Figures. The qualitative data from key informant interviews was synthesized and incorporated in this thesis through discussion.

3.5 Ethical Consideration

Before embarking on the research, the study protocol was approved by the Institutional Research and Ethics Committee (IREC) at Moi Teaching and Referral Hospital, Moi University, Kenya (Appendix3). Permission for conducting the study was also obtained from the National Commission for Science, Technology, and Innovation and from Kenya forest service at Meru station as shown in Appendix 4 and 5 respectively.

Prior to interviewing, the consent was sought from the respondent to partake the study at will. The researcher made sure that the information obtained was specifically used for the purpose of the research only. To ensure confidentiality, respondents names were not captured on the questionnaire instead numerical codes were used.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0. Introduction

This chapter presents the results of the study. The chapter starts with a presentation of the results obtained from the analysis of land sat imageries for 1986, 2001 and 2016. Then it goes on to present the result of the cross-sectional survey that was conducted to address the causes as well as the effects of land use change in the study area. The discussion has also been made based on the information contained in the results and where possible effort has been made to compare and contrast the results of this study with the results of other studies done elsewhere.

4.1. Land Use Changes in Imenti Forest from 1986-2016

4.1.1. Extent of land use change in Imenti forest from 1986-2016

The land use classification map for 1986 from TM satellite image showed in Figure 4.1a revealed that during this year, indigenous forest was the largest class while bare/built up area was the smallest class. Accordingly, indigenous forest and bare/built up area classes occupied 32.3% and 5.7 % of the total land area respectively. Other land use classes; plantation forest, grassland, and agriculture occupied 30.0%, 16.2% and 15.7% of the total area as indicated in Table 4.1.

However, the land use classification for 2001 of the ETM+ satellite image showed in Figure 4.1b and Table 4.1, revealed that by the year 2001, the area under indigenous forest, plantation forest, and grassland classes had decreased to 26.4%, 25.8%, and 10.7% respectively. On the other hand, the area under agriculture and bare/built up area had increased to 29.8% and 7.3 % respectively. During this year the largest area was under agriculture while the smallest area was under bare/ built up area class.

The last land use classification for 2016 from OLI/TIRS satellite image showed in Figure 4.1c revealed that, still agriculture was the largest land use class during this year while the grassland was smallest. In addition, the result showed that the area under indigenous forest, plantation forest, and grassland classes had decreased further to 20.2%, 20.8%, and 7.5% respectively. On the other hand, the area under agriculture and bare/built up area had increased further to 42.6% and 8.9 % as illustrated in Table 4.1 below.

Table 4.1: Extent of Land use change in Imenti forest for the year 1986, 2001 and 2016

	1986		2001		2016	
Land use classes	Area ha)	%	Area (ha)	%	Area (ha)	%
Indigenous Forest	15059.6	32.3	12294.7	26.4	9406.8	20.2
Plantation Forest	13994.0	30.0	12002.3	25.8	9704.4	20.8
Grassland	7564.3	16.2	4989.6	10.7	3503.4	7.5
Agriculture	7322.0	15.7	13898.8	29.8	19856.6	42.6
Bare/ Built up Areas	2655.3	5.7	3409.7	7.3	4123.9	8.9
Total Area	46595.2	100.0	46595.2	100.0	46595.2	100.0

Source: Field work data (2017)

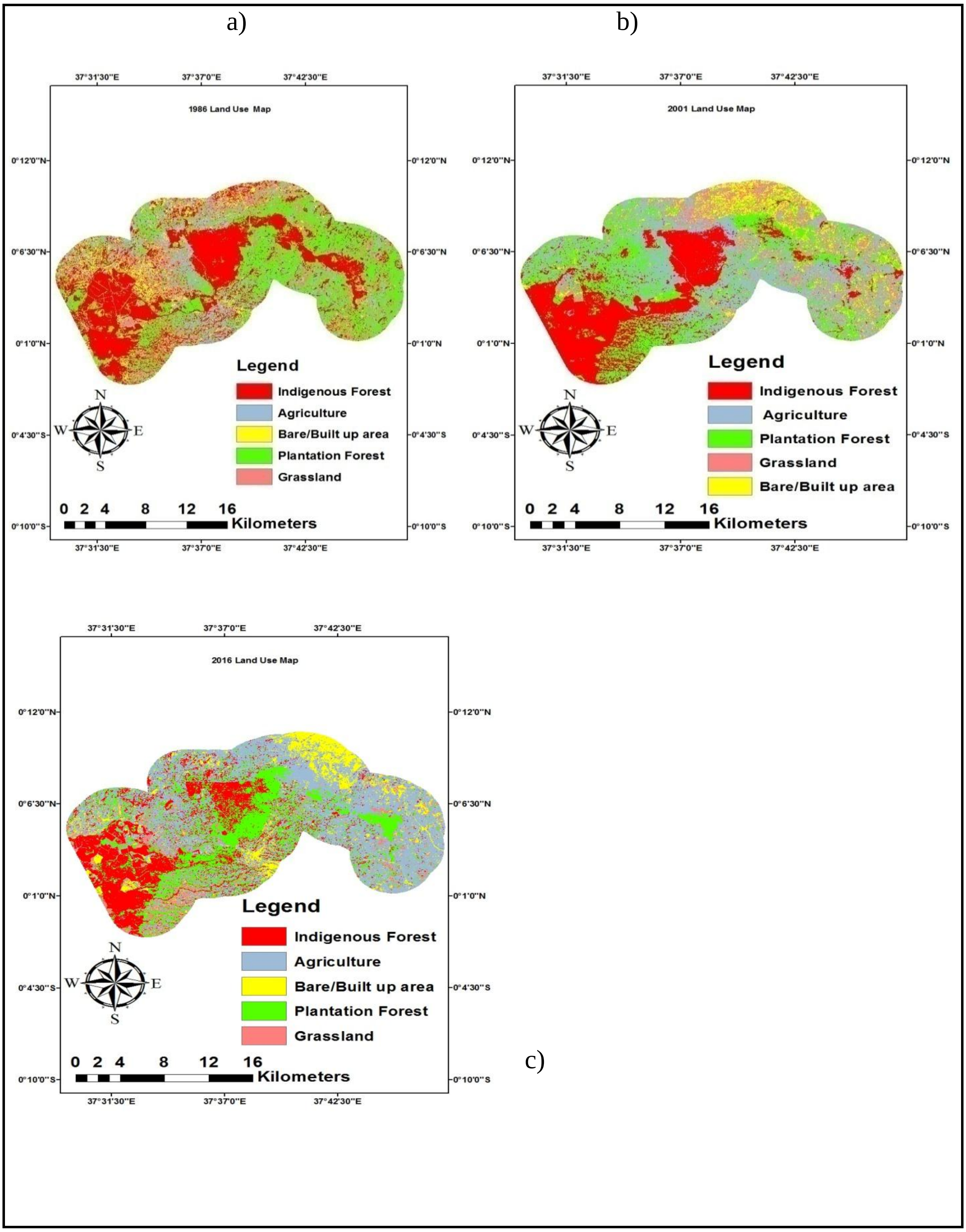


Figure 4.1: Land use classification maps for Imenti forest for 1986 (a), 2001 (b) and 2016 (c)
Source: Field work data (2017)

4.1.1.1 The extent of Indigenous, plantation forest and grassland classes

The area under indigenous forest, plantation forest and grassland classes decreased from 32.3%, 30.0% and 16.2% in the year 1986, to 26.4%, 25.8% and 10.7% in 2001, and lastly to 20.2%, 20.8% and 7.5 in 2016. The general decline in the area under indigenous forest and grassland land use classes in this study can be compared with the findings of Hailemariam *et al*. (2016), in Bale Mountain, Ethiopia. In their study, Hailemariam *et al* revealed that the area under forest and grassland had decreased from 20.8% and 19.1% in the year 1985 to 20.6% and 18.6% in the year 1995, and then to 18.8% and 18.3% in 2005, and lastly to 17.5% and 16.9% in the year 2015.

However, the above finding on changes in the area under indigenous forest and grassland differs with the findings of Mdemu *et al*. (2012) in Pugu and Kazimzumbwi forest, Tanzania. Mdemu *et al* revealed that in Pugu forest reserve, the area under closed forest and grassland classes had increased from 56.3% and 0.8 % in the year 1985, to 65.5% and 3.7% in 1995 and then they subsequently decreased to 42.5 % and 2.7 % % in the year 2010. Further, their study revealed that in Kazimzumbwi forest reserve, the area under a closed forest increased from 34.6 % to 39.8 %, and subsequently declined to 24.6 %, while the area under grassland increased from 14.8% to 19.9% and then to 32.2 % during the same study years.

On the other hand, the findings on the general decrease in the area under plantation forest varies with the findings of Kuria, Mutange, Musiega, and Muriuki (2010) in Kakamega forest, Kenya and those of Kindu, Schneider, Teketay, and Knoke (2013) in Munessa-Shashemene area, Ethiopia. Kuria *et al*. (2010) established that the area under plantation forest had increased from 18% to 31.5% and then to 50% during the year 1986, 1995 and 2005 respectively. While the study by Kindu *et al.* (2013) found out that the area under plantation forests had increased from 1% to 1.6% during the period of 1986-2000 and then decreased to 1.2% in the year 2012.

4.1.1.2 The extent of agriculture and bare/built up area

The area under agriculture and bare/built up area classes increased throughout the study period. The general increase in the area under above land use classes concurs with the findings of Kindu *et al.* (2013) and Warinwa, Mwaura, Kiringe, & Ndubi (2016) but contradicts with the findings of Kuria *et al*. (2010).

In their study, Kindu *et al* found out that the area under cropland and bare land had increased from 13% and 0.3% to 30% and1.4%, then to 39.5% and 1.5% and lastly to 48.5% and 1.7% during the year 1973,1986, 2000 and 2012 respectively. While in kirisia forest, Kenya the area under cropland and built up area was found to have increased from 0.0 km^2 and 2.5 km^2 in 1973 to 19.5 km^2 and 4.8 km^2 in 1986, then to 20.2 km^2 and 5.0 km^2 in 2000. However, in 2015 the area under crop decreased slightly to 19.4 km^2 while the area under built up area increased further to 5.6 km^2 (Warinwa *et al.*, 2016).

On the other hand, the study by Kuria *et al* found that the area under agriculture had increased from 5% to 24% and then decreased drastically to 2.6% during the year 1986, 1995 and 2005 respectively. In addition, the above study found that the area under built up area class had remained at 0.1 % during the same study period.

4.1.2 Accuracy assessment

The 1986 land use map had an overall accuracy of 85% and a kappa coefficient of 0.81 as shown in Table 4.2. Further, all land use classes had a producer and user accuracy both ranging between 82 to 88%.

Table 4.2: Confusion matrix for 1986 land use map

	Reference data						
Land use classes	1	2	3	4	5	Total	User Accuracy
1:Indigenous Forest	44	6	0	0	0	50	88
2:Plantation Forest	6	43	0	0	2	51	84
3:Grass land	0	0	42	2	7	51	82
4: Agriculture	0	0	6	42	0	48	88
5: Bare/built up area	0	1	2	6	41	50	82
Total	50	50	50	50	50	250	
Producer Accuracy	88	86	84	84	82		
Overall Accuracy	85						
Kappa Coefficient	0.81						

Source: Field work data (2017)

Nonetheless, the 2001 land use map had an overall accuracy of 93% and a kappa coefficient of 0.91. In addition, the producer and user accuracy of all land use classes ranged between 90 to 96% and 91 to 96 as indicated in Table 4.3 below.

Table 4.3: Confusion matrix for 2001 land use map

	Reference data						
Land use classes	1	2	3	4	5	Total	User Accuracy
1:Indigenous forest	47	1	0	0	1	49	96
2:Plantation forest	2	48	0	3	0	53	91
3:Grassland	1	1	45	0	2	49	92
4:Agriculture	0	0	3	46	1	50	92
5: Bare/built up area	0	0	2	1	46	49	94
Total	50	50	50	50	50	250	
PA	94	96	90	92	92		
Overall Accuracy	93						
Kappa Coefficient	0.91						

Source: Field work data (2017)

Lastly, the 2016 land use map had an overall accuracy and a kappa coefficient of 94% and 0.92 respectively as in Table 4.4. Similar to the 2001 land use map, all land use classes had a producer and user accuracy ranging between 90 to 96% and 91 to 96 as in Table 4.4.

Table 4.4: Confusion matrix for 2016 land use map

	Reference data						
Land use classes	1	2	3	4	5	Total	User Accuracy
1:Indigenous Forest	45	2	0	0	0	47	96
2:Plantation Forest	4	48	0	0	0	52	92
3:Grass land	0	0	46	0	2	48	96
4: Agriculture	1	0	2	47	0	50	94
5: Bare/built up area	0	0	2	3	48	53	91
Total	50	50	50	50	50	250	
Producer Accuracy	90	96	92	94	96		
Overall Accuracy	94						
Kappa Coefficient	0.92						

Source: Field work data (2017)

From the above accuracy assessment results, it is clear that all classified maps that is the 1986, 2001 and 2016 maps met the minimum overall accuracy requirement of 85% set by Anderson, Hardy, Roach, and Witmer (1976) for land use land cover change analysis. More also, all classified maps had a kappa of above 0.80 which is considered to be a strong agreement by Congalton (1991).

However, it can be observed from Table 4.3 and 4.4 that the 2001 and 2016 land use maps had higher accuracies compared to 1986 land use map (Table 4.2). This could be attributed to additional panchromatic band of 15 m resolution in EMT+ and OLI/TIRS sensor which has finer resolution compared to medium resolution of 30m in TM sensor.

4.1.3 The rate of land use change

The rate of land use changes over the study period is presented in Table 4.5 below. The aforesaid table shows that indigenous forest, plantation forest and grassland land use classes changed at an annual rate of 1.2%, 0.9% and 2.3%, to 1.6%, 1.3% and 2.0%, and to 1.3%, 1.0% and 1.8% in the first (1986-2001), second (2001-2016) and third or overall period (1986-2016) respectively. At the same periods, Agriculture and bare/built up area classes changed at an annual rate of 6.0% and 1.9% to 2.9% and 1.4 % and to 5.7% and 1.8% respectively.

In addition, it can be observed from Table 4.5 that the annual rate of change in indigenous and plantation land use classes was higher in the second period than in the first and in the overall period, while in agriculture and bare/built up area land use classes, the annual rate of change was lower during the second period compared to the first and to the overall period. However, grassland class experienced continuous decline in the annual rate of change.

Table 4.5: Rate of land use change

	1986-2001	2001-2016	1986-2016	Annual rate of change		
Land use classes	Area changed (ha)	Area changed(ha)	Area changed(ha)	1986-2001	2001-2016	1986-2016
Indigenous forest	-2764.9	-2887.9	-5652.8	-1.2	-1.6	-1.3
Plantation forest	-1991.7	-2297.9	-4289.6	-0.9	-1.3	-1.0
Grassland	-2574.7	-1486.2	-4060.9	-2.3	-2.0	-1.8
Agriculture	6576.8	5957.8	12534.7	6.0	2.9	5.7
Bare/Built up areas	754.5	714.2	1468.6	1.9	1.4	1.8

(-) Means decrease

Source: Field work data (2017)

The rate of deforestation in indigenous forest depicted in Table 4.5 above is high compared to the nation's deforestation rate of 0.4% for the period 1990-2000, 2000-2010 and 1990-2010 by FAO (2010b). These findings can be compared with that of Pandit (2011) in a laljhadi forest corridor, Nepal, which showed an annual rate of deforestation of 3.6% during the period of 2002-2010, that was above the nation's deforestation rate of 1.2% at that period. However, they can be contrasted with the findings of Wachiye, Kuria, and Musiega (2013) that reported an annual deforestation rate of 0.00665% that was lower than the nation's annual estimated deforestation rate of 3% during that time.

4.1.4. Distribution of Land use change

The Figure 4.2-4.4 and Table 4.6 shows the distribution of land use change that occurred in this study area over three comparison period. The detail description of the distribution in each land use class is as follows.

4.1.4.1. Indigenous forest

Indigenous forest land use class lost 22.0%, 33.7% and 24.7% of its area to plantation forest, 3.3%, 6.9% and 7.3% to grassland, 18.0%, 9.1% and 22.2% to agriculture while 4.4%, 2.6% and 6.0% of its area was lost to bare/built up area class during the period of 1986-2001, 2001-2016 and 1986-2016 respectively as depicted in Table 4.6 and Figure 4.2- 4.4. Further, from the same Table, it can be seen that this class type lost more of its area than it gained from other land use classes except to grassland and agriculture classes during the first and the second comparisons period respectively. However, it is clear that much of the area under indigenous forest was lost to plantation forest (22.0% and 24.7%) and agriculture (18.0% and 22.2%) during the first and the third comparison period and to the plantation forest (33.7%) during the second comparison period.

The above distribution of most of the area lost by indigenous forests class can be contrasted with the study of Wachiye *et al.*(2013), which found out that most of the area under natural forest was lost to the sparse forest (1370.97ha and 2558.34ha) during the period of 1986-1995 and 1995-2006. More so, a study by Adjei, Buor, and Addrah (2014), in the Lake Bosomtwe Basin forest zone, Ghana found out that during the period of 1986-2002 and 2002-2008, much of the area under forest land class was lost to rangeland (41.9% and 50%), the findings which can also be said to be in disagreement with the findings of this study.

4.1.4.2. Plantation forest

Plantation forest land use class on the other hand lost 19.8%, 7.2% and 9.7% of its area to indigenous forest class, 13.8%, 14.7% and 8.1% to grassland, 31.0%, 51.4% and 48.2% and 9.5%, 9.3% and 8.8% to agriculture and bare /built up area was respectively during three comparison period as showed in Table 4.6 and Figure 4.2-4.4. In addition, it can be seen from Table 4.6 that plantation forest class lost more area than it gained from other classes expect to indigenous forest and grassland classes during the first comparison period and to indigenous class during the second and third comparison period. Besides that, the above result reveals that over comparison periods, most of the area under plantation forest class was being lost to agriculture.

The above distribution of most of the area lost by plantation forest compares with those of Kuria *et al.*(2010) which revealed that plantation forest lost most of its area to agriculture (748.2 ha and 520.3ha) during the period of 1986-1995 and 1995-2005. Similar to our findings, a study by Oyinloye and Oloukoi (2013), in Omo forest, Nigeria revealed that most of the area under plantation forest (11460.9 ha) was lost to shrub/arable land during the comparison of 1986-2002.

4.1.4.3. Grassland

During the three comparison periods, grassland class type lost 8.8%, 4.9% and 7.1% of its proportional area to indigenous forest, 34.7%, 8.0% and 13.1% to plantation forest, 27.5%, 65.6% and 58.1% to agriculture while 12.0%,18.5% and 11.9% of its area went to bare/built up area as depicted in Table 4.6 and Figure 4.2-4.4. Further, this class type was found to have lost most of its area than it gained to other land use classes except to indigenous and plantation forest classes during the second and the third comparison period as showed in Table 4.6. That notwithstanding, it is clear that much of the area under this land use type was being lost to plantation forest (34.7%) and active agriculture (27.5%) in the first comparison period and to active agriculture (65.6% and 58.1%) in the second and the third comparison period.

These findings compares favourably with those of the study by Hyandye, Mandara, and Safari (2014), in Usangu Catchment, Tanzania which found that grassland was losing most of its area to shrub (1196.9km^2) and agriculture (902.4 km^2) during the period of 2000-2006 and to agriculture (934.1 km^2) in the period of 2006-2013.

4.1.4.4. Agriculture

This land use class type lost 9.2%,16.8%, and 17.3% of its area to indigenous forest, 21.3%, 20.8% and 16.1% to plantation forest,12.1%, 3.7% and 4.2% to grassland and lastly 3.7%, 5.4% and 8.2% of its proportionate area went to bare/built up area as revealed in Table 4.6 and Figure 4.2-4.4. This means that agriculture lost most of its area to plantation class (during the first comparison period), and to indigenous and plantation forest in the second and third comparison periods. However, this class gained more area than it lost to other land use classes except to the indigenous forest during the second comparison period.

The higher gain than loss exhibited by agriculture class can be compared with the findings of other researchers like Hyandye *et al.*(2014) and Badjana *et al*.(2015) who also found that agricultural land gained more from most of land use classes than it lost to them. For example the study of Badjana *et al* in Binah River watershed, West Africa revealed that agricultural land lost 6.41%, 27.56%, 12.05% and 0.76% of its area to the forest, savannah, settlement and water classes respectively during the period of 1987-2013. Further, they also revealed that during the same comparison period agricultural land gained 21.94%, 46.26%, 52.02% and 19.93% from forest, savannah, settlement, and water respectively.

4.1.4.5. Bare/built up area

Bare/built up area lost 12.0%, 2.7% and 9.8% of its area to indigenous forest class, 33.2% ,5.6% and 10.2% to plantation, 14.6%, 6.5% and 8.4% to grassland and 31.1%, 55.2% and 53.3% to agriculture during the three comparison periods as shown in Table 4.6 and Figures 4.2-4.4. The above result reveals that bare/built up area lost much of its area to plantation forest and agriculture during the first comparison period and to agriculture during the second and third comparison period. However, throughout the comparison periods, this class type gained more area than it lost to other land use classes except to the agriculture class as depicted in Table 4.6.

The above findings on the big gain by built/built up class in relation to other land uses classes compare favourably with those of Kindu *et al*.(2013) which revealed that bare class mainly lost less of its area than it was gaining from other land use land cover classes. That is, they found that bare class lost 0, 0, 227.3, 20.5, 13.8, 0.9, 0 and1.1ha to natural forest, plantation forest, cropland, grassland, settlement, tree patches, and wood land, and to water respectively during the period of 1973-2012. On other hand their study found out that this class type it gained 238.6, 0, 310.9, 922.3, 1.3, 16.1, 187.9 and 5ha from natural forest, plantation forest, cropland, grassland, settlement, tree patches, wood land, and from water respectively during the same comparison period.

Table 4.6: Land use change matrix in hectares (ha)

Change from	change to	1986-2001		2001-2016		1986-2016	
		Ha	%	Ha	%	Ha	%
	1	7873.9	52.3	5876.2	47.8	5992.3	39.8
	2	3309.3	22.0	4141.4	33.7	3721.5	24.7
	3	491.5	3.3	845.3	6.9	1100.3	7.3
	4	2718.0	18.0	1116.2	9.1	3335.8	22.2
1	5	666.9	4.4	315.7	2.6	909.8	6.0
	1	2766.7	19.8	861.5	7.2	1351.9	9.7
	2	3634.3	26.0	2087.3	17.4	3535.3	25.3
	3	1933.8	13.8	1769.3	14.7	1138.0	8.1
	4	4335.5	31.0	6167.1	51.4	6739.7	48.2
2	5	1323.7	9.5	1117.2	9.3	1229.2	8.8
	1	663.1	8.8	245.7	4.9	535.8	7.1
	2	2621.5	34.7	397.9	8.0	994.5	13.1
	3	1290.3	17.1	147.9	3.0	735.7	9.7
	4	2078.4	27.5	3273.4	65.6	4397.4	58.1
3	5	911.0	12.0	924.8	18.5	901.0	11.9
	1	671.3	9.2	2330.4	16.8	1266.3	17.3
	2	1556.1	21.3	2886.0	20.8	1182.3	16.1
	3	887.0	12.1	519.8	3.7	306.0	4.2
	4	3939.8	53.8	7418.4	53.4	3968.6	54.2
4	5	267.8	3.7	744.1	5.4	598.7	8.2
	1	319.7	12.0	93.1	2.7	260.6	9.8
	2	881.1	33.2	191.9	5.6	270.8	10.2
	3	387.0	14.6	221.1	6.5	223.6	8.4
	4	827.1	31.1	1881.5	55.2	1415.2	53.3
5	5	240.4	9.1	1022.1	30.0	485.2	18.3

1=Indigenous forest, 2=Plantation forest, 3=Grassland, 4=Agriculture and 5=Bare/built up area

Source: Field work data (2017)

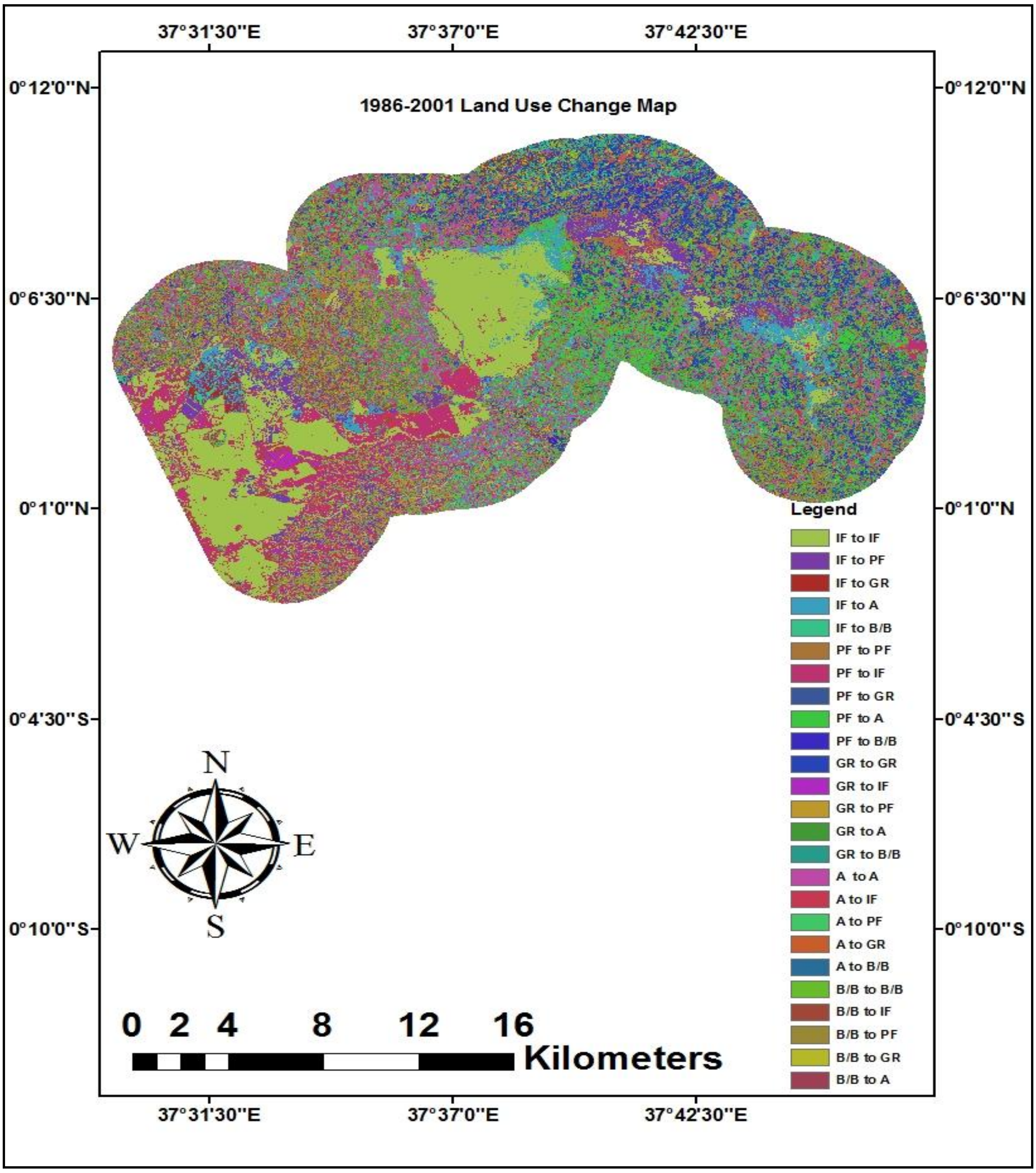


Figure 4.2: 1986-2001 land use change map

IF=Indigenous Forest, PF=Plantation forest, GR=Grassland A=Agriculture and B/B=Bare/built up area

Source: Field work data (2017)

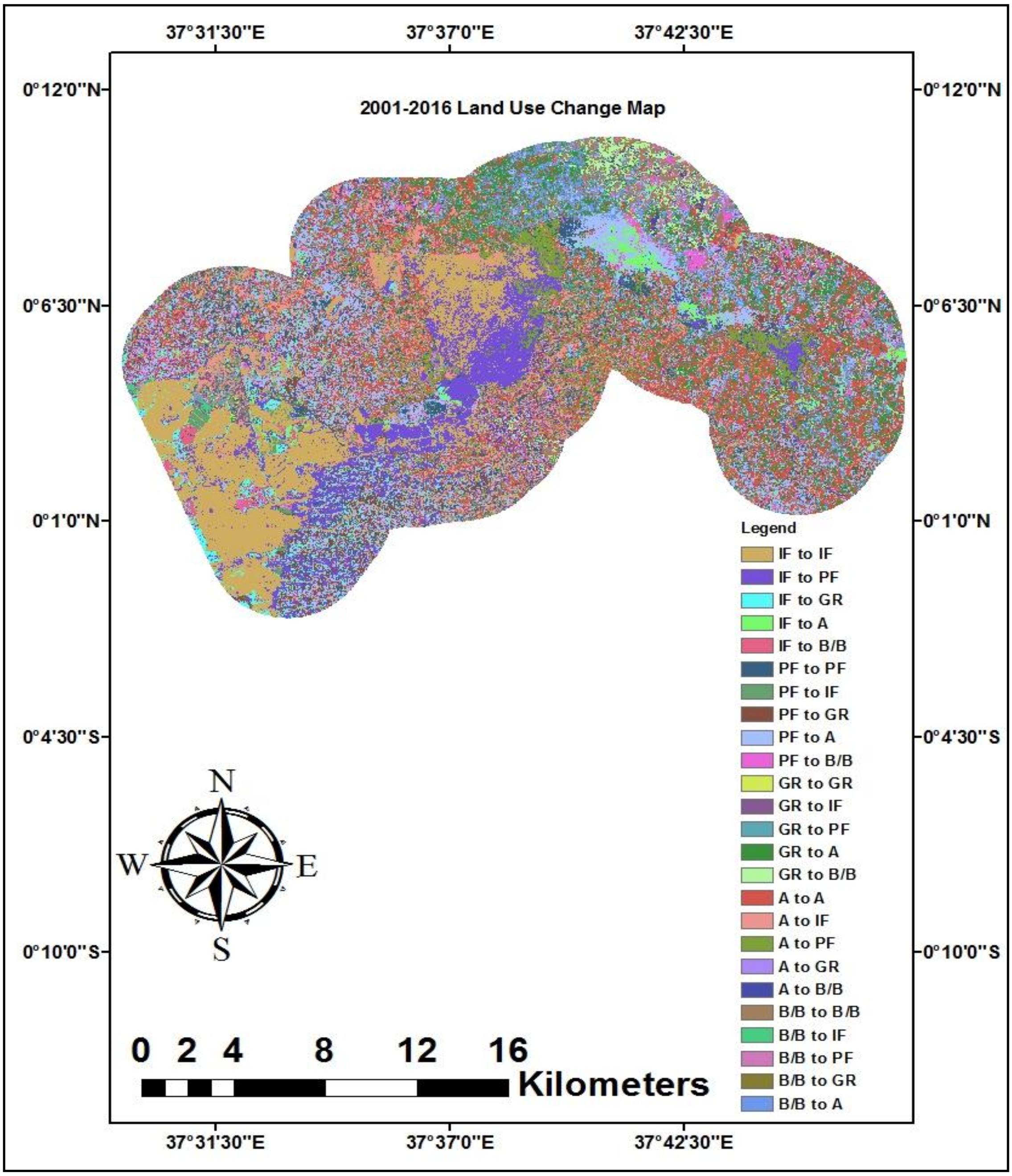


Figure 4.3: 2001-2016 Land use change map

IF=Indigenous Forest, PF=Plantation forest, GR=Grassland A=Agriculture and B/B=Bare/built up area

Source: Field work data (2017)

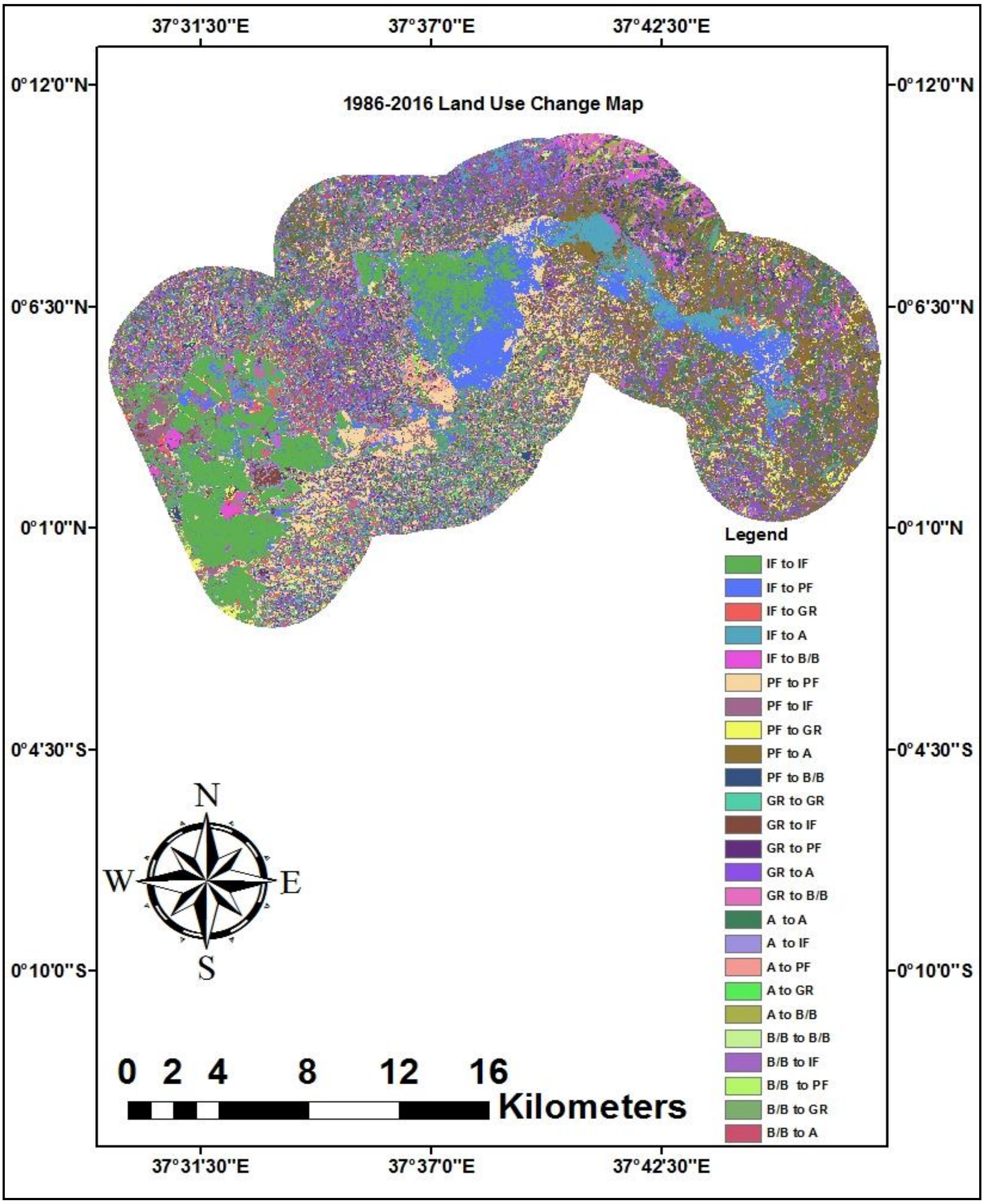


Figure 4.4: 1986-2016 land use change map

IF=Indigenous Forest, PF=Plantation forest, GR=Grassland A=Agriculture and B/B=Bare/built up area

Source: Field work data (2017)

4.2 General Information of the Respondents

The results of this study revealed that out of 198 respondents sampled, majority (83.3%) of them (majority) aged above 41years, of whom 49.5% were between 41-50 years and 33.8% were above 51years. The rest proportion (16.7%) of the respondents aged below 41years and constituted of 11.1% and 5.6% of the respondents who were between 31-40 and 18-30 years respectively as in Table 4.7 below. Regarding the gender of the respondents, the results of this study presented in Table 4.7 revealed that the majority (77.3%) of the respondents were male while female respondents constituted the least proportion that is 22.7%.

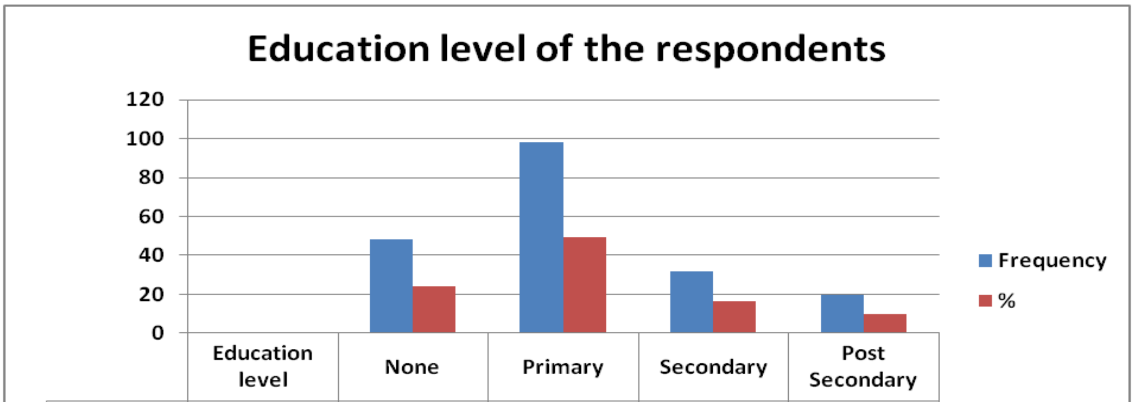
Table 4.7: Age-sex of the respondents

Age	Sex		Total	%
Years	Female	Male		
18-30	4	7	11	5.6
31-40	5	17	22	11.1
41-50	18	80	98	49.5
Above 51	18	49	67	33.8
Total	45	153	198	100.0
%	22.7	77.3	100.0	

Source: Field work data (2017)

Since in many rural societies in Africa, men are the main decision makers concerning land, and for one to better understand the changes in land use that have occurred in a certain location, he or she requires a long time experienced population (Houessou *et al*., 2013). Thus the above results on age and gender of the respondents imply that the majority of respondents had valuable experience and information concerning changes in land use that had occurred in this study area.

Onside of the education level of the respondents, it is clear from Figure 4.5 below that, 24.2% of the respondents had no education at all, 49.5% of the respondents had primary education, 16.2% of them had secondary education, and only 10.1% of them had post- secondary education.

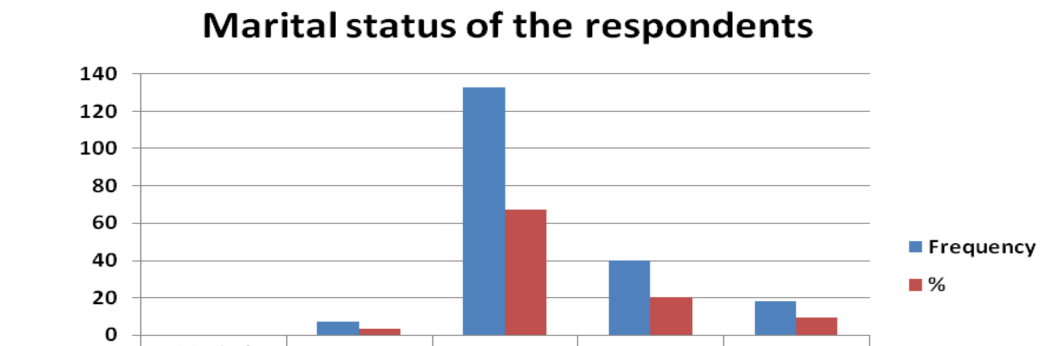


	Education level	None	Primary	Secondary	Post Secondary
Frequency		48	98	32	20
%		24.2	49.5	16.2	10.1

Figure 4.5: Education level of the respondents
Source: Field work data (2017)

The above results on the education level of the respondents imply that the majority (89.9%) of respondents were between illiterate to basic education (primary and secondary education). This low education level of the respondents might be having a negative impact on the management of land in this study area. This so because studies, for instance, that of Olson, Masina, Campbell, Mbonile, and Mugisha (2004) revealed that low education level of the respondents was one of the main causes of land degradation in their study site.

Regarding the marital status of the respondents, the results of the study revealed that, 67.2% of the respondents were married, 20.2 % were divorced, while 9.1 % of them were widowed and 3.5 % were not married as showed in Figure 4.6 below.



Marital status	Not married	Married	Divorced	Widowed
Frequency	7	133	40	18
%	3.5	67.2	20.2	9.1

Figure 4.6: Marital status of the respondents
Source: Field work data (2017)

4.3 Livelihood Activities

Concerning the livelihood activities of the respondents, the study found out that majority (90.9%) of the respondents were involved in mixed farming as their major livelihood activity. Further, the results of the study also revealed that only small proportions of the respondents were involved in crop production (5.6%) and animal rearing (3.5%) as their main livelihood activities as it can be seen in Figure 4.7.

More so, the study results revealed that most of the respondents were also involved in other livelihood activities apart from a few (11.1%) as indicated in Figure 4.7 below. However, most of the respondents (84.3% and 77.3%) were involved in agricultural and forest based off-farm activities and only 35.9 % respondents were involved in other activities (professional activities). This means that there is high pressure on farm and forest land in this study area as most of the people, mainly relied on them for subsistence and monetary income to meet their daily needs.

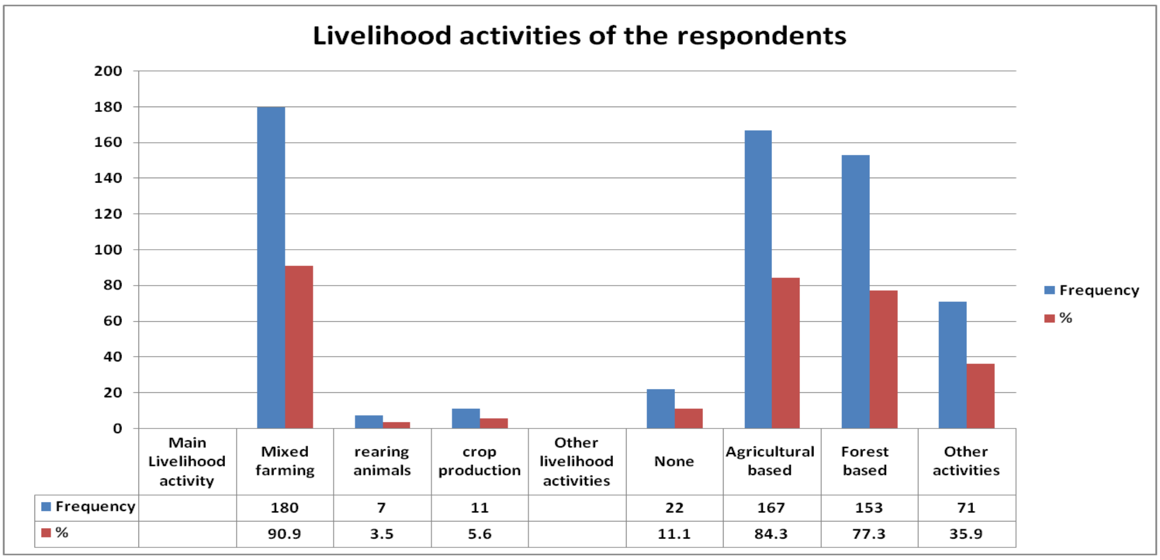


Figure 4.7: Livelihood activities of the respondents
Source: Field work data (2017)

4.4 Size of Land and Status

Regarding the size of land owned by the respondents, the results of the study revealed that more than half (58.6%) of the respondents owned 1-2 acres, 25.3% of them owned less than 1 acre, while 12.1 % owned more than 2 to 4 acres and very few respondents (4%) owned more than 4 acres as shown in Table 4.8 below.

Table 4.8: Responses on the size of land

Size of land	Frequency	%
1- 2 acres	116	58.6
Less than 1 acre	50	25.3
Above 4 acres	8	4.0
More than 2 to 4 acres	24	12.1
Total	198	100.0

Source: Fieldwork data (2017)

Moreover, the study established that majority (89.4%) of respondents perceived that the land was becoming scarce, while 8.1% of them perceived that the land was still abundant and 2.5 % perceived that the land had not changed. In addition, out of 89.4%

of the respondents who felt that land was becoming scarce, 59.9 % of them felt that population increase was the cause of land scarcity, 22% of them felt that land scarcity was as a result of loss of land fertility, while 15.3% felt that it was due to inadequate off-farm activities and lastly 2.8% of them felt that the land scarcity was as a result of government taking away their land as indicated in Figure 4.8 below.

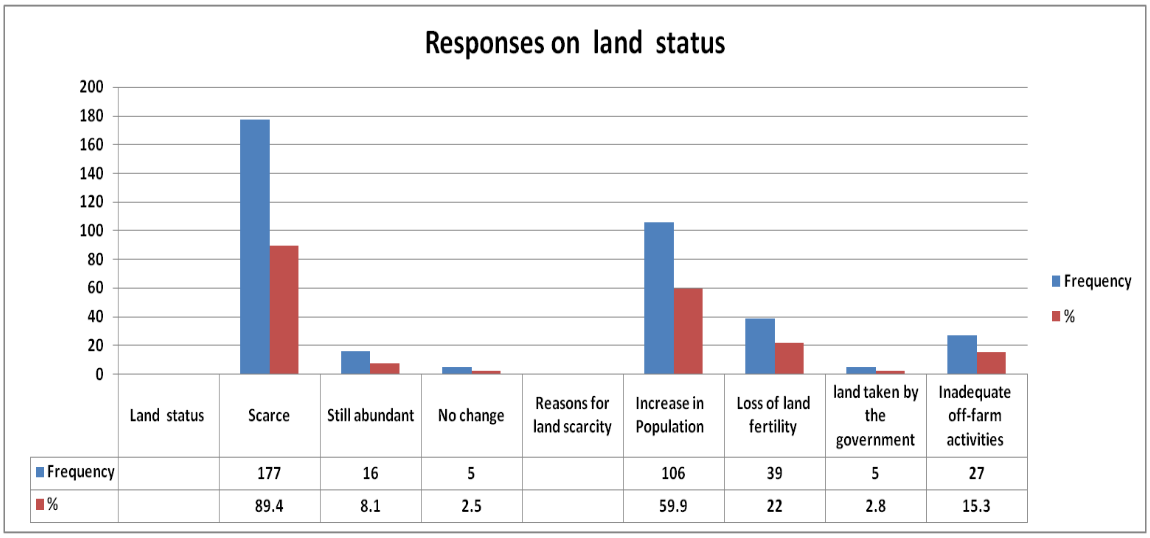


Figure 4.8: Responses on land status
Source: Fieldwork data (2017)

The above results indicate a need for the residents in this study area to look for extra piece of land to cater for their needs, thus exposing the Imenti forest to the risk of being deforested.

4.5 Benefits and conservation of Imenti forest

Concerning the benefits of Imenti forest, most of the respondents reported that they greatly benefited from Imenti forest as indicated in Table 4.9 below. Accordingly, 74.2% of the respondents harvested firewood, 51.0 % of them harvested fodder and grazed their animals in the forest, and 20.2% of them harvested fruits, herbs, and honey from the forest, while 8.6 % of them harvested building materials from the forest.

However, only 3.0% of the respondents reported that they did not benefit from Imenti forest.

Table 4.9: Responses on benefits of Imenti forest (IF)

Benefits of Imenti forest (multiple responses)	Frequency	%
Firewood	147	74.2
Building materials	17	8.6
Fodder/grazing	101	51.0
Fruits, herbs and honey	40	20.2
No benefit	6	3.0

Source: Field work data (2017)

The above findings on benefits derived from Imenti forest are consistent with the findings of other researchers like Mdemu *et al.*(2012) and Chan and Sasaki (2014) who found out that forest adjacent communities derived their livelihood from forest by harvesting firewood for energy and sales, collecting fodder and grazing their cattle, harvesting timber for construction and building, harvesting plants parts for herbal medicine and fruits and also practicing beekeeping both for their own consumption and commercial purposes among others.

Nonetheless, the study results revealed that majority of the respondents were actively involved in the conservation of the Imenti forest. Accordingly, out of 198 respondents, 58.1% of them reported that they used permits, 36.9% of them were involved in planting seedlings and 10.6 % of them acted as watchdogs. However, 3.5% of the respondents reported that they never participated in the conservation of the Imenti forest as indicated in Figure 4.9.

Concerning the reasons for not doing more to conserve the Imenti forest, the results of this study revealed that out of 198 respondents, 62.1% of them felt that it was because land insecurity, while 31.8% and 6.1% of the respondents felt that it was lack of time and benefits as shown in Figure 4.9 below.

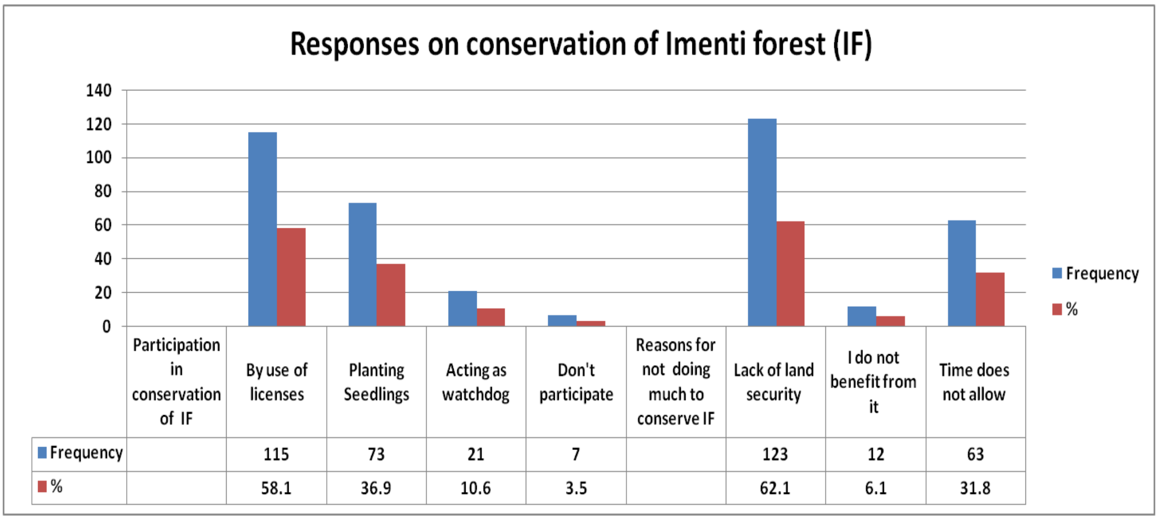


Figure 4.9: Responses on conservation of Imenti forest
Source: Field work data (2017)

This is a clear indication that the majority of the respondents valued the existence of Imenti forest and are willing to participate its conservation only that some factors such insecurity in their land propelled them to attack the common resource that is Imenti forest. The above findings can be related to those of Bett (2005), Mogaka *et al*.(2001) and Chan and Sasaki (2014). These authors revealed that forest adjacent communities were actively participating in the conservation of forests, but, they faced insecurity challenges associated with lack of compensation for the losses caused by forest-dwelling animals and lack of sense of ownership of the forest.

4.6. Land Ownership, Productivity and Conservation

The analysis of the results of this study indicated that more than half of the respondents (54.5%) did not have the title deeds for their land, 26.8% of them had the title deed for some parts of their land while 18.7% had a title deed as in Figure 4.10 below. In addition, the analysis also revealed that 84.3% of the respondents perceived a decrease in land productivity, while 12.1% of them viewed that the productivity of their land had increased, and the rest (3.5%) of the respondents perceived that the productivity of their land had remained the same over the years.

Further, 51.5 % of the respondents who reported a decrease in land productivity revealed that rainfall fluctuation was the main cause, 34.1% of them said it was due to loss of soil fertility, 9% of the respondents attributed it to inadequate of application of fertilizers and other modern inputs while 5.4% of the respondents attributed the decrease in land productivity to in access to extension services as showed in Figure 4.10.

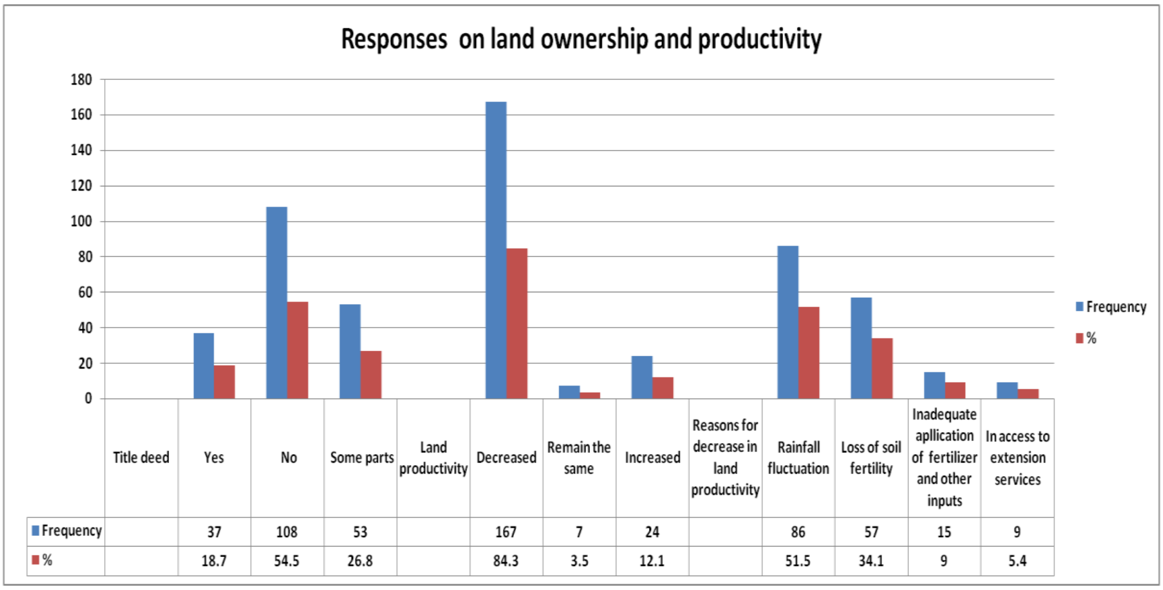


Figure 4.10: Responses on land ownership and productivity
Source: Field work data

Onside of land conservation measures, 39.4% of the respondents reported to have been using terraces, 23.7% reported intercropping, 16.7% reported contour planting, 13.6% said tree planting and the rest proportion (6.6%) said to have been using fertilizer and compost manure as method for land conservation as depicted in Figure 4.11 below.

Moreover, 64.6% of them reported that lack land tenure was the cause for not doing much to conserve their land, 26.8% said it was due to inadequate income while 3.5% said that it was because of inadequate knowledge as indicated in the Figure 4.11.

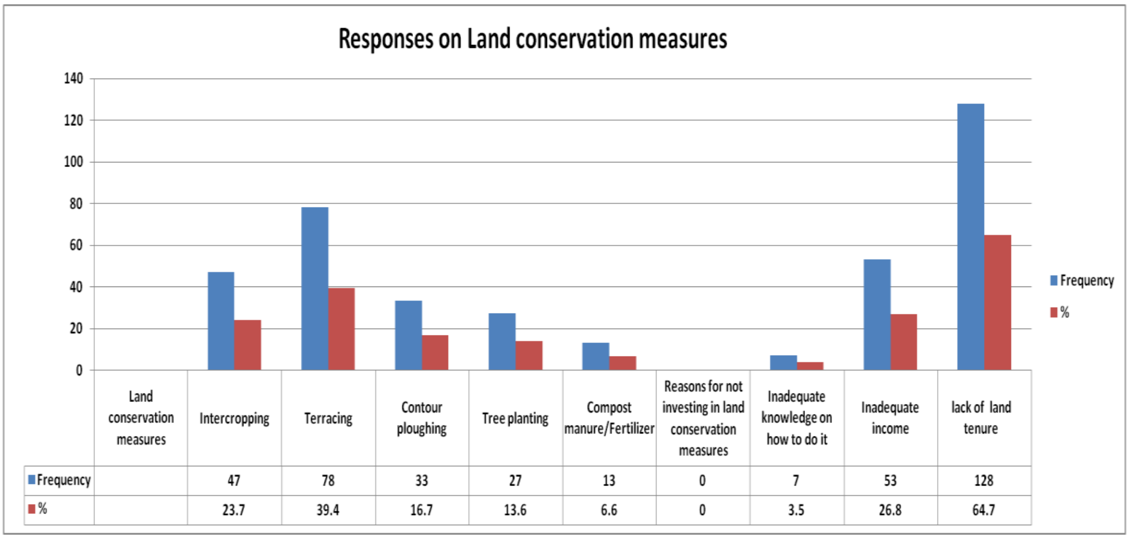


Figure 4.11: Responses on land conservation measures
Source: Field work data (2017)

The above result implies that the productivity of land is decreasing in this area, which can be associated with fluctuation in rainfall and loss of soil fertility. In addition, the above result implies that insecure land tenure is the main reason for not investing in land conservation measures in this study area. This is in line with the observation of Olson *et al.* (2004) that individuals find no need of investing in the land when they are not sure of the user and ownership rights.

4.7 Respondents observed Changes in Land use

The study also inquired on observed changes in land use in this study area. From the analysis of the result, 86.9% of the respondents had observed a change in land use, while 13.1% of them had not observed any change in land use as shown in Table 4.10. Moreover, out of 86.9% (172) respondents who had observed changes in land use, the majority of them (97%, 73%, and 66%) had observed an increase in bare/built up area, cropland and degraded land respectively. In addition, 91% and 63% of 172 respondents had observed a decrease in forest and grassland respectively as shown in the Table 4.10 below.

Table 4.10: Responses on observed changes in land use

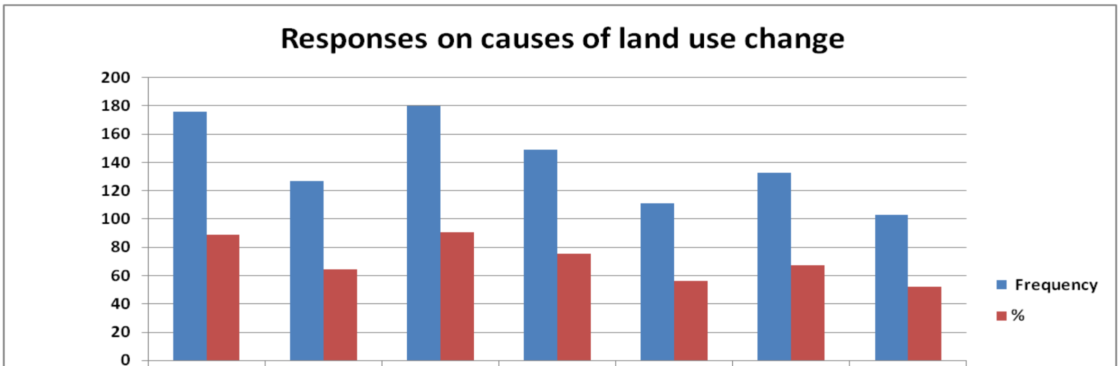
Observed changes in land use	Frequency		%	
Yes	172		86.9	
No	26		13.1	
Land use change	Increase	%	Decrease	%
Changes in crop Land	125	73	47	27
Changes in forest cover	16	9	156	91
Changes in degraded land	114	66	58	34
Changes in grassland	63	37	109	63
Changes in bare/built up area	166	97	6	3

Source: Fieldwork data (2017)

When we compare these result with those obtained from analysis of the three satellite imageries in Figure 4.1, the trend is almost similar. In addition, the key informants underlined that there was a general decrease in forest and grassland land, but cropland and bare/ built up land were generally increasing.

4.8 Causes of Land Use Change

The respondents were requested to state the major causes of land use change in their area and the analysis of their responses is presented in Figure 4.12 below. From Figure 4.12 majority of respondents mentioned farmland expansion (90.9%), followed by population increase (88.9%), access to road and expansion of urban centers (75.3%), demand for forest products and grazing land (67.2%), insecure land tenure (64.1%), inadequate participation in other livelihood activities (56.1%) and lastly ineffective management of Imenti forest (52%) as the causes of land use change in this study area. Each of these causes is discussed in detail in the subsequent parts.



	Population increase	Insecure land tenure	Farmland Expansion	Access to road and expansion of urban centres	Inadequate participation in other livelihood activities	Demand for forest products and grazing land	Ineffective management of Imenti Forest
Frequency	176	127	180	149	111	133	103
%	88.9	64.1	90.9	75.3	56.1	67.2	52

Figure 4.12: Responses on causes of land use change
Source: Fieldwork data (2017)

4.8.1. Expansion of farmland

Farmland expansion was mentioned by the largest proportion (90.9%) of the respondents the as the cause of land use change in this study area (Figure 4.12 above). This is in line with the findings presented in Table 4.1 which shows a tremendous increase in the area under agriculture class from 15.7% to 42.6% between the year 1986 and 2016. In addition, during the field visit, it was also observed that people had their farmland close the forest as shown in Plate1 below. Similarly, most of the key informants described that the high dependence on agriculture as the main means of livelihood in the community had led to the clearing of more vegetation cover to produce crops.

Plate 1: Farmlands encroaching Imenti forest

Source: Field observation (2017)

4.8.2. Population increase

Population increase was another cause of land use change reported by 88.9 % of the questionnaire respondents as indicated in Figure 4.12. In addition, the key informant interview excerpt like "*Today we are many. More land is being fragmented into small farms. People have even dried the holy water of lake Nkunga and cleared some pockets of forests (tungu) that were used for cultural activities*", implies that population increase has brought some changes in land use in this area.

More so a closer look at the population data covering the study area (Imenti north, Tigania west, and Imenti central constituencies) from ILRI and KNBS further supports these findings. According to the population data in Table 4.11 below, the population density for North Imenti, Tigania west and Central Imenti constituencies increased from 266.8, 70.2 and 167.3 in 1989 through 427.3, 197.7 and 248.2 in 1999 to 509, 298 and 351 persons per km^2 in the year 2009.

Table 4.11: The 1989, 1999 and 2009 population density of study area

	Year/ population density per km^2		
Constituencies	1989	1999	2009
North Imenti	266.8	427.3	509
Tigania West	70.2	197.7	298
Central Imenti	167.3	248.2	351

Source: ILRI 2007 (1989 and 1999) and KNBS (2009)

With the problem of land scarcity and decline in land productivity in this area as revealed in section 4.7 and 4.9 of this chapter, further increase in human population will likely resort to Imenti forest exacerbating further land use change.

4.8.3. Access to roads and expansion of urban centers

This was another cause of land use change mentioned by 75.3 % of the respondents as in Figure 4.12. Further, some of the key informants utterance such as " *development like that of Meru to Nanyuki and Meru to Isiolo road, Meru agriculture Showground and Meru technical school among other brought a lot of changes in land use in this community*" concur with these results. In addition, these results agree with those of the analysis of satellite imageries presented in Table 4.1 and in Figure 4.1 that revealed continuous expansion bare/built up area class from the year 1986-2016. Further, during the field visit, the researcher observed that there was a collection of large Murram deposits (right) and stone blasting (left) for construction in this study area as showed in Plate 2 below.

Plate 2: Stone blasting near Meru technical college (left) and Murram deposit (right) along Naari foot path

Source: Field observation (2017)

4.8.4. Demand of grazing land and forest products

Local residents, mainly harvest firewood, fodder and graze animals in Imenti forest as already revealed in section 4.8 of this chapter. Besides that, 67.2% of the questionnaire respondents perceived the demand of grazing land and forest products was the cause of land use change as in Figure 4.12. During field visit, it was also observed that people grazed and extracted firewood from the Imenti forest (Plate 3 and 4).

Moreover, key informants interview excerpts such as "*In the past, the residents of this area used to harvest firewood and grazing before the onset of rain and crop harvest. Nowadays it is done through the year*" further support these findings. With the increase in population and inadequate participation in other livelihood activities apart from forest and agricultural based activities as revealed in section 4.11.2 and 4.6 respectively. This demand is likely to increase in the near future if no well-informed measures are put into place.

Plate 3: Women getting out of Imenti forest with bundles of firewood

Plate 4: Goats (left) cattle and sheep (right) grazing in Imenti forest

Source: Field work data (2017)

4.8.5 Land tenure insecurity

Further, the results of this study also revealed that land tenure insecurity was also one of the causes of land use change in this study area as stated by (64.1%) % of the household respondents in Figure 4.12. The issue land tenure insecurity in this area was also pinpointed by one of the elderly key informants who stated that "*many land cases have been piled in court in this community; we do not know what will happen to some people when they will be resolved*". This implies that some local residents are in fear of losing their land.

Moreover, it partially explains why a large proportion of the respondents had no title deed and why some of them do not invest in land as revealed in section 4.9 (Figure 4.10) of this chapter. In addition the disrupted forest boundary that was found in the lower part of Imenti forest during field visit (Plate 5) and the statement from one of the forest officer key informant that "*disagreement on the position of forest boundary had caused decline in forest cover in some part of Imenti forest*" underline the impact of land tenure insecurity on land use in this study area.

Plate 5: Disrupted forest boundary near Ruiri

Source: Field observation (2017)

4.8.6. Inadequate participation in other livelihood activities

Inadequate participation in other livelihood activities as a cause of land use change was stated by 56.1 % of the household respondents as indicated in Figure 4.12. This also confirms that most of the respondents in this study area are mainly involved in either agriculture or forest based off-farm livelihood activities as revealed in section 4.6, Figure 4.7. In line with this one of elderly the key informants underlined that "*in this region, most of the people are entirely involved in agricultural and forest activities either directly or indirectly. We have very few people who are nurses, teachers, masons or even hairdressers*".

4.8.7. Ineffective management of Imenti forest

Ineffective management of Imenti forest was also one of the causes of land use change stated by 52.0 % of the questionnaire respondents as in Figure 4.12. Similarly, one of the elderly key informants interviewed stated that "*the ban of shamba system brought a lot of changes in this area. It left some of the people landless and poor. I do not know whether the ban will get out of some people's memory*". In support of this Imo *et al* (2009), also noted that the ban of the Shamba system and establishment of Nyayo Tea Development and Corporation Zone was against the wish of the local communities.

In addition, another elderly key informant noted that "*the engagement of municipal council in the management of Imenti forest lead to loss of many livestock due to the dumping of waste into the forest. Any change that is of good will to us should be made in consultation with Njuuri Nceeke (traditional Meru Governing Council), otherwise it for the demise of this community*". Further, a dump site was observed in forest (Plate 6) during the field work which confirms that there are some inadequacies in the management of Imenti forests

Plate 6: Bottles dumped into the forest
Source: Field observation (2017)

4.9 Effects of land use change

Concerning the impacts of land use change, all respondents had observed or experienced effects of land use change their community. The Figure 4.13 below presents the responses of the questionnaire participants on the effects of land use change in their local environment. Each of these effects is discussed separately in the subsequent parts below.

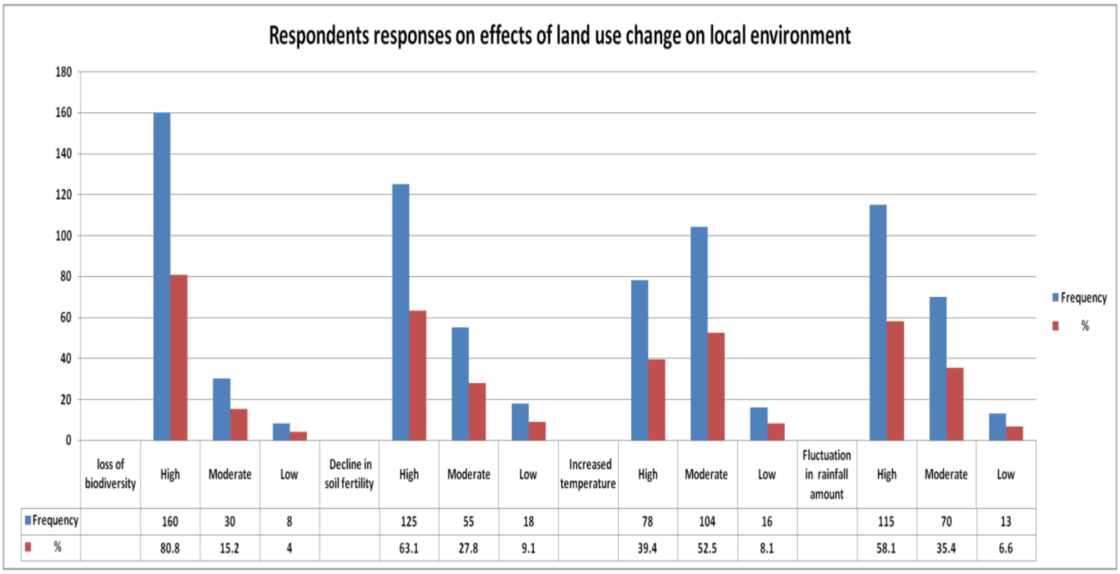


Figure 4.13: Responses on effect of land use change in local environment
Source: Field work data (2017)

4.9.1. Loss of biodiversity

According to the Figure 4.13 above, the majority (80.8%) of the respondents observed that the loss of biodiversity was high, 15.2% stated that it was moderate, while only a small proportion of the respondents (4%) had observed that the loss of biodiversity was low in this area. The key informants also noted that the loss of biodiversity was high in this area. These results agree with those of Ayuyo and Sweta (2014), who found out that land use land cover change in Mau complex, had resulted in loss of biodiversity.

Moreover, both questionnaire participants and key informants were inferred on tree and animal species which were abundantly found in the area about 5 to 10 years ago but today they have declined or disappeared owing to changes in land use. Regarding the plant species, most of these respondents stated that; Muuru (*Vitex Keniensis*), Mukima (*Gravillea robusta*), Murundu (*Celtis Africana*), Muringa (*Cordia Africana*), mubiribiri (*Podocarpus Latifolius*) and Mukurwe (*Albizia Gumifera*) were disappearing from their community. While, Muthigiri (*Lonchocarpus Bussel*), Mwiria (*Prunus Africana*), Mururuku (*Terminalia brownii*), Muroroma (*Ximenia Americana*), Mwariki (*Ximenia Americana*), Mugaa (*Acacia Senegal*) and Murumu (*Fagaropsis Angolensis*) were stated to be have declined over the last 5-10 years due to land use change.

Regarding the animal species, most of the key informant and household respondents pinpointed that lion, elephants, baboon, vervet monkey, hyena, squirrel, fox, salamander, and gecko had declined over the years. On other side, leopards, wild hares, antelopes, snails and concupines were described to have disappeared from the community.

More so key informants interview excerpts such as "*we no longer find Nthia (antelope) and Nduru (squirrels) crisscrossing the paths. People nowadays walk for long distance in search of medicinal trees, long lasting firewood, and durable timber trees. We used to harvest some of these trees near our homestead in past*". All these expresses the negative effect of land use change on biodiversity in this community.

4.9.2. Decline in soil fertility

Out of the total sampled respondents, 63.1% of them observed that loss of soil fertility was high, 27.8 % of them observed that it was medium, while the rest of the respondents (9.1 %) noted that the loss of soil fertility was low as showed in Figure

4.13. This is in line with the findings of Miheretu and Yimer (2017) who reported that land use land cover change had aggravated soil infertility. The loss of soil fertility was earlier revealed as one of the major reasons for the decrease in the productivity of land in section 4.9 of this chapter, which underlies its impact on the livelihood of the residents in this community.

Moreover, the explanation from the agricultural officer that the "*amount of chemical fertilizer supplied to the farmers is increasing over the time*" further underlie the impact of the loss of soil fertility in this study area. In addition, the researcher observed that some farmers had dug terraces in their farm and they mainly planted a mixture of crops. However, it was also observed that mono-cropping was also practiced (Plate 7).

Plate 7: Observed terrace in middle front (left) and tobacco Mono cropping (right)

Source: Field observation (2017)

4.9.3. Fluctuation in rainfall

As far as fluctuation in rainfall amount was concerned, 58.1% of the sample respondents ascertained that rainfall fluctuation was high, 35.4% said that it was moderate, and very small proportion, 6.6% replied that the fluctuation in the amount of rainfall in their area was low as showed in Figure 4.13. The fluctuation in rainfall amount in this community is a challenge because the majority of the respondents had earlier associated the decline in land productivity with its fluctuation (section 4.9). Further, the key informants also concurred that there was fluctuation in the amount of rainfall in the area. These results can be related to that of Ayuyo and Sweta (2014), which revealed that land use land cover change had partly led to the fluctuations and reduction in rainfall.

More so, some of the key informants express the fluctuation in rainfall amount in area when they explained that "*some of our traditional ways of predicting onset of rainfall like alignment of certain types of clouds on mountains, the shape of moon and appearance of cluster of stars like 'Kilimila' are no longer applicable now days*". In relation to this, the rainfall data representing the study area in Table 4.12 below also displays some variation in the amount of rainfall and number of rainy days from year to year, which the research related it to the effect of land use change in this area.

Table 4.12: Total rainfall amount (mm) for study area from year 2009-2017

Year/Day	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	167.6	84.3	182	495	290	64	16.2	51	46	516	372	X
Days	19	22	23	29	30	25	12	27	20	27	26	31
2010	203.5	283	X	X	314	140	201	344	255	401	480	283
Days	23	24	31	30	26	24	27	31	29	31	30	26
2011	168.4	200	363	394	400	370	274.7	347	300	568	802	345
Days	24	13	28	29	31	29	28	29	30	31	30	28
2012	30.8	167	117	875	528	296	376.6	224	210	423	560	357
Days	7	15	20	30	31	30	31	30	29	31	30	31
2013	140.7	89.2	469	795	267	410	342	176	213	237	429	376
Days	25	21	31	30	31	30	30	30	29	30	30	31
2014	97.4	307	293	228	235	239	161.9	198	189	295	409	275
Days	20	22	30	27	30	30	31	30	28	31	30	30
2015	23.5	26.1	65.2	202	87	28	18.4	31	36	30	235	143
Days	11	17	15	29	29	22	17	14	21	21	27	27
2016	158	56.4	59.5	204	150	81	33.1	35	30	64	84	46
Days	27	12	25	25	29	20	29	25	22	21	30	27
2017	27.6	48.4	27	101	89	21	25.0	X	X	X	X	X
Days	23	23	26.3	26	31	18	24	X	X	X	X	X

X indicates missing data
Source: WWO (2017).

4.9.4. Increase in local temperature

From Figure 4.13, more than half (52.5%) of the respondents described that the temperatures had moderately increased in this locality, 39.4% reported that temperatures had highly increased, and 8.1% of them replied that the temperatures had increased slightly in their area. In a similar manner one of the elderly key informants explained that "*when trees were many, we experienced a cool and pleasant breeze during the sunny days. We used to do dig, weed and harvest our crops any time of the day, today most of the people carry out these activities mainly in the morning and evening hours only due to the hot sun (increase in temperatures)"*. Further, a closer examination of the average temperature data for the study area in Table 4.13 revealed some increase in the average temperate from 2009-2017 which also the research related it to the effect of land use change in this area.

Table 4.13: Average temperature (ºc) for the study area from 2009-2017

Year	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	19	20	22	21	20	21	20	20	21	20	19	19
2010	19	21	20	21	21	20	19	19	20	20	18	19
2011	19	21	21	20	20	19	19	19	20	20	19	19
2012	20	20	21	20	19	19	18	19	20	20	19	19
2013	20	21	21	20	20	19	18	20	22	22	20	20
2014	21	22	22	21	21	21	20	21	21	22	21	20
2015	22	24	23	23	22	22	21	21	23	23	22	22
2016	22	23	25	23	22	21	20	21	22	23	21	21
2017	22	22	24	33	22	22	22	X	X	X	X	X

X indicates missing data

Source: WWO (2017).

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0. Introduction

This chapter starts with the presentation of the summary of research findings based on the research objectives, followed by the conclusions and recommendations for practice and to the scholars and researchers.

5.1. Summary of the main research findings

Forests provide functions and services that support livelihoods and ecosystem processes. However, land use~~s~~ changes emanating from factors that vary from one geographical location to another, jeopardize their ability to effectively function resulting in many adverse impacts. The purpose of this study, therefore, was to evaluate how land use had been changing in the Imenti forest from 1986 to 2016, identify their causes and effects.

To this effect, a combination of longitudinal and cross-sectional research designs was adopted. The primary data used in this study came from questionnaires, interview schedules, and the camera. On the other hand, the secondary data used was the 1986, 2001 and 2016 land sat and Google Earth imageries, the 1997 topographic, population and climatic data as well as information from relevant articles and books. The analysis of data was carried out in arc GIS 10.1 and in excel spreadsheet version 2013.

The major findings from the analysis of satellite imageries were:

There was a general decline in the area under indigenous forest, plantation forest and grassland classes while the area under agriculture and bare/built up classes were increasing over the study period.

The annual rate of change in indigenous and plantation forest was higher in the second period (-1.6 and -1.3) than in the first (-1.2 and -0.9) and in the overall period (-1.3 and -1.0). While in agriculture and bare/built up land use classes, the annual rate of change was lower in the second period (2.9 and 1.4) compared to the first (6.0 and 1.9) and to the overall period (5.7and 1.8). However, grassland class was found to have experienced a continuous decline in the annual rate of change that is it declined at an annual rate of 2.3, 2.0 and 1.8 during the first, second and the third comparison period.

Concerning the distribution of land use change, indigenous forest class was found to have lost more of its area than it gained from other land use classes except to grassland and agriculture classes during the first and the second comparison periods respectively. In addition, most of the area under this class was lost to plantation forest (22.0% and 24.7%) and agriculture (18.0% and 22.2%) during the first and the third comparison period while in the second period much of its area lost went to plantation forest class (33.7%).

On other hand, plantation forest class lost more area than it gained from other classes expect to indigenous forest and grassland classes during the first comparison period and to indigenous class during the second and third comparison period. However, throughout the comparison periods, most of the area under this class type was being lost to agriculture class (31.0%, 51.4%, and 48.2 %).

On the side of grassland class type, it was found out that this class type lost more area than it gained to other land use classes except to indigenous and plantation forest classes during the second and the third comparison period. However, this class lost much of its area to plantation forest and agriculture classes (34.7% and 27.5%) during the first comparison period while in the second and third comparison period, most of its area lost went to agriculture (65.6% and 58.1%).

Agriculture class on the other hand was found to have lost most of its area to plantation forest (21.3%) during the first comparison period and to the indigenous forest (16.8% and 17.3%) and plantation forest (20.8% and 16.1%) in the second and third comparison periods. In addition, this class type was found to have mainly gained more area than it lost to other land use classes except to indigenous forest during the second comparison period.

Lastly bare/built up area class lost much of its area to plantation forest (33.2%) and agriculture (31.1%) during the first comparison period and to agriculture (55.2 % and 53.3%) during the second and third comparison periods. Like agriculture, this class type was also found to have gained more area than it lost to other land use classes except to the agriculture class.

On the side of socioeconomic data, the study results revealed that:

Most of the respondents (84.3% and 77.3%) were mainly involved in agricultural and forest based off-farm activities. In addition, the study found out that most of the respondents (89.4%) perceived that their lands were becoming scarce, and population increase was the main cause. Further, the study results established that majority of the respondents benefited from Imenti forest and were willing to conserve this forest, but land insecurity deterred them from doing much to conserve it.

On side of ownership and productivity of land, the study established that more than half (54.5%) of the respondents did not have title deeds for their land and that most of them (84.3%) viewed that the productivity of their land was decreasing over time. Further, the study results revealed that although all respondents invested in land conservation measures, the majority of them (64.6%) viewed that lack land tenure as the block towards investing in land conservation measures.

Further, farmland expansion, population increase, access to road and expansion of urban centres, demand for forest products and grazing land, insecure land tenure, inadequate participation in off-farm activities and ineffective management of Imenti forest were found to be the causes of land use change in this area with farmland land expansion taking the highest lead (90.9%). This could be as a result of rising needs of the increasing population compounded by the factors such land scarcity, decline in productivity of land and inadequate participation in non-agricultural related activities among others

Concerning the effects of land use change, the study result revealed that: the loss of biodiversity was high and that there were some tree and animal species that were abundantly found in this study area in the last 5-10 years but they have declined and some have disappeared owing to land use change. Further, the study also found out that the majority of the respondents viewed that the decline in soil fertility and fluctuation in rainfall amount was high in this study area while temperatures were reported to have moderately increased.

5.2. Summary of the Main Conclusion

Basing on the general objective of the study, the above summary of the results implies that a lot of unpleasant land use changes which were driven by a variety of factors have occurred in this study area since 1986 to 2016 and have resulted in many negative effects.

From the answers to the first objective, it can be concluded that indigenous forest, plantation forest, and grassland classes were experiencing a net loss in their area coverage while agriculture and bare/built up classes were experiencing a net gain in their area coverage during the study period. Further, it can also be concluded that all land use classes changed at a fluctuating rate except grassland class. Lastly, on the same objective, it can be concluded that the distribution of change in each land use class varied from time to time and that plantation forest and active agriculture were the main land use classes up taking indigenous forest the while plantation forest was mainly being up-taken by the agriculture class.

On the side of the second objective on the causes of land use change, the study concluded that land use change in this study was being caused by a variety of factors and that farmland expansion was the main cause.

Lastly basing on the answers to the third objective, it was concluded that land use changes in this study area were negatively manifested through loss of biodiversity, a decline in soil fertility, fluctuation in rainfall amount, and increases in temperature.

5.3. Recommendation for practice

Due to notable unpleasant land use changes that have been observed in this area, the study recommends that continuous studies on land use change in Imenti forest should be done as a way of ensuring that up to date information on the changes that are taking place is made available to the relevant authorities for the necessary mitigation measures.

The trend of indigenous forest shifting to plantation forest and lastly to agriculture clearly indicates that population increase is an underlying driver of land use change in this study area. This is because of high dependence on farm and forest related activities as a source of livelihood by the majority of people. Therefore population increase control may be through intensifying family planning efforts and educating people on the effects of population on land resources will be a timely action. Further, people should be highly encouraged to take part in different livelihood activities apart from agriculture and/or forest based activities.

More so, it was noted that some trees and animal species had declined and others had disappeared over the last 5-10 years due to changes in land use in this study area. Thus reforestation and afforestation activities, especially growing of these trees along with agricultural crops by the local community will help in the restoration of biodiversity. In addition, it will reduce pressure on forests for timber, fodder, and fuel-wood demands among others.

As Olson *et al.* (2004) noted that individuals find no need of investing in the land when they are not sure of the user and ownership rights. In a similar manner, it was noted that land tenure insecurity was a major block towards land conservation, thus speedy issuance of title deeds to the residents can help in solving the problem of land conservation in this study area.

5.4. Recommendations for Future Research

Due to unavailability of cloud-free same season images, the current study determined changes at an interval of 15 years, which could have concealed some important changes that might have taken place, thus future research should consider a shorter timeframe interval, for instance, five years so as to capture the slightest changes. In addition, future studies should consider using higher resolution images.

As it was noted in the literature, land use change has profound impacts on climate, soil, water, biodiversity and human well being among others (Lambin *et al*., 2003). However, due to time constraint only environmental effects of land use change were inquired into, thus future research in this study area should incorporate the socioeconomic impacts of land use change in Imenti on the adjacent rural people.

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APPENDICES

Appendix 1: Household Questionnaire

Good morning /Afternoon. I am a student from Moi University, Geography department. This questionnaire is being used to gather information regarding the changes in land use that has occurred in this area, their cause and effects. I understand that your schedule is busy, but I will be grateful if you please respond to these questions frankly and honestly. I want you to know that your responses will be of great value to the completion of this study. I also wish to assure you that the information that you will provide will be treated with a lot of confidentiality and will be used solely for the purpose of this study.

Thank you in advance for your cooperation.

1) Date………………. 2) Sub-location……………… questionnaire No……….

Part I- General information

1) Gender:

1) Female [] 2) Male []

2) Marital Status

1) Single [] 2) Married [] 3) Divorced [] 4) Widowed []

3) Age bracket (in years):

1) 18-30 [] 2) 31-40 [] 3) 41-50 [] 4) above 51 []

4) Level of education:

1) None [] 2) Primary [] 3) Secondary [] 4) post-secondary []

Part 2 - Livelihood activities, land size, ownership and status

5) What is the major livelihood activity of your household?

1) Mixed farming [] 2) Rearing animals [] 3) crop production [] 4) Other, specify----

6) Apart from the above-stated livelihood activities what other types of work/activity do you or any other member of this household gets involved in? ----------------------------

7) How big is your land in acreage?

1) Less than 1 acre [] 2) 1- 2 acres [] 3) 3-4 acres 4) above 4 acres

8) Do you have a title deed? 1) Yes [] 2) No [] 3) only some part []

9) Is your land becoming scarce, abundant or it has not changed at all?

1) Scarce [] 2) still abundant [] 3) No change

10) If scarce, what are the reasons for scarcity?

1) Increase in human population [] 2) Loss of land fertility [] 3) Inadequate off-farm activities [] 4) Land taken by government [] 5) other specify--------

Part 3- Benefits and conservation of Imenti forest

11) What are major benefits do you get from Imenti forest? (Multiple answers)

1) Firewood [] 2) Building material 3) Fodder/grazing []

4) Fruits, herbs and honey [] 5) No benefit [] 6) other specify----

12) How do you participate in the conservation of Imenti forest?.

1) By use of licenses [] 2) by Planting seedlings [] 3) by Acting as watchdog []

4) Don’t participate [] 5) other specify----

13) What reasons keep you from doing more to conserve Imenti forest?

1) Lack of land security [] 2) Time does not allow me [] 3) I do not benefit from it [] 4) others specify---------

Part 4- Land productivity

14) How do you consider the productivity of your land over the last 5-10 years?

1) Has decreased, [] 2) has Increased [] 3) has been same

15) If it as decreased, what are the major reasons

1) Fluctuation in Rainfall amount [] 2) loss of soil fertility [] 3) inadequate application of fertilizers and other inputs [] 4) In access to extension services [] 5) other, specify----

16) Which is your main method for land conservation?

1) Terracing [] 2) contour ploughing [] 3) tree planting [] 4) Intercropping [] 5) Compost manure / fertilizer [] 7) other, specify----------

17) What keeps you from investing in land conservation methods?

1) Inadequate income [] 2) lack of land tenure [] 3) Lack of knowledge [] 4) Other, specify------

Part 5- Causes of Land use change

18) Have you observed any changes in land use in this area over the last 5-10 years or so?

1) Yes [] 2) No []

19) What changes have you observed?

Changes in:

Land use type	Increased	Decreased
Cropland		
Forest cover		
degraded land		
Grassland		
Bare/built up area		

20) What are the causes for the observed land use change in your area? (Multiple answers allowed possible)

1) Population increase [] 2) insecure land tenure [] 3) Farmland expansion 4) Access to road and expansion urban centres [] 5) inadequate participation in other livelihood activities [] 6) demand for forest products and grazing land [] 7) Ineffective management of Imenti forest [] 8) other, specify-------------

Part 6- Effects of land use change

21) Have you observed or experienced any effects of land use change in your community?

1) Yes [] 2 No []

22) If yes in question 21 what are the effects of land use change on the livelihood of your community in terms of;

Effects	High	Moderate	Low
Decline in soil fertility			
Increase in local temperature			
Rainfall fluctuation			
Loss of biodiversity			

23) Do you know of any tree species or wild animal which existed abundantly in the last 5-10 years has disappeared or declined today owing to land use change?

1) Yes [] 2) No []

24) If yes in question 25 above Please fill the Table below

Name of a tree		Name of wild animal	
Disappeared	Decline	Disappeared	Decline

Thank you for your cooperation and sincerity

Appendix 2: Key Informants Interview Schedule

Good morning /Afternoon. I am a student from Moi University, Geography department. This interview schedule is being used to gather information regarding the changes in land uses that have occurred in this area, their causes and effects. It is also helpful to get additional information which may or may not be responded by the questionnaire respondents. I kindly request you to respond to these questions frankly and honestly. I also want to assure you that your response will be kept strictly anonymous and confidential.

Thank you in advance for your cooperation.

The person interviewed……………… sub location…………………

1) What is a major livelihood activity of rural households in this community?

2) Are there changes in this area with regard to vegetation cover, surface water and land use pattern over the past 5-10 years or so? If any, please explain the changes that have occurred in: - a) Forest cover b) Degraded land c) Cropland d) Grassland e) bare/ built up area.

3) Please explain the major causes for these changes.

4) Have you observed or experienced any impacts of land use change in this community? If yes, please explain them in terms of: Biodiversity, soil fertility, rainfall pattern and temperature.

5) In the last 5-10 years have you observed a decline or loss of tree species and wild animals in your area? If yes, please describe.

Thank you for your co-operation and sincerity

Appendix 3: IREC Permit

INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471/2/3

MOI UNIVERSITY
SCHOOL OF MEDICINE
P.O. BOX 4606
ELDORET
Tel: 33471/2/3

Reference: IREC/2017/52

30th March, 2017

Lucyline Kajira Njeru,
Moi University,
School of Arts and Social Sciences,
P.O. Box 3900-30100,
ELDORET-KENYA.

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
30 MAR 2017
APPROVED
P. O. Box 4606-30100 ELDORET

Dear Ms. Njeru,

RE: EXPEDITED APPROVAL

The Institutional Research and Ethics Committee has reviewed your proposal titled:

"Analysis of Land Use Land Cover Change using GIS and Remote Sensing within Imenti Forest and Adjacent Areas, Meru County Kenya".

The proposal has been granted an Expedited Approval on 30th March, 2017 and you are therefore permitted to commence your investigations.

Note that this approval is for 1 year; it will thus expire on 30th March, 2018. If it is necessary to continue with this research beyond the expiry date, a request for continuation should be made in writing to IREC Secretariat two months prior to the expiry date.

You are required to submit progress report(s) regularly as dictated by your proposal. Furthermore, you must notify the Committee of any proposal change (s) or amendment (s), serious or unexpected outcomes related to the conduct of the study, or study termination for any reason. The Committee expects to receive a final report at the end of the study.

Sincerely,

PROF.E.WERE
CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc: CEO	-	MTRH
Principal	-	CHS
Dean	-	SOM
Dean	-	SON
Dean	-	SPH
Dean	-	SOD

Appendix 4: NACOSTI Permit

CONDITIONS

1. The License is valid for the proposed research, research site specified period.
2. Both the Licence and any rights thereunder are non-transferable.
3. Upon request of the Commission, the Licensee shall submit a progress report.
4. The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.
5. Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.
6. This Licence does not give authority to transfer research materials.
7. The Licensee shall submit two (2) hard copies and upload a soft copy of their final report.
8. The Commission reserves the right to modify the conditions of this Licence including its cancellation without prior notice.

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No.A 15713

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MS. LUCYLINE KAJIRA NJERU
of MOI UNIVERSITY, 0-60400 CHUKA,has been permitted to conduct research in ***Meru County***

on the topic: ***ANALYSIS OF LAND USE LAND COVER CHANGE IN AND AROUND IMENTI FOREST, MERU COUNTY, KENYA***

for the period ending:
12th September,2018

Permit No : NACOSTI/P/17/86022/18890
Date Of Issue : 12th September,2017
Fee Recieved :Ksh 1000

....
Applicant's Signature

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

Appendix 5: KFS Permit

Telephone: 064-30605
E-Mail:zmmerucentral@kenyaforestservice.org

KENYA
Forest Service

ECOSYSTEM FOREST CONSERVATOR
P.O BOX 110 - 60200
MERU

CONF.5/3B/2
And Date:
14th August 2017

Lucyline Kajira Njeru
Moi University
P.O. BOX 3900
ELDORET

AUTHORITY TO CARRY OUT RESEARCH IN IMENTI FOREST –MERU

your unreferenced letter dated 14th August 2017 refers.

Authority is hereby granted to you to carry out research and analyze the Land use and Land cover change in and around Imenti forest.

By a copy of this letter the station managers for Meru station and Lower Imenti forest are therefore requested to facilitate your access to the station.

(S.K. MUKUNDI)
ECOSYSTEM CONSERVATOR
MERU

C.C
Forest Managers –
Meru
Lower Imenti

ECOSYSTEM CONSERVATOR
MERU
P.O.BOX 110-60200, MERU