TREE STAND STRUCTURE, SPECIES COMPOSITION AND VEGETATION COVER CHANGES IN LONDIANI FOREST KENYA

Kosgey Chepkoech Evalyne

A Thesis submitted in partial fulfillment for the requirement of the award of Master of Science Degree in Environmental Science of Masinde Muliro University of Science and Technology

November, 2023

DECLARATION

This thesis is my original work and has not been presented for any degree award in any learning institution.

Signature……………………………………….Date…………………………………

Kosgey Chepkoech Evalyne

SEV/G/01-53285/2018

CERTIFICATION

The undersigned certify that we have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology this thesis titled '**Tree Stand Structure, Species Composition and Vegetation Cover Changes in Londiani Forest Kenya'.**

Signature …………………………………Date……………………………………….

Dr. Humphrey Agevi

Department of Biological Sciences

School of Natural Sciences (SONAS)

Masinde Muliro University of Science and Technology (MMUST)

Signature…………………………………Date………………………………………...

Dr. Henry Lung'ayia

Department of Biological Sciences

School of Natural Sciences (SONAS)

Masinde Muliro University of Science and Technology (MMUST

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DEDICATION

I dedicate this thesis to my awesome parents Mr John Kosgey and Mrs Rose Kosgey thank you so much for your endless support, my brothers and sisters, my all-time motivation, and finally to my husband Mr David Madakwa Otaka and my sons Nathan and Jothan I love you all.

ACKNOWLEDGEMENTS

This thesis is a result of generous contributions and assistance of a number of organizations, institutions and individuals both within and outside Masinde Muliro University of Science and Technology (MMUST).

My gratitude goes to MMUST through the Department of Biological Sciences for availing the necessary resources that made it possible to come up with this thesis. I also wish to extend my special thanks to my able supervisors Dr. Humphrey Agevi and Dr. Henry Lung'ayia for their useful insights, helpful suggestions, guidance and supervision throughout this thesis development and final write up. To Dr Phillip Ogutu the Chairman of the Department of Biological Sciences for his support and encouragement.

I also wish to convey my heartfelt gratitude to all who contributed to this exercise including Kenya Forestry Research Institute (KEFRI) Londiani, Kenya Forest Service (KFS) Londiani, Focus Group Discussion (FGDs) participants, Londiani Community Forest Association (LOCOFA) members, area Village chiefs, and all others whose names and designation may not have been stated in this report. Above all, much thanks to the Almighty God without whose blessings, grace and wisdom this study report would not have been what it is.

ABSTRACT

Vegetation is an important variable in land-atmosphere interactions. Sustainable forest management requires monitoring of vegetation cover dynamics to help improve forest health. Many studies have been conducted in many forest ecosystems in Kenya but only a few have analyzed vegetation cover dynamics of the Londiani Forest on tree stand structural heterogeneity. The main aim of this study was to assess tree stand structure, species composition and forest cover change in Londiani Forest in Kericho County over the past 20 years. Specifically, the study aimed to (i) determine tree stand structure and species composition, (ii) determine forest cover change of Londiani Forest, and (iii) evaluate the roles of the forest adjacent community (FAC) influencing vegetation dynamics. Londiani Forest is divided into Kedowa, Chebewor and Londiani. From each of these blocks transect running 100m from the edge of the forest were laid. Quadrats measuring 100x100m were established every 200 meters for the length of the transect. Data on standing/live trees, abundance and tree species were determined and recorded in a data sheet. Diameter at Breast Height (DBH) was measured 1.3m from the ground using a diameter tape. Tree height was also measured using a Suunto clinometer. Nested 25x25m-quadrats for saplings and 1x1m for seedlings were laid where all the saplings and seedlings for each tree species were recorded. Stumps of trees which had been cut previously were counted in addition to identifying tree species which each tree stump was derived from. The use of Normalized Difference Vegetation Indices (NDVI) to detect forest cover changes was employed in the study. Landsat Thematic Mapper TM images were acquired and processed with the Arc Map GIS software version 10. Supervised classification was carried out to delineate the images into three classes (forest, grasslands/ bush lands and bare lands/ water bodies) to analyze the extent of forest cover changes in the selected years (2000, 2003, 2010, 2015 and 2020). Adjacent to each of these forest blocks, 9 villages were selected using the purposive sampling method. Structured questionnaires and interviews were administered; Focus group discussions (FGDs) and interviews were held with the key informants and institutional managers involved in forest management to ascertain the role of the community in vegetation dynamics. Quantifiable data were entered in Ms Excel for data management and calculation of; Total density, species density, diversity, abundance, richness, similarity, evenness and basal area. Predictive Analytics Software (PASW) version 25 was used to analyze various variables between and within the study sites. A total of 1,308 individual trees belonging to 34 different species from 24 families were recorded. Kedowa had an abundance of 457 trees and richness 27, Chebewor 417 trees, richness 19 and Londiani 434 trees, richness 14. Kedowa block had a diversity of H'= 0.864, Chebewor H'= 0.855 and Londiani H'= 0.792. A total of 58 charcoal making spots were recorded. NDVI maps showed that Natural forests increased by 30% between 2000 and 2010, plantation forest increased by 50% between 2000 and 2010. NDVI values for natural forest ranged from 0.4 recorded in the year 2000 to 0.7 in 2010, plantation forest 0.2 in 2000 to 0.5 in 2010. The Londiani Forest Adjacent Communities (FAC) is involved in forest activities confirmed by the high Community Forest Associations (CFA) membership of 81% under different user groups like ecotourism at 10%, bee keeping at 6%, seed and seedling collection at 30% and tree nursery at 53%. The study findings would inform sound decision making on forest management and recommends for adoption of its findings and suggestions by forest management institutions and agencies for a better understanding of forest cover changes which is urgently needed to strengthen operations on forest management.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CARPE	Central Africa Regional Programme of the Environment
CBO	Community Based Organizations
CFA	Community Forests Association
CIFOR	Center for International Forestry Research
COP	Conference of the Parties
DBH	Diameter at Breast Height
EANHS	East African Natural History Society
ERDAS	Earth Resources Data Analysis System
ETM	Enhanced Thematic Mapper
FAC	Forest Adjacent Community
FAO	Food and Agriculture Organization of the United Nations
GFR	Global Forest Review
GIMMS	Global Inventory Monitoring and Modeling Studies Working Group
GIS	Geographic Information System
GFW	Global Forest Watch
GOK	Government of Kenya
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
IPNI	International Plant Names Index
ISLA	Initiative for Sustainable Landscapes
KEFRI	Kenya Forestry Research Institute
KFS	Kenya Forest Service
KIFCON	Kenyan Indigenous Forest Conservation Programme

KNBS	Kenya National Bureau of Statistics
KWS	Kenya Wildlife Service
LOCOFA	Londiani Community Forest Association
LSI	Life Science Identifier
LULC	Land Use Land Cover
MMUST	Masinde Muliro University of Science and Technology
MODIS	Moderate resolution Imaging Spectroradiomater
MPA	Marine Protected Area
NDVI	Normalized Difference Vegetation Index
NEMA	National Environment Management Authority
NFRA	National Forest Resources Assessment
NRM	Natural Resource Management
PASW	Predictive Analytical Software
PELIS	Plantation Establishment for Livelihood Enhancement Scheme
PFM	Participatory Forest Management
REDD	Reducing Emissions from Deforestation and Forest Degeneration
SDG	Sustainable Development Goal
TM	Thematic Mapper
UNEP	United Nations Environment Programme
WRI	World Resource Institute

DEFINITION OF OPERATIONAL TERMS

Tree Stand Structure: Is the overall look of a forest stand. It describes the general components of a given forest both vertically and horizontally. The distribution of various components of forest like crown layers, shrubs, seedlings and saplings, the stem, height, diameter among other key features of a forest according to Helms, (2010). In this study this term refers to the presence and physical arrangement of various biological and physical components of the forest.

Tree species composition: In this study this term refers to the biodiversity (includes all living organisms both plants and animals) of a forest system, including the variety of species, genes, ecosystems and communities.

Forest cover change: In this study this term means the decline or increase in forest cover over time. Percentage of forests land areas.

Forest cover analysis: This is a procedure used in identifying differences in forest cover over time. In this study, multi-temporal sets were used to quantify forest cover changes.

Normalized Difference Vegetation Index (NDVI): This is a technique used in this study to detect change in green vegetation.

Land use land cover change: In this study, Land cover change means any alteration in key land features like the vegetation type that had previously existed for a long period of time giving it a new look. Land use change on the other hand describes a certain shift in how land is used or managed by humans.

Sustainable forest management: Proper utilization and conservation of forests for the present and future generations.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Forests are important to human beings especially the communities adjacent to them both for development and survival (Hansen *et al.*, 2012). Their enormous contributions range from control of hydrological, biogeochemical cycles like carbon, nitrogen and phosphorus, to air purification, provision of ecosystem goods and services also habitat for a great diversity of fauna (Jianbang *et al.,* 2016). In developing nations, forests play a crucial role in sustaining the livelihoods of populations residing nearby (World Bank, 2012). The Rural communities in developing countries obtain approximately 22% of income from forest products (FAO, 2012). According to research done in Tigray, northern Ethiopia, forest products represent the locals' second-largest source of income, behind agriculture (Jean, 2001). Apart from income, forests also are the main source of fuel wood for over 2.4 billion people worldwide (WRI, 2021).

Despite international efforts in forest protection, the loss of tropical primary forests has persisted over the past decade (WRI, 2021). The rate of forest loss today is similar to that of 2010 but what has changed is the relative contributions of forest growth from different countries for example; between the years 2002 and 2020, Indonesia added 6.96Mha of forest, the United States gained 13.8Mha, Russia added 16.2Mha of forest, Canada 9.11Mha and Brazil 7.59Mha (GFR, 2022). Kenya is a country with a low percentage of forest cover, and it has also had to deal with the difficulty of declining forest cover, which resulted in the loss of over 241,000 ha of forest between

1990 and 2010 (KFS, 2012). Recently, Kenya attained a 10% forest cover, half of the target of 20% cover by 2030 (KFS, 2022).

Tropical rainforest biodiversity is threatened by intense anthropogenic pressure that include, deforestation, habitat degradation, fragmentation, exploitation, invasive species, pollution, and global climate change (Maraga *et al.*, 2010). Besides, synergies among these drivers have had a major negative impact on biodiversity and alter the stand structure of the forest ecosystems (Krishnamurthy *et al.*, 2010). Tropical forest restoration which models the natural regeneration has been adopted as a strategy for restoring degraded forests (Abebe *et al.*, 2022). The patterns of regeneration drive the structure and composition of the forests and influence the species composition of tropical forests at different spatial scales (Danková & Saniga 2013). Data and information are key to sustainable management of forests (Wright *et al.*, 2021). Such information is obtained mainly through forest inventories. Forest inventories are crucial in forest management because they provide the data for planning, monitoring, evaluation, research, growth and yield, biodiversity, and timber sale (Marengo, 2013). Monitoring and protection of forest resources are essential to protect the environmental equilibrium (Purnomo *et al*., 2018). There are techniques used for monitoring vegetation primarily with the help of Remote Sensing and Geographic Information System (GIS) (Dong *et al*; 2010). Such methods include the Normalized Difference Vegetation Index (NDVI) which is one of the most important and popular method as it has been used by several researchers and produced very high accuracy and benefits for planning purpose (Dong *et al*; 2021). In this context, this study therefore sought to find out the tree stand structure, species composition and vegetation cover change in Londiani Forest, Kenya.

1.2 Statement of the Problem

Forests are crucial and important resources to the forest adjacent communities who depend on them for livelihood (Rosende *et al.,* 2021). However mass deforestation continues to threaten tropical forests, through the loss of their biodiversity which interferes with their ability to provide ecosystem goods and services (Runyan and D'Odorico, 2016). Forests face a lot of threats which are either natural or as a result of anthropogenic activities. Human-caused disturbances, either through logging or development activities, can alter the ecological relationships significantly making them different from those governing wilder environments (Tye *et al.,* 2022). These include wildfire, conversion of forest lands to agricultural lands, livestock ranching, and logging for timber, among others (Tye *et al.*, 2022). Forests cover 31% of the total land area of the Earth but annually 75,700 km^2 (18.7 million acres) of forest is lost (Vallee *et al*., 2022). In 2013, Kenya's forest cover was at 6.99% then dropped to 5.99% in 2018 (KFS, 2022). Kenya recently attained a 10% tree cover and now stands at 12.13 %, the forest cover though is still below the 10% threshold but is at 8.83% up from 5.9% of 2018 (KFS, 2022).

Londiani Forest which is part of Mau Forest complex ecosystem is facing various threats such as; forest excision, encroachment, illegal logging, overgrazing, rampant charcoal production, political interferences, unsustainable Plantation Establishment for Livelihood Improvement Scheme (PELIS) system, ballooning of plantation forest, pollution from factories wastes both liquid and solid and debarking of trees for medicinal purposes and construction of bee hives (KFS, 2018). The resultant impact of these threats is evident in the change in land cover where forest land decreased by 21,740ha while cropland increased by 14,849ha inside the gazetted forest of Mau between 1990 and 2016 (UNEP, 2016). A forest inventory system should be developed to support physical planning purposes, environmental policy and sustainable land use and development. While studies have been done on Londiani Forest, there is limited focus on the vegetation cover change in the forest over time and what triggers the change. In addition, there are limited documents that link the forest adjacent communities to the dynamics in the forest cover. This study therefore sought to assess vegetation dynamics of Londiani Forest and the role forest adjacent communities' play in creating these changing aspects. For the first time, this study reports finding on the current forest stand structure, species composition and vegetation cover change of Londiani Forest. This information will help strengthen Kenya Forest Service (KFS) and Community Forest Association (CFA) operations geared towards forest sustainability. In this context, this study helped to generate information on tree stand structure, species composition and vegetation cover changes of Londiani Forest, which is very crucial in understanding human and natural phenomena interactions for better management of forests.

1.3. Justification of the Study

A small number of locations on Earth are still unaltered from their original state and have not been affected in any manner by anthropogenic activities (Meyfroidt *et al.*, 2011). By 2030, all nations must protect and restore water-related ecosystems, including forests, according to Sustainable Development Goal (SDG) number 6. This project also supports SDG number 13, which aims to incorporate climate change mitigation measures into national strategies, policies, and planning. Improvements to education, awareness-raising, and institutional and human capacity for climate change adaptation, mitigation, early warning, and damage reduction (UNEP, 2016). World nations in the 2021 Climate Change meeting (COP 26) agreed that they will conserve protect and increase tropical forests so as to reduce climate change (IPCC, 2021). Kenya, being one of the nations, promised to stop deforestation by the year 2030. Kenya Forest Act 2016 defines the rights in forests and makes provision for use, conservation and management of forests. Londiani Forest is one of the most degraded forests in Kenya and requires immediate attention to halt further destruction and encourage reforestation efforts. In this context, this study helped generate information on tree stand structure, species composition and vegetation cover change of Londiani Forest which will help forest institutions, agents and managers to understand relationships between human and nature for better forest management. The findings of the study sought to generate information which will support physical planning purposes, contribute to environmental policy and sustainable land use and land development required by decision makers and planners to strengthen CFA operations in forest conservation. It has also contributed to the existing literature and knowledge on forest conservation and opened gaps for future research.

1.4 Objectives

1.4.1 General objective

The main objective of the study was to assess the tree stand structure, species composition and vegetation cover changes in Londiani Forest in Kenya.

1.4.2 Specific Objectives

The specific objectives of this study were to determine;

1. Species composition and forest stand structure of Londiani Forest.

2. Forest cover change of Londiani Forest for selected years of last 20 years.

3. The roles of the forest adjacent communities influencing vegetation dynamics.

1.5. Research Questions

1. What is the current species composition and stand structure of Londiani Forest?
2. How has Londiani Forest cover changed over time within the last 20 years?
3. Do the forest adjacent communities play a significant role in vegetation dynamics of Londiani Forest?

1.6. Limitations of the Study

The study was limited to the residents of Londiani area targeting those who have lived in the area for the past 10 years. A sample size of households was surveyed out in the area due to time and financial limitations. The basic assumption was that the communities can successfully conserve and manage the forests if allowed to participate in forest conservation projects. Other assumptions were that the views given by those interviewed and responded to the questionnaires reflect the views held by the whole community.

The study was subject to the availability and quality of data collection equipment, like clinometer or altimeter and rangefinder for tree height estimation, measuring tape for quadrat sampling, global positioning systems (GPS), topographical maps and compass for navigation inside the forest, camera for digital picture coverage. The study was also subject to area accessibility and the availability of the people to assist in administering the questionnaires and household heads to respond to the questionnaires.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the review of literature guiding the study. Forests are under threats and efforts to halt further degradation are being encouraged currently. Few studies have directly addressed the question of what the current tree stand structure is in Londiani Forest, species composition, how the vegetation cover has changed over the last 20 years and the role the forest adjacent communities play in forest cover change. What is known about each of the three specific objectives is reviewed and finally the gaps of knowledge identified are discussed.

2.2. Determination of Forest Composition and Stand Structure

Forest stand structure is the vertical and horizontal components distributions of a stand which include the diameter, height, stems of trees, shrubs, crown layers, herbaceous understory and down woody debris (Helms, 2010). Zhang *et al.,* (2017) defined structure as the arrangement of various physical features and also the biological components of any given ecological system. Forest composition on the other hand refers to the biodiversity of an ecological system that includes genes varieties, species, communities, and ecosystems as a whole (Zhang *et al.*, 2017)

The biological diversity of a forest is a broad term in nature and refers to all life forms existing within forested areas and the roles they play ecologically (Nouri *et al.*, 2017). The variety of animals, plants, and microorganisms that live in forest environments as well as their related genetic diversity are all included in the term "forest biological di versity," which goes beyond merely trees (Nouri *et al.*, 2017). The biological diversity of a forest can be considered at different levels where complex interactions can occur within and amongst these levels, like the landscapes, ecosystem, species, genes and populations (Ali *et al*., 2019).

Biological diversity in forests is produced through evolutionary processes that are infl uenced by ecological influences taking place over thousands and at times even millions of years, such as climate, human and natural disturbances, fire and competition in themselves resulting in high levels of adaptation, that is a feature of forest ecosystems which is an integral component of their biological diversity (Culas, 2007). Biodiversity, a very broad term is generally measured within three precise areas starting from the species diversity, genetic diversity, and finally the ecological diversity (Ali *et al*., 2019). The evenness and richness of the tree composition in any particular forest can be used to measure the lowest measurement point, or species diversity (Culas, 2007). The number of different tree species present in a forest is called its richness while Evenness compares the number of individuals of each of those species present in the forest (Ali *et al*., 2019). For a complete understanding of a forest's biodiversity, the evenness value helps measure the distribution and abundance of tree species. The forest structural diversity includes both above and below ground, horizontal and vertical structure (Zhang *et al*., 2017). An understory and overstory are parts of a diverse vertical structure containing shrub, tree and forb layer. Layer variation across the terrain is part of a complex horizontal structure (Culas, 2007). The processes taking place inside a forest ecosystem are referred to as the function of a forest, also known as forest functional diversity (Trosper, 2011). Numerous functions of forests include the cycling of nutrients, the production of oxygen, the construction of carbon-based products (such as leaves, twigs, stems, and bark), and the creation of a natural home for animals (Bonan, 2008). Forests also provide ecosystem services like, forests products, aesthetic value and recreational opportunities which are beneficial to human beings (Bonan, 2008).

To achieve sustainable forest management, important activities like monitoring, assessing and reporting on biological diversity should be carried out (Ali *et al*., 2019). Monitoring of biological diversity and early detection of any changes that might be caused by forestry and other land use practices is important in assessing the effectiveness of forest management (Butler *et al*., 2008). Forest structure changes over time, and therefore, a stand examination is always important to measure forest at any point in time (Zhang *et al.*, 2017). Foresters often assess what is present, state what is desired in the future, and then develop precise guidelines of forest structure management to successfully manage wood quality, wildlife habitat, desired growth rates and a myriad of other forest management objectives (Ali *et al.*, 2019). A lot of forests have experienced multiple and often overlapping perturbations such as illegal logging, over grazing and forest fires, leading to forest cover change (FAO, 2012). Illegal logging results in huge changes in forest structure and composition because it removes large, fire tolerant trees, leaving behind bare forest lands (Keeling, 2006).

In the western U.S for example, semi-arid low and middle elevation forests have experienced significant changes including shifts in species composition, increases in density of trees and changes in resource availability since the settlement of Euro-Americans implicating the landscape and stand level causing ecosystem dysfunction in many modern forests (Butler *et al*., 2008). Historically, evidence of ecosystem dysfunction has been cited as disturbances, altered structure and composition, diminished resilience, lack of spatial heterogeneity and have since become ecological restoration focus, perceived by many as the best solution for impaired ecosystem function (Bonan, 2008).

2.2.1 Mapping Forest Stand Structure

Aerial photography and Landsat (SPOT) French word *Satellite Pour l'Observation de la Terre*, geographic information systems (GIS) and remote sensing techniques have progressively enhanced their capacity to measure forest stand structure, and now advanced radar and multidirectional sensors (Wright *et al.,* 2021). To provide a more complete spatial and temporal coverage a multisensory approach is valuable at times. Iverson *et al*., (1995) for example; used both Advanced very-high-resolution radiometer (AVHRR) and TM data in a project in Midwestern United States to map forest cover of a 13-state region in a study, Cohen *et al.,* (1995) combined both SPOT and TM to generate data that was used to estimate forest structure of conifer forests found in the Pacific Northwest. Additionally, Cohen *et al.,* (1995) accurately mapped forest cover on more than 1.3 million ha. Similar to this, Olsson, (1994) distinguished between thinned and un-thinned stands of Norway spruce and Scots pine in Sweden using multispectral indices that were also derived from TM data.

Other international studies from which nation-specific land cover maps have recently been established include the Tropical Ecosystems Environment observation by Satellites (TREES) 1 and 2 projects (Malingreau *et al.,* 1995); (Richards *et al.,* 2000). NASA Landsat Pathfinder Project (Zhang *et al.,* 2017); and the Global Rain Forest Mapping Project (Mayaux *et al.,* 1999). The TREES project, for instance, was carried out by the Joint Research Center at Ispra with the goal of mapping tropical ecosystems throughout the world. The study used 1.1 km AVHRR data to create a base map of a tropical forest and pinpoint regions that were actively being deforested (Malingreau *et al.,* 1995). Their TREES project produced a set of maps showing the tropical forest cover and statistics on the amount of forest land in each nation. In the first phase of the TREES project, tropical forest cover was mapped using a wall-to-wall strategy using atmospheric administration (NOAA) AVHRR and National oceanic data, while the second phase of the project used coarse resolution ERS Along Track Scanning Radiometer (ATSR-2) to enhance the thematic content of the low resolution forest cover maps by highlighting areas of rapid change, also known as "hotspot" detection.

Shantz and Marbut, (1923), Keay, (1959), and later White, (1983) made earlier attempts to map the African continent's vegetation at the continental and sub-continental levels (central African sub-region). In order to create a land cover map for the central African sub-region, Laporte *et al.,* (1998) used a multi-resolution, multi-temporal NOAA AVHRR dataset, a fusion of Local Area Coverage (LAC), Global Area Coverage (GAC), and ancillary information (political and park boundaries, settlements, rivers, and roads). The project's final product was a map made for the Central African Regional Program of the Environment (CARPE) that provided a comprehensive overview of the area covered by the dense humid forest in central Africa. Later, the same map was validated by combining field trips with imagery with a higher resolution (Landsat MSS).

The greatest still complete and continuing continuous area of moist tropical forest on the African continent is found in Central Africa, primarily in the Congo basin, and it makes up the second-largest forest in the world after the Amazon forest (Mayaux *et al.,* 1999). The Congo basin forest is very important globally since it has wide biological diversity and is significant both for endemic species and for the total number of species existing there and so efforts are currently being encouraged to protect the forest (FAO, 2012). Under the African forest mapping several studies have been carried out like the one that used supervised pixel-based classification using Maximum Likelihood Classifier (MLC) and the Nearest Neighbour (NN) object-based classification implemented to map the tropical forests of the mount Cameroon (Mayaux *et al.,* 1999). The relevant thematic maps and a visual examination of the demarcation of land cover/use categories were used to evaluate the effectiveness and correctness of both methodologies utilized in mapping the woods of Cameroon. Baldyga *et al*., (2007) did an assessment of land cover changes in the eastern block of Mau Forest Complex and found out that there has been a reduction in forest cover along river Njoro watershed as small scale farming communities encroach on the forest. The Kenya Indigenous Forest Conservation Programme (KIFCON) prepared data sets for all forests in Kenya and these can be used to identify regions with forest cover in Kenya (Blackett, 1994).

2.3. Analysis of Forest Cover Change using Normalized Difference Vegetation Indices

In recent years, remote sensing data has been used and has shown to be incredibly helpful in identifying, assessing, and tracking the changing patterns of vegetation (Mayaux *et al.,* 1999). Satellite data has been used to measure change in green vegetation because it has several advantages for instance satellite data are available from the past 5 decades (1970) until the present times, and obtaining records of land cover information especially for large geographic areas is very easy and accessible (Smith and Allesandro, 2002). The data are multi-spectral in nature, allowing for the differentiation of various materials found on the surface of the earth. The Normalized Difference Vegetation Index (NDVI), a ratio that employs the NIR and red bands to discern the differences between vegetation and non-vegetation, can be used to assess changes in greenery. NDVI has been frequently used to monitor change in vegetation because it takes into account differences in shadow caused by changes in the sun's elevation angle and is least affected by terrain (Lillesand *et al*., 2004).

Among other techniques, vegetation indices like the NDVI are reliable for detecting changes in the vegetation (Lillesand *et al*., 2004). The visible, near-infrared, and mid-infrared regions of the electromagnetic spectrum (EMS) are where NDVI receives its information on vegetation bio-physical properties (Owen *et al*., 1998). This approach is based on the observation that healthy vegetation has low reflectance in the visible region of the EMS due to Chlorophyll and other pigment absorption and high reflectance in the NIR due to internal reflectance (Owen *et al*., 1998). NDVI calculated as a ratio of Red and NIR bands of a sensor system has values ranging from -1 to +1. Healthy vegetation is represented by high NDVI values between 0.1 and 1 because of high reflectance in the NIR portion of the EMS and non-vegetated surfaces such as pavements, buildings and water bodies yields (-1 to 0) negative values of NDVI (Lillesand *et al.,* 2004).

China is a country that harbors diversified forest types ranging from tropical rainforest to boreal coniferous forest. Over the past several decades, China has implemented large-scale reforestation/afforestation programs, which results in a change in the country's forest cover (Zhang *et al*., 2017). In India, Multi-Temporal LandsatTM imageries from the years 1989, 2001, 2003, 2009, and 2010 were utilized to detect changes in the amount of forest cover in the areas near Reingkhyongkine Lake using remote sensing technologies and geographic information systems (Lillesand *et al*., 2004). Following that, NDVI was used to identify locations where the forest cover has changed over the course of the research years. Additionally, quantitative data resulting from NDVI were generated and summarized using remote sensing, GIS software, and spreadsheets (Lillesand *et al*., 2004). The categories that resulted from the researchers' crossing of the NDVI-derived maps of 1989 and 2010 to create the change map of vegetation cover were lowered, some declined, some raised, and increasing forest cover (Lillesand *et al.,* 2004). The study revealed that the Indian forest cover of the study areas changed significantly during 1989 to 2010 due to natural and anthropogenic activities like; illegal forest cutting, hill erosion, forest fires, cultivation, and forest encroachment due to poor land tenure system (FAO, 2012). In Croatia Madimurje County, a study to evaluate LULC was done to detect land cover change between 1978, 1992 and 2007 using Landsat satellite images Multi-Spectral Scanner (MSS), TM and ETM (Li *et al*., 2008).

As test locations for the potential use of remote sensing for resource surveying, mapping, planning, and development in 1970, the Food and Agricultural Organization (FAO) selected Sudan and two other nations in South America and Asia. For this study images for some parts of Sudan were obtained by land sat–1 from August 1972 to March 1973 (Olsson, 1995). Olsson (1995) used spatial models, GIS, and remote sensing methods to map the semi-arid Sudan while tackling an integrated study of desertification. The project's objectives were to establish technique for integrating sensing data with auxiliary data in raster and vector formats using GIS in semi-arid Sudan and to apply it to the study of desertification.

The east Africa region has known severe vegetation degradation over the past decades due to several causes both anthropogenic and natural (FAO, 2012). The effects of climatic conditions on vegetation dynamics in the East Africa region from 1982 to 2015 were evaluated using data from the Advanced Very High Resolution Radiometer (AVHRR) version 3, NDVI, and Climate Research Unit (CRU) for temperature and precipitation (Butler *et al*., 2008). In Kenya, many studies have been carried out in forest inventory using remote sensing tools for example a study done by Kairo *et al.*, (2008) on the status of Kenya Mangrove forest within and adjacent to Kiunga MPA in Lamu using means of Ariel photographs and intensive ground truthing. The study showed a degraded mangrove forest due to anthropogenic activities. Another investigation on the Aberdare forest was conducted by Ochego in 2003 to assess the scope and consequences of deforestation over a 13-year period (1987–2000). Landsat TM images were used as a source of data. The study downloaded LANDSAT images, processed and analyzed them using IDRIS Software. Further NDVI differencing was also done to further support technique in determining change in biomass (Ochego, 2003).

2.4. Role of Forest Adjacent Communities in Vegetation Dynamics

Most of the forests in the globe are found in some of the highly populated and impoverished regions of the planet (Porter and Brown, 1991). A lot of pressure is placed on the forest and its resources since forests directly support 90% of the 1.3 billion people living in extreme poverty globally (WRI, 2014). This has led to a very unhealthy relationship between forests and poverty with extreme deforestation is linked to extreme poor living standards/poverty (FAO, 2012). In the past 25 years, the inclusion of forest adjacent communities in state-owned forest management has become increasingly very common. According to Schreckenberg *et al.,* (2006), the majority of African and Asian nations have started to aggressively encourage rural communities' full engagement in the exploitation and management of natural forests and woodlands. This is done through some kind of participatory forest management (PFM). In Brazil farmers have been educated to halt deforestation in favor of cattle ranching activities (Zeppel, 2006). This program is funded by The Amazon Fund. Other countries supporting the Amazon Fund Program are Norway, Germany, United Kingdom, Guyana-Norway, Peru, Bolivia, and Venezuela among others. Communities in these countries maintain low deforestation rates (Meyfroidt *et al.,* 2011). Beginning in the late 1980s, innovative policies in India managed to motivate activities at all tiers of Indian society, from the national government to rural communities, with a net forest increase between 2005 and 2010 as a result (FAO, 2012). Elsewhere in Mexico paying for ecosystem services since its introduction has reduced the rate of deforestation and loss of carbon sinks by half from 5.1% per decade in the 1990's to 2.6% per decade in the 2005 (FAO, 2012).

A study that was done in Nicaragua employed the satellite-derived NDVI to assess the ecological impact of a reforestation project (Reddy, 2006). The project up to date is still working with farmers from Northern Nicaragua and is led by a Canadian NGO called Taking Root. This organization employs a Payment for Ecological Services (PES) system that is based on the performances and needs of the farmer (Runyan & D'Odorico, 2006). Farmers who are participating in the program not only get paid based on their reforestation performance interventions, but also based on the needs and also the currently available budget of the farmer assessed by the organization employees (Runyan and D'Odorico, 2016). Training and technical assistance are given to the farmers participating in the projects to make their efforts on the field more effective. An agreement that require farmers to reach certain tree establishment and tree growth milestones in the program is signed (Purnomo *et al.*, 2018).

In Africa, community forest management is taking form. Most forests are now under CFA's which have shown a remarkable decline in deforestation rates and more reforestation efforts embraced throughout the continent (Hillstrom *et al.,* 2014). In Madagascar, President Marc Rava Omana made a commitment to triple Madagascar's land area under protection converting about a tenth of the country (more than 600,000 Km^2) to Ambositra Vondroso Corridor (COFAV). Instead of prohibiting any production within this protected region, the program sought to establish sustainable economies within the corridor that involved adjacent local people as project managers. Community forest management is currently acknowledged in Madagascar as a crucial component of efforts to cut emissions and deforestation (FAO, 2012).

The Eastern Arc, also known as Kaisagu, stretches from southwestern Kenya through Tanzania and is the site of one of the longest-running private efforts at large-scale conservation. Over the past ten years, it has been expanded into REDD program designed to protect the carbon stock of about 200,000ha of wood land and dry forest (Dinerstein *et al.,* 2017). The Eastern Arc was originally established in the late 1990s to provide a corridor for elephant's migration between the two Tsavo East and West National Parks. The region's emissions were brought down to very low levels by offering alternatives to slash-and-burn farming. Second, the land that had been leased to cattle ranchers was transferred to a lease with Wildlife Works for the carbon rights of their properties (Wildlife works, 2011), with the landowners getting around a third of the proceeds from the sale of carbon credits. According to a recent analysis of the governance of the Kaisagu corridor project, local members overwhelmingly backed the initiative (Atela, 2013). Participatory management in the Miombo Wood lands of Tanzania and Mozambique have reduced global warming emissions, protected ecosystems and also guarded forest, an important resource to many people and more generations both the present and future (FAO, 2012).

In 1997, the Arabuko Sokoke Forest served as the site of Kenya's initial implementation of the Participatory Forest Management (PFM) approach (Atela, 2013). The PFM strategy was made legal in 2005 with the passage of the Forest Act, which also resulted in the establishment of the Kenya Forest Service (KFS), an organization tasked with managing all state forest. The Act's Article 46(1) mandates the creation of Community Forest Associations (CFAs), which have the responsibility for managing and protecting designated forests in accordance with a forest management plan that was created in accordance with the rights of traditional users and aiding in the enforcement of the Forest Act. Currently, there are around 325 registered CFAs located all over the nation (MENR, 2012).

2.5. Conclusion

In the first decade of the twenty first century, many countries have begun to take the threats of climate change seriously and have moved to reduce their global warming emissions (Schreckenberg *et al.*, 2006). At the centre of these efforts a major realization is the direct relationship between communities and forest (Lamb *et al*., 2005). The main problem in forest management is contained in how to take fast, consistent, and up to date information (Lamb *et al*., 2005). In land use planning and mapping, the detection of land cover situation using remote sensing facilities is indispensable method for determining the status quo and for identifying land use trends. Land use maps provide the basis for discussions with local land users and stakeholders on improving land management practices in order to achieve sustainability (Schreckenberg *et al.,* 2006). Forests are important to us all and therefore we need to know if they are being degraded and, if so, what the causes are, so that steps can be taken to arrest and reverse the process. Good information on forest condition and the extent of forest degradation will enable the prioritization of human and financial resources to prevent further degradation and to restore and rehabilitate degraded forests. A lot of forest inventory studies have been done globally and even in Kenya but a few have focused on assessing the forest vegetation cover dynamics especially in Londiani Forest. This study therefore sought to assess the vegetation dynamics of Londiani Forest; determine forest stand structure and composition, analyze the forest cover change of Londiani Forest using Normalized Differenced Vegetation Index (NDVI), and to evaluate the roles of the forest adjacent community in vegetation dynamics in Londiani Forest.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter describes the methods and materials that were used to execute this study. It describes the study area, the research design, sampling procedures and finally outlines how the sampled data was analyzed and presented.

3.2. Study Area

Londiani Forest is located in three counties; Nakuru, Kericho and Baringo and has an area of 18,938 ha (KFS, 2018). It was gazetted via legal notice No. 44 of 1932 to conserve the forest. It lies to the West of Nakuru town, East of Bomet County and along the Kericho-Nakuru highway. Londiani town is about 200km from the capital city of Nairobi, Latitude 0.17º South, Longitude 35.6º East and Elevation 2326m above sea level (GoK, 2000). (Figure 1)

Londiani Forest and its environs experience moderate rainfall that varies between 1500- 1700 mm per year (KFS, 2018). The area receives a bimodal rainfall pattern where long rains come in between mid-March and June and short rains between mid-October and December. The precipitation varies by 133 mm between the driest and the wettest month (KFS, 2018). There are low temperatures throughout the year and a very high humidity up to 70% especially during the rainy seasons and as low as 18% during the dry seasons. The average annual temperature in Londiani Forest is 18.92°C with an average high temperature of 23°C and the lowest average temperature is 12°C (Mutwiri *et al.*, 2017). Londiani Forest has generally flat topography with a local relief of less than 300m above sea level. Some areas are quite high including Mt. Blackett, Lemotit Hill, Tulwap Kipsigis and other raised grounds (KFS, 2018).

Londiani Forest has clay and loam soils, which are well drained, deep, dark-reddish brown, of moderate to high fertility with acid humic top soil. The region is represented by volcanic as well as igneous and metamorphic complexes (GoK, 2009.) This region is well drained by rivers including Rivers Yurith, Kiptaret, Timbilil, Maramara, Kipchorian and Malaget. All the rivers drain into Lake Victoria.

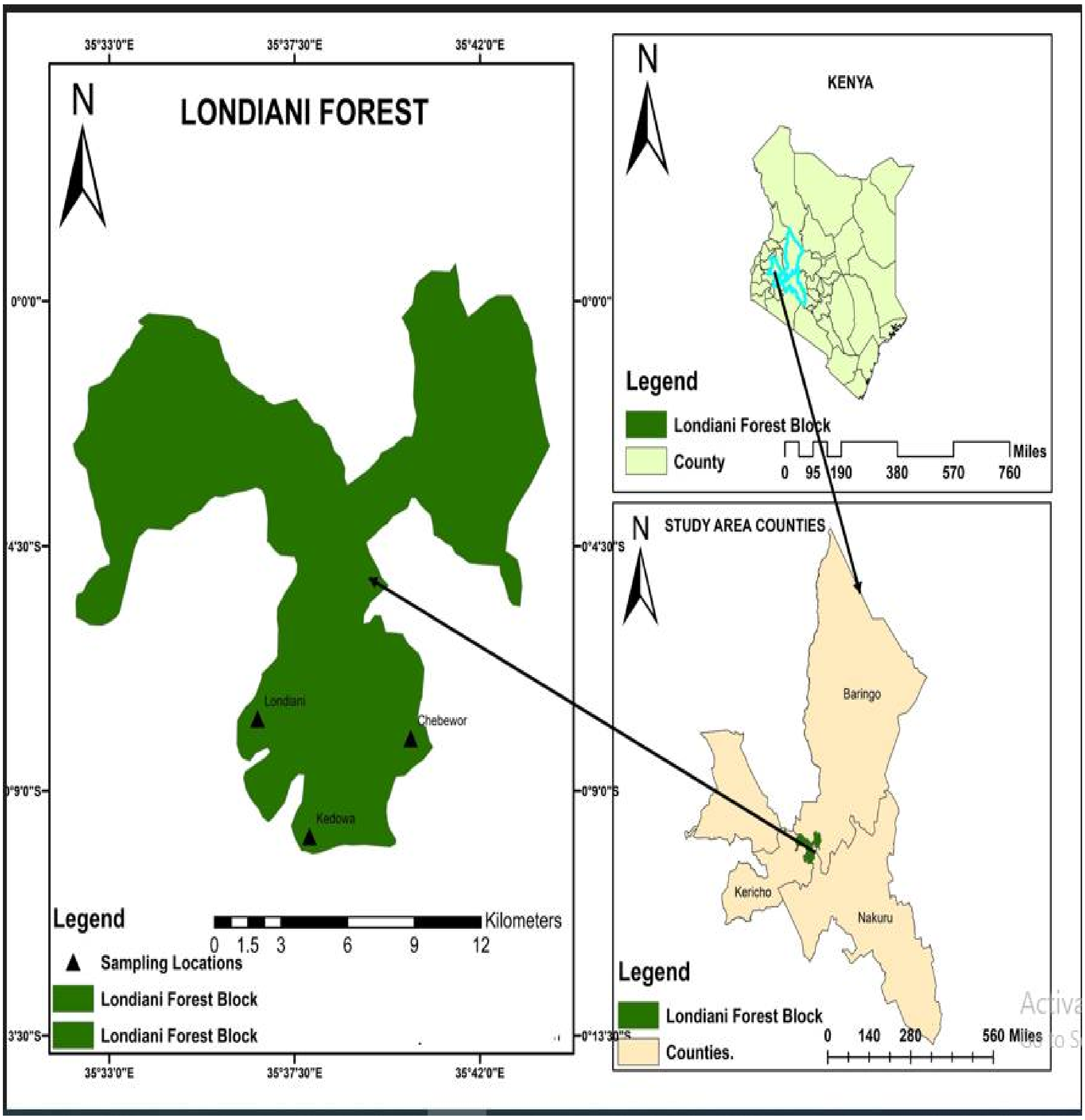


Figure 1: Map showing the position of Londiani Forest within Nakuru, Baringo and Kericho in Kenya. Source: Author 2023.

Londiani Sub County has a population of 137,580 people, with an average household size of 4.3 people per household and a population density of 344 persons per km^2 (KNBS, 2019). The average land size per household is less than 1ha (KNBS, 2019). This has made people turn to forest for more land (KFS, 2018). The main economic activities are farming mainly crops production and livestock keeping. Crops grown are maize, beans, sorghum, millet, soya beans, tomatoes, potatoes and vegetables. Dairy cattle farming are also practiced and other livestock kept are sheep, goats, pigs, poultry and rabbits. All these economic activities have direct impact on Londiani Forest (GoK, 2000).

3.3 Research Design

The cross-sectional research design was used in this study. This design entailed data collection on more than one case and at a single point to collect quantitative or quantifiable data in connection to two or more variables which are examined to detect a pattern of association (Mugenda, 2003). Data on forest stand structure and composition were collected in addition to data on the community and the forest at the same time. The research was carried out from 2nd May 2020 to 31st October 2020. Six quadrats were laid in each of the Londiani Forest blocks and 270 pre-tested open-ended questionnaires were offered to the households to collect data on Londiani Forest. Three (3) focus groups discussions (FGDs) were held in each of the forest blocks with the community members.

3.4 Target Population

The study used a purposive sampling method to target residents adjacent to Londiani Forest who have lived in the area for more than 10 years to allow for consistency in forest conservation practices (Mugenda, 2003). Adjacent to each of the 3 forest blocks of Londiani Forest (Londiani, Kedowa and Chebewor), 9 out of 28 villages adjacent to Londiani forest were purposively selected (villages that are adjacent to the forest). The purposive sampling method was used to select the 270 households to whom the questionnaires were administered (Emery, 2012). These villages formed a representative of the whole region to form the study sites (Emery, 2012). The household heads were targeted because they are well acquainted with what has been happening in the region concerning forest conservation. Key informants in the forest sector like the forest the conservator of Londiani area, the village area chiefs, the Community Forest Association (CFA) Chairperson, the Plantation Establishment for Livelihood Improvement Scheme (PELIS) program head person, members of Forest Field Schools (FFS), the Kenya Forestry Research Institute (KEFRI) administration representative were interviewed to gather information on the study objective.

3.5 Sample Size Determination

The study targeted a population representative of 270 household heads out of the total population of approximately 900 households living in the (Londiani, Kedowa and Chebewor) forest adjacent villages (KNBS, 2019). Yamene, (1967) population proportionate formula was used as shown below;

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

$$n = \frac{900}{(1 + 900 \times 0.05)^2}$$

$$n = 276$$

Where (n) is the sample size of the strata, (Ne) is the population size of the strata, (N) is the total population n=900/ (1+ (900) $(0.05)^2$) n= 276.

3.6 Sampling Design

A purposive and stratified sampling method was employed in this study (Mugenda, 2003). To ensure that generalizations of sample findings are typical of the population, the stratified random sampling method was employed to direct the selection of an appropriate sample. The household heads that would get the questionnaire were chosen using this method. The other technique adopted was purposive sampling (Mugenda, 2003). This technique was used to identify key informants like officers from Kenya Forest Service (KFS), village area chiefs and Kenya Forestry Research Institute (KEFRI) to conduct the interviews. A purposive sampling method was used to select the villages that are adjacent to the forest.

3.7 Data Collection

Both primary and secondary data sources were used for this study. The primary data came from a six months field survey from May 2020 to October 2020 in the Londiani Forest and adjacent communities. The secondary data was obtained from other sources namely satellite image interpretation of Landsat images downloaded from the USGS website (Earthexplorer.usgs.gov) accessed on 20th November 2020 to 10th December 2020 to study Londiani forest cover changes.

3.7.1 Determination of Species Composition and Forest Stand Structure

In each of the 3 forest blocks, belt transects measuring 1km were laid 100 metres from the edge of the forest to reduce edge effects (Cheboiwo *et al.*, 2015). Six (6) Quadrats measuring 100×100m were laid every 200 meters apart for the length of the transect summing up to 18 plots in the whole forest (Mutiso, 2009). In each quadrat, both deforestation and reforestation data were collected. The number of trees in each quadrat was counted and recorded. Data on the standing/live trees abundance and tree species was determined and recorded in a data sheet (Mutiso, 2009). Diameter at breast height (DBH) was measured using a diameter tape 1.3m from the ground. Tree-height was measured using a Suunto angular clinometer. A 25x25m quadrat was nested in the 100x100m quadrat for saplings and 1x1m quadrat for seedlings (Mutiso, 2009). All the saplings and seedlings for each tree species were counted and recorded respectively and summed up for the entire study area. Observed tree stumps were counted including identifying tree species which the tree stump was derived from. Any charcoal making spots were also quantified and recorded (Mutiso, 2009).

3.7.2 Determination of the Forest Cover Change

Normalized Difference Vegetation Index (NDVI) data was obtained for the years 2000, 2003, 2010, 2015 and 2020 from 1km resolution SPOTVEGETATION sensor for closed woody vegetation type for Londiani Forest. (LandsatTM image for the year 2005 had errors, 2003 image was used instead). Vegetation response to yearly seasonal variations was then plotted and used to compare deviations by specific years. The greenness range was divided into five discrete classes by slicing NDVI value ranges then the thresholds for NDVI classification were fixed using the method of Natural Breaks (Jenks). Similar steps were followed for all the five (5) different year's image classification. High spatial resolution and hyper-spectral imageries for detecting land cover changes and deforestation detection was analyzed using conventional vegetation indices computed with the following formula by Nouri *et al.*, (2017).

$$\text{NDVI} = \frac{(NIR - R)}{(NIR + R)}$$

Where NDVI is Normalized Difference Vegetation Index, (NIR) is Near Infra-Red reflection and R is Red reflection.

To assess the land use/land cover changes, satellites Landsat-5 and Landsat-8 imagery data was used. Images were downloaded from USGS earth explorer website (Earthexplorer.usgs.gov) and Supervised Image classification was performed using downloaded Landsat Images for the selected years 2000, 2003, 2010, 2015 and 2020 for the study area in order to establish the spatial and temporal changes that have occurred in Londiani forest cover within the study period. The 2005 image had an error so 2003 image was used instead. The images were divided into 5 land cover types (Table 1).

Table 1: Land Cover types in Londiani region (Source KFS, 2018)

Land Cover	Description
Forest	Areas covered by both indigenous, planted forests and marshland forest vegetation categories
Shrubs/ Grasslands	Consists of grassed and shrub areas
Bare lands/ water bodies/ rocks	Commercial, residential and transport infrastructure Rivers/streams and water reservoirs

Downloaded Landsat images were acquired and processed in Arc GIS to ascertain any changes in land use land cover types in Londiani area. Supervised image classification was then carried out and area under each LULC types calculated in km^2. The Arc Map administrator was connected with Google earth pro so when one goes to the particular area on satellite imagery the Google earth automatically goes to that place on that particular date and hence it was easy to classify various land features and compare with the current land features.

3.7.3 Role of Forest Adjacent Communities in Vegetation Cover Changes.

3.7.3.1 Semi-structured Interviews

Interviews (Agevi *et al.*, 2014) were used for the key informants who included (area village chiefs, Community Forest Association (CFA) chairperson, Plantation Establishment for Livelihood Improvement Scheme (PELIS) head person, Kenya Forestry Research Institute (KEFRI) administration and the Kenya Forest Service Officer). Different interview guides were used for the various informants to collect data on Londiani Forest (Appendix 5: Interview guide). The Respondents were given exactly the same content of questions (both closed and opened ended questions inclusive) so that the replies could be aggregated (Appendix 4: Questionnaire guide). It also offered the interviewer the opportunity to further clarify issues of relevance to the study (Agevi *et al.*, 2014).

3.7.3.2 Self-administered questionnaires

The research also used self-administered questionnaires to solicit individual views of heads of households regarding the research questions (Mugenda, 2003). The questionnaires were pre-tested for their validity before the actual research was carried out. Respondents had equal range of questions to answer with the guidance of the research assistants (Mugenda, 2003). This is because some questions needed to be interpreted to the respondents and the replies aggregated by the researcher. Through this, the various responses were compared and contrasted to establish a pattern of thoughts (Mugenda, 2003).

3.7.3.3 Participant Observation

Another crucial method for gathering data was participant observation or ethnography, which produces qualitative information (Mugenda, 2003). The researcher was immersed into the community for six (6) months, through direct observation and listening to conversations first-hand knowledge about many facets of the research issues were gathered.

3.8 Data Analysis and Presentation

The quantifiable data was tested for normality using Kolmogorov-Smirnov test and analyzed statistically using techniques for descriptive and inferential statistics through the aid of Predictive Analytics Software (PASW) version 25. Population structure of the tree species was analyzed across fifteen DBH classes with an interval of 10cm apart. Population structure of the tree species was also analyzed across eleven Height classes with an interval of 5metres apart. Data from the quadrats were entered into Microsoft excel to calculate basal area and other tree data calculations as shown below.

1. Stem Density (trees/ha) $= \frac{trees\ sampled}{Plot\ area\ (m^2)} \times\ 10000\ m^2/ha$

$$\text{Species Stem density (trees/ha)} = \frac{species\ X\ sampled}{Plot\ area\ (m^2)} \times\ 10000\ m^2/ha$$

$$\mathbf{2}.\ \text{Total Basal Area}(\text{m}^2/\text{ha}) = \sum \frac{\text{individual tree basal areas}}{\text{plot area}\ \{\text{m}^2\}} \times 10000\text{m}^2/\text{ha}$$

$$\text{where individual tree basal area } (\text{m}^2\ ) = \pi \times (1\text{m}^2\ \ 10{,}000c\text{m}^2)$$

$$\text{Species Basal Area } (\text{m}^2/\text{ha}) = \sum \frac{Sp.\ X\ individual\ tree\ basal\ areas}{Plot\ area\ \{\text{m}^2\}} \times 10000\text{m}^2/\text{ha}$$

$$\mathbf{3}.\ \text{Total Density} = \frac{Total\ no.\ of\ trees\ sampled}{plot\ area\ \{\text{m}^2\}} \times\ 10000\text{m}^2/\text{ha}$$

$$\text{Relative density} = \frac{No.\ of\ trees\ of\ a\ species}{Total\ no.\ of\ trees\ of\ all\ tree\ species}$$

$$= \sum \frac{Sp\ X\ individual\ tree\ basal\ areas}{Plot\ area\ \{m^2\}\ \times \frac{10000m^2}{ha}}$$

4. Species Diversity

Diversity was calculated using Shannon diversity index (H), calculated as:

$$H = -\sum pi \times \ln(pi)$$

where Σ: A Greek symbol that means "sum" (ln) is Natural log, and (pi) is the proportion of the entire community made up of species i. (Roswell *et al.*, 2021)

5. Evenness

Hmax = ln(S) = Maximum diversity possible. E= Evenness = H/Hmax

S = number of species = species richness

6. Jaccard Similarity Index

The Jaccard similarity index was calculated as, SJ $= c/(a + b + c)$ Where *SJ* is the similarity index, *c* is the number of shared species between the two sites and *a* and *b* are the number of species unique to each site (Hancock, 2004).

7. Frequency and Relative frequency

This is the number of quadrats of appearance per species and relative frequency is the total number of quadrats of a species appearance divided by the total number of quadrats laid multiplied by 100 (Bonan, 2008).

8. Dominance and Relative Dominance

Dominance is the total basal area of a species while relative dominance is total basal area of a species divided by total basal area of all species multiplied by 100 (Bonan, 2008).

9. Importance Value Index

The Importance Values Index (IVI), which indicates the ecological importance of a tree species, was determined using the following equation (Hancock, 2004).

IVI = RD + RF + RDo where RD is Relative density, RF is relative frequency and RDo is relative dominance. Where;

$$RD = \frac{Number\ of\ all\ individuals\ of\ a\ species}{Total\ number\ of\ all\ individuals} \times 100$$

$$RF = \frac{Number\ of\ plots\ where\ a\ species\ occurs}{Total\ occurrences\ of\ all\ species\ in\ all\ plots} \times 100$$

$$RDO = \frac{Basal\ area\ of\ a\ species}{Total\ basal\ area} \times 100$$

10. Abundance

Abundance is the total number of individuals of a species in all quadrats (Emery 2012).

The quantifiable data were tested for normality using a Kolmogorov–Smirnov test and analysed statistically using techniques for descriptive and inferential statistics. A chi-square one-way non-parametric analysis of variance test was used to determine differences in abundance, diversity, density of trees and saplings among the forest blocks. The Ryan–Einot–Gabriel–Welsch Multiple Range Test (REGWQ) was used in post hoc tests to determine the source of variation among means at the 5% significance level. Data from interviews and questionnaires were coded then entered into Ms Excel and PASW to establish relationships. The univariate data was analyzed using measures of central tendency and frequency tables, and were presented using pie charts and bar charts.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents results on forest stand structure, species composition, forest cover change from the year 2000 to 2020 and evaluation of the roles of forest adjacent communities in influencing vegetation dynamics.

4.2 Species Composition and Forest Stand Structure of Londiani Forest

4.2.1 Tree Abundance

A total of 1,308 trees belonging to 34 different species were counted and recorded. *Cupressus lusitanica* was the most abundant species recording a total of 273 trees (54.6%), while the species with the least abundance was *Grevillea robusta* 2 trees (0.15%), (Appendix 8). In Kedowa Forest block the most abundant species was *Cupressus lusitanica* (41.3%) and the least abundant species was *Syzygium guineense* (1%). In Chebewor Forest block the most abundant species was *Juniperus procera* (54.6%) and the least abundant species was *Grevillea robusta* (1%). In Londiani Forest block the most abundant species was *Cupressus lusitanica* (73.5%) and the least abundant was *Prunus africana* (1.4%). There was a statistically significant difference in the tree species distribution in the three forest blocks (X^2 = 30.242 df= 18 p=0.035). Figure 2 shows a rank-abundance plot for Londiani Forest, where the abundance of each species is plotted on a logarithmic scale against the species' rank, in order from the most abundant to the least abundant species. The most abundant species is given rank 1, the second most abundant is 2 and so on. The species rank abundance of Londiani Forest ranked from 47 to 273. *Cupressus lusitanica* was ranked number 1 with 273 abundance followed by *Pinus patula* with 196, *Eucalyptus* *globulus* 147 and ranked number 10 was *Croton megalocarpus* recording abundance of 47.

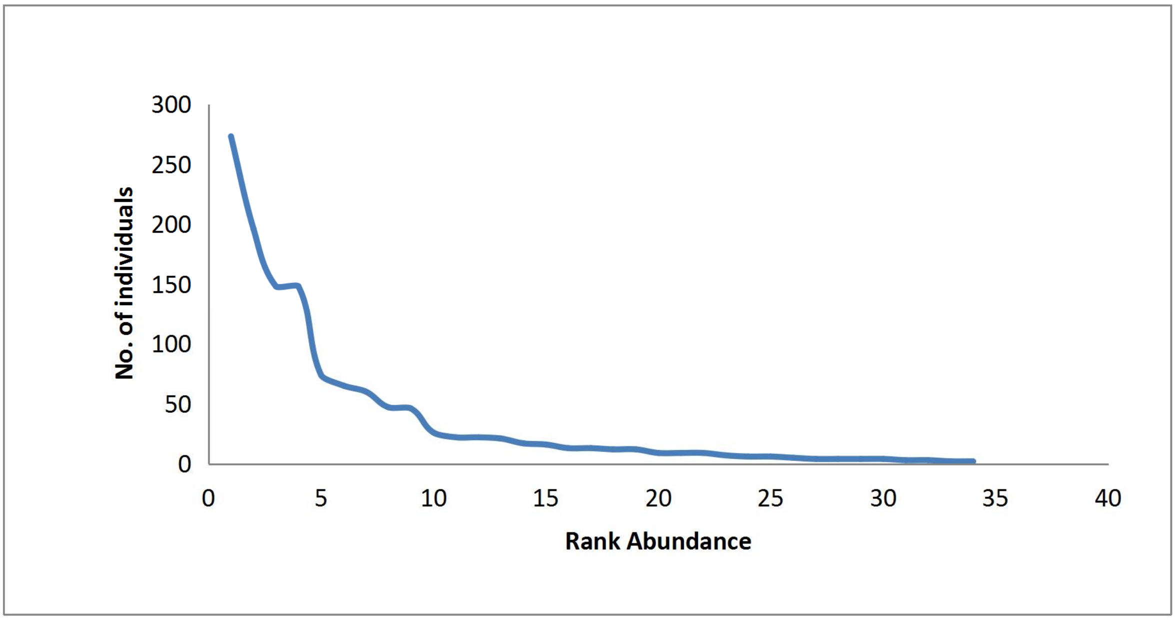


Figure 2: Species Rank Abundance of Londiani Forest

4.2.2 Woody Species Richness and Important Value Index (IVI)

A total of 34 woody tree species representing 24 families were recorded. Tree species richness ranged from 14 to 27. The study showed that Kedowa Forest block had the highest species richness of 27 equivalent to 45% followed by Chebewor Forest block with 19, equivalent to 31.7% of tree species recorded and then Londiani Forest block with only 14, equivalent to 23.3% tree species. Indigenous trees were 45.1% and exotic trees were 54.9%. The Kedowa Forest block recorded 54.4% indigenous trees and 45.6% exotic trees, the Chebewor Forest block recorded 53.5% indigenous trees and 46.5% exotic trees while Londiani Forest block recorded 27.4% indigenous trees and 72.6% exotic trees. Family Cupressaceae had the highest number of woody plants 32%, followed by Pinaceae 15%. The family with the least woody plants were Proteaceae and Rhamnaceae each having 0.2% (Appendix 6). There was no statistically significant difference in richness distribution among the three forest blocks (X^2 =12.000 df=9, p= .21). Analysis of importance value indices of woody species IVI for the three forest blocks ranged from 31.48% to 48.25%. Kedowa forest block had the highest IVI of 48.25%, followed by Londiani block with 42.86% and then Chebewor Forest block 31.48% (Appendix 8).

4.2.3 Species Distribution in Londiani Forest

Tree density, species frequency, Total Basal Area, Dominance, Relative dominance (RD), Importance Value Index (IVI) and Relative Abundance (RA) are as shown in (Appendix 8). Kedowa block recorded a total of 457 trees, followed by Londiani block recording 434 trees and Chebewor had 417 trees. Tree density ranged from 69.5 to 76.17 stems ha^{-1}. Table 2 is a summarized tree data from Appendix 8 showing tree abundance, density, relative density, richness and diversity for the three forest blocks.

Table 2: Species Distribution data for the three Forests Blocks

Forest Block	Abundance	Density	Relative Density	Richness	Diversity
Kedowa	457	76.17	34.9	27	0.864
Chebewor	417	69.5	31.9	19	0.855
Londiani	434	72.33	33.18	14	0.792

4.2.3.1 Species Density and Relative Density

Species density in Londiani Forest ranged from 0.11 stems ha^{-1} to 15.17 stems ha^{-1} (Appendix 8). Of all the trees species counted *Cupressus lusitanica* had the highest species density of 15.17 stems ha^{-1}, followed by *Pinus patula* with a species density of 10.89 stems ha^{-1} then *Eucalyptus globulus* and *Juniperus procera* were third in the row with 8.22 stems ha^{-1} species density each *Grevillea robusta* had the least density of 0.11 stems ha^{-1}. There was no statistically significant difference in the distribution of density within the three forest blocks (p = 0.199). *Cupressus lusitanica* recorded the highest relative density of 20.8%, followed by *Pinus patula* 14.9%, the least relative density was recorded by *Grevillea robusta* 0.15%.

4.2.3.2 Frequency and Relative frequency

Figure 3 shows that *Eucalyptus globulus* had the highest frequency of 11 appearances and a relative frequency of 61.1%, followed by *Dombeya goetzenii* appearing 10 times with a relative frequency of 55.5%, *Juniperus procera* and *Olea africana* each had 8 frequency and a relative frequency of 44.4%, *Acacia nilotica*, *Cupressus lusitanica* and *Prunus africana* each had an appearance of 5 with a relative frequency of 27.7% (Appendix 8). The species with the least frequency of 1 and a relative frequency 5.6% were very many including; *Arundiana alpina, Brassica actinophylla, Croton macrostachyus, Grevillea robusta, Maesopsis eminii, Ocotea usambarensis* among others.

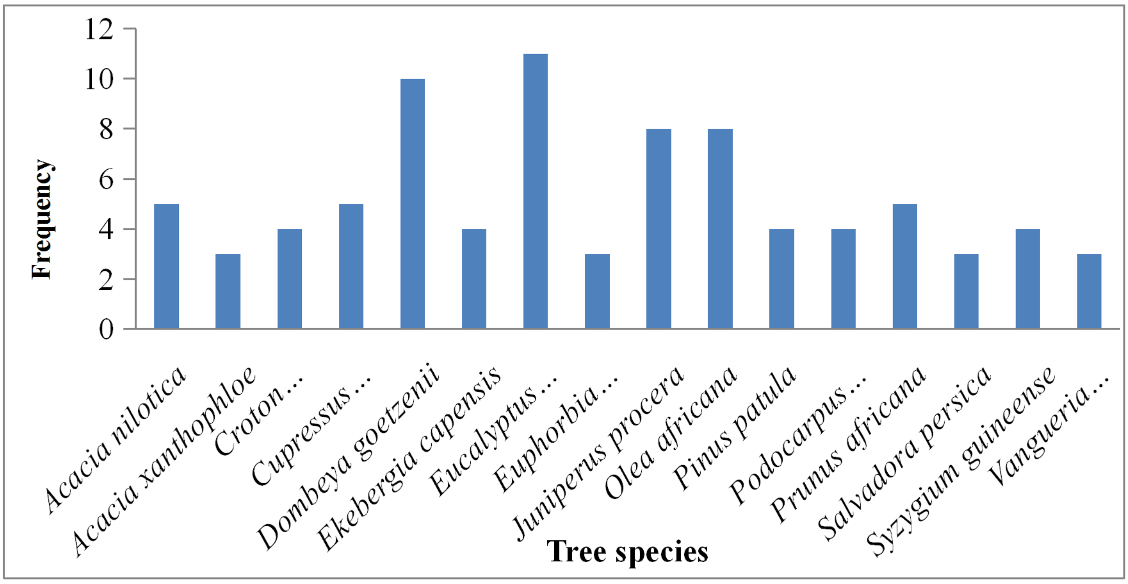


Figure 3: Tree species frequency distribution of Londiani Forest

4.2.3.3 Basal Area, Dominance and Relative Dominance of Londiani Forest

This study showed that the total basal area of all species recorded in the entire forest was 122.6419 m^2 and the relative dominance was spread across 34 species as shown in appendix 8. *Cupressus lusitanica* recorded the highest total basal area of 41.31 m^2

and the species with the least basal area of 0.047 m^2 was *Grevillea robusta*. There was no statistically significant difference in basal area distribution within the three forest blocks (X^2 = 12.000 df = 9 p = 0.213). *Cupressus lusitanica* recorded the highest relative dominance of 33.69% and the species with the least relative dominance of 0.038% was *Grevillea robusta*. Figure 4 below shows the total basal area of the three forest blocks. Kedowa block recorded a total basal area of 45.40 m^2, Chebewor 29.75 m^2 and Londiani block 47.51 m^2 appendices 9a, 9b, and 9c.

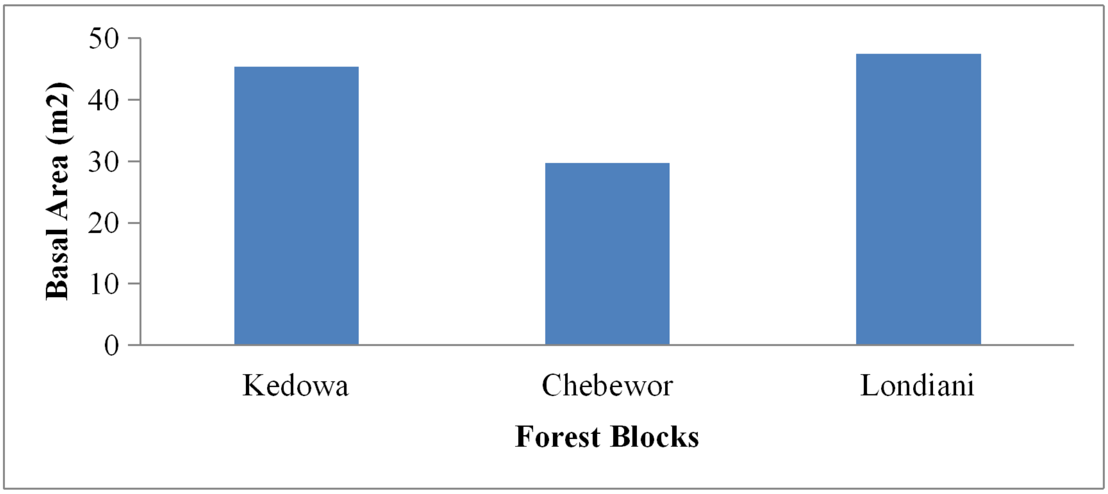


Figure 4: Basal area distribution in Kedowa, Chebewor and Londiani forest blocks

4.2.4 Abundance, Richness and Diversity of Saplings and Seedlings in Londiani Forest

Londiani Forest recorded a total of 740 saplings and 832 seedlings. Kedowa Forest block recorded saplings' abundance of 384 and 294 seedlings, Chebewor had 182 and 337 while Londiani block recorded 174 and 198 saplings and seedlings respectively (Figure 5).

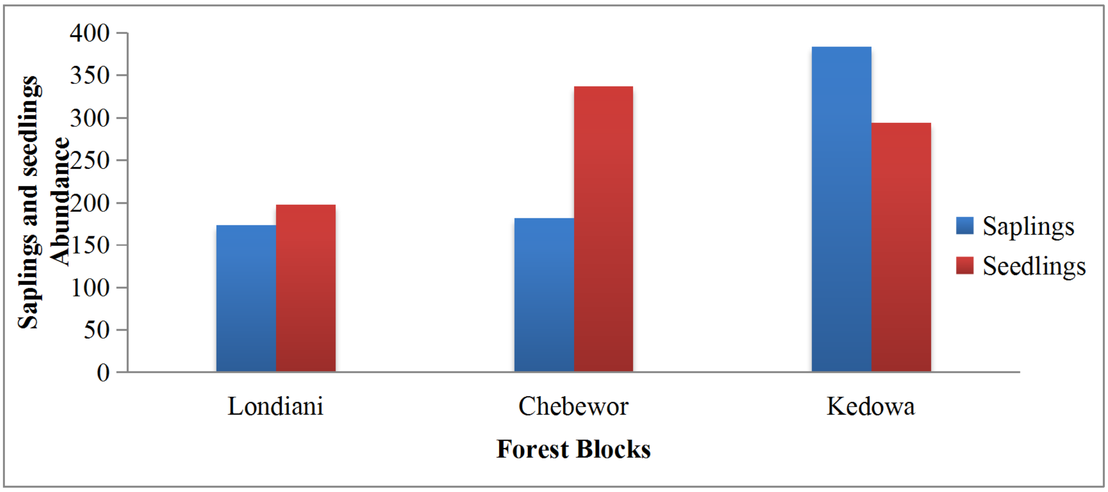


Figure 5: Species abundance distribution for saplings and seedlings for the three forest blocks.

Saplings richness for Kedowa Forest block was 17, Chebewor 12 and Londiani 8 while seedlings richness for Kedowa Forest block was 22, Chebewor 9 and Londiani 7 (Figure 6).

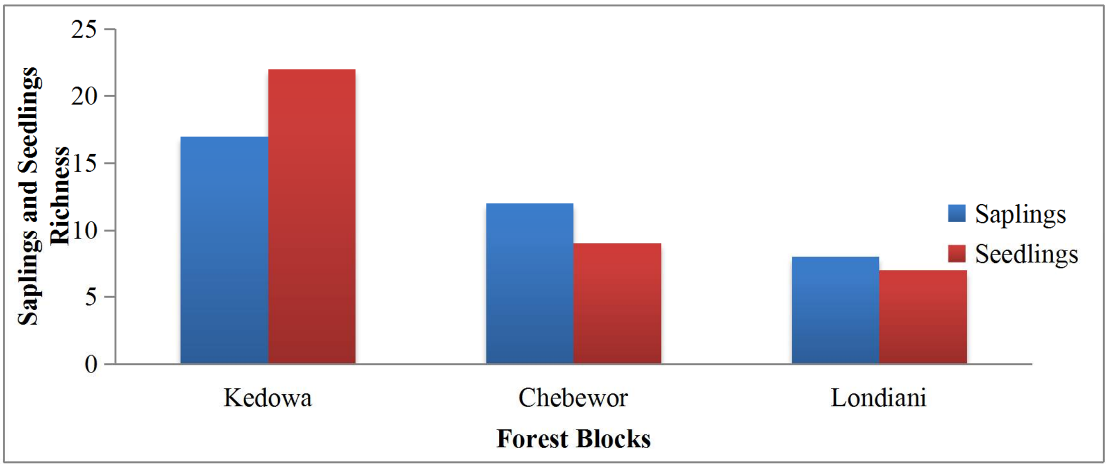


Figure 6: Species richness distribution for saplings and seedlings for the three forest blocks

Saplings diversity for Kedowa Forest Block was H′= 2.01, Chebewor, H′= 2.89 and Londiani block H′= 1.64. Seedlings diversity for Kedowa Forest block was H′= 1.62, Chebewor block H′= 2.58 and Londiani block seedlings diversity is H′= 1.78.

Results in Table 3 show that Kedowa block saplings ranged between 2 to 128, *Cupressus lusitanica* recorded 128 saplings equivalent to 33.4% of the total saplings recorded in the forest block, *Vangueria madagascariensis* recorded only 2 saplings equivalent to 0.5% recording the least number of saplings. *Cupressus lusitanica* had the highest percentage of seedlings 66.7% followed by *Croton megalocarpus* 4.37% and, *Eucalyptus globulus* at 4.04% came in third. *Pinus patula* did not record any seedlings since the trees were still young and had not reached maturity stage where they can produce seeds which would later become seedlings.

Table 3: Distribution of tree species seedlings and saplings in Kedowa Block

(IPNI) Number	Genus and species names	Saplings			Seedlings		
		N	RF (%)	Density	N	RF (%)	Density
921695-1	*Acacia nilotica*	13	3.4	208	10	3.4	160
54565-1	*Anthocleista vogelii*	9	2.3	144	2	0.67	32
4263-2	*Arundiana alpina*	0	0	0	2	0.67	32
36160-2	*Brassia actinophylla*	0	0	0	1	0.33	16
342917-1	*Croton macrostchyus*	3	0.78	48	7	2.4	112
342969-1	*Croton megalocarpus*	12	3.1	192	13	4.37	208
330505-2	*Cupressus lusitanica*	128	33.4	2,048	198	66.7	3,168
823043-1	*Dombeya goetzenii*	56	14.7	896	5	1.68	80
578362-1	*Ekebergia capensis*	21	5.5	336	3	1.01	48
592965-1	*Eucalyptus globulus*	46	11.9	736	12	4.04	192
345923-1	*Euphorbia candelabrum*	0	0	0	1	0.34	16
77308414-1	*Ficus sycamorus*	4	1.04	64	0	0	0
262311-1	*Juniperus procera*	31	8.1	496	8	2.69	128
717624-1	*Maesopsis eminii*	0	0	0	1	0.34	16
610616-1	*Olea africana*	17	4.4	272	8	2.69	128
263196-1	*Pinus patula*	0	0	0	0	0	0
263490-1	*Podocarpus gracilior*	4	1.04	64	2	0.67	32
91769-1	*Polyscias fulva*	0	0	0	1	0.34	16
729417-1	*Prunus africana*	18	4.7	288	8	2.69	128
718580-1	*Rhamnus prinoides*	0	0	0	0	0	0
70715-1	*Rhus natalensis*	11	2.8	176	4	1.34	64
601750-1	*Syzygium guineense*	4	1.04	64	5	1.62	80
520167-1	*Tamarindus indica*	5	1.3	80	2	0.67	32
796766-1	*Vangueria madagascariensis*	2	0.5	32	2	0.67	32
969503-1	*Vipris nobilis*	0	0	0	0	0	0
77192411-1	*Vitex keniensis*	0	0	0	2	0.67	32
775746-1	*Zanthoxylum gilleti*	0	0	0	0	0	0
	Total	**384**	**100**		**297**	**100**	

IPNI- International Plant Names Index- Life Science Identifier (Plants of the world website) https://www.ipni.org/. N- number of seedlings; RF-relative frequency

In Chebewor forest block *Juniperus procera* had highest percentage of saplings 34.6%, followed by *Eucalyptus globulus* 21.4%, *Acacia mearnsii* 16.48%, *Rhus natalensis* 5.49%. Seven of the species had zero saplings including *Cupressus lusitanica*. *Juniperus procera* recorded most seedlings 45.4%, followed by *Eucalyptus globulus* at 23.7% seedlings. The rest of the species had no seedlings at all (Table 4). Some trees species recorded poor number of seedlings because of a number of reasons; poor flowering, fruiting and seeding of the mother tree. Other trees were young not yet mature to reproduce.

Table 4: Distribution of tree species seedlings and saplings in Chebewor Block

IPNI Number	Species name	Saplings			Seedlings		
		N	**RF (%)**	**Density**	**N**	**RF (%)**	**Density**
921695-1	*Acacia nilotica*	7	3.85	112	47	13.9	752
470860-1	*Acacia mearnsii*	3	16.5	480	0	0	0
54565-1	*Anthocleista vogelii*	0	0	0	0	0	0
342969-1	*Croton megalocarpus*	4	2.19	64	9	2.67	144
330505-2	*Cupressus lusitanica*	0	0	0	0	0	0
823043-1	*Dombeya goetzenii*	1	6.04	176	22	6.52	352
592965-1	*Eucalyptus globulus*	3	21.5	624	80	23.7	1,280
345923-1	*Euphorbia candelabrum*	2	1.09	32	0	0	0
50798-3	*Grevillea robusta*	0	0	0	0	0	0
262311-1	*Juniperus procera*	6	34.6	1,008	153	45.4	2,448
467675-1	*Ocotea usambarensis*	3	1.64	48	12	3.56	192
610616-1	*Olea africana*	6	3.29	96	9	2.67	144
263483-1	*Podocarpus falcatus*	0	0	0	2	0.59	32
729417-1	*Prunus africana*	5	2.75	80	0	0	0
779348-1	*Salvadora persica*	0	0	0	0	0	0
70715-1	*Rhus natalensis*	1	5.49	160	0	0	0
601750-1	*Syzygium guineense*	2	1.09	32	3	0.89	32
520167-1	*Tamarindus indica*	0	0	0	0	0	0
769766-1	*Vangueria madagascariensis*	0	0	0	0	0	0
	Total	**182**	**100**		**337**	**100**	

In Londiani forest block the saplings ranged from 0 - 121. *Acacia xanthophloe* had the most 69.5% saplings, followed by *Juniperus procera* 10.3% saplings, *Eucalyptus* *globulus* recorded only 1.28% saplings the rest of the species had no saplings. *Acacia xanthophloe* recorded the most 65.7% seedlings, followed by *Juniperus procera* with 14.7% seedlings, *Dombeya goetzenii* recorded only 1.01% seedlings. The rest of the species had no seedlings; (Table 5) reason varied from dormancy, palatability, shelter due to closed canopy.

Table 5: Distribution of tree species seedlings and saplings in Londiani Block

IPNI Number	Species names	Saplings			Seedlings		
		N	RF (%)	Density	N	RF (%)	Density
921695-1	*Acacia nilotica*	7	4.02	112	14	7.07	224
471815-1	*Acacia xanthophloea*	121	69.5	1,936	130	65.65	2,080
330505-2	*Cupressus lusitanica*	0	0	0	0	0	0
823043-1	*Dombeya goetzenii*	4	2.29	64	2	1.01	32
578362-1	*Ekebergia capensis*	4	2.29	64	7	3.54	112
592965-1	*Eucalyptus globulus*	2	1.28	32	0	0	0
262311-1	*Juniperus procera*	18	10.3	288	29	14.65	464
467675-1	*Ocotea usambarensis*	0	0	0	0	0	0
610616-1	*Olea africana*	11	6.3	176	11	5.56	176
263196-1	*Pinus patula*	7	4.02	112	0	0	0
263490-1	*Podocarpus gracilior*	0	0	0	0	0	0
729417-1	*Prunus africana*	0	0	0	0	0	0
110660-1	*Spathodea campanulata*	0	0	0	0	0	0
601750-1	*Syzygium guineense*	0	0	0	5	2.52	80
	Total	**174**	**100**		**198**	**100**	

There was no statistically significant difference in density distribution of saplings (X^2 =5.000 df =2, p= .082) and seedlings within the three forest blocks (X^2 = 8.000 df= 6 p= .238).

4.2.5 Species Diversity

4.2.5.1 Woody Species Diversity

The species diversity for the three forest blocks of Londiani ranged from 0.792 to 0.864 Kedowa block had the highest Diversity H′= 0.864 followed by Chebewor forest block with H′= 0.855 and finally Londiani had the least diversity H′= 0.792 (Appendix 8). There was no statistical significant difference in woody species diversity in the three forest blocks ($X^2 = 12.000$ df= 9 $p= .213$).

4.2.5.2 Species Evenness

Evenness was fairly spread across the three forest blocks with the highest value of 0.92 recorded in Kedowa block plot 1 and the least value 0 recorded in plots with 1 species occurrence as shown in Table 6 below.

Table 6: Diversity and Evenness of tree species per Forest block

Forest Block	Plot ID	Abundance	Richness	Diversity (H')	Evenness (H/Hmax)
Kedowa	Plot 1	86	16	2.56	0.92
	Plot 2	72	12	2.14	0.86
	Plot 3	65	1	0	0
	Plot 4	63	7	1.53	0.79
	Plot 5	77	2	0.59	0.86
	Plot 6	95	1	0	0
Chebewor	Plot 1	67	7	1.71	0.87
	Plot 2	80	5	1.79	1.11
	Plot 3	71	7	1.45	0.74
	Plot 4	65	8	1.51	0.73
	Plot 5	74	8	1.73	3.16
	Plot 6	60	8	1.62	0.78
Londiani	Plot 1	72	4	0.96	0.69
	Plot 2	89	12	2.26	0.91
	Plot 3	66	1	0	0
	Plot 4	73	1	0	0
	Plot 5	60	5	1.39	0.86
	Plot 6	74	1	0	0

4.2.5.3 Similarity between Sites

Results from Table 7 that similarity index ranged from 35% to 47% Kedowa and Chebewor had a relatively higher similarity index (47%) which implied that the two vegetation types probably shared more woody species than Londiani and Kedowa.

Table 7: Jaccard's similarity Index for the three forest blocks

Forest	Jaccard's Similarity Coefficient (S)		
	Kedowa	Chebewor	Londiani
Chebewor	0.47		
Londiani		0.35	
Kedowa			0.34

4.2.6 Woody Species Stand Structure

4.2.6.1 Diameter at Breast Height (DBH) Size Class Distribution

The DBH class distribution assumed an inverted "J" shaped pattern with majority of trees having smaller DBHs while fewer trees having larger DBHs. The DBH ranged between 10cm and 150cm in Londiani Forest. The mean DBH for Chebewor Forest block was 24.8 cm, Kedowa 32.4 cm and for Londiani Forest block it was 34.2 cm (Figure 7).

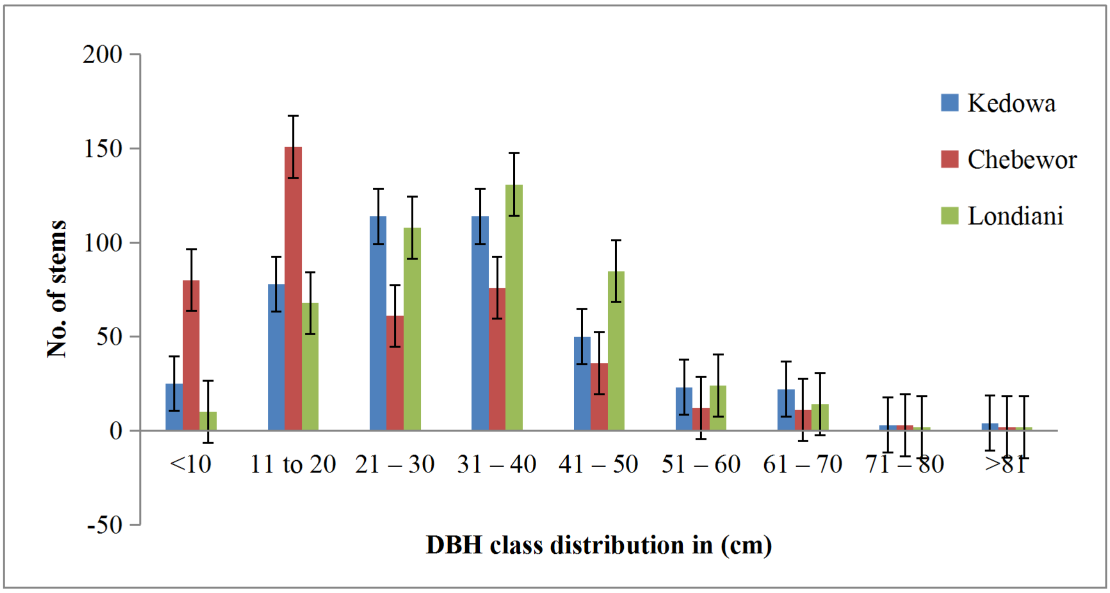


Figure 7: DBH distribution classes of the tree species recorded in Londiani Forest

Kedowa and Londiani Forest blocks had more trees in the DBH ranges of 21–30 cm, 31–40 cm and 41–50 cm. Chebewor, on the other hand, had more trees in the 11–20 cm DBH range. In all the forest blocks, there were trees with a DBH of <10 cm, which were mainly saplings. A total of 1177 (89.9%) trees out of 1308 trees from the entire forest recorded a small DBH below 50 cm, showing that the forests consist of young, still growing trees. The results revealed no statistical significant differences in the mean DBH distribution among the three forest blocks (F = 0.560; p = 0.729).

4.2.6.2 Height Distribution of Trees

The spectrum of tree height in Londiani Forest ranged from 1–50 m. The mean height for the Chebewor Forest block was 16.9 m that for the Kedowa Forest block was 23.9 m and 25 m for the Londiani Forest block (Figure 8).

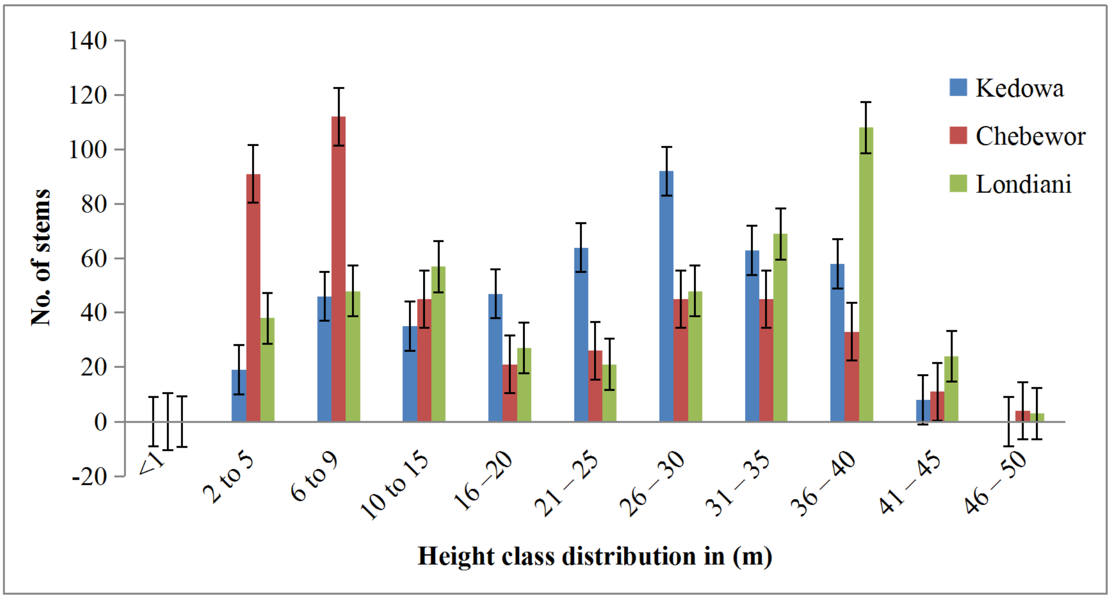


Figure 8: Tree height class distribution for the three forest blocks.

The height of trees in the Kedowa Forest block ranged from 11 m to 45 m, while the height of trees in Chebewor and Londiani Forest blocks ranged from 11 m to 50 m, respectively. There was no statistically significant difference in height distribution classes between the three forest blocks (F = 0.821, p = 0.558).

4.2.7 Degeneration Status of Londiani Forest

Kedowa Forest Block had *Cupressus lusitanica* with the highest number of cut trees 49, followed by *Juniperus procera* with 15 cut trees. In Chebewor Forest Block, *Juniperus procera* which was the most dominant species in the area had the highest number of cut trees 76, followed by *Eucalyptus globulus* with 45. In Londiani Forest Block, *Cupressus lusitanica* which was the dominant species in the block had the highest number of cut trees 39 followed by *Pinus patula* with 28 cut trees (Table 8). Trees in the study area were mainly cut for firewood, charcoal burning, illegal logging and poles for construction. A total of 58 charcoal burning spots were observed and recorded from the forest. Kedowa Forest Block recorded 27 charcoal burning spots, Chebewor 26 and Londiani 5.

Table 8: Summary of cut tree species in Londiani Forest

Kedowa Block			**Chebewor Block**			**Londiani Block**		
Species Name	**Cut trees**		**Species**	**Cut trees**		**Species**	**Cut trees**	
	No.	**%**		**No.**	**%**		**No.**	**%**
Dombeya goetzenii	12	10.1	*Olea africana*	1	0.7	*Pinus patula*	28	26.9
Prunus africana	3	2.5	*Eucalyptus globulus*	45	29.4	*Olea africana*	8	7.7
Croton megalocarpus	8	6.7	*Dombeya goetzenii*	9	5.9	*Dombeya goetzenii*	3	2.9
Tamarindus indica	4	3.4	*Croton megalocarpus*	3	1.9	*Ekebergia capensis*	2	1.9
Podocarpus gracilior	5	4.2	*Juniperus procera*	76	49.7	*Cupressus lusitanica*	39	37.5
Juniperus procera	15	12.6	*Prunus africana*	3	1.9	*Acacia xanthophloe*	3	2.9
Ficus sycamorus	2	1.7	*Syzygium guineense*	11	7.2	*Acacia nilotica*	2	1.9
Cupressus lusitanica	49	41.2	*Acacia mearnsii*	4	2.6	*Juniperus procera*	15	14.4
Eucalyptus globulus	10	8.4	*Salvadora persica*	1	0.7	*Eucalyptus globulus*	4	3.8
Ekebergia capensis	6	5						
Pinus patula	5	4.2						
Total	**119**	**100**		**153**	**100**		**104**	**100**

4.3 Forest Cover Changes

4.3.1 Processing and classification of NDVI Images

Water bodies, rocks, bare grounds and built up lands yielded negative values ranging from -0.3 to 0.2 values, because their reflectance was more visible rather than near IR wavelengths. Bush lands, shrubs and scanty vegetation showed positive values ranging from 0.1 to 0.4. Denser vegetation like plantation forest values ranged from 0.2 to 0.5. Natural forests yielded positive values from 0.4 recorded in the year 2000 to 0.7 recorded in the year 2010 (Table 9).

Table 9: NDVI values for land cover types of Londiani Forest for the selected study years

Land cover types	**Selected study years**				
	2000	**2003**	**2010**	**2015**	**2020**
Natural forest	0.4	0.4	0.7	0.6	0.5
Plantation forest	0.2	0.3	0.5	0.4	0.4
Shrubs/grasslands	0.1	0.2	0.4	0.3	0.3
Bare lands/rocks/water bodies	-0.3	-0.1	0.1	0.1	0.2

Comparison of vegetation cover change from multiple dates of LandsatTM derived NDVI imageries was carried out and the findings showed low vegetation reflectance in the year 2000 image, with a decrease in NDVI values. The vegetation reflectance was slightly higher in 2010 but a decrease of the NDVI values in 2015 and 2020 was recorded. Figure 9,10 ,11 are NDVI classified output images for Londiani Forest for the selected years of study (2000, 2003, 2010, 2015 and 2020).

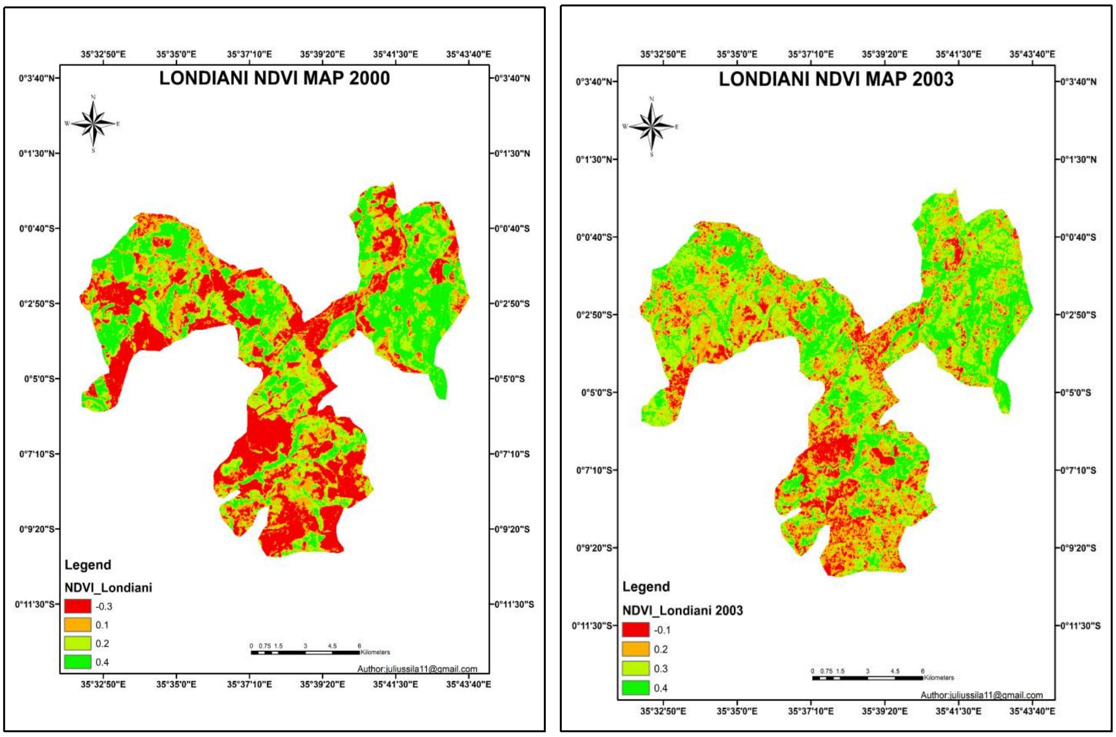


Figure 9: Output image for the year 2000 and the year 2003.

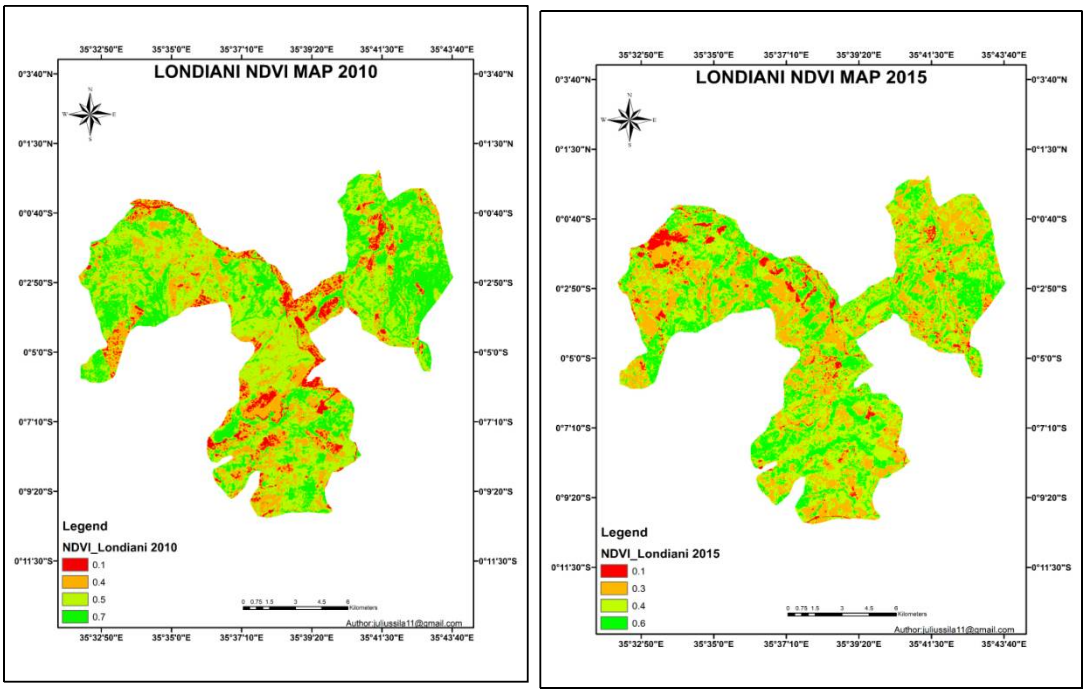


Figure 10: Output image for the year 2010 and the year 2015

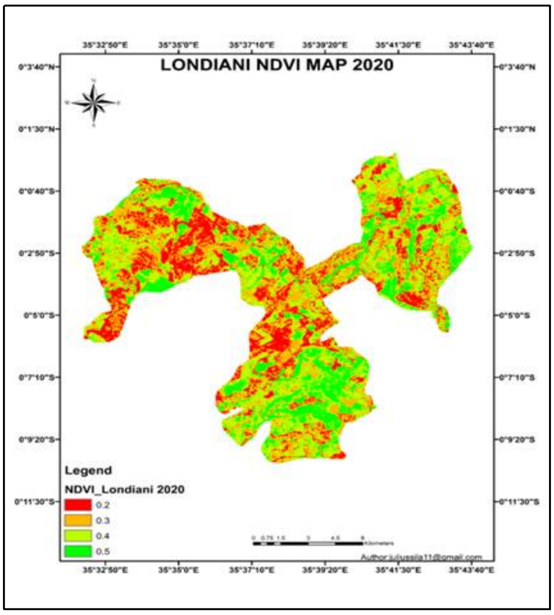
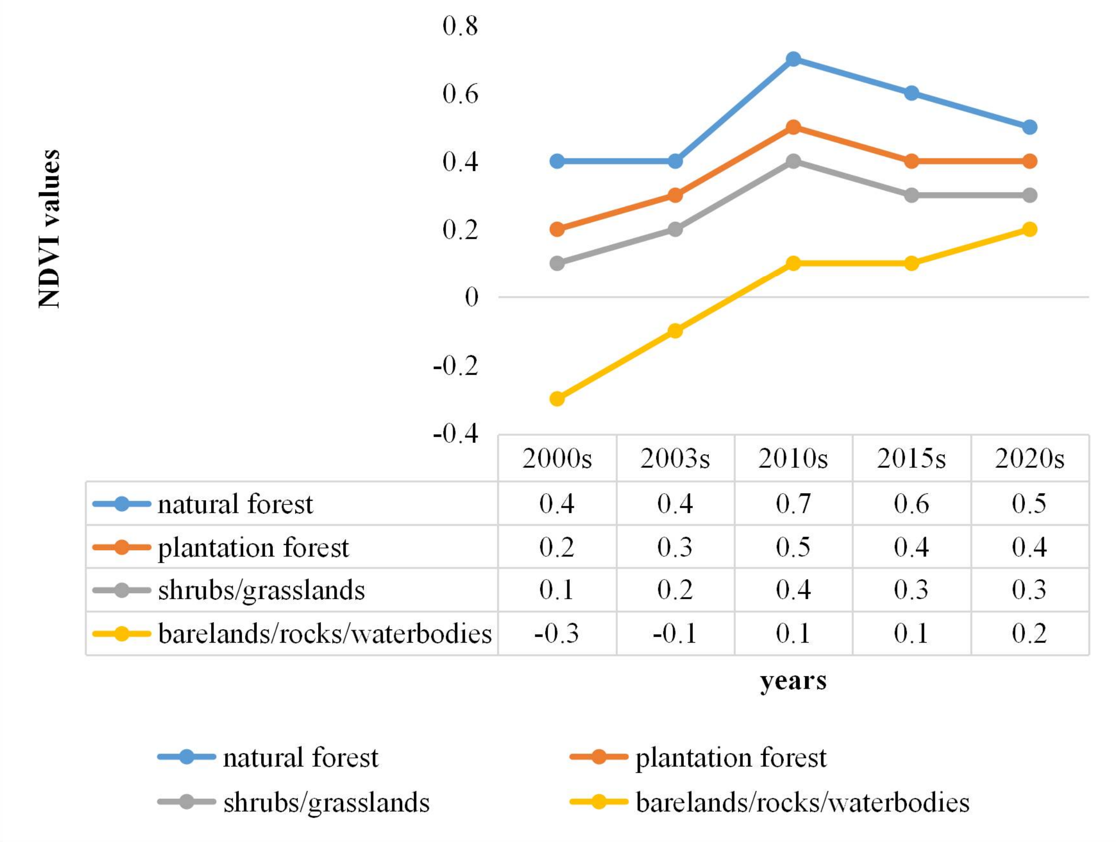


Figure 11: Output image for the year 2020

The NDVI output images showed vegetation reflectance health for the selected study years. In the year 2000 output image, the NDVI values for water bodies/bare lands were at -0.3 and covered a large portion as shown by the red coloured patches in the image/legend. In the year 2003, the same category recorded NDVI values of -0.1 showing a slight drop in the area covered by bare lands and water bodies and this translated to a slight rise in the area under plantation and natural forests evident by slightly higher NDVI values recorded in the year 2003 image, 0.3 and 0.4 respectively a rise from 0.2 and 0.3 recorded in the year 2000 image. The output image of the study year 2010 shows a healthy forest vegetation cover evident by more areas under green colour compared to the red coloured patches reflecting bare lands and also NDVI values of 0.5 and 0.7 respectively compared to the previous years, this values were the highest. There was a slight drop in NDVI values under forests however in the study year 2015 plantation forests recording 0.4 and natural forests 0.6 a further drop was observed in the final year of study where the same land cover type under forests recorded NDVI values of 0.4 and 0.5 respectively. As the years went by forest health and vigour was affected negatively by both natural causes like forest fires, pests and diseases and anthropogenic activities like charcoal making, illegal logging and fire wood collection among others. Efforts should be put in place to return to the study year 2010 image which had the healthiest forests.

4.3.2 Vegetation Index Change over the Years

Figure 12 shows the NDVI values ranging from -1 to 1 categorized into 4 classes in terms of vegetation coverage (Natural forests, plantation forest, shrubs and grasslands and bare lands/rocks/water bodies). The values for plantation forest ranged from 0.2 recorded in 2000 to 0.5 recorded in 2010. For natural forests NDVI values ranged from 0.4 recorded in the year 2000 to 0.7 recorded in 2010.



	2000s	2003s	2010s	2015s	2020s
natural forest	0.4	0.4	0.7	0.6	0.5
plantation forest	0.2	0.3	0.5	0.4	0.4
shrubs/grasslands	0.1	0.2	0.4	0.3	0.3
barelands/rocks/waterbodies	-0.3	-0.1	0.1	0.1	0.2

Figure 12: Vegetation index change over the years

4.3.3 Vegetation index Percentage Cover Change for the years 2000-2020

The NDVI value based category percentage cover was also calculated using the total counts for every category in Arc GIS and changed to percentage coverage for the selected study years and the results in Figure 13 showed that for natural forest the vegetation cover percentage ranged from 20% recorded in 2000 to 50% recorded in 2010. The plantation forest percentage cover ranged from 40% recorded in the years 2000 and 2003 to 70% recorded in 2010

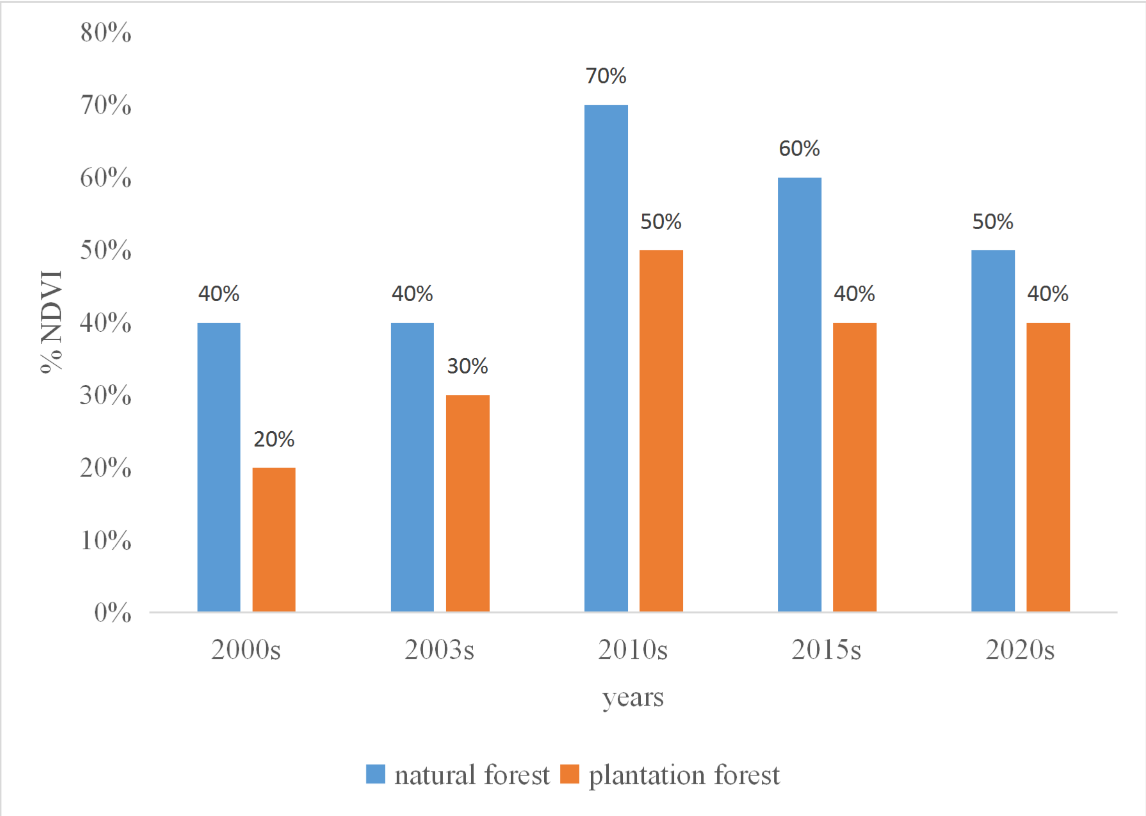


Figure 13: Percentage (%) NDVI over the years

There was an increase in forested area coverage in the year 2010 but a slight decrease in forest cover was recorded in 2020 the final year of study (Table 10).

Table 10: Percentage cover change of natural and plantation forest between the study years 2000, 2010 and 2020

NDVI value based category	Category % value 2000	Category % value 2010	% change	Category % value 2010	Category % value 2020	% change
Natural forest	40	70	30	70	50	-20
Plantation forest	20	50	30	50	40	-10

4.3.4 Land Use Land Cover Change for Londiani forest

The land cover trends and patterns of the study area depicting forest areas and other LULC types were as shown in Figures 14, 15, 16, 17 and 18.

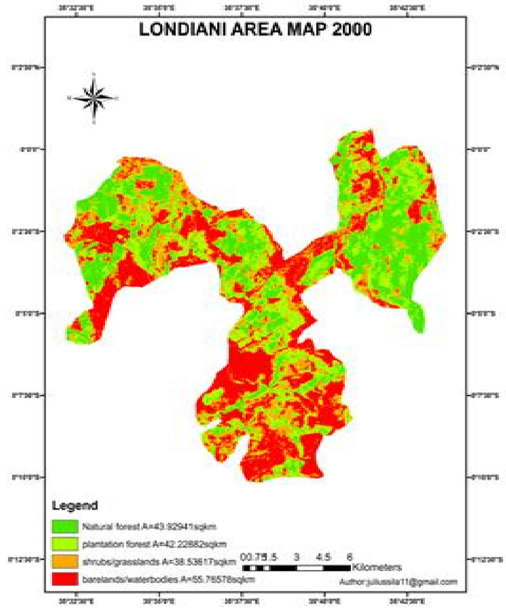


Figure 14: Land cover types year 2000

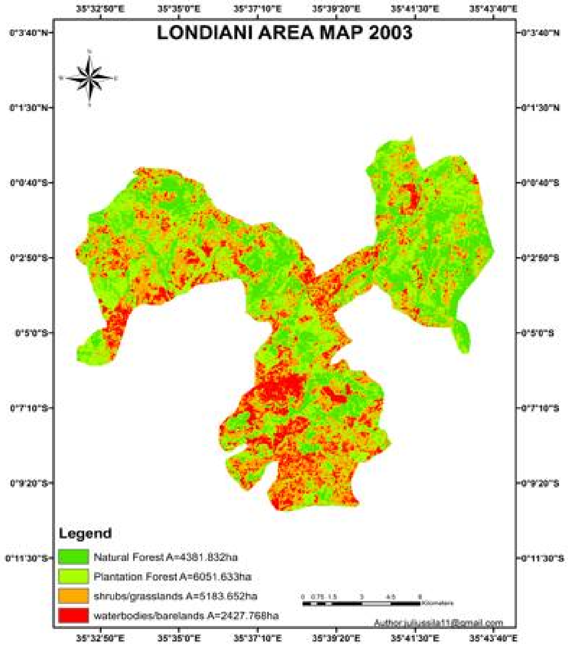
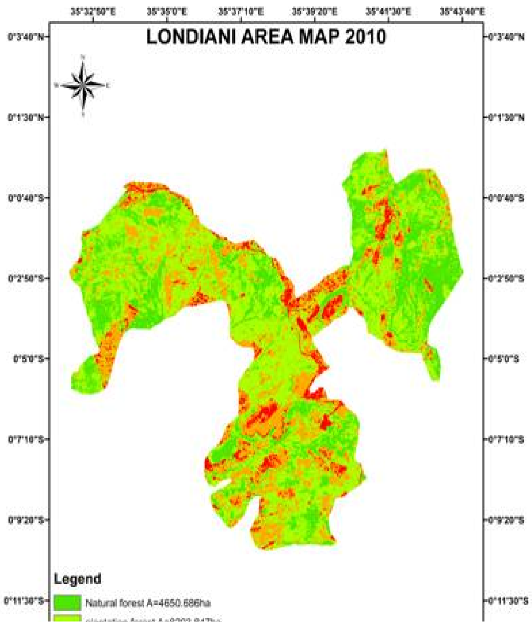
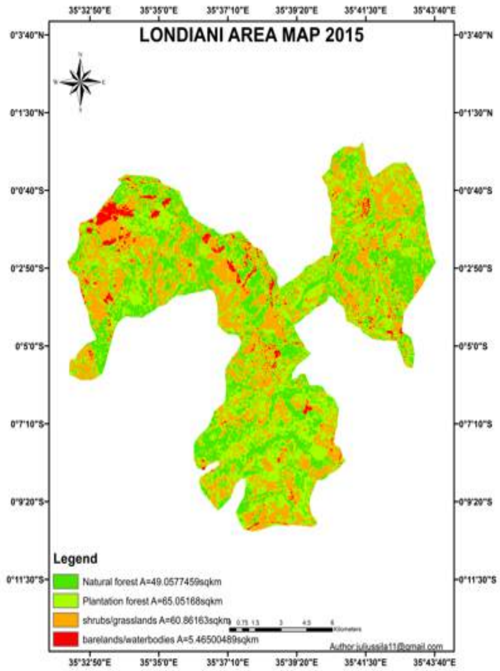


Figure 15: Land cover types year 2003





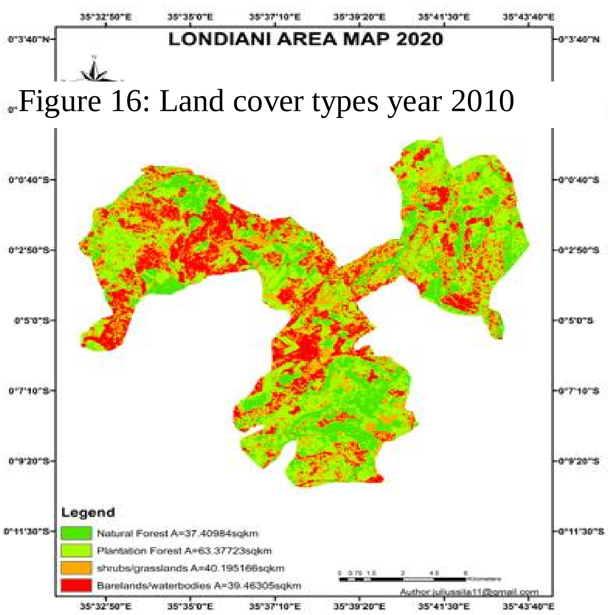


Figure 16: Land cover types year 2010

Figure 17: Land cover types year 2015

Figure 18: Land cover types year 2020

Land cover types output images showed a positive trend in forest cover of the study area over the selected study years for instance in the image output of the year 2000, the area under bare lands was high evident by a lot of red coloured patches in the image and consequently the area under forests cover was low as shown by the green coloured patches in the image. This image shows a degraded forest ecosystem compared to output image of the study year 2010 which recorded large area under forest both natural and plantation shown by the green coloured area in the image. There was a slight drop in the green coloured patches of the image in the study years 2015 and 2020 indicating that more forests areas were being encroached, trees were being cleared converting forests lands to bare lands.

4.3.4 Land Cover Area

The land cover area images above showed a decreasing trend in the area under natural forest which recorded a total of 43.9km^2 in the year 2000, a slight increase to 49.1km^2 in the study year 2015 then a drop to 37.4km^2 recorded in the study year 2020. The area under plantation forest showed a positive increase from 42.2km^2 recorded in the study year 2000 to 82.03km^2 recorded in 2010 then a slight drop to 63.4km^2 in the study year 2020. This study showed an increase in cover area under plantation forest in the year 2010 but natural forest cover area remained relatively stable over the study period (Figures 19 and 20).

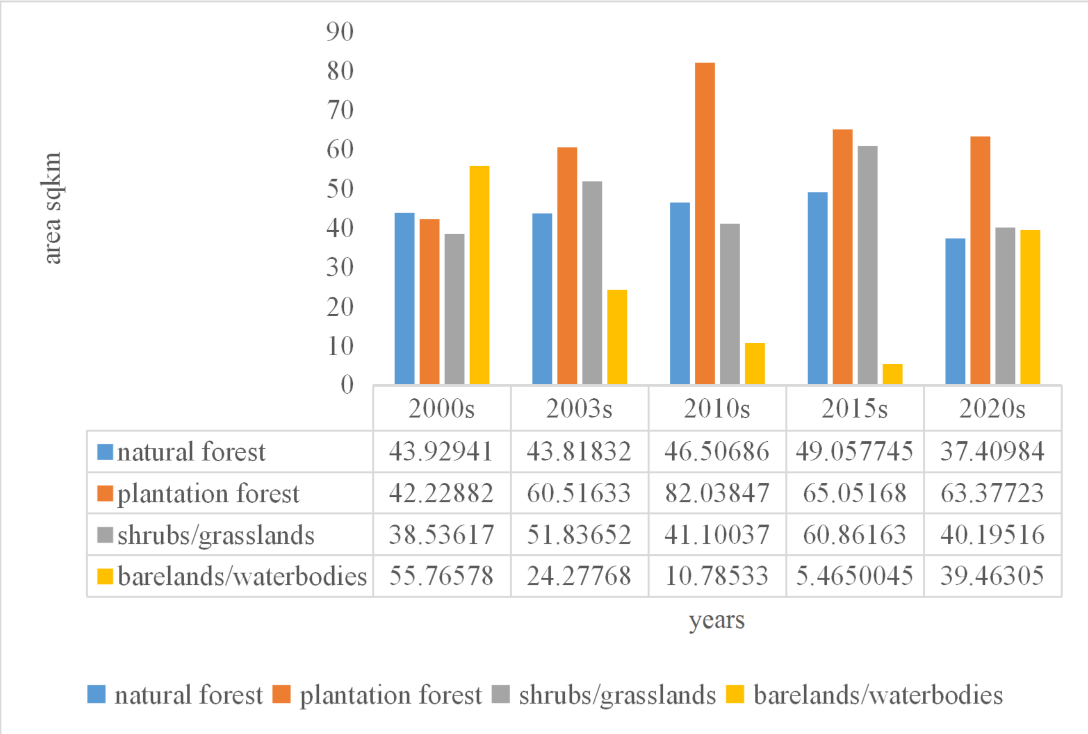


Figure 19: Land cover area in km^2 of Londiani Forest.

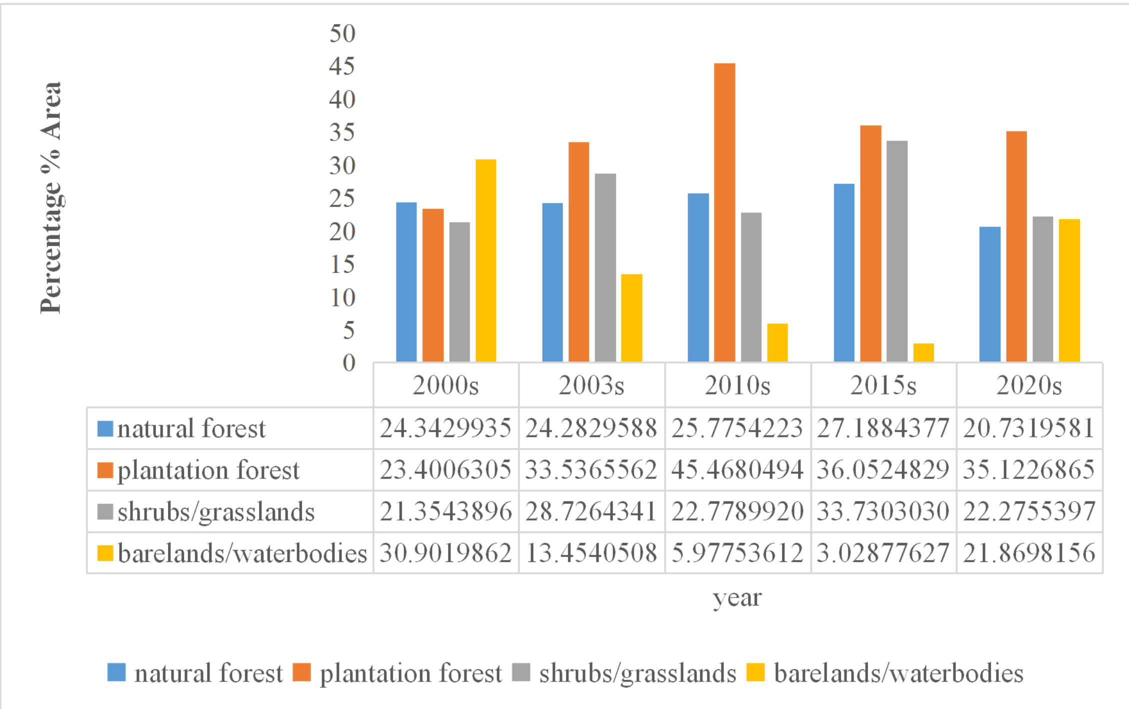


Figure 20: Land cover area percentage over the study period for Londiani Forest

4.4 Role of Forest Adjacent Community influencing Vegetation Dynamics

4.4.1 Gender composition of the respondents

A total of 270 respondents were administered with pre-tested questionnaires 90 from each of the forest blocks. Sixty six percent of the respondents were male while (34 %) were female. (Figure 21) A chi-square test of independence was performed to examine the relationship between gender and CFA membership. There was statistically significant difference between gender and CFA membership (X^2= 65.049 p = 0.000). More males than females are CFA members.

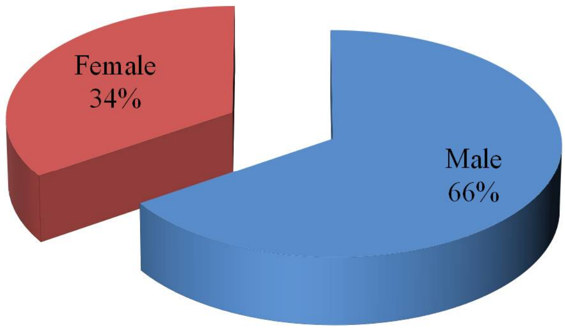


Figure 21: Gender composition of the respondents from the forest adjacent community

4.4.2 Age Distribution of the Respondents

Respondent's age ranged from below 20 years to above 60 years (Table 11). Most of the respondents (50%) in Londiani block were aged between 41-50 years, followed by 20% aged between 31-40 years. Only 3.3% were below 20 years of age. In Chebewor block 46.7% were aged between 41-50 years, followed by 20% aged between 31-40 years. In Kedowa block 43.3% were aged between 41-50 years followed by 26.7% aged between 31-40 years, and 6.7% above 60 years. Age distribution in the three forest blocks was statistically significant (X^2= 84.663 p = 0.000). In all the three forest blocks the respondents were mostly middle aged people. When subjected to Chi-square analysis to establish whether there was a relationship between age and forest conservation membership, the results show that there was a statistically significant relationship between age of the respondents and CFA membership. (X^2=73.641 P= 0.000). The middle aged people above 41 years old are more involved in forest conservation compared to the younger generation.

Table 11: Age distribution of the respondents per forest block

S/No	Age class years	Londiani Block (n)	Londiani Block %	Chebewor Block (n)	Chebewor Block %	Kedowa Block (n)	Kedowa Block %
1	Below 20	3	3	3	3	9	10
2	21-30	9	10	15	17	12	13
3	31-40	18	20	18	20	24	27
4	41-50	45	50	42	47	39	43
5	Above 60	15	17	12	13	6	7
	Total	**90**	**100%**	**90**	**100%**	**90**	**100%**

4.4.3 Level of Education

Majority 37% of the respondents (Table 12) in Londiani Forest Block had attained primary school education, 23.3% secondary school education, 20% informal, 13.3% tertiary level and 6.7% did not have any formal education. Chebewor Forest Block had the majority 43.4% of the respondents with primary education, 3.3% did not have any formal education. In Kedowa Forest Block the majority 46.7% of the respondents had attained primary school education, and 3.3% did not have any formal education. There was a statistically significant difference in education level distribution across the three forest blocks (X^2=72.225 p= 0.000). In all the three forest blocks more respondents had attained secondary and tertiary education level compared to informal and primary school education. A chi-square test of independence showed that there was a statistically significant association between level of education and CFA membership, (X^2=74.010 p = 0.000). There was a higher percentage of CFA membership across all the levels of education compared to non CFA memberships.

Table 12: Education level of the respondents of the forest adjacent community

Level of Education	Londiani Block Number	%	Chebewor Block Number	%	Kedowa Block Number	%
Informal	18	20	18	20	12	13
Primary	33	37	39	43	42	47
Secondary	21	23	21	24	24	27
Tertiary Level	12	13	9	10	9	10
Not Attended School	6	7	3	3	3	3
Total	**90**	**100**	**90**	**100**	**90**	**100**

4.4.4 Sources of income

The majority (39%) of the people are self-employed; 23% practiced mixed agriculture (cropping and livestock keeping). Twenty one percent engaged in business; retailing industry, hawking, transport industry (taxi motor cycle/ bodaboda), 14% were employed either by the government like teachers and civil workers and 3% under others earn their source of living through art and music, preaching and other income generating activities Figure 22.

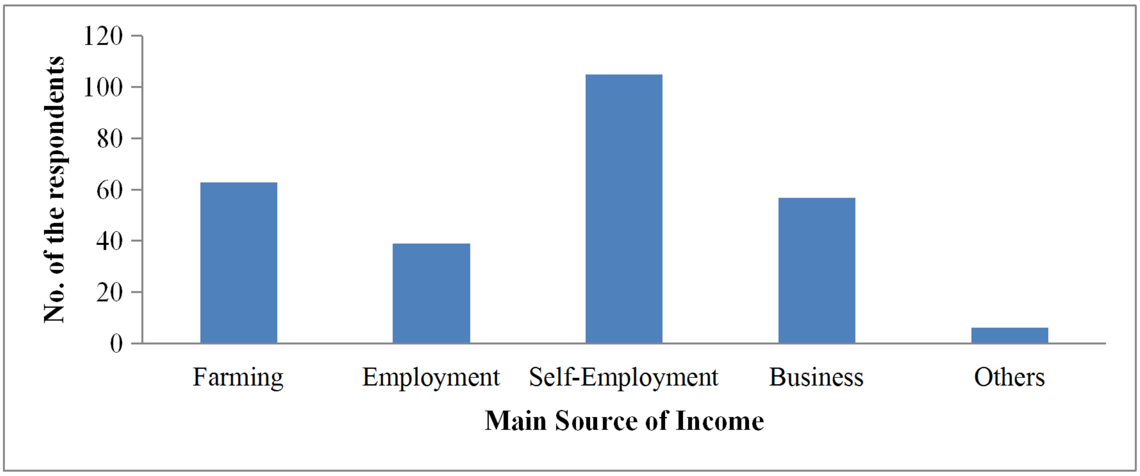


Figure 22: Source of income within the forest adjacent community

4.4.5 Average Monthly Income

The income of the respondents ranged between Kenya Shillings (KES) 1,000 to 20,000 per month. Most (37%) of the respondents earn an average monthly income of between KES 1,001-5,000, followed by 21% earning KES 5,001- 10,000, 12% earn KES 15,000-20,000 per month this group mainly consist of those who are employed like teachers and civil workers. A small percentage 8% earns less than KES 1,000 monthly and only (6%) earn above KES 20,000 per month Figure 23.

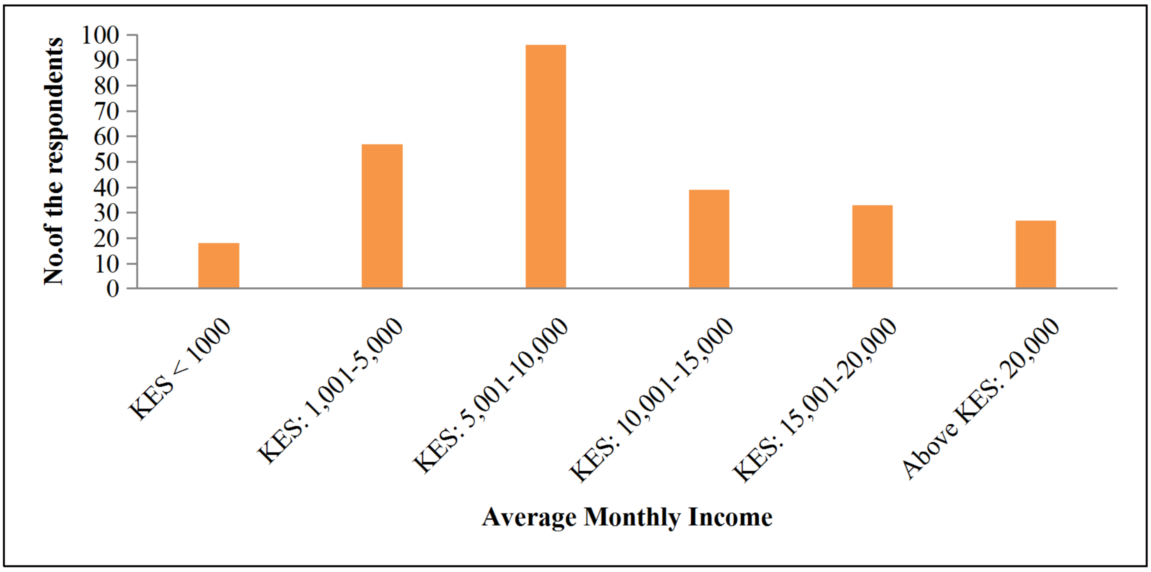


Figure 23: Average monthly income of the respondents in KES for the forest adjacent community

4.4.6 Average size of land in acres

Forty one percent of the respondents owned 1.5 to 2 acres of land, followed by 23% who owned 2.5 to 3 acres and 16.7% owned above 3 acres (Table 13). This indicates that most of the respondents were small scale land owners.

Table 13: Size of land in acres per forest block

S/No	Land Size in acres	Londiani		Chebewor		Kedowa	
		(n)	%	(n)	%	(n)	%
1	0.5 – 1	18	20	21	23.3	27	30
2	1.5 – 2	39	43.3	45	50	42	46.7
3	2.5 – 3	27	30	15	16.7	18	20
4	Above 3	6	6.7	9	10	3	3.3
	Total	**90**	**100**	**90**	**100**	**90**	**100**

4.4.7 Importance of Londiani Forest to the Forest adjacent community

The Londiani forest adjacent communities depend on the forest for numerous resources and services. The study established that different user groups that are active in the forest under the umbrella of Community Forest Association (CFA) called Londiani Community Forest Association (LOCOFA) carry out different activities within and outside the forests. The study showed that many people depend on the forest for fuel wood, construction materials, medicine and education represented by all the above uses (74%), while for fuel wood only was 10%, construction 8%, education where school children visit the forest to learn about the environment 4%, and 2% for food/fruit and medicine respectively (Figure 24) This shows that the forest forms an important source of livelihood to the residents who obtain many products from it.

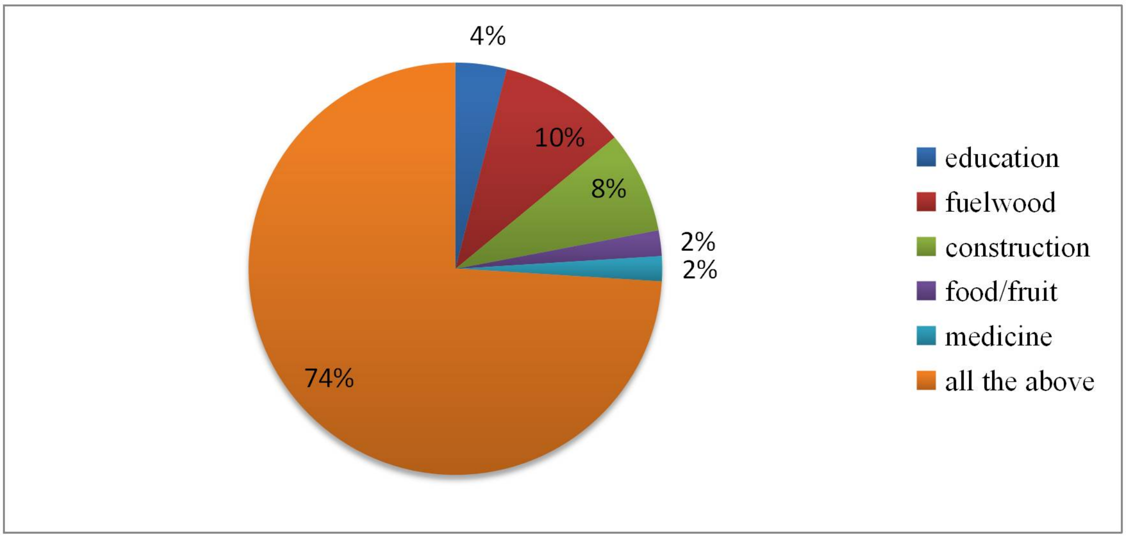


Figure 24**:** Uses of Londiani Forest to the forest adjacent community

4.4.8 Main source of animal feed

This study showed that Londiani Forest plays a key role in livestock keeping and to the economy of the residents as it provides the largest percentage of animal feed (74%) in form of direct forest grazing of livestock, or planting of fodder crops in the forest under the shamba system (PELIS) and sometimes cutting grass then carrying it to feed the animals at home especially the young and sick ones. This was followed by on-farm grazing at 22% a small percentage graze their animals along the roads 2) and 2% under others feed their livestock from the remains of crops like maize stalks, vegetable peelings, napier grass and hay (Figure 25)

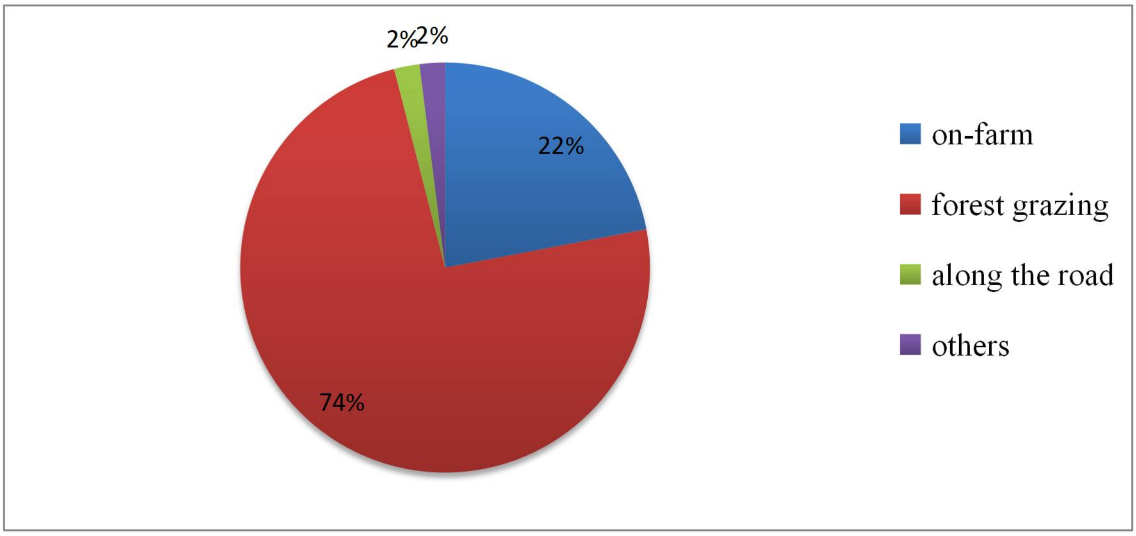


Figure 25: Sources of livestock feed for the forest adjacent community.

4.4.9 Source of energy for cooking and lighting

Figure 26 show that Londiani Forest is the main source of fuel wood which is widely used by the community for cooking and lighting. It was noted that 92% of the respondents rely on fuel wood from the forest for cooking and lighting, 4% had access to electricity, and only 2% use solar and paraffin respectively. This could have contributed partly to deforestation as trees are felled down for charcoal making and fuel wood production.

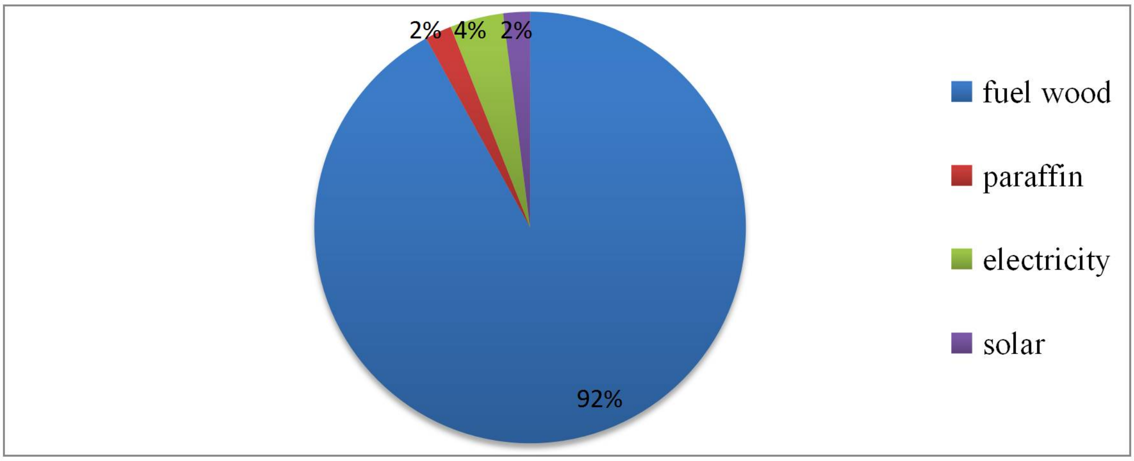


Figure 26: Main sources of energy for cooking and lighting for the forest adjacent community**.**

4.4.10 Threats facing Londiani Forest

Results in Table 14 shows that Londiani forest is decreasing according to the Kedowa adjacent communities who all (100%) agreed that the forest is decreasing. In Chebewor 93%, said that the forest cover was decreasing and only 7%, thought that the forest was increasing. In Londiani forest block 80% said that the forest cover was decreasing while 20% a relatively high number compared to the other villages thought that the forest was increasing.

Table 14: Status of Londiani Forest cover over the years (Increased or Decreased

S/No	Forest cover	Londiani		Chebewor		Kedowa	
		(n)	%	(n)	%	(n)	%
1	Decreasing	72	80	84	93	90	100
2	Increasing	18	20	6	7	0	0
	Total	**90**	**100**	**90**	**100**	**30**	**100**

4.4.11 Involvement of the forest adjacent community members in forest conservation

4.4.11.1 Persons Responsible for Forest Conservation

Londiani Forest adjacent community members thought that the forest should be conserved by both the government and the community as an important resource amongst them. The residents of Londiani area understand the forest belongs to them and that they own it and so they should conserve it. A high number (38%) said that the forest should be conserved by the public (common citizens), 32% admitted that the forest should be conserved by the communities adjacent to the forest while 14% said that non-governmental organizations are responsible for forest conservation (Table 15).

Table 15: Respondents thoughts on who should be responsible for forest conservation

S/No	Persons responsible for forest conservation	Londiani		Chebewor		Kedowa	
		Number	%	Number	%	Number	%
1	Public	30	33	33	37	39	43
2	Private	15	17	12	13	12	13
3	Civil Societies	9	10	9	10	6	7
4	Communities around forest	24	27	30	33	27	30
5	INGO's	3	3	0	0	3	3
6	NGO'S	3	3	3	3	0	0
7	All the above	6	7	3	3	3	3
	Total	**90**	**100**	**90**	**100**	**90**	**100**

When asked who manages the affairs of Londiani Forest, the residents' responses were as follows; 57% said that KFS manages the forest affairs, 21% said the community, 16% County Government, 4% said both KFS and KWS, and only 2% said KWS manages the affairs of the forest (Table 16). This indicates that Londiani residents recognize KFS as the main conservator of the forest.

Table 16: Responses on who manages the forest affairs per forest block

S/No	Persons managing forest affairs	Londiani		Chebewor		Kedowa	
		(n)	%	(n)	%	(n)	%
1	KFS	51	57	54	60	48	53
2	KWS	3	3	0	0	3	3
3	KFS & KWS	3	3	6	7	3	3
4	County Government	12	13	12	13	18	20
5	Community	21	23	18	20	18	20
	Total	**90**	**100**	**90**	**100**	**90**	**100**

4.4.12 Average Number of Trees Planted by Individuals for Reforestation Purposes

Londiani residents are actively involved in reforestation practices as shown by their willingness to participate in any reforestation activities organized by their forest conservation groups and others as shown by the total number of trees ever planted by individuals on government forest for reforestation purposes. Most of the respondents (29%) have planted between (201 and 300) trees for reforestation purposes in government forest, followed by 14% who have planted (101-200) trees, 12% have planted (201-300) trees, 10% have planted less than (100) trees, 5% have never planted any tree in government forest for reforestation purposes. (Figure 27)

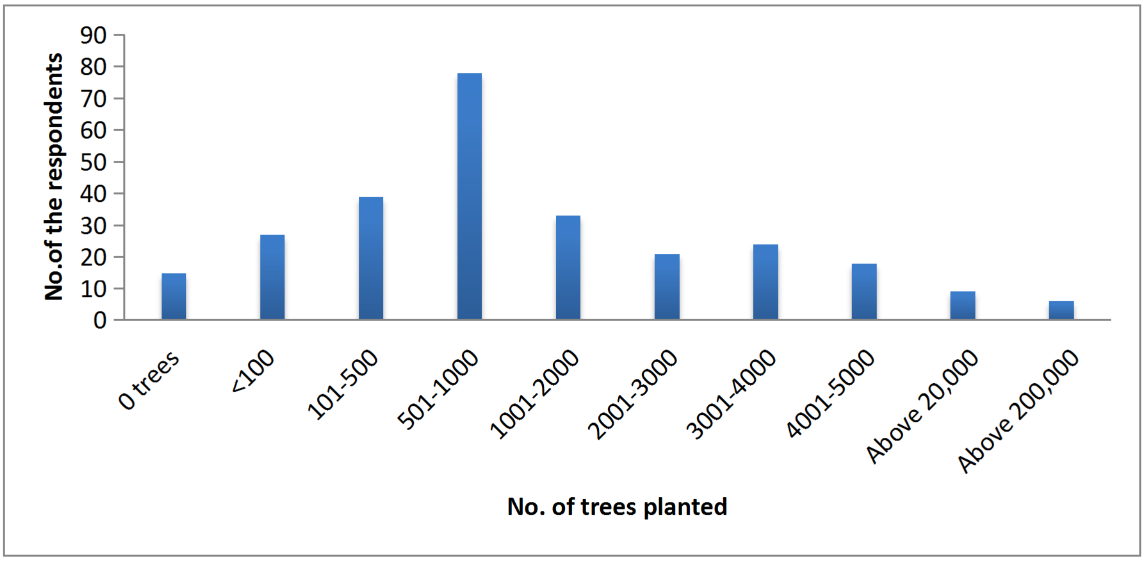


Figure 27: Total number of trees planted by individuals in government forests.

Apart from trees planted in government forests, the community members have also planted some trees on their farms mainly for fuel wood production. Trees planted on farm were counted and the results showed that 34% of the respondents have planted between (51-100) trees on their farms, followed by 22% who have planted between (101-200) trees, then 17% have planted between (101-150) trees 5% had not planted any tree on their farms and only 2% had planted more than 300 trees on their farms (Figure 28).

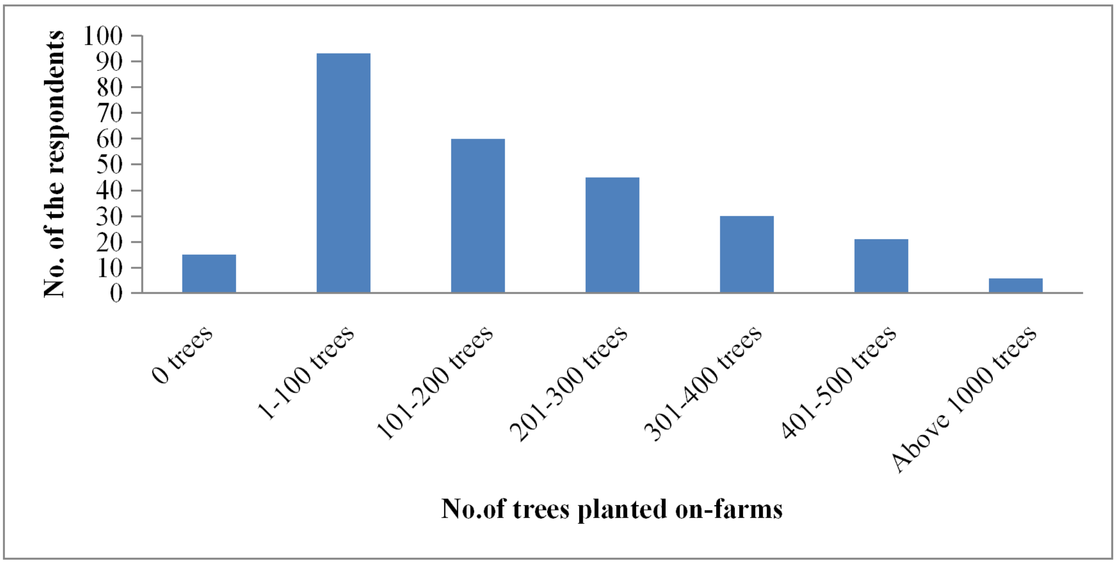


Figure 28: Total number of trees planted on-farms by the respondents

4.4.13 Source of tree seedlings

Most of the residents (38%) obtain tree seedlings from their on-farm tree nurseries, followed by 30% from KFS provision, 19% from tree nurseries in the local market (nearest shopping centre) and 13% from organizations in the area which plant tree seedlings (Figure 29).

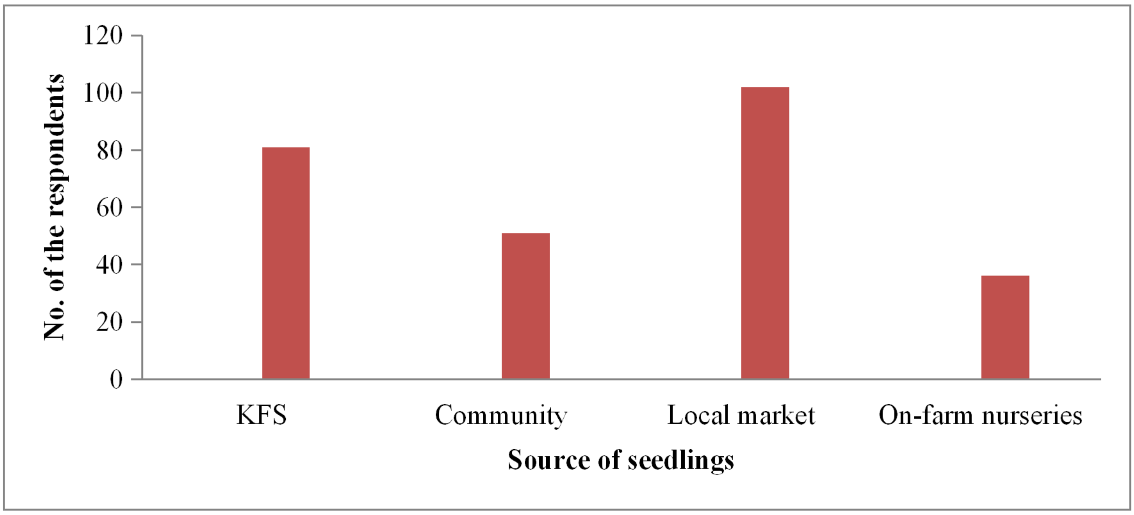


Figure 29: Major source of tree seedlings to the respondents.

Table 17 show analysis of the responses on the major source of tree seedlings per forest block in Londiani area

Table 17: Major source of tree seedlings to the community per forest block

S/No	Source of seedlings	Londiani		Chebewor		Kedowa	
		(n)	%	(n)	%	(n)	%
1	KFS	39	43	27	30	24	26
2	Community	18	20	15	17	18	20
3	Local Market	24	27	39	43	33	37
4	On-farm nurseries	9	10	9	10	15	17
	Total	**90**	**100**	**90**	**100**	**90**	**100**

4.4.14 Membership to Forest Conservation Group/Organization

A large percentage (81%) of the population in the area belong to either one or more than one forest conservation group under the umbrella of Londiani Community Forest Association (LOCOFA) and 19% are not yet members (Table 18 , Figure 30).

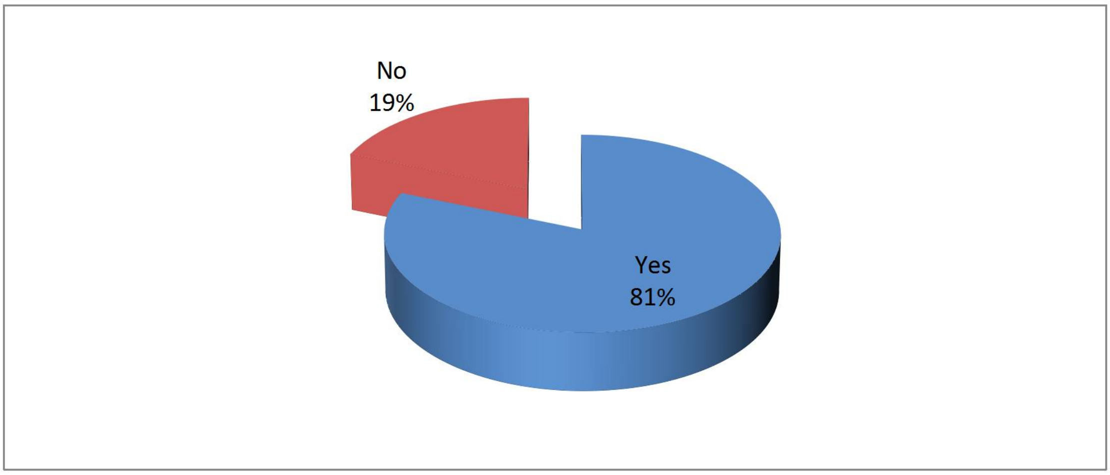


Figure 30: CFA membership among the respondents

Table 18: Analysis of CFA membership of the respondents per Forest block

S/No	CFA membership	Londiani		Chebewor		Kedowa	
		(n)	**%**	**(n)**	**%**	**(n)**	**%**
	Male	48	53	42	47	39	43
	Female	30	33	33	36	27	30
	Not members	12	14	15	17	24	27
	Total	**90**	**100**	**90**	**100**	**90**	**100**

In Londiani forest block, many respondents (43%) are members of a tree nursery user group, 23% seed and seedling collection user group, 13% were not yet members to any user group. In Chebewor forest block, the respondents user group membership were as follows, 37% tree nursery user group, 23% seed and seedling collection, 17% were not yet members. In Kedowa forest block there was no membership to ecotourism user group, the forest has no tourist attraction sites unlike Londiani and Chebewor which have beautiful sceneries and a mountain (Mount Blackett) conducive for mountain climbing, camping and bird watching. The largest membership in Kedowa was 40% to tree nursery user group, followed by 27% seed and seedling, 27% were not members to any user group a number relatively high compared to the other forest blocks (Table 19).

Table 19: User groups membership per forest block

S/No	User Groups	Londiani		Chebewor		Kedowa	
		(n)	**%**	**(n)**	**%**	**(n)**	**%**
1	Tree nursery	39	43.4	33	36.7	36	40
2	Ecotourism	12	13.3	15	16.7	0	0
3	Bee keeping	6	6.7	6	6.7	6	6.6
4	Seed & seedling collection	21	23.3	21	23.2	24	26.7
5	Not members	12	13.3	15	16.7	24	26.7
	Total	**90**	**100**	**90**	**100**	**90**	**100**

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter presents discussion on forest stand structure, species composition, forest cover change from the selected years of study and evaluation of the roles of forest adjacent communities in influencing the vegetation dynamics. The chapter interprets the meaning of the results or findings of the study, put them in context of the previous research and explains why the findings matter and contribute to new knowledge.

5.2 Species Composition, Distribution and Forest stand structure of Londiani Forest

5.2.1 Tree Abundance and Diversity in Londiani Forest

A total of 1,308 adult trees belonging to 24 families and 34 species were identified in Londiani Forest reflecting a relatively species diverse forest common in tropical forests. This observation corresponds to the findings of other studies done in the same area. For instance KFS, (2018) reported a total of 27 species while Mutiso *et al*., (2012) identified 38 plant species. The high number of species recorded in Londiani Forest could be attributed to the past and present disturbances, both natural and anthropogenic, which stimulates the establishment of varied species (Kinyanjui, 2013). The high number of species in Londiani Forest could also indicate that it has an ideal habitat for floral growth; same sentiments shared by Mutiso *et al*., (2011) who concluded that tropical rainforests and Montane forests are habitats for many different plant species. The results of this study compare well with studies that have been done in other forests in Kenya such as Kakamega Forest (Habwe, 2017), Mount Elgon Forest (Hitimana, 2004) and Nabkoi Forest (Wanjohi, 2017). All the forests recorded over 200 plant species.

Cupressus lusitanica was the most abundant species in Londiani Forest. It is a secondary exotic species planted under Plantation Establishment for Livelihood Improvement Scheme (PELIS) program to replace the indigenous trees after the forest experienced disturbances. Mutiso *et al*., (2011) recorded *Cupressus lusitanica* as the most abundant exotic species in the Mau Forest Complex which Londiani Forest is part of. Numerous exotic conifer species have been successfully introduced in Kenya since 1910 for wood supply, mainly for plywood industries, timber and pulp production purposes. Plantation development programmes in the country adopted and incorporated species that showed faster growth and stem and wood quality traits unlike the slower growing indigenous species. Kagombe, (2023) reported that among the conifers introduced, *Pinus patula* and *Cupressus lusitanica* have adapted well to local growing conditions and have managed to become key species widely planted in commercial plantations (Kuria *et al*., 2019).

Kuria *et al*., (2019) reported that currently, about 80% of the 186,000 ha state-owned forest plantation estate in Kenya is composed of the two conifer species, *Cupressus lusitanica* and *Pinus patula.* The two species are very important in contributing towards efforts to raise the country's tree cover to over 30% target as targeted to be achieved by 2030 (KFS, 2022). The fact that the two species have been a part of the Kenyan environment for some time now gives them the advantage of having silviculture, management regimes, and other growth characteristics that are already known (Kuria *et al.*, 2019). The only indigenous conifer species, *Juniperus procera*, was recorded in Londiani Forest but had a very low abundance. The findings of this study corroborate well with those of Cheboiwo *et al*., (2015) who found out that

Juniperus procera is found growing naturally in the Western rainforest and the high-altitude Montane forest types like the Kenya Mau Forest Complex.

Prunus africana is another species that was recorded with high abundance in Chebewor block but low abundance in Londiani and Kedowa blocks. This probably could be due to variation in the intensity of anthropogenic activities such as illegal logging and charcoal making within the blocks. Previous studies have shown strong negative relationship between logging incidences and trees sizes (Bolognesi *et al*., 2015). Sedano *et al.,* (2016) reported that charcoal making is one of the major factors leading to degradation of forests and reduced tree abundance. Previous studies have shown that charcoal making causes death of trees around the kiln and also lead to deforestation due to logging (Hansen *et al*., 2012; and Bolognesi *et al*., 2015).

Tree diversity in Londiani block was very low only 14 species recorded with a very low density as well. Charcoal making, clear cutting to pave way for more agricultural land and illegal logging have seen this forest site decline both in species number and tree density per hectare as well. There were ongoing disturbances observed in the study site which further affects forest diversity. Livestock were grazing freely and unsupervised, charcoal making was observed ongoing in Chebewor and Kedowa blocks at the remaining indigenous portion of the forest. These disturbances have led to decline in climax economic important species. Similarly, Sapkota *et al.,* (2010) noted that species diversity reduced in after disturbances occur in any forest. The findings of this study are also supported by those of Mutiso *et al*., (2013), who observed that unsupervised forest grazing resulted in recurrent browsing and trampling of undergrowth by cattle, sheep, donkeys, and other livestock. This prevents the emergence of shade-tolerant later successional species. Arun *et al.,* (2013) and Emery, (2012) both emphasize the need for early successional species to give way to late non-pioneer successional species in order to restore the stand structure and species diversity of a pre-disturbance forest. Rehabilitation strategies in Londiani Forest should be geared towards promoting regeneration, successful recruitment of non-pioneer species and suppression of invasive species. Kenya Forestry Research Institute (KEFRI) based at Londiani area showed a lot of positive efforts in collection and storage of seeds. This is crucial because the change from pioneer life history depends on the persistence of seeds in seed banks and the rate at which young plants grow from seedlings to saplings until they reach maturity. This should be encouraged in the three forest blocks studied if the most critical life histories of non-pioneer species is to be achieved (Sapkota *et al*., 2010).

5.2.2 Woody Tree Species Richness in Londiani Forest

The findings show that Kedowa block is rich in tree species compared to the other two blocks. This observation was supported by KFS, (2018). There are many indigenous tree species fully matured and with saplings and seedlings unlike Londiani block which had a small area with indigenous tree species same observations were recorded by Mutiso *et al.,* (2011). Chebewor block had over 50% of indigenous tree species but had faced numerous anthropogenic disturbances. Efforts of restoration could be seen where many secondary planted indigenous tree species some matured while other plots were still young trees growing under shamba system program. In Londiani block secondary planted forest cover about 90% of the forest with exotic tree species planted fully matured but with no saplings or seedlings. Kedowa block indigenous forest part has faced tremendous impacts by human activities (KFS, 2018) either through charcoal making a fact confirmed by presence of several charcoal burning spots in each quadrat. Cheboiwo *et al.*, (2015) recorded several charcoal burning spots in Mau Forest Complex. Fuel wood collection is also another anthropogenic factor leading to diminishing indigenous forest tree species in Londiani Forest same sentiments were shared by KFS, (2018). Secondary self-regeneration was observed in Kedowa indigenous portion of the forest evidenced by the presence of a high percentage of saplings and seedlings.

Past and present disturbances both natural and mainly human caused have led to low numbers of species found in Londiani Forest block, a fact that resonates with Mutiso *et al.,* (2011) findings on floristic composition of Mau Forest Complex. Such alterations of species composition according to the author affect the future forest ecosystem resilience, integrity, and sustainability. Similar concerns are expressed by Smith, (2010) who state that due to excessive biotic interferences, many forests are now losing their tremendous intrinsic ability of self-maintenance. High species richness in any forest is very important because it guarantees that other species in the family will take up the ecosystem's parallel and cyclical arrangement in the event that a member disappears, it prevents the collapse or extinction of a particular family or genera (Mutangah *et al.,* 2014). It is very important for forest managers in Londiani region to maintain species richness after a disturbance as a strategy to counteract ecosystem collapse and enhance ecosystem stability. Large populations, according to Jianbang *et al.,* (2016), are less likely to go extinct than small ones. The observed decline in species richness in Londiani Forest is attributed to the past disturbances a fact that resonate with Sapkota *et al.,* (2010) who observed same species reduction in forests that had gone through heavy disturbances. *Olea africana* normally regenerates under shaded area but Londiani forest canopy is wide open due to excessive deforestation in the area. Invasive species have choked up efforts of self-regeneration of indigenous tree species and very important species as observed in Kedowa and Chebewor forest blocks where *Trychocladus ellipticus* was observed to be aggressively colonizing the forest suffocating other species' seedlings and saplings.

Post-disturbance processes of various plant structures should be well understood by foresters and they should be in a position to relate them to a particular forest and its vegetation dynamics. Further studies should be conducted in Londiani Forest to understand the aggressiveness of the invasive species so that efforts can be geared towards maintaining them and if possible eliminating them at an early stage in the forest. Elsewhere in Mt Elgon and Kakamega forests, Mutiso *et al.*, (2013) attributed the production of charcoal in any particular forest to the spread of exotic species that altered regeneration patterns. Forest managers should document these indicator species of disturbances as is stressed by Mutangah *et al*., (2014) so that care should be taken as soon as these species are seen germinating after a disturbance has occurred in a given forest ecosystem. The responsibility of forest managers is to identify any potentially dangerous invasive species early enough and take the proper measures (UNO, 2014). Hitimana *et al.*, (2004) documents similar case of *Solanum mauritianum* an invasive species that was fast growing in Kakamega and Mt Elgon forests post disturbances. The weed had out-competed natural regeneration of the native species because of its aggressive proliferation strategies and as a result reduced species diversity and richness drastically.

5.2.3 Woody tree species Density and Relative Density in Londiani Forest

According to this study, plants species in the three forest blocks studied differed in density and composition. Several species were associated with different ecological zones (AEZ) for instance native species like *Eucalyptus globulus* growing on low levels near water sources, *Olea africana* in shaded region and *Prunus africana* on the hilly sides of the forest. These opinions concur with those of Myster, (2004) who concluded that following establishment, different combinations of tree species are formed based on the compatibility of local environmental conditions. In forests, site indices are used to show indicators of productivity (KFS, 2018), and differences in forest yield and species composition are expected as a result in differences in AEZ. Kedowa and Chebewor blocks recorded higher species densities compared to Londiani forest block which had faced numerous anthropogenic disturbances. Kenya's land has less than 20% portion regarded to as high potential that can be used for cultivation for food production (KFS, 2022), this is low when compared against a fast growing human population (Omondi, 2018). For this reason forests of the country are encroached threatening them further. Agriculture and human habitation are prioritized in these arable areas, and trees are frequently cut down, excised, or overexploited (KEFRI, 2018). A similar scenario has happened to the Mau Forest Ecosystem (MFE), the most expansive single block of montane forests in Kenya which has faced degradation for a long period of time (Cheboiwo *et al.*, 2015). Mau forestland was converted into settlements and cropland as a result, there was loss of floristic characteristics of the forest, vegetation density, forest health was compromised and biodiversity reduced (Cheboiwo *et al.*, 2015).

The indigenous tree species in Londiani Forest recorded lower densities compared to the exotic secondary planted species like *Cupressus lusitanica*, *Pinus patula* and

Eucalyptus globulus that recorded higher densities. These findings corroborate with the sentiments shared by Ministry of Environment and Natural Resources (MENR), 2012 report which stated that the MFE, which is a montane forest because it's in a high altitudinal place has two broad forest types; On the drier sides of the forest the Afromontane conifer species dominated by *Juniperus procera* and *Podocarpus latifolius* which are indigenous conifers are found growing there and on the moist sides of mountain trees species found there are like *Polyscias fulva*, and *Prunus africana.*, which are the Afromontane mixed forests with broad-leafed species.

5.2.4 Woody Tree Species Frequency and Relative Frequency in Londiani Forest

The probability of finding a tree species within a particular area in forestry is called frequency (Akande *et al*., 2019). Forest management leads to changes in structure and species composition of stands. The frequency of species varied significantly in the three forest blocks, and this could be explained by the impacts of disturbances and management practices that encourage the regeneration of specific species well adapted to the prevailing climatic and environmental conditions. *Eucalyptus globulus* which prefers wet conditions is the most frequent species in Londiani Forest followed by *Dombeya goetzenii.* Species that preferred dry conditions were rare for instance *Acacia xanthophloe, Acacia mearnsii* and *Acacia nilotica* all recording a frequency of below 5 in Londiani Forest. This is because Londiani Forest Complex is generally wet. Mutiso *et al.,* (2011) asserts montane species respond differently to changing environmental and climatic conditions. *Podocarpus latifolius* showed preference for wetter conditions while *Olea capensis* showed preference to slightly drier conditions. Sapkota *et al.* (2010) in a study in Sal Forests recorded similar families having one species a condition attributed to recruitment limitations and pioneer species that only respond to major disturbances.

Biotic and abiotic disturbances in MFC have led to the observed scattered small groups of remnant indigenous broadleaf forests including Hagenia, Dombeya, Croton, Juniperus, Prunus, Olea and Podocarpus species (Mutiso *et al*., 2013). Selective harvesting of trees species is quite common in any given forest ecosystem and this in addition to large scale land-use transition and collection of poles, fuel wood and non-timber forest products affects the frequency of species found in a forest at a given period of time. Most targeted species like *Ekebergia capensis, Prunus africana, Rhus natalensis, and Maesopsis eminii* all recorded a frequency of 1 in Londiani Forest. The government has introduced an intensive tree replanting after harvesting and this explains the remains of indigenous trees species partitioned into plantation plots.

5.2.5 Tree Species Basal Area, Dominance and Relative Dominance in Londiani Forest

An important measure of species composition in a forest is dominance, which refers to a species' relative importance in its habitat and also determines the degree of influence the species has on the ecosystem (Wanjohi, 2017). In this study, the dominance of tree species was ranked using the basal areas of each tree belonging to a specific species same method was used by Mutiso, (2009). Dominance in Londiani forest was shared by 34 different species recorded in the study area and the results show that *Cupressus lusitanica* had the highest dominance, followed by *Pinus patula* and *Eucalyptus globulus.* The findings of this study corroborates well with those of Cheboiwo *et al.*, (2015) who noted that in a natural forest, it’s difficult to find a single dominant species unless it’s a plantation forest. According to the authors, there are near to or more than 60 different tree species in the Mau Forest, and depending on the regional environmental and ecological conditions, one of these species may rank somewhat above the others. Where there is no disturbance, Mutiso, (2009) have shown that based on a species ecological niche, one can possibly predict the species occurrence in a habitat. The authors defined “rough distribution areas” as areas with absence or over dominance of species which can be associated with stress factors like forest fires and over extraction a condition that well characterise the Mau forest complex.

According to MENR (2012), species association is a strong vegetation characteristic of the MFC, and co-dominance in that forest has led to different forest formations. However, in some areas, anthropogenic disturbances have interfered with the floristic composition and characteristics of the forest. This scenario favours the non-commercial species while reducing the dominance of the commonly exploited species. Over dominance of fire tolerant *T. stapfiana* and the pioneer species *Neoboutonia macrocalyx* according to Mutiso *et al*., (2011) may have been brought about by frequent forest fires occurring in some parts of the MFC for example, the Londiani Forest Complex, which is in a high-risk area for flames, frequently sees forest fires. From the years 2013 to 2017, there were a total of 217 forest fire incidents, with an average of 43 incidents per year in Londiani Forest, according to Wafuta *et al.*, (2019). The regeneration potential of some species according to KFS, (2022) has been compromised affecting their dominance due to human disturbances.

5.2.6 Species Richness of Saplings and Seedlings in Londiani Forest

The observed low floristic composition especially at Londiani block at saplings and seedling stages indicates a condition of poor recruitment and establishment. This is a result of ongoing disturbances mainly anthropogenic ones like charcoal making fuel wood collection and even quarrying as observed in the forest blocks. These results agree with those of Cheboiwo *et al.,* (2015). The authors recorded a negative recruitment and regeneration process due to ongoing disturbances in the Mau Forest Complex. A further study conducted in the Mau Forest Complex by Sapkota *et al.,* (2010) further demonstrates how prior disturbances changed natural regeneration regimes to a more individualistic successional pathway. These patterns of regeneration, which were also found in the Londiani Forest Complex, encourage mono-dominant forests with little redundancy and a lack of species coexistence in the presence of natural disturbance regimes. These findings agree with those of Taylor and Chen (2010). Invasive species *Trychocladus ellipticus* was observed in Kedowa and Chebewor blocks. This might have replaced the pre-disturbance stable regeneration regimes and has led to low floristic composition at saplings and seedling stages (Mutiso *et al*., 2013). Illegal logging slows regeneration process and further opens up the inner parts of the forests exposing it to further destruction a fact that resonates with KFS, (2012) report on status of Kenyan forest cover. Mwangi and Wardell, (2012) findings on factors impacting natural recruitment of species in Mau Forest Complex states that tree poaching and forest grazing were the main culprits. To achieve post-disturbance establishment in Londiani Forest, a lot has to be put into considerations. Forests managers in this region are required to understand all the factors leading to achievements of pre-disturbance floristic composition as explained by Mwangi & Wardell, (2012) as series driven by factors interacting to determine emergence and net recruitment. According to their findings, it’s a complex process which includes stochastic mechanism process, abiotic constraints and neighbor plant interactions determined by natural resources such as nutrients, light, and water.

The strong recruitment pattern by *T.ellipticus* in Londiani Forest Complex is due to the fact that the species is aggressive invasive and a pioneer species associated with disturbances. This resonates with Mutiso *et al.,* (2011) who documented that *T.ellipticus* effectively invades disturbed forest ecosystem because it is a colonizer species. Some invasive species according to the author are quite difficult to control and can out-compete natural regeneration of native species. Indigenous species in Kedowa and Chebewor blocks showed poor regeneration status evident by low saplings and seedling stages while exotic trees like *Cupressus lusitanica* and *Eucalyptus globulus* had a good number of seedlings and saplings especially in Kedowa block. The pattern kept fluctuating between seedlings and saplings in many species because of the past and even present disturbances. Studies have shown that some species may have low densities or even vanish at the sapling stage as a result of disturbances, while others become more prominent at this stage (Hitimana *et al.,* 2004).

Improved shamba system currently promoted under the Plantation for Livelihood Improvement Scheme (PELIS) program has proven to be very effective in regeneration of trees in Londiani region. In all the three forest blocks, food crops were notably planted alongside both exotic and indigenous trees seedlings (Kagombe, 2014). PELIS has proven to be cost-effective and efficient plantation method in industrial plantation programs, but its seedlings survival rates has shown some inconsistent results according to Kagombe, (2014). A high seedlings survival rate of 79% has been recorded in Nyandarua County, in Trans-nzoia County a 51% survival rate has been recorded and a National mean of 67% according to KFS data on the

2012/2013 planting season although further research accounting for the heterogeneous performances is yet to be done according to Gichuru, (2015).

Londiani forest have a very low population density of saplings and seedlings indicating a poor regeneration status of the forest in the near future, therefore, development of management options that takes into considerations conservation goals, socio-economic realities and development priorities should be designed to assist regeneration process a fact that resonates with Kinyanjui *et al.,* (2013). Regeneration status of Londiani forest may remain poor for a long time if ongoing disturbances like illegal logging, charcoal burning, forest encroachment, unsupervised forest grazing, wood and timber production fail to subside and may require over 5 decades to return to pre-disturbance conditions.

5.2.7 Species Evenness and Similarity in Londiani Forest

The three forest blocks are similar in the sense that they all had 7 similar species namely; *Acacia nilotica, Cupressus lusitanica, Dombeya goetzenii, Eucalyptus globulus, Juniperus procera, Olea africana* and *Syzygium guineense.* Kedowa forest block had 10 tree species unique to the block and not found in the other blocks namely; *Arundiana alpina, Brassia actinophylla, Croton macrostchyus, Ficus sycamorus, Maesopsis eminii, Polyscias fulva, Rhamnus prinoides, Vipris nobilis, Vitex keniensis* and *Zanthoxylum gilleti.* Chebewor block had 4 unique species not seen in the other blocks namely; *Acacia mearnsii, Grevillea robusta, Podocarpus falcatus,* and *Salvadora persica*. Londiani block on the other hand had few species but like the other blocks it also had 2 unique tree species not found in the other forest blocks namely, *Acacia xanthophloe* and *Spathodea campanulata.*

Based on Jaccard similarity indices, the three forest blocks have very low similarity index less than 0.5. The important thing worth noting is that in all the three forest blocks there is a certain level of species sharing especially between Chebewor and Kedowa block. This can be greatly attributed to neighborhood and endemism effects. Myster, (2004), quote neighbor plant interaction being a factor that determines plant formations after a disturbance. This homogeneity of plant formations in Kedowa and Chebewor block as was observed could also be attributed to minimum disturbances levels as opposed to Londiani block which had a very small percentage of its forest with indigenous species. All trees in Londiani block had faced major disturbances and currently monoplanting of exotic trees like *Pinus patula* and *Cupressus lusitanica* was observed. Different stands take different trajectory successional pathways depending on the severity of the disturbance (Mutangah *et al*., 2014). It is advisable for forest managers to maintain forest stand stability by taking action against individualistic successional pathways. Actions like enrichment planting are advised by Sovu *et al.,* (2010) to help natural forests that have lost significant species as a result of post-disturbance succession or are at low densities. Similar approach is also advocated for by Sapkota *et al*., (2010).

5.2.8 Woody Species Stand Structure in Londiani Forest

This study show that the diameter at breast height ranged between 30 cm and 50 cm though previous studies in Kenya have recorded DBH of over 1 m (Hitimana *et al.,* (2004); Orwa *et al.,* (2009). Most trees in Londiani Forest are still young and growing evidence of below 50 cm DBH. This study recorded a mean height of 21 m. This height concurred with findings reported by Navarro-Cerrillo *et al.,* (2018) and Stewart and Spittlehouse, (2003) of 30 m to over 40 m. This is an indication that the tree height within the country has not changed much over the years. Tree size such as girth and height are influenced generally conditions of growth such as soil type, rainfall pattern, age, and disturbance among others (Mligo, 2009). All the three forest blocks experience relatively similar weather pattern and soil characteristics, therefore, variation in height can thus be attributed to human disturbance, age of the tree or both same sentiments were shared by Mutiso *et al.,* (2011) on a study done on Mount Blakett Forest located within the Londiani Forest Complex. Several tree stamps were observed and recorded as cut trees in all the three forest blocks under study. This is an indication that bigger trees are being harvested for timber and charcoal leaving behind small ones. Hansen *et al.,* (2012) recorded a negative correlation between number of bigger trees and logging incidences consequently attributing the low number of bigger trees to logging.

5.2.9 Degeneration Status of Londiani Forest

Londiani Forest which is part of Mau Forest complex ecosystem is facing various threats such as forest excision, encroachment, illegal logging, overgrazing, rampant charcoal production, political interferences, unsustainable PELIS system, ballooning of plantation forest, pollution from factories wastes both liquid and solid wastes and debarking of trees for medicinal purposes and construction of bee hives. The resultant impact of these threats is evident in the change in land cover where forest land decreased by 21,740 ha while cropland increased by 14,849 ha inside the gazetted forest between 1990 and 2016 (UNEP) report (2016). Suleiman *et al.,* (2017) identify the increasing anthropogenic disturbances caused by relative changes in land use and the constant rising human population as the main causes of tropical forest deforestation. Agriculture is considered generally as a key driver of tropical forest loss. This sector covers many practices ranging from permanent export-oriented plantations to traditional shifting cultivation (Hosonuma *et al.,* 2012). Similarly, Omondi, (2018) highlighted the role played small-scale agriculture expansion, as a result of high population growth. In the case of Londiani Forest which is part of the Mau Forest Complex, government allocated forest land to small-scale farmers leading to recent deforestation. When 61,023 ha, or 14% of the entire Mau Forest, were excised in 2001, primarily in the Eastern block to make place for small-scale farmers, there was a significant loss of gazetted forest in this region (UNEP, 2018).

Conflicts over resource use have recently increased among the communities that surround the Londiani Forest as a result of competition for scarce natural resources brought on by the negative effects of climate change, population development, and forest degradation. According to UNEP, (2016), gaps in the legal and institutional framework have caused inadequate coordination in the lead agencies, which has exacerbated conflicting roles. The failure of the region's inadequate institutional framework to implement existing laws and regulations, such as the Forest Act of 2016 (which forbids people from residing inside the forest) and the Charcoal Rules of 2009 (for sustainable charcoal production), is another factor contributing to the degradation of the region's forests. Unsustainable initiatives are also a result of inadequate or nonexistent methods for enhancing community ownership of projects. Weak relationships and connections between the parties responsible for planning and carrying out programs in the forest result in needless overlap and duplication of conservation efforts (NEMA, 2012).

5.3 Forest Cover Changes

Normalized difference vegetation index (NDVI indicates a plant’s health based on how a plant reflects different light waves (Nouri *et al.*, 2017). The higher the NDVI values, the healthier the vegetation is. Low values indicate degeneration in the health and vigour of the vegetation (Reddy, 2006). The results of the NDVI used to complement the cover classification exercise in this study revealed a general degradation in plant health in Londiani Forest over time. The similar observations were made by Kinyajui, (2011) in a study done in the Mau Forest Complex which revealed a drop in NDVI values over the years indicating degeneration status of the forest due to human encroachment among other factors leading to deforestation. The findings of the present study in Londiani Forest showed NDVI percentage (%) values under natural forest as 40% recorded in the year 2000, this value rose to 70% in 2010 but a slight decrease of 20% was observed in 2020. Plantation forest recorded 20% in the year 2000, 50% in 2010 and a drop in 2020 to 40% NDVI percentage (%) cover area. These results show that, over time between the year 2000 and 2020, the general vegetative cover and the greenness of the forest decreased as trees became less healthy (less chlorophyll content) and less dense (Lamb *et al.,* 2005). Farming and illegal logging were the main cause of deforestation in Londiani Forest similar observations were recorded by (Kinyajui, 2011).

These alterations could also be linked to an increase in human economic activities, which resulted in more forest land being cleared for agriculture, settlement, and even clearing for the purpose of obtaining wood for building, among other things. Similar observations and views were shared by Marney and Anglaaere, (2014). These processes continued adding to the increase in areas under non vegetated cover. The slight increase in the area under forest recorded in the year 2010 is most probably a result of efforts put in forest regeneration and successful law and policy regulations in the country over the past decade (KFS, 2018).

Land use and land cover change (LULCC) over time have been regarded as a primary source of global environmental change such as global climate change, green-house gas emissions, biodiversity loss and loss of soil resources, same ideas have been shared by Abebe *et al.,* (2022) This study shows that the forest cover compared to other LULC types is shrinking with time and the reason is hugely associated with change of forest land into agricultural and settlement farms due to high human population that keep rising over the years. More and more land is needed for residential purposes and to put under farming so as to produce enough food to feed the growing population. This concurs with Meyfroidt *et al.,* (2011) who found out that population growth, urbanization, expansion of agricultural land and land scarcity are among the many drivers of LULCC in the world. Considering the huge human population, Maina *et al.,* (2020) claim that LULCC reacts to influences like political, cultural, socioeconomic, demographic, and environmental concerns. Kenya has about 20% arable land and approximately 75% of the population engages in agriculture therefore the current increase in population may strain the arable land further, and this will accelerate changes in environmental and ecosystem processes in the country (Maina *et al.,* 2020).

This study showed that there was a very small percentage increase of forest cover over the study period. In the year 2000 the area under natural forest recorded 24%, coverage of the study area, in the year 2010 it recorded 25% and final year of study 2020 it recorded 20% dropped from the previous years. Plantation forest recorded 23% in 2000, 45% in 2010 then dropped to 35% in 2020. A similar trend was recorded by GoK, (2016) report in a study done on Kenyan LULCC between the years 1990 and 2010 which indicated a decrease in forest cover from 7.9% to 5.9% equating to a loss of 1.8 million hectares. The main causes of forest cover loss in

Londiani area is poor management by the stakeholders due to poor policies regulation and enforcements, over-exploitation of forest ecosystem services, illegal logging, human settlement and agricultural expansion in formerly forested areas. Same ideas were put forward by Muhati *et al.*, (2018) in a study in Marsabit Forest Reserve. Unsustainable grass harvesting, unsupervised livestock grazing in the forest, illegal logging of both native and exotic species planted for timber, charcoal production, forest encroachment for crop cultivation and settlement, forest fires, and poor solid and liquid waste management in the forest margins bordering urban areas, as it was observed in the Londiani forest block, are all major contributors to the ongoing decline of Londiani Forest.

The findings of this study are in line with those of Ongugo *et al.*, (2014) who noted that the driving forces of deforestation were lack of income among the forest adjacent communities, population pressure, high demands for charcoal, fire wood, pasture areas putting pressure on land and in turn forces communities to undertake unplanned land use practices. As the population grows, demand for agricultural land increases as a result, unplanned land use changes occur and this becomes a major contributor to LULCC that has brought in further land fragmentation and degradation sentiments also shared by Allen *et al.*, (2014). Uncontrolled infrastructure development, uncontrolled land sub-division, mining, charcoal making, over extraction of fire wood and poor land tenure practices are all anthropogenic causes of LULCC in the study area (KFS, 2018). High population growth according to KFS, (2018) puts a lot of pressure on the small arable land, forcing people to turn to protected forested areas for agricultural production and this causes degradation and encroachment that impacts negatively on sustainable natural resource management.

Adjacent to Londiani forest there are urban settlements coming up rapidly leading to impacts of urbanization on the forest (KFS, 2018). This directly leads to change in land cover as the forest is cleared to give way for buildings, tarmac roads and other infrastructure (Kagombe, 2014). Also the problem of solid and liquid waste disposal as the forest becomes the dumping site and these results in pollution of the forest endangering both the wild animals living in the forest and the domestic ones grazing there as well (KFS, 2018). Solid wastes also affect the aesthetic value of the forest as was witnessed in Londiani block. On the other hand urbanization has created an exponential increase in the demands and markets for forest products and services same observation was recorded by Mutiso *et al.,* (2011). This demand can positively impact forest health by providing markets for forest products like fuel wood, charcoal, timber and poles for construction, services like water and carbon sequestration on a sustainable basis but if not controlled, urbanization could negatively impact the forest as it raises the demands for land and forest products beyond its capability leading to degradation and fragmentation of forest land same views shared by Cheboiwo *et al.,* (2015).

Loss of forest cover has far reaching changes on water flows leading to drying up of rivers and hence shrinking of lakes. Forest loss also exacerbates the effects of climate change as indicated by IPCC, 2021. In the study area loss of forest cover has led to water loss, aggravated soil erosion, biodiversity loss, climate induced drought, siltation and flooding of river banks and lakes, habitat loss and all these directly impacts on the social and economic status of the Londiani forest adjacent communities. Moinde *et al*., (2007) noted that deforestation made permanent rivers to dry up completely lowering availability of water for various users and impair biological resources sustainability. Further destruction of Londiani Forest will lead to plant diversity loss in the forest, environmental functions impairment and loss of ecosystem services which support livelihoods in the surrounding area; a fact shared by Blackett (1994). According to Ongugo *et al.,* (2014), sustaining livelihoods of communities and entire country's economy will be affected if continued deforestation leading to an ultimate depletion of forest cover is not halted endangering ecosystem services provision and loss forest products vital for economy.

Even though lots of forest cover depletion was witnessed in the study area, there was some small percentage of forest gains between the years 2000 and 2020. This is could be attributed to reforestation success in the region done mainly through the modern shamba system PELIS program which seems to be the best method to involve the community in forest resource management (KFS, 2018). Increase in forest cover in Londiani region is also a clear indication of the success of forest policies and legislation in the area. A lot of policies and Acts to protect the forest and the environment as a whole in Kenya led to positive gains in forest cover (MENR, 2012). The policy instruments implementation led to increased tree planting and reforestation as well as restricting communities from forest encroachment. In the study area, the reintroduction of shamba system currently known as PELIS program has really boosted reforestation activities because the communities are fully involved in harvesting matured trees and are given a chance to participate in re-introducing tree seedlings in the place where they had been harvested as they plant food crops alongside the tree seedlings (KFS, 2018). Even though the Landsat images indicates a positive increase of about 5% in Londiani Forest cover, further studies should be conducted on ground to ascertain if the same is true because the increase could also be attributed to invasive species which sprout up after the forest experienced a disturbance. Mutiso *et al.,* (2011) in a study on Mau forest which Londiani Forest is a part of noted that there was a massive growth of an invasive species *T.ellipticus* which grew after the forest went through a huge disturbance mainly illegal logging, over production of charcoal and wood fuel, forest encroachment for agricultural production and uncontrolled overgrazing in the forest.

Deforestation is a large contributor of global warming and climate change because trees are carbon sinks. In the recent past, warmer temperatures have been experienced changing weather patterns and the usual balance of nature disrupted (Marengo *et al.,* 2013) posing many risks to all forms of life on Earth and humans too. Hotter days and huge heat waves are being felt in almost all land areas year 2020 reported as the hottest years on record (IPCC, 2021). Changes in temperature cause directly leads to changes in rainfall patterns (Marengo *et al*., 2013) and this either leads to severe drought or frequent storms resulting in homes destruction, loss of lives and impacts negatively on the economy as billions of pounds are lost due to landslides and severe flooding. Water is becoming scarcer in more regions. Many people at the moment are facing starvation and the threat of water scarcity on a regular basis (Chou *et al.*, 2014) in many regions in the world; deserts are expanding due to extended droughts shrinking land for food growing.

United States residents are currently facing the climate change consequences ranging from wildfires and heat waves to coastal storms and flooding (IPCC, 2021). In Kenya climate change impacts are increasingly affecting the environment and the citizen's lives. Frequent extreme weather events like storms, floods and droughts lasting longer than usual are now regularly felt in Kenya (MENR, 2012). There is evidence of diminished livelihoods, reduced livestock and crop production, loss of human lives and damaged infrastructure as a result of extreme weather events occasioned by climate change. Kenya had catastrophic flooding and torrential rain from March to May of 2018 as an example of the negative effects. Communities that were already battling to recover from a protracted drought were devastated.

5.4 Role of Forest Adjacent Community influencing Vegetation Dynamics

5.4.1 Gender composition of the respondents

The research aimed at collecting opinions from both genders however the findings show that the male were more than the female same observations were recorded by Jean, (2001) in a study on communities and forests in Western Europe. According to the area chief of Kedowa village in an interview, the male in this region are considered the household heads and this is the reason why they have a larger percentage. The culture of the study area is accommodative allowing women to participate in development projects like forest conservation activities (KFS, 2018). It was evident that women benefit a lot from the forest resources and services like firewood for cooking and lighting, some of the women were observed carrying firewood to the markets for sale making it an important income generating activity to them in addition to this the women were seen cutting grass from the forest to feed their livestock at home, some collecting vegetables and fruits from the forest, medicinal plants in the indigenous part of the forest and these benefits from the forests make them the sole bearers of forest conservation and so their opinion matters a lot and should be taken into consideration, for this reason the women have been compelled to join Londiani CFA thus reducing gender parity in CFA membership a fact that resonates with a study done by Agevi *et al*., (2014). The authors define participatory forest management (PFM) as a set of processes and procedures that enable those with a direct stake in forest resources to participate in decision-making on all facets of forest management, including the process of formulating policy. This study considers the women as stakeholders in forest resources and so qualifies to participate in PFM activities in Londiani forest region.

5.4.2 Age Distribution of the Respondents

The researcher noted that respondents above 40 years old were more than respondents below 30 years old in all the three villages targeted. This assertion depicted that middle aged/older people were more willing and ready to participate in any forest conservation activities and environment protection in general unlike the youth who may have other commitments like learning, seeking for employment in urban areas or working away from the rural areas. These findings agree with those of (Maraga *et al,* 2010). The authors established that elder people were more willing and readily available for forest conservation more than the youth in a study done on Kimothon forest. The Forester at Londiani forest station echoed the same sentiments during an interview, According to him, older people have families/people depending on them for upkeep and this forces them to rely on the forest for resources to provide for their family's needs and upkeep like fuel wood which is a major source of energy for cooking and lighting in the area, grazing their livestock in the forest, timber and poles for construction needs, charcoal production among other resources from the forest contrary to the findings of Persha *et al.,* (2016) where most conservation initiatives are done by young people aged between 18-35 years according to her findings. Empirical studies done related to this show different results in respect to age being a factor influencing forest conservation for instance; a study done by Richards *et al.,* (2000) revealed that age had no influence at all in participation in forest conservation activities. However, studies done for instance by Smith, (2010) indicates that age was a major factor influencing forest conservation and environment protection in general. He established that the youth are more involved in caring for the environment more than the older generation. This is contrary to this study where elder people are involved more in forest conservation than the youth.

5.4.3 Level of Education of the respondents

The youth with tertiary level of education were away from home either working or some still learning these sentiments were shared by KFS manager at Londiani Forest station. He also said that education has played a major role in forest conservation awareness among the community members making them more willing to be involved in forest conservation. From observation, there was no relationship between education level and access to the forest resources same sentiments were shared by (Jean, 2001). All forest adjacent community members had equal opportunity to access forest resources and services a fact confirmed by the three area chiefs during interview schedules. The researcher found out through observation that there was a difference though when it comes to interests on what forest resources each age set get from the forest, same findings were reported by (Maraga *et al.,* 2010). Older people are more interested in economic related products from the forest like food, fruits, vegetables, charcoal, fuel wood, construction materials and grazing of their livestock while the youth may have different prevalence like aesthetic value of the forest. More than 50 youth mainly male were observed playing soccer in the forest. All the three forest blocks had several football pitch fields, about 30 children were seen swimming in the rivers as observed in Kedowa block, and a few were observed participating in mountain climbing at Mt. Blackett found in Kedowa forest block, other activities done by the youth every once in a while in the forest are like bird watching, hiking, camping, and educational research. So all the community members have equal opportunities to access forest resources irrespective of their level of education, this is an aspect that resonates with the study done by Tacconi, (2007). The author indicates that there were no relationship between education level and access to forest resources.

This study also deduced that education level raises environmental awareness among individuals making them more willing to participate in forest conservation. “It’s easier to teach literate people things like silvicultural and forestry practices than illiterate ones” said the forester at Londiani. According to him education level plays a key role in environmental awareness and helps in environmental advocacy contrary to the research findings of Maraga *et al.,* (2010) that affirmed that, education level does not influence community awareness on forest conservation. The findings in this study depicts that education tends to increase ones awareness and encourages one to willingly participate in environmental protection activities in this case, forest conservation.

5.4.4 Main Sources of income

Farming is no longer the major source of income in this region because land is becoming smaller as the population grows said a senior manager at KEFRI research centre in Londiani forest during an interview. Many people have diverted to self-employment activities like entrepreneurial, while some few, who still own a relatively large land do mixed cropping and livestock keeping, crops grown in this area are; vegetables like kales, cabbages, spinach, indigenous vegetables like (saga, sujaa, dodo, nderema among others) tomatoes, potatoes. Cereals like maize which is the staple food in the region planted relatively in a large scale compared to other crops, others cereals include beans, peas, sorghum and millet. Livestock kept in the area are mainly cattle both for milk and meat production, sheep, goats and donkeys. Chicken farming is also a key economic activity in the region, the hens are kept for meat and eggs production both for subsistence use and a larger portion is for sale at the local markets. A number of community members are involved in business like retailing industry, hawking, transport industry (bodaboda) among others. A very small percentage of the population are employed either by the government like teachers and civil workers. Knowing the occupation of the forest adjacent communities was key to this research because it helps the researcher know how dependent the community is on the forest a fact that resonates with a study done by Jepkosgei, (2018). According to her findings, it is very important to assess the occupation of the respondents in order to gauge how dependent they are on the forest, and if they had alternative sources of livelihood.

5.4.5 Average monthly income of the respondents

The researcher noted that the community is not so well off but still struggling to grow economically. It was observed that the standard living conditions of the respondents was still very low. Some members of the community earn below KES 1,000 per month which is relatively very low and this could be an indicator of high poverty levels among the members of the community. Lack of employment has forced the youth to involve themselves in illegal logging to make timber and wood for sale to earn an income as alluded to by the area chief Kedowa same sentiments shared by KFS, (2018). This has impacted the forest resulting in high deforestation rates as was observed in Kedowa forest block. Poverty among the forest adjacent communities has forced them to rely on the forest both for livelihood and to generate income (Cheboiwo *et al.,* 2015). This study shows that charcoal burning and fuel wood production were the leading income generating activities in the region. This has reduced the size of forest especially the indigenous part threatening extinction of some tree species and affecting the entire ecosystem based on these indigenous forests. As was mentioned earlier in the literature review, poverty and forest are interlinked in a very dangerous web that may lead to great damage to the forest if not kept under check, but on the other hand according to Macharia, (2015), this provides an opportunity to encourage people especially those within poor living conditions to participate in forest management activities. Persha *et al.*, (2011) came to the conclusion that locals will only be motivated to change their land use patterns and devote their resources to investing time and effort in forest conservation initiatives if they are aware of how the products and services provided by the forests benefit them.

This study found out that there is a great opportunity in Londiani region to mobilize the youth to engage in forest conservation activities and benefit from the same instead of indulging themselves in illegal logging a fact that resonates with Macharia, (2015) who found out that the community members were satisfied with income generating activities carried out by the Community Based Organizations (CBO) that enables them get an income to sustain their families. The benefits accruing from the project was shared as per each member's contribution to the CBOs activities. The same idea can be adopted in Londiani forest to encourage forest conservation and improve the members' livelihoods.

5.4.6 Average size of land in acres

The researcher observed land fragmentation in the area due to the rising population a fact that was confirmed by the respondents when asked how big their land was in acres. Most residents are farmers making the size of land a key economic factor (KFS, 2018). High population however has led to land fragmentation forcing people to turn into forest for more land to put under cultivation as alluded to by Chebewor village area chief during a focus group discussion. Shamba system through PELIS Programme has assisted many people in Londiani where the government after harvesting mature trees allocates farmers portions of the forest to put under cultivation as they take care of seedlings planted to replace those cut said PELIS chairperson Londiani Forest Station during an interview. His sentiments agrees with the findings of a study done by Gichuru, (2015) on Mucheene Forest that proved that PELIS Programme has played a key role in improving the livelihood of forest adjacent communities and at the same time increasing the forest cover gradually over the years since its introduction. There was ongoing shamba system activities observed in Kedowa block crops like vegetables, peas, beans, maize, millet, sorghum, tomatoes, potatoes, fodder crops and carrots were observed grown alongside trees seedlings.

5.4.7 Importance of Londiani Forest to the Forest adjacent community

The Londiani forest adjacent communities depend on the forest for resources and services. This study showed that many plants in Londiani Forest are important to the households next to the forest both for timber and also non-timber forest services. The results of this study are consistent with those of Pandey *et al*., (2016) who claimed that forests provide for many rural and urban households, mostly in developing nations, in terms of their needs for food, energy for cooking and lighting, and building materials. This study established that different user groups that are active in CFA in Londiani area engage in different activities within and even outside the forests. Generally, timber harvesting, bee keeping, livestock grazing, tree planting and modern shamba system are the leading activities carried out inside the forest. Timber harvesting in the region is mainly done by saw milling factories in a large scale like Kioo Saw millers in Kedowa block and Tim sales millers in Londiani block based at Molo town, poles harvesting, charcoal burning, grass cutting, farming through PELIS, tree nurseries, fuel wood collection and small mining activities like rock extraction done mainly in Kedowa block. Wood from this forest is used majorly for the production of timber, firewood, building and electrical power poles and telephone poles (KFS, 2018). Forest also plays a major role in soil erosion control as it provides the necessary soil cover. This study confirms that Londiani Forest is of much significance to the community as they obtain many products from it such as; grazing for their animals, food/ fruits under shamba system, education purposes and also medicine. The study found out that the water used by the community for domestic and livestock use comes from Londiani forest.

Londiani Forest plays a major role in livestock keeping and to the economy of the residents as it forms the largest percentage of animal feed in form of direct forest grazing of livestock, same sentiments shared by Mutiso *et al.,* (2011) or planting of fodder crops in the forest under the shamba system and sometimes grass cutting then carry to feed the animals at home especially the young and sick ones. The researcher observed different types of livestock (cattle, sheep, goats, and donkeys), grazing in all the three forest blocks. The livestock were grazing with no supervision by the herdsmen as observed by the researcher in all the three forest blocks, this can be dangerous because the animals can damage the tree seedlings and saplings (KFS, 2018) and may at times debark the trees making it easier for pest and diseases to attack the trees and sometimes the trees dry off and die. Some trees also can be uprooted by livestock as they feed unattended to.

This study's findings are in line with those of the Kenya Institute of Public Policy Research and Analysis (KIPPRA, 2010), which found that a significant portion of the population roughly 70% of consumers use biomass as a source of energy for cooking and lighting, compared to 30% who use fuels like liquid petroleum gas (LPG), biogas, and electricity. This shows how important Londiani Forest is to the community and must be conserved by all means so that it can continue providing the same services to the community. Fuel wood production is becoming an issue in the area as the population increases posing a real threat to the forest as alluded to by the CFA chairperson Londiani Forest in a focus group discussion. Currently deforestation rate is so high in Londiani region which has led to the current alarming rate of forests diminishing (KFS, 2018). According to him, immature trees are fallen down for fuel wood and charcoal production in a large scale. Illegal logging heightens the problem especially in Kedowa block. Reforestation practices are the key aspects to return the forest to its glory or something close to it, these were the sentiments shared by those attending the focus group discussion. The researcher had a brief chance to talk with the woman carrying fuel wood and she said that she was headed to Londiani junction town where she was going to sell the fuel wood to hotel owners at KES 100 per trip. She does 5 trips per day so she can get enough money to feed her children and take care of other household needs. Many women do the same a fact confirmed by the area chief of Chebewor Village and this is a toll in the forest worsening the already existing high rates of deforestation in the area.

5.4.8 Threats facing Londiani Forest

Londiani Forest is decreasing according to the forest adjacent communities who answered in a large percentage yes the forest is decreasing when asked whether the forest cover was increasing or decreasing over the time they have lived in the area. Their responses concur with those of Mutiso *et al.*, (2013) who reported that forests are constantly shrinking as time goes by due to human disturbances. Those that said the forest cover had decreased mentioned a number of factors that have led to the decrease as follows, timber harvesting on a large scale by saw milling factories like (Kioo saw millers based at Kedowa block, and Tim sales millers based at Molo next to Londiani block) were the largest contributor of forest cover decrease as sited to by the respondents, these saw millers are issued with permits without minimum regulations and so they cut trees beyond sustainable limits. Tea manufacturing factories like Kuresoi Tea Factory were the second large scale consumers because they cut trees in a large scale then dry them to make fuel to drive their furnaces. The researcher visited this factory and witnessed three tractors delivering logs of wood from the Kedowa Forest block, several trips. This was later confirmed by the manager in an interview that they harvest matured trees to split them to make fuel wood needed to dry tea. One tractor carries 5 tonnes per trip and each tractor makes at least 5 trips per day. To compensate for the same the manager confirmed with photos from the factory archives that they are actively involved in reforestation activities.

Another factor leading to deforestation is illegal logging (KFS, 2018) especially in Kedowa block where unemployed youth cut trees and carry them out of the forest to make timber using power saw machines then later sell them at the local market and use the money to indulge in drug abuse. This was a major problem in the village as alluded to by Kedowa area chief, he mentioned an increase in crimes level in the village reason being the youth who are now engaging in drug abuse and illegal activities in an increasing number (Jepkosgei, 2018). Other factors reducing forest cover as mentioned by the villagers are charcoal and fuel wood production, unregulated permit issuance, less supervision of the forest by the forest rangers, minimum or no punishment to the law breakers encouraging deforestation. The few that thought the forest was increasing said that the main contributor to forest cover increase was reforestation efforts mobilized by the CFA members in the area a fact that resonates with findings by Ongugo *et al.,* (2014), the author established that

Forest Associations is a way of decentralizing the forest resources management and contribute to sustainable utilization of forests products and services in rest of the world especially Kenya.

Deforestation is a major threat facing Londiani Forest according to the forester at Londiani station. The high rates of deforestation have left Londiani forests bare (KFS, 2018). The forests margins are moving further and further away. Indigenous trees face a lot of this challenge as it is the main target by the population due to the notion that it has the best firewood and makes the best charcoal quality, sentiments shared by all three area chiefs. Deforestation has adverse environmental impacts that have led to economic impacts in the region (Macharia, 2015). The main problem is soil erosion as was observed by the researcher which carries away the fertile soil mostly needed by the residents who are farmers. Efforts to restore the forests by reforestation are still low and face a lot of challenges due to poor coordination, and less capital and support by the donor according to the forester at Londiani station.

Apart from deforestation, there are other threats facing Londiani Forest listed by the respondents as natural and human caused disturbances. Under natural causes of forest loss the community listed pests and diseases attacks, wild animals such as monkeys debark trees, forest fires and human/wildlife conflicts same views shared by Sapkota *et al.,* (2010). On the other hand anthropogenic threats include: overgrazing, forest fires, illegal charcoal burning, solid waste dumping in the forest, illegal removal of forest products (posts, logs, etc.) and livestock trampling on the young trees damaging them. Possible causes of these human impacts on the forest cover could be extreme poverty and lack of employment amongst the forest adjacent communities that has made them turn to the forest for their livelihood, uncaring attitude and in a few cases the use of fire while harvesting honey (KFS, 2018). People de-bark trees for medicinal purposes and also to speed up their drying up so they can cut them down for fuel wood production both for sale to earn a living and also subsistence use. The findings also show that people use the forest as solid waste dumping site which affects the aesthetic value of the forest. It also leads to pollution in the forest in case of chemical or oil spillage which could lead to dying of trees and pose a danger to the livestock grazing in the forest too. This problem is huge in the Londiani Forest block because the forest is close to Londiani town and residential areas.

Londiani Forest adjacent communities proposed some possible achievable mitigation measures and solutions to forest loss as follows; raising awareness on the importance of the forest and forest conservation among the villagers, increase forests patrols and arrests of forest related law breakers. Government through KFS should employ more personnel to help in forest protection like forest rangers to help in constant patrols and forest surveys of its boundaries to control encroachment. Forest roads should be repaired and infrastructure improved like vehicles for patrols. Adequate funding of KFS, rangers and community scouts should be rewarded for their efforts to encourage more people to be involved in forest conservation.

5.4.9 Involvement of the forest adjacent community in Londiani Forest conservation

Forest Associations formation as a way of decentralizing forest resources management according to Agevi *et al*., (2014) should be encouraged and according to Ongugo *et al*., (2014), doing this will result in sustainable utilization and management of forests resources. In Londiani area for example, there is a CFA called Londiani Community Forest Association (LOCOFA) that is very active in forest management.

This study found out that a lot of the respondents are members to either one or two user groups under CFA membership in the region. Both male and female are involved in CFA membership. Most residents are actively involved in reforestation practices as shown by their willingness to participate in any reforestation activities organized by their forest conservation groups as shown by the total number of trees ever planted by individual on government forest for reforestation purposes. Apart from trees planted on government forests, the community members have also planted some trees on their farms mainly for fuel wood production but the small size of land has posed a great challenge to agroforestry (KFS, 2018). They prefer to plant food crops to feed their families instead of trees the few trees planted are mainly for subsistence fuel wood purposes. Examples of tree species planted by farmers are Cyprus (*Cupressus lusitanica*), Forest Damboya (*Damboya goetzenii*), Grevillea (*Grevillea robusta*), Pinus (*Pinus patula*), African Olive (*Olea africana*) few farmers had plots of trees mainly eucalyptus (*Eucalyptus globulus*) for poles for sale.

This study showed that most of the residents obtain seedlings from the local markets and on-farm nurseries, this reveals the laxity in the KFS office whose main role is to supply farmers with tree seedlings and any other necessary support (KFS, 2018) but as the results show, they are coming after the on-farm nursery which is wrong. This was one of the challenges raised by the community in their forest conservation activities. The community has established an integrated tree nursery with hundreds of different tree species seedlings both exotic and indigenous trees species, flowers, fruits among others. Even though they are doing a good job in tree seedlings production they face a lot of challenges as gathered by the researcher during an interview with the chairperson. According to him, the major challenges they face are lack of tools and equipment like wheelbarrows, rakes and hoes, no vehicle for delivery services, scarcity of water during dry seasons so they need a storage water tank, poor prices of the seedlings and very low market among others.

Kenya enacted the Forest Conservation and Management Act 2016 alongside other subsidiary legislations that encourage forest management aimed at attaining sustainable forest resource and services utilization and management. In Londiani region, the local residents through Londiani Community Forest Association (LOCOFA) are actively engaging in Londiani Forest management activities organized by forest agents, stakeholders and institutions.

CHAPTER SIX

CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

6.1 Introduction

This chapter provides a conclusion of major findings on tree stand structure, species composition and vegetation cover changes in Londiani Forest. It further highlights recommendations to be implemented and suggestion for further research in gaps identified and considered important by the researcher during the study.

6.2 Conclusions

Based on this study, the following conclusions were made;

- Physical observation showed low floristic composition in Londiani Forest both at mature stage, seedlings and saplings stages, an indication of poor establishment and recruitment as a result of ongoing anthropogenic disturbances in the forest.
- NDVI analysis revealed decreasing health and vigour of the forest over the study period with a small rise in NDVI values recorded in the final year of study 2020. Change detection process showed a continuous forest cover loss from the year 2000 to 2015, thereafter a small gain of forest cover between 2005 and 2010 was recorded. Population pressure and anthropogenic factors linked to lax implementation of relevant forest laws, policies, and regulations were shown to be the main causes of forest cover decrease in the research area.
- Community Forest Associations (CFAs) in Londiani area are actively involved in reforestation practices and general management of Londiani Forest but not to their full capacity because their efforts are limited to forest protection only. They should be encouraged to learn and participate in other silvicultural activities as

well. The government should provide incentives that are directly beneficial to communities and also do value addition to forest products to strengthen the CFAs ensuring their full participation in Londiani Forest management.

6.3 Recommendations

Based on the findings of this study, the following recommendations can be made;

- Kenya Forest Service in Londiani area should encourage further research to be done on the aggressive invasive species in Londiani Forest and sustainable ways to control its growth and widespread in the forest.
- Further research should be conducted to investigate the impacts of forest cover change on socio-economic wellbeing of the forest neighboring communities both in Londiani Forest and other forests as well in the country.
- Further research should be done on the anthropogenic disturbances like charcoal production, illegal logging and tree poaching by suggesting other sustainable ways to generate income amongst the youth in Londiani area that were identified as the biggest culprits in illegal logging and charcoal burning in the area.

6.4 Achievable mitigation measures focused on Londiani Forest conservation

- Anthropogenic activities in the forest should be minimized to levels which can allow for regeneration/recovery of disturbed areas and improvement of floristic composition and diversity.
- Forest cover loss has been observed gradually over time. To minimize this, forest managers should increase patrols and enforcement of forest protection and conservation laws, policies and regulation.
- Involvement of the CFAs should be strengthened further, for example, they should also be engaged in other income generating activities to reduce the

pressure on forest resources like, modern methods of commercial livestock keeping/ bee keeping, agriculture/horticulture, cultivation of fodder crops, and medicinal plants.

- Improvement in infrastructure including good roads, well-equipped health centers, schools, and other utilities as well as public education as part of incentives to help in conservation of the forest and its resources.

REFERENCES

Abebe, G., Getachew, D and Ewunetu, A. (2022). Analyzing Land Use Land Cover Changes and its Dynamics using Remote Sensing and GIS in Gubalafito District, Northeastern Ethiopia. *Journal of Environmental and Public Health*. Vol 4, pp 30-41.

Agevi, H., Wabusya, M., and Tsingalia, HM. (2014). Community Forest Associations and Community-Based Organizations: Redesigning their Roles in Forest Management and Conservation in Kenya. *International Journal of Science and Research* Vol 3 pp 358. ISSN (Online): 2319-7064.

Akande, A., Ahmad, Y., Shuaib, B and Jeje, A. (2019). Distribution and Relative Density of Trees Species in Kainji Lake National Park, Nigeria. *World News of Natural Sciences*. Vol 22, pp 52-61.

Ali, A., Jamil, M and Naveed, N. (2019). Forest stand structure and functioning: Current knowledge and future challenges, Ecological Indicators, *Elsevier*. Volume 98, Fresenius Environmental Bulletin. Pages 665-677, ISSN 1470-160X, https://doi.org/10.1016/j.ecolind.2018.11.017.

Allen Craig D., David D. Breshears and Nate G. McDowell. (2014). On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. Ecosphere Journal. Vol 6 pp 8-12.

Arun, K., Brian, D., Suzanne, B., Marilou, B and Alain, L. (2013). Constraints to Partial Cutting in the Boreal Forest of Canada in the Context of Natural Disturbance-based Management. *An International Journal of Forest Research*, Vol 87, pp 11–28.

Atela, Joanes. (2013). Governing REDD+ Governing REDD+: global framings versus practical evidence from the Kasigau Corridor REDD+ Project, Kenya. STEPS CENTRE. Working Paper No 55.

Baldyga Tracy J., Scott N. Miller, Kenneth L. Driese & Charles Maina Gichaba. (2007). Assessing land cover change in Kenya's Mau Forest region using remotely sensed data. African Journal of Ecology. Vol 46 pp 46-54

Blackett, H.L. (1994). Forest Inventory Reports for Kenya's Indigenous Forests. KIFCON Report, Nairobi.

Bolognesi, M., Vrieling, A., Rembold, F and Gadain, H. (2015). Rapid Mapping and Impact Estimation of Illegal Charcoal Production in Southern Somalia based on Worldview-1 Imagery. *Energy for sustainable Development*. Vol 25 pp 40-49.

Bonan, G.B. (2008). Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests. *Science* Vol 320 pp 1444 - 1449.

Butler, Brett and Larry, Majumdar, Indrajit and Teeter. (2008). Characterizing Family Forest Owners: A Cluster Analysis Approach. *Forest Science.* Vol 54 pp 176-184.

Cheboiwo, K., Joshua, M., Robert, O., Mbinga, J., and Festus, M. (2015). Potential Growth, Yields and Socioeconomic benefits of Four Indigenous Species for Restoration in Moist Forest, Mau Kenya. *Journal of Environment and Earth Science*. Vol 5, pp 6-15.

Cheboiwo, K., Mutua, J., Kiprob, D., and Gattama, S. (2016). Public Private Partnerships Opportunities for Forestry Sector Development in Kenya: Synthesis of Primary and Secondary Production Actors, Trade. *Journal of Environment and Earth Science*. Vol. 8. No.1, ISSN 2224-3216.

Chou, S.N., Lyra, A., Mourão, C. and Dereczynski. (2014). Assessment of Climate Change over South America under RCP 4.5 and 8.5 Downscaling Scenarios. *American Journal of Climate Change*. 03. 512-527. 10.4236/ajcc.2014.35043.

Cohen, J.W., Asim, B., Nilam, K., Michael J.F and Michael A.W. (1995). Forest Monitoring Using Landsat Time Series Data: A Review, *Canadian Journal of Remote Sensing*, 40:5, 362-384, DOI: 10.1080/07038992.2014.987376

Culas Richard J. (2007). Deforestation and the Environmental Kuznets Curve: An Institutional Perspective. Ecological Economics, https://doi.org/10.1016/j.ecolecon.

Dankova, L. and Saniga, M. (2013). Canopy gaps and tree regeneration patterns in multi-species unmanaged natural forest Sitno ID:128895683 https://api.semanticscholar.org/Corpus. Accessed on 21st November 2023.

Dinerstein, E.O., David, J., Anup,V., Carly and Burgess, N. (2017). An Ecoregion-Based Approach to Protecting Half the Terrestrial Realm. BioScience. 1. 1-12. 10.1093/biosci/bix014.

Dong, J., Dafang, Z., Xinliang, X., and Lei, Y. (2010). Integrated Evaluation of Urban Development Suitability Based on Remote Sensing and GIS Techniques*;* Beijing Vol *Sensors* 8, pp 59-75.

Emery, S. (2012). *Succession: A closer look.* Nature Education Knowledge. Vol 3 pp 10-45.

FAO, WFP and IFAD. (2012). The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome, FAO.

Gichuru, I. (2015). An Evaluation of Factors Contributing to the Success of PELIS Strategy in Forest Plantation Establishment in Mucheene Forest.

International Journal of Social Sciences and Project Planning Management Volume 1, Issue 3, pp. 15-43.

Global Forest Report. (2022). The Forest Transition: From Risk to Resilience. Disclosure Insight Action. https://www.cdp.net/en/research/global-reports/global-forests-report-2022. Accessed on 21st November 2023.

GoK. (2000). District development Plan Kericho. Kericho County. www. kericho.go.ke. Accessed on 20th September 2021.

GoK. (2009). District development Plan Kericho. Kericho County. www. kericho.go.ke. Accessed on 20th September 2021.

GoK-NEMA. (2012). Quarterly publications. website: www.nema.go.ke. Accessed on 2nd September 2020.

Habwe, W.B., Njunge, J., Otieno, D., Oyoo-Okoth, E. (2017). Plant species composition, structure and diversity in Nabkoi Forest Reserve (Kenya). *Journal of Forestry*. Vol 4 pp 3-9.

Hancock, P. R. (2004). Book Reviews. *Review of Radical Political Economics, 36*(2), 260–263. https://doi.org/10.1177/0486613404264194.

Hansen, J., M. Sato, and Ruedy, R. (2012). Perception of Climate Change. *Proc. Natl. Acad. Sci.*, 109, 14726-14727, E2415-E2423, doi:10.1073/pnas.1205276109.

Helms, M.M. and Nixon, J. (2010) Exploring SWOT Analysis-Where Are we Now? Journal of Strategy and Management, 3, 215-251. https://doi.org/10.1108/17554251011064837.

Hillstrom, M., Couture, J., Lindroth, R. (2014). Elevated carbon dioxide and ozone have weak, idiosyncratic effects on herbivorous forest insect abundance, species richness, and community composition. Vol 7 pp 10- 21.

Hitimana, J., Kiyiapi, J and Njunge, J. (2004). Forest Structure Characteristics in Disturbed and Undisturbed Sites of Mt Elgon Moist Lower Montane Forest, Western Kenya. *Forest Ecology and Management.* Vol 194, pp 269-291.

Hosonuma, N., Herold, M., Fries, R., Brockhaus, M., VerchoT, L., Angelsen, A., and Romijn, E. (2012). An assessment of Deforestation and Forest Degradation Drivers in Developing Countries, *Environmental Research Letter*, Vol 7 pp 154-166.

IPCC. (2021): *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.

Iverson, L., Dana and Houghton, R. (1995). Aboveground Forest Biomass and the Global Carbon Balance. *Global Change Biology*. Vol 11 pp 945-958.

Jean Renaud. (2001). *Communities and Forest Management in Western Europe*. A Regional Profile of the Working Group on Community Involvement in Forest Management St. George. Switzerland.

Jepkosgei Rebecca. (2018). Influence of Community Dependence on Forest Conservation in Maasai Mau Forest, Kenya https://api.semanticscholar.org/CorpusID:89608402

Jianbang, G., Cerutti, P., Masiero, M., Pettenella, D., Andrighetto, N and Dawson. (2016). *Forests, Logging, Law Enforcement, Policy, Timber Trade Series.* IUFRO World Series no. 35 Vienna, Austria, International Union of Forest Research Organizations.

Kagombe J.K. (2014). *Contribution of PELIS in Increasing Tree Cover and Community Livelihoods*. Nairobi: KEFRI.

Kagombe, J.K. (2023). An Assessment of the Policy and Legislative Frameworks for Commercial Forestry Management in Kenya. *American International Journal of Business Management* (AIJBM) Vol. 6 pp 30-41.

Kairo, J.G., Sigi, L., Kipkorir, Dahdouh-Guebas, F., Bosire, J., and Karachi, M. (2008). Structural development and productivity of replanted mangrove plantations in Kenya. *Forest Ecology and Management*. Vol 10 pp 255. 262.

Keay, R. W. (1959). An Outline of the Nigerian Vegetation. Lagos: Federal Department of Forest Research, Federal Ministry of Information.

Keeling. E.G., Sala, A.D., and Thomas H. (2006). Effects of fire exclusion on forest structure and composition in unlogged ponderosa pine/Douglas-fir forests. *Forest Ecology and Management.* Vol 237 pp 418-428

KEFRI. (2018). National Tree Improvement Strategy 2018-2022, KEFRI Muguga, Kenya.

KFS. (2022). Tree Cover Assessment Report 2021. Kenya News Agency. Information For Development. Counties, Editor’s Pick, Environment Nairobi.

Kenya National Bureau of Statistics (KNBS). (2019) Kenya Population and Housing Census (KPHC). http://www.knbs.or.ke. Accessed on 10th September 2020

Kenya Forest Service. (2018). Londiani Participatory Forest Management Plan 2018-2022. Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Kenya Forest Service. (2012). Forester Magazine: A quarterly magazine of KFS. Issue no.6. Kenya Forest Service; Annual Report 2009/2010

KIPPRA. (2010). Kenya Economic Report 2010 on Enhancing Sectoral Contribution towards Reducing Poverty, Unemployment and Inequality in Kenya. KIPPRA Publications.

Kinyanjui, M. (2011). NDVI Based Vegetation Monitoring in the Mau Forest Complex, Kenya. *African Journal of Ecology*, Vol 3. Issue 49, pp 165-174.

Kinyajui, M., Karachi, M., and Ondimu, N. (2013). Natural Regeneration and Ecological Recovery in Mau Forest Complex Kenya. *African Journal of Ecology*. Vol.3. No. 6 pp 417-422.

Kittur, B., Swamy, S., Bargali, S and Jhariya, M. (2014). Wildland fires and Moist Deciduous Forests of Chhattisgarh, India: Divergent Component Assessment, *Journal of Forest Research* Vol 10 pp 1676-1687.

Krishnamurthy, Y., Prakasha H., Nanda, A., Krishnappa, M., Dattaraja, H and Suresh, H. (2010). Vegetation Structure and Floristic Composition of a Tropical Dry Deciduous Forest in Bhadra Wildlife Sanctuary, Karnataka, *India Tropical Ecology* Vol 51 pp 235-246.

Kuria, N. C., Balozi, K and Kipkore, W. (2019). Growth and Yield Models for Plantation-Grown Cupressus lusitanica for Central Kenya, *African Journal of Education, Science and Technology* Vol 5 pp 34-58.

Lamb, D., Peter D.E., and John A.P. (2005). Restoration of Degraded Tropical Forest Landscapes. *Science* Vol 310 pp 1628- 1634. DOI: 10.1126/Science.1111773.

Laporte J., Wilkie C.O, Davi, Zhang, Brunner, J, Donoghue and Cinde. (2001). Central African forests, carbon and climate change. *Climate Research* Vol 17 pp 229-246. 10.3354/cr017229.

Li, Q., Morimoto, K., Kobayashi, M., Inagaki, H., Katsumata, M.,Hirata, Y and Hirata. (2008). Visiting a Forest, but Not a City, *International journal of immunopathology* Vol 21 pp 117-127.

Lillesand, T., Kiefer, R., and Chipman, J. (2004). Remote Sensing and Image Interpretation (Fifth Edition). 10.2307/634969.

MacDicken, K., Jonsson, Ö., Piña, L., Maulo, S., Contessa, V., Adikari, Y., and D'Annunzio, R. (2016). Global forest resources assessment 2015: how are the world's forests changing? FAO: ISBN: 978-92-5-109283-5.

Macharia, Beth W. (2015). Factors influencing community participation in forestry conservation projects: a case of Kithoka-Twajai forest community based organization, Meru county Kenya. Conference Proceedings

Maina, J., Wandiga, S., Gyampoh, B and Charles. (2020). Assessment of Land Use and Land Cover Change using GIS and Remote Sensing. A case study of Kieni Central Kenya. *Journal of Remote Sensing & GIS*. Vol 9 pp 270-274.

Malingreau HJ, JP. and Stibig. (1995). Forest cover of insular southeast Asia mapped from recent satellite images of coarse spatial resolution. *AMBIO A Journal of the Human Environment.* Vol 32 pp 469-475.

Maraga, J., Kibwage, K., and Oindo B. (2010). Factors Determining Community Participation in Afforestation Projects in River Nyando Basin, Kenya. *African Journal of Environmental Science and Technology.* Vol 4 pp 853-859.

Marengo, J., Borma, L.A., Rodriguez, D., and Wagner, R.P. (2013). Recent Extremes of Drought and Flooding in Amazonia: Vulnerabilities and Human Adaptation, American Journal of Climate Change, Vol 2 pp 2-10.

Marney, I.E and Anglaaere, L.L. (2014). Intraspecific root plasticity in agroforestry systems across edaphic conditions. Agriculture, Ecosystems and Environment. Vol 185 pp 16-23.

Maua, J. O., Tsingalia, H. M., & Cheboiwo, J. (2019). Economic Value of Non-timber Forest Products Utilized by the Households Adjacent to the South Nandi Forest Reserve in Kenya. *East African Agricultural and Forestry Journal*, Vol 4, pp 368-391.

Mayaux, Philippe and Massart, Michel and Vancutsem, Christelle and Cabral, Ana and Nonguierma, A. and Diallo, O. and Pretorius, C. (1999). A land cover map of africa carte de l'occupation du sol de l'afrique.

Meyfroidt, P., Lambin, F. and Tracey, G. (2011). Global Forest Transition: Prospects for an End to Deforestation. *Annual Review of Environment and Resources*. Vol 36, pp 343-371.

Meshesha, T., Tripathi, S., and Khare, D. (2016). Analyses of land use and land cover change dynamics using GIS and remote sensing during 1984 and 2015 in the Beressa Watershed Northern Central Highland of Ethiopia. *Modeling Earth Systems and Environment.* Vol 2 pp 214-222. DOI: 10.1007/s40808-016-0233-4.

Ministry of Environment and Mineral Resources, MENR. (2012). Kenya Wetlands Atlas. Ministry of Environment and Mineral Resources.

Mligo, Cosmas. (2009). Diversity and Distribution Pattern of Riparian Plant Species in the Wami River System, Tanzania, Journal of Plant Ecology, Vol 10, pp 259–270.

Moinde, N., Oguge, N., Karere, G., Otina, D., and Suleiman, M. (2007). Human and Natural Impacts on Forests along Lower Tana river, Kenya: Implications towards conservation and management of endemic primate species and their habitat. *Biodiversity and Conservation*. Vol 16 pp 335-347.

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

Muhati, G., Olago, D., and Olaka, L. (2018). Land use and land cover changes in a sub-humid Montane forest in an arid setting: A case study of the Marsabit forest reserve in northern Kenya. *Global Ecology and Conservation*. Vol 16 pp 512-523.

Mutangah, J., Mwangangi, O., and Mwaura, P. (2014). Mau Forest Complex Vegetation. *Journal of Ecology*. Vol 4 No.10 pp 619-627.

Mutiso, F. (2009). *Applicability of Selected Sampling Designs to Forest Health Assessment: The Case of Kakamega Moist Tropical and Mt Elgon Montane Forests.* M.Phil. Thesis, Department of Forestry and Wood Science, Moi University, Eldoret, Kenya.

Mutiso, F., Hitimana, J., Kiyiapi, J., Sang, F., and Eboh, E. (2013). Recovery of Kakamega Tropical Rainforest from Anthropogenic Disturbances, *Journal of Tropical Forest Science, Forest Research Institute Malaysia.* Vol. 25, pp. 566-576.

Mutiso, F., Mugo, M., and Cheboiwo, J. (2011). Post-disturbance Tree Species Regeneration and Successional Pathways in Blackett and Kedowa forest blocks, Mau ecosystem. *Research Journal of Environmental and Earth Sciences* Vol 3 pp 745-753.

Mutwiri, F., Odera, P., and Kinyanjui, M. (2017). Estimation of Tree Height and Forest Biomass Using Airborne LiDAR Data: A Case Study of Londiani Forest Block in the Mau Complex, Kenya. *Open Journal of Forestry*. Vol 7 pp 255-269.

Mwangi, E and Wardell, A. (2012). Multi-level governance of forest resources Source: *International Journal of the Commons*, Vol. 6, pp. 79-103 https://www.jstor.org/stable/26523097.

Myster, R.W. (2004). Comparing and contrasting flooded and unflooded forests in the Peruvian Amazon. Seed rain. *New Zealand Journal of Forestry Science*. Vol 5 pp 45-67. DOI10.1186/s40490-015-0033-z.

Navarro-Cerrillo, R.M., Rodriguez-Vallejo, C., Silveiro, E., Hortal, A., Palacios-Rodríguez, G., Duque-Lazo, J., Camarero, J.J. (2018). Cumulative Drought Stress Leads to a Loss of Growth Resilience and Explains Higher Mortality in Planted than in Naturally Regenerated *Pinus pinaster* Stands. *Forests* , Vol 9, pp 358-367.

Nouri, H; Anderson, S., Sutton, P., Beecham, S., Nagler, P., Jarchow, C and Roberts, D. (2017*).* NDVI, scale invariance and the modifiable areal unit problem: An assessment of vegetation in the Adelaide Parklands. *Science of the Total Environment.* Vol 8 pp 584-599.

Ochego, H. (2003). Application of Remote Sensing in Deforestation Monitoring: A Case Study of the Aberdares (Kenya).

Olsson, H. (1995). Changes in satellite-measured reflectances caused by thinning cuttings in Boreal forest, Remote Sensing of Environment, *Elsevier.* Vol 50, Issue 3, pp 221-230, ISSN 0034-425.

Omondi F. S. (2018). Early Growth Performance and Survival of Pine Hybrids in Turbo, Kenya. *East African Agricultural and Forestry Journal*. Vol 1 pp 84-96.

Ongugo, P., Langat, D., Oeba, V., Kimondo, J., Owuor, B., Njuguna, J., Okwaro, G and Russell, A. (2014). A review of Kenya's National Policies Relevant to Climate Change Adaptation and Mitigation Insights from Mount Elgon. *Conservation and society*. Vol 10 pp 182-189.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., Anthony, S. (2009). *Agroforestry Database: A tree reference and selection guide version* 4.0. World Agroforestry Centre, Kenya. www.worldagroforestry.org. accessed on 4th May 2021

Owen M.S., Carolyn H.S., Catherine, A.G, and Bowker, M. (1998). Above and below ground responses to tree thinning depend on the treatment of tree debris. *Forest Ecology and Management*. Vol. 259 pp 71-80.

Pandey, L., Mahendra, S., and Jayachandran, U. (2016). Impact of Agricultural interventions on the Nutritional Value Status in South Asia: A review. *Food Policy*. Vol. 62 pp 28-40.

Persha, L., & Agrawal, Arun & Chhatre, Ashwini. (2011). Social and Ecological Synergy: Local Rulemaking, Forest Livelihoods, and Biodiversity Conservation. *Science* (New York, N.Y.). Vol 331 pp 1608-1614.

Porter, G., and Brown J.W. (1991). Global Environmental Politics (London: WestviewPress) Vol 21 pp 1177-1185.

Purnomo, B.O., AdeAyu, D., Ramadhani, A., Kartodihardjo, H., Pacheco, P and Kartika S.J. (2018). Reducing forest and land fires through good palm oil value chain governance: Forest Policy and Economics. Vol 91 pp 94-106.

Reddy, M. (2006). *Textbook of Remote Sensing and Geographical Information Systems*. BS Publications, Hyderabad, India BSP paperback Book publishers. ark:/13960/t6840f76q.

Richards, M., Maksha, M., and Keshav, K. (2000). Economics, Poverty and Transparency: Measuring Equity in Forest user Groups. *Journal of Forest and Livelihood* Vol 3 pp 134-144..

Rosende, T., Gibbs, D., Harris, N and Osipova, E. (2021). *World Heritage Forests. Carbon sinks under pressure* Vol 3 pp 978-1004.

Roswell, M., Dushoff, J., and Winfree, R. (2021). A Conceptual Guide to Measuring Species Diversity. *Oikos, Advancing Ecology*. Vol. 130 pp 321-338.

Runyan, C.W and D'Odorico, P. (2016) *Global Deforestation,* Cambridge University Press, New York. https://doi.org/10.1017/CBO9781316471548.

Sapkota, I., Tigabu, M., and Oden, P. (2010). Changes in Tree Species Diversity and Dominance across Disturbance Gradient in Napelese Sal (Shorea robusta Gaertn. f.) *Journal of Forestry*. Vol 21 pp 25–32.

Schreckenberg, K., Luttrell, C., and Moss, C. (2006). Participatory forest management.

Sedano, F., Silva, JA., Machoco, R., Meque, CH., Sitoe, A., Ribeiro, N., Anderson, K., Ombe, ZA., Baule, SH., and Tucker, CJ. (2016). The impacts of Charcoal Burning Production on Forest Degradation. A case study in Tete, Mozambique. *Environmental letters*; Vol 11 pp 940-952.

Shantz, H.L and Marbut, C.F. (1923). Land classification map of Africa / by vegetation and soils of Africa. American Geographical Society of New York. Research series No. 13, pl. II.

Smith, O. (2010). Community Forest Associations in Kenya; Challenges and Opportunities. *Forest Policy and Economics*. Vol 58, pp 47-55.

Smith, J., and Allesandro, K. (2002). Afforestation and reforestation in the clean development mechanism of the Kyoto Protocol: implications for forests and forest people. *International Journal of Global Environmental Issues*. Vol 2 pp 322-343, https://api.semanticscholar.org/CorpusID:56024528.

Sovu, V., Tigabu, M., Savadogo, P., Odén, P and Xayvongsa, L. (2010). Enrichment planting in a logged-over tropical mixed deciduous forest of Laos, *Journal of Forestry Research* Vol 21, pp 273–280.

Stewart, R.B, and Spittlehouse, D.L. (2003). Adaptation to Climate Change in Forest Management. *BC Journal of Ecosystems and Management.* Forest Research Extension Partnership, Vol 4, pp 1-7.

Suleiman, M.S., Wasonga, V.O., and Mbau, J.S. (2017). Non-timber Forest Products and their Contribution to Households Income around Falgore Game Reserve in Kano, Nigeria. *Ecology Process*. Vol 6, pp 23-27

Tacconi, Luca. (2007). Decentralization, forests and livelihoods: Theory and narrative. *Global Environmental Change.* Vol 17 pp 338-348. 10.1016/j.gloenvcha.2007.01.002.

Taylor, A. and Chen, H. (2010). Multiple successional pathways of boreal forest stands in central Canada, Ecography Vol 34 pp 177-352.

Trosper, R.L. (2011). *Traditional Forest-Related Knowledge*: Sustaining Communities, Ecosystems and Bio cultural Diversity. Springer. ISBN: 978-94-007-2143-2. DOI: https://doi.org/10.1007/978-94-007.

Tye, S., Rob, J and Lomeli, G. (2022). The potential for Nature Based Solutions Initiaves to Incorporate and Scale Climate Adaptation. World Resource Institute. DOI:10.46830/wriwp.21.00036.

United Nations Organization UNO. (2014). Annual report on reducing emissions from deforestation and forest degradation in developing countries.

United Nations Environment Programme UNEP. (2016). Annual report on emissions from deforestation and forests degradation with adequate social and environmental safeguards.

United Nations Environment Programme UNEP. (2018). Annual Report, on issues from fighting pollution of the air and sea to helping nations meet their goals of reducing greenhouse gas emissions.

Vallee, M., Moukouri, S., Vauthier, V and Labaste, S. (2022). Independent Forest Monitoring in the Congo Basin; Taking Stock and Thinking Ahead. World Resource Institute 2022.

Wafuta, P., Sirmah, P., and Mbira, G: (2019). Forest fires incidences, causes and associated losses: A case study of Londiani Forest in Kenya. *East Africa Journal of Ecology & Agroforestry*. Vol 4. Issue 1, 2019: ISSN:1346-5637.

Wanjohi, B., Njunge, J., Otieno, D and Oyoo-Okoth, E. (2017). Plant species composition, structure and diversity in Nabkoi Forest Reserve (Kenya). *Journal of Forestry*. 4.

Wekesa Chemuku and Alemayehu. (2017). Structure and natural regeneration of Mangroves in areas exposed to different agents of degradation in Kenya. *Journal of Global Biosciences* Vol 6(1): pp 4695-4707.

White, F. (1983). The Vegetation of Africa. Natural Resource Research, UNESCO, Vol 20, pp 1-356.

Wildlife Woks. (2011). Kasigau Corridor REDD + Project. Forests and Agriculture. Annual report. https://www.wildlifeworks.com/kasigau-kenya.

World Bank annual report (2012). Main report Washington, D.C. World Bank Group. http://documents.worldbank.org/curated/en/168831468332487486.

World Resource Institute. (2014). Global Forest Watch. Annual report. wri.org/annualreport/2014. Accessed on 20th September 2022.

Wright, D., Harder, C and Wilson, E. (2021). Maps for Saving the Planet. International Kindle Paper white. *GIS for Science* Vol 3 pp 189-902.

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

Zeppel, H. (2006). Sustainable development and management of indigenous ecotourism. Indigenous Ecotourism: Sustainable Development and Management (pp. 278-293). Ecotourism Series No. 3. Wallingford, UK: CABI Publishing.

Zhang, M., Liu, N., Harper, R., Li, Q., Liu, K and Wei, S. (2017). A global review on hydrological responses to forest change across multiple spatial scales: Importance of scale, climate, forest type and hydrological regime. *Journal of Hydrology.* Vol 546 pp 44-59.

APPENDICES

Appendix 1: Approval Letter

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

Tel: 056-30870
Fax: 056-30153
E-mail: directordps@mmust.ac.ke
Website: www.mmust.ac.ke

P.O Box 190
Kakamega – 50100
Kenya

Directorate of Postgraduate Studies

Ref: MMU/COR: 509099

9th September 2022

Kosgey Chepkoech Evalyne
SEV/G/01-53285/2018

Appendix 2: NACOSTI Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 163275

Date of Issue: 06/December/2022

RESEARCH LICENSE

This is to Certify that Miss.. Evalyne CHEPKOECH Chepkoech of Masinde Muliro University of Science and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Kericho on the topic: Vegetation dynamics of Londiani Forest for the period ending : 06/December/2023.

License No: NACOSTI/P/22/21604

163275

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

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See overleaf for conditions

Appendix 3: Tree Stand structure and Composition Data Collection Sheet

Plot ID:				**Plot area (m^2):**
Description: Forest Type(N/S/P)				
Quadrat Number:				
GPS Latitude:		**GPS Longitude:**		**Weather:**
Tree #	**Genus and species**	**DBH(cm)**	**Height (m)**	**Remarks**
1				
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3				
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Appendix 4: Questionnaire

Questionnaire on Assessment of Vegetation Dynamics in Londiani Forest

My name is Evalyne Chepkoech, a Master of Science student from Masinde Muliro University of Science and Technology (MMUST) pursuing Master of Science, Environmental Science. My topic of research is **Tree Stand Structure, Species Composition and Vegetation Cover Changes in Londiani Forest-Kenya.** I have therefore identified you as one of the respondents for this research. The information you provide to me will be valuable in assisting with this report and in efforts to the conservation of Londiani Forest. This will also be **treated with utmost confidentiality and shall not be used for any other purpose except the one stated.**

Instructions: use a tick (√) where appropriate.

A. <u>DEMOGRAPHIC DETAILS.</u>

1. **Residence:** Location………………… Sub-location………………… Village……………
2. Kindly indicate your gender.
   A. Male [ ] B. Female [ ]
3. What is your age bracket?
   [A] Below 20 years [B] 21-30 years [C] 31-40years [D] 41-50years [E] Above 61
4. Level of education
   [A] Informal [B]. Primary Education [C]. Secondary school
   [D] Tertiary level [E] Not attended school
5. What is your main source of income?
   [A] Farming [B] Employment [C] Self-Employment [D] Business [E] Others
6. What is your average monthly income (KES)?
   [A] KES :< 1000 [B] KES: 1000-5000 [C] KES: 5001-10000
   [D] KES: 10001-15000 [E] KES: 15001-20000 [F] KES: Above 20000

B. <u>FOREST RELATED ACTIVITIES</u>

7. Are you a member of a Community Forest Association (CFA)? A. Yes [ ] B. No [ ].
   If yes, which user group? A. Tree nursery [ ] B. Ecotourism [ ] C. Bee Keeping [ ] D. Seed and Seedling Collection [ ]

8. What is the approximate distance of your land to the nearby forest edge?

A.100 metres [ ] B. 101-500 metres [ ] C. 501m- 1km [ ] D. Over 1 km [ ]

9. How long have you stayed in this place?

A. Less than 1 year [ ] B. 1-5 years [ ] C. 5- 10 years [ ] Over 10 years [ ]

10. How big is your land?

A. 0.5-1 acres [ ] B. 1- 2.5acres [ ] C.3- 4.5 acres [ ] D. above 3 acres [ ]

11. What is the major land use?

A. Cash crops growing [ ] B. livestock keeping [ ] C. trees growing [ ]

D. Mixed cropping [ ] E. Others (Specify…………………….

12. What is your Source of animal feed?

A. On-farm [ ] B. Forest grazing [ ] C. Along the road [ ] D. Others

13. Name your major source of energy for cooking & lighting.

A. Fuel wood [ ] B. Paraffin [ ] C. Electricity [ ] D. Others [ ]

14. How frequent do you visit the forest?

A. Daily [ ] B. Weekly [ ] C. Bi weekly [ ] D. Monthly [ ]

15. When you visit the forest, what activities do you engage in?

A. Fuel wood collection [ ] B. Grazing [ ] D. Grass cutting [ ] E. Collection of herbs and medicinal products [ ] F. Research [ ] G. Cutting of timber and Poles [ ]

16. Which of the forest resources do you obtain from the forest? (Tick the resource and frequency removed from the forest)

Forest product / resource	**Frequency of removal (daily / weekly / monthly / seasonal / yearly)**	**Amounts removed**
Game animals		
Fuel wood		
Charcoal		
Seedlings		

Wood/Timber/Poles		
Edible fruits and Vegetables/mushrooms		
Honey		
Grazing / pasture		
Thatch grass		
Medicine		
Other (specify)		

17. Are these products sold or used for subsistence only?

A. For sale [ ] B. Subsistence only [ ]

If sold how much do you sell per product?

Forest product / resource	**Amounts removed**	**Value (Ksh)**
Game animals		
Fuel wood		
Charcoal		
Seedlings		
Wood/Timber/Poles		
Edible fruits and Vegetables/ Mushrooms		
Honey		
Grazing / pasture		
Thatch grass		
Medicine		

18. Have you noticed a difference in availability of any of the resources within the forest?

A. Yes ( ) B. No ( )

If yes, what do you think has caused the difference?

....
....

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19. Do you in any case consider yourself to be one of the contributors of the change in no.18 above? A Yes ( ) 2. No ( )

20. What do you think should be done?

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21. Who should be responsible for forest conservation?

a. Public
b. Private
c. Civil societies
d. Communities around forests
e. International Non-governmental Organizations (INGOs)
f. Non-Governmental Organizations (NGOs)
g. Any other specify

C. FOREST MANAGEMENT

22. Who manages the affairs of the forest block you have mentioned?

A. KFS [ ] B. KWS [ ] C. KFS and KWS [ ] D. County government [ ] E. Community [ ]

23. In your opinion, for the time you have lived in this area, is the forest cover

A. Increasing [ ] or B. Decreasing [ ]

24. Estimate the number of trees you have ever planted

No. Planted	Where Planted	Reason for planting (Reforestation/ fuel production/ sale/ specify others)	Source of seedlings (KFS , Community, local market, on-farm nurseries or others)
	Government forest		
	On- farm		

25. What do you think can be done to promote public participation in forest conservation?

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26. In your own opinion, what can the government do to promote forest conservation practices?

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The End….

Thanks for your participation

Appendix 5: Observation Checklist

Check on the following;

- Status of Londiani forest; size remaining of natural forest, plantation forest, fragmentation, age of trees and tree species.
- Other forest users, e.g. lumbering entities like saw millers etc., if they are in vicinity……and how much forest products they harvest, take away each year
- Economic activities undertaken by residents of Londiani location.
- Human activities in the forests and products obtained from the activity.
- The participation of community in reforestation by observing plantations.
- What the KFS are doing to conserve and protect the forests.
- Level of poverty in the village

GUIDE TO KEY INFORMANTS INTERVIEW. FD GROUP

- Their organization's role in forest conservation.
- Their initiatives in forest conservation and how they involve the community.
- Level of community participation in forest restoration.
- Challenges in community participation in reforestation projects.
- Opportunities in community participation in reforestation. How it can be improved for further reforestation for sustainable forest management.

INTERVIEW SCHEDULE (OFFICER)

- Are there any CFM organizations in your zone?
- What activities do they do?
- How active are they?
- What assistance do you offer them?
- How has your office helped in community participation in forest replenishment

In your opinion, what long term solutions and strategies can you put in place to better forest conservation?

Appendix 6: List of trees species found in Londiani Forest. Source: Author2023

Scientific Name	(IPNI) Number	Richness	Family Name
Acacia nilotica	921695-1	17	Fabaceae
Acacia mearnsii	470860-1	26	Fabaceae
Acacia xanthophloea	471815-1	22	Fabaceae
Anthocleista vogelii	54565-1	13	Fabaceae
Arundiana alpina	4263-2	4	Ericaceae
Brassia actinophylla	36160-2	9	Betulaceae
Croton macrostchyus	342917-1	6	Euphorbiaceae
Croton megalocarpus	342969-1	47	Euphorbiaceae
Cupressus lusitanica	330505-2	273	Cupressaceae
Dombeya goetzenii	823043-1	74	Dombeyoideae
Ekebergia capensis	578362-1	46	Oleaceae
Eucalyptus globulus	592965-1	148	Myrtaceae
Euphorbia candelabrum	345923-1	9	Euphorbiaceae
Ficus sycomorus	77308414-1	7	Moraceae
Grevillea robusta	50798-3	2	Proteacea
Juniperus procera	262311-1	148	Cupressaceae
Maesopsis eminii	717624-1	2	Rhamnaceae
Ocotea usambarensis	467675-1	5	Lauraceae
Olea africana	610616-1	60	Oleaceae
Pinus patula	263196-1	196	Pinaceae
Podocarpus falcatus	263483-1	12	Podocarpaceae
Podocarpus gracilior	263490-1	21	Podocarpaceae
Polyscias fulva	91769-1	9	Araliaceae
Prunus africana	729417-1	22	Rosaceae
Rhamnus prinoides	718580-1	3	Rhamnaceae
Rhus natalensis	70715-1	12	Anacardiaceae
Salvadora persica	779348-1	65	Salvadoraceae
Spathodea campanulata	110660-1	4	Bignoniaceae
Syzygium guineense	601750-1	16	Myrtaceae
Tamarindus indica	520167-1	6	Combretaceae
Vangueria madagascariensis	769766-1	13	Rubiaceae
Vepris nobilis	969503-1	4	Rutaceae
Vitex keniensis	77192411-1	3	Lamaiaceae
Zanthoxylum gilleti	775746-1	4	Rutaceae

(IPNI) - International Plant Names Index – Life Science Identifier (Plants of the world website) https://www.ipni.org/ accessed on 5th August 2022

Appendix 7: Trees species recorded per Forest Block. Source: Author 2023

S/No	Kedowa tree species	Chebewor tree species	Londiani tree species
	Indigenous trees	**Indigenous trees**	**Indigenous trees**
1	*Acacia nilotica*	*Acacia nilotica*	*Acacia nilotica*
2	*Anthocleista vogelii*	*Acacia mearnsii*	*Acacia xanthophloe*
3	*Arundiana alpina*	*Anthocleista vogelii*	*Dombeya goetzenii*
4	*Brassia actinophylla*	*Croton megalocarpus*	*Ekebergia capensis*
5	*Croton macrostchyus*	*Dombeya goetzenii*	*Eucalyptus globulus*
6	*Croton megalocarpus*	*Euphorbia candelabrum*	*Juniperus procera*
7	*Dombeya goetzenii*	*Eucalyptus globulus*	*Ocotea usambarensis*
8	*Ekebergia capensis*	*Juniperus procera*	*Olea africana*
9	*Eucalyptus globulus*	*Ocotea usambarensis*	*Podocarpus gracilior*
10	*Euphorbia candelabrum*	*Olea africana*	*Prunus africana*
11	*Ficus sycamorus*	*Podocarpus falcatus*	*Spathodea campanulata*
12	*Juniperus procera*	*Prunus africana*	*Syzygium guineense*
13	*Maesopsis eminii*	*Rhus natalensis*	**Exotic Trees**
14	*Olea africana*	*Salvadora persica*	*Cupressus lusitanica*
15	*Podocarpus gracilior*	*Syzygium guineense*	*Pinus patula*
16	*Polyscias fulva*	*Tamarindus indica*	
17	*Prunus africana*	*Vangueria madagascariensis*	
18	*Rhamnus prinoides*	**Exotic Trees**	
19	*Rhus natalensis*	*Cupressus lusitanica*	
20	*Syzygium guineense*	*Gravillea robusta*	
21	*Tamarindus indica*		
22	*Vangueria madagascariensis*		
23	*Vipris nobilis*		
24	*Vitex keniensis*		
25	*Zanthoxylum gilleti*		
	Exotic Trees		
26	*Cupressus lusitanica*		
27	*Pinus patula*		

Appendix 8: Species Distribution data for Londiani Forest

Species	Abundance	RD	F	RF (%)	Total Basal (m^2)	RDo (%)	RA	IVI	Species Density
Acacia nilotica	17	1.29	5	27.7	0.97	0.788	3.4	29.78	0.94
Acacia mearnsii	26	1.98	2	11.1	0.71	0.576	13	13.66	1.44
Acacia xanthophloe	22	1.68	3	16.7	0.56	0.457	7.3	18.84	1.22
Anthocleista vogelii	13	0.99	2	11.1	0.17	0.144	6.5	12.23	0.722
Arundiana alpina	4	0.31	1	5.6	0.01	0.013	4	5.918	0.22
Brassia actinophylla	9	0.68	1	5.6	1.88	1.533	9	7.813	0.5
Croton macrostchyus	6	0.45	1	5.6	0.11	0.09	6	6.14	0.33
Croton megalocarpus	47	3.59	4	22.2	0.74	0.607	11.7	26.39	2.61
Cupressus lusitanica	273	20.8	5	27.7	41.3	33.69	54.6	82.25	15.17
Dombeya goetzenii	74	5.65	10	55.5	3.03	2.477	7.4	63.63	4.11
Ekebergia capensis	46	3.51	4	22.2	4.32	3.527	11.5	29.24	2.56
Eucalyptus globulus	148	11.3	11	61.1	16.2	13.19	13.5	85.60	8.22
Euphorbia candelabrum	9	0.68	3	16.7	0.60	0.492	3	17.87	0.5
Ficus sycamorus	7	0.53	2	11.1	1.77	1.443	3.5	13.07	0.39
Grevillea robusta	2	0.15	1	5.6	0.05	0.038	2	5.788	0.11
Juniperus procera	148	11.3	8	44.4	17.7	14.46	18.5	70.17	8.22
Maesopsis eminii	2	0.15	1	5.6	0.01	0.01	2	5.76	0.11
Ocotea usambarensis	5	0.38	1	5.6	0.49	0.402	5	6.382	0.28
Olea africana	60	4.58	8	44.4	2.19	1.782	7.5	50.76	3.33
Pinus patula	196	14.9	4	22.2	17.7	14.57	49	51.75	10.89
Podocarpus falcatus	12	0.91	2	11.1	0.19	0.152	6	12.16	0.67
Podocarpus gracilior	21	1.6	4	22.2	2.74	2.233	5.25	26.03	1.167
Polyscias fulva	9	0.68	1	5.6	2.99	2.435	9	8.715	0.5
Prunus africana	22	1.68	5	27.7	1.15	0.934	4.4	30.31	1.22
Rhamnus prinoides	3	0.22	1	5.6	0.14	0.117	3	5.937	0.17
Rhus natalensis	12	0.91	1	5.6	0.29	0.238	12	6.748	0.67
Salvadora persica	65	4.96	3	16.7	1.27	1.039	21.7	22.69	3.61
Spathodea campanulata	4	0.3	1	5.6	0.52	0.423	4	6.323	0.22
Syzygium guineense	16	1.22	4	22.2	1.89	1.545	4	24.96	0.89
Tamarindus indica	6	0.45	2	11.1	0.21	0.168	3	11.72	0.33
Vangueria madagascariensis	13	0.99	3	16.7	0.17	0.142	4.3	17.83	0.72
Vipris nobilis	4	0.3	1	5.6	0.23	0.191	4	6.091	0.22
Vitex keniensis	3	0.22	1	5.6	0.08	0.068	3	5.888	0.17
Zanthoxylum gilleti	4	0.3	1	5.6	0.02	0.032	4	5.932	0.22
Total	**1308**	**99.6**	**107**	**594**	**122**	**100**	**326**	**794**	**72.7**
Mean	**38.47**	**2.93**	**3.15**	**17.5**	**3.61**	**2.94**	**9.59**	**23.3**	**2.14**

Appendix 9: Trees species Abundance and distribution for the three forest blocks

Appendix 9a). Kedowa Forest Block

Species	Abundance	Density	RD	F	RF	DO	RDo	IVI
Acacia nilotica	6	3	1.39	2	33.33	0.42	0.91	35.64
Anthocleista vogelii	4	4	0.93	1	16.67	0.12	0.27	17.87
Arundinaria alpina	4	4	0.93	1	16.67	0.02	0.04	17.63
Brassaia actinophylla	9	9	2.08	1	16.67	1.88	4.14	22.89
Croton macrostchyus	6	6	1.39	1	16.67	0.12	0.26	18.31
Croton megalocarpus	14	14	3.24	1	16.67	0.36	0.79	20.70
Cupressus lusitanica	124	41.3	28.70	3	50.00	22.4	49.24	127.9
Dombeya goetzenii	45	15	10.42	3	50.00	2.33	5.14	65.55
Ekebergia capensis	29	14.5	6.71	2	33.33	2.87	6.33	46.37
Eucalyptus globulus	35	35	8.10	1	16.67	1.97	4.35	29.12
Euphorbia candelabrum	5	2.5	1.16	2	33.33	0.47	1.05	35.54
Ficus sycomorus	7	3.5	1.62	2	33.33	1.77	3.90	38.85
Juniperus procera	4	4	0.93	1	16.67	0.40	0.88	18.47
Maesopsis eminii	2	2	0.46	1	16.67	0.01	0.03	17.16
Olea africana	4	4	0.93	1	16.67	0.27	0.58	18.18
Pinus patula	73	73	16.90	1	16.67	3.64	8.03	41.59
Podocarpus gracilior	18	6	4.17	3	50.00	1.79	3.95	58.11
Polyscias fulva	9	9	2.08	1	16.67	2.99	6.58	25.33
Prunus africana	5	2.5	1.16	2	33.33	0.33	0.73	35.22
Rhamnus prinoides	2	2	0.46	1	16.67	0.14	0.32	17.45
Rhus natalensis	5	5	1.16	1	16.67	0.12	0.27	18.09
Syzygium guineense	1	1	0.23	1	16.67	0.54	1.18	18.08
Tamarindus indica	3	3	0.69	1	16.67	0.01	0.03	17.39
Vangueria madagascariensis	7	3.5	1.62	2	33.33	0.10	0.22	35.17
Vipris nobilis	4	4	0.93	1	16.67	0.24	0.53	18.12
Vitex keniensis	3	3	0.69	1	16.67	0.08	0.19	17.55
Zanthoxylum gilleti	4	4	0.93	1	16.67	0.04	0.09	17.68
Mean	**16**	**10.3**	**3.70**	**1.4**	**24.07**	**1.68**	**3.70**	**31.48**
Grand Total	**457**	**277.8**	**100**	**39**	**650**	**45.4**	**100**	**100**

Appendix 9b) Chebewor Forest Block

Species	Abundance	Density	RD	F	RF	D	RDo	IVI
Acacia mearnsii	26	3	6.02	2	33.33	0.71	2.37	41.73
Acacia nilotica	1	1	0.23	1	16.67	0.21	0.69	17.59
Anthocleista vogelii	9	9	2.08	1	16.67	0.05	0.18	18.93
Croton megalocarpus	33	11	7.64	3	50.00	0.39	1.30	58.94
Cupressus lusitanica	2	2	0.46	1	16.67	0.02	0.06	17.19
Dombeya goetzenii	19	3.8	4.40	5	83.33	0.17	0.59	88.32
Eucalyptus globulus	98	19.6	22.69	5	83.33	11.23	37.7	143.76
Euphorbia candelabrum	4	4	0.93	1	16.67	0.13	0.45	18.04
Gravillea robusta	1	1	0.23	1	16.67	0.05	0.16	17.06
Juniperus procera	100	20	23.15	5	83.33	13.29	44.7	151.15
Ocotea usambarensis	3	3	0.69	1	16.67	0.15	0.50	17.86
Olea africana	23	4.6	5.32	5	83.33	0.26	0.89	89.54
Podocarpus falcatus	12	6	2.78	2	33.33	0.19	0.63	36.74
Prunus africana	15	7.5	3.47	2	33.33	0.48	1.60	38.40
Rhus natalensis	7	7	1.62	1	16.67	0.17	0.57	18.86
Salvadora persica	65	21.7	15.05	3	50.00	1.27	4.28	69.33
Syzygium guineense	7	3.5	1.62	2	33.33	0.72	2.42	37.37
Tamarindus indica	2	2	0.46	1	16.67	0.19	0.64	17.77
Vangueria madagascariensis	5	5	1.16	1	16.67	0.08	0.25	18.08
Mean	**22.74**	**7.09**	**5.26**	**2.26**	**37.72**	**1.57**	**5.26**	**48.25**
Total	**417**	**134.7**	**100**	**43**	**716.67**	**29.75**	**100**	**916.67**

Appendix 9c) Londiani Forest Block

Species	Abundance	Density	RD	F	RF	D	RDo	IVI
Acacia nilotica	10	5	2.25	2	33.33	0.34	0.71	36.30
Acacia xanthophloe	22	7.3	4.95	3	50.00	0.56	1.18	56.13
Cupressus lusitanica	147	73.5	33.11	2	33.33	18.93	39.85	106.29
Dombeya goetzenii	10	5	2.25	2	33.33	0.53	1.12	36.71
Ekebergia capensis	17	8.5	3.83	2	33.33	1.45	3.06	40.22
Eucalyptus globulus	14	14	3.15	1	16.67	2.98	6.27	26.09
Juniperus procera	42	21	9.46	2	33.33	4.04	8.51	51.31
Ocotea usambarensis	2	2	0.45	1	16.67	0.34	0.72	17.84
Olea africana	33	16.5	7.43	2	33.33	1.66	3.49	44.26
Pinus patula	123	41	27.70	3	50.00	14.22	29.93	107.63
Podocarpus gracilior	3	3	0.68	1	16.67	0.95	1.99	19.33
Prunus africana	2	2	0.45	1	16.67	0.34	0.72	17.83

Spathodea campanulata	4	4	0.90	1	16.67	0.52	1.09	18.66
Syzygium guineense	15	15	3.38	1	16.67	0.64	1.34	21.39
Mean	**31.71**	**15.6**	**7.14**	**1.71**	**28.57**	**3.39**	**7.14**	**42.86**
Total	**434**	**217.8**	**100**	**24**	**400**	**47.51**	**100**	**600**

Appendix 10. List of indigenous tree species with medicinal value in Londiani Forest. Source KFS, 2018

S/N	Scientific Name	Local Name	Ailment perceived to treat/uses
1	*Rhamnus prinoides*	Kosisitiet	Stomach ache
2	*Olea africana*	Emitiot	Back ache & toothache, making sour milk
3	*Myrsine melanophloeos*	Osegeteti	Stomach ache and headache
4	*Prunus africana*	Tendwet	Prostate cancer
5	*Rhus natalensis*	Siriat	Sweetening soup
6	*Warburgia ugandensis*	Soget	Cold, deworming
7	*Vepris nobilis*	Kuriot	Allergy
8	*Senna didymobotrya*	Senetwet	Souring milk
9	*Olea welwitschii*	Masaita	Malaria

Appendix 11. Plates of Tree Nursery

Plate1, The researcher in the field, Plate 2, tree nursery, a few examples of tree seedlings species found in the nursery, established by the local community in Kedowa Block. Source: Author 2023

Plate 1

Plate 2

Appendix 12: Plates showing ongoing PELIS activities

Plate 1 and 2, showing ongoing shamba system activities in Kedowa Block. Crops like vegetables, potatoes, tomatoes, carrots, maize, millet, sorghum, beans, peas among others grown alongside tree seedlings for this case Cyprus (*Cupressus lusitanica*). Source: Author 2023

Plate 1 Plate 2

Appendix 13: Plates showing quarrying and bee keeping:

Plate 1 showing quarrying activities in Kedowa block, and plate 2 showing a bee hive evidence of bee keeping in Londiani forest. Source: Author 2023

Plate 1 Plate 2

Appendix 14: Plates showing livestock grazing

Plate 1, taken at Londiani bock showing cattle grazing and plate 2, sheep grazig at Chebewor forest block. Source: Author 2023

Plate 1 Plate 2

Appendix 15: Plates shwoing fuelwood collection:

Plate 1 showing a woman carrying fuelwood collected from Chebewor block and plate 2 showing cut trees for fuelwood production. Source Author 2023

Plate 1 Plate 2

Appendix 16: Plates showing charcoal making spot:

Plate 1; a charcoal burning spot taken in the remaining indigenous forest portion in Kedowa block and plate 2; shows deforestation at Londiani Forest Block in the forefront and efforts of reforestation at the back. Source: Author 2023

Plate 1

Plate 2

Appendix 17: Plates showing debarkd trees and solid wastes

Plate 1: Photo showing debarked trees in Kedowa block. Plate 2: Photo showing solid waste dumped in Londiani forest block. Source Author 2023

 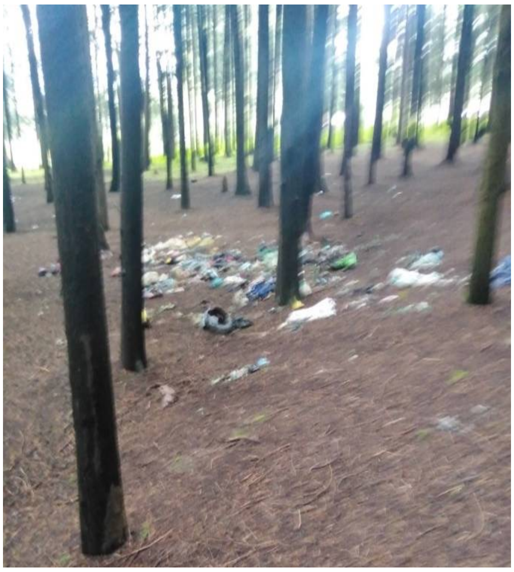

Plate 1 Plate 2

Appendix 18: Plates showing marked trees ready to be harvested.

Appendix 19: A photo of *T.ellipticus*

Plate 1: A photo of *T.ellipticus* invasive species aggressively growing in Kedowa block **Plate 2:** A photo showing seedlings of *Cupressus lussitanica* in Kedowa block. Source: Author 2023

Plate 1

Plate 2

Appendix 21: Plates showing the researcher in the field collecting data