ANTHROPOGENIC INFLUENCES ON TREE SPECIES COMPOSITION, DIVERSITY AND DENSITY: A COMPARATIVE STUDY OF MUSEVE AND MUTULUNI FOREST FRAGMENTS, KITUI COUNTY, KENYA

MUSAU JOSHUA MUTATA

N221/1930P/13

A THESIS SUBMITTED TO THE SCHOOL OF NATURAL RESOURCES AND ENVIRONMENTAL STUDIES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES (ENVIRONMENTAL BIOLOGY), KARATINA UNIVERSITY

OCTOBER 2016

DECLARATIONS

Declaration by the Candidate

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

Signature....................................... Date..

Joshua Mutata Musau

Registration no.: N221/1930/P/13

Declaration by Supervisors

We confirm that the work reported in this thesis was carried out by the candidate under our supervision and has been submitted with our approval as University supervisors.

Signature....................................... Date..

Dr. Mugo J. Mware

Department of Natural Resources Management, School of Natural Resources Management and Environmental Studies, Karatina University

Signature....................................... Date..

Dr. Flora N. Namu

Department of Natural Resources Management, School of Natural Resources Management and Environmental Studies, Karatina University

DEDICATION

I dedicate this work to the Lord's grace for granting me the wisdom and to my family for inspiring me to work harder in accomplishing the research work and writing the thesis.

ABSTRACT

Dryland forest ecosystems are key catchment and biodiversity conservation areas in Arid and Semi-Arid Lands. Besides, they support livelihoods of human population found in these areas. However, unsustainable exploitation has resulted into habitat destruction and degradation in many dryland forests. In addition, baseline data such as plant species present, diversity and density for many dryland forests is rare or completely lacking. Thus, this study aimed at documenting human activities and determining how they affect tree species composition, richness, diversity and density in Museve and Mutuluni forest fragments in Kitui County; Kenya. Two belt transects of 20m wide and 500m long were established in each forest. Along the transect, nested sample plots of 20m by 20m, subplots of 10m by 10m and microplots of 2m by 5m were established for concurrent data collection. In the main plots of 20m by 20m, data on human activities, tree species identification and diameter measurements for mature trees was taken. In the 10m by 10m subplots, saplings identification and diameter measurements were done. Seedlings identification and count was done in the 2m by 5m microplots. Basal area and stem density were computed to compare tree densities while species richness, Jaccard coefficient index and Shannon-Weiner diversity index were computed and used to compare tree species richness, similarity and diversity respectively. The z-test, t-test, Mann-Whitney U test and logistic regression statistics were used for data analysis at 5% level of significance. Human activities documented in the two forests during the study were tree cutting, grazing, footpaths, remnant exotic species and tree debarking. The frequency of occurrence of human activities were higher in Museve forest than in Mutuluni forest. Tree species richness, diversity and basal area density were not significantly different in the two forests, but stem density varied between the two forests. Logistic regression statistics revealed that tree cutting adversely affected ($p<0.05$) tree density, species richness and diversity in Museve forest and only the tree density in Mutuluni forest. Presence of exotic species enhanced ($p<0.05$) tree density in Museve but not in Mutuluni forest. Further, presence of exotic species adversely affected tree species composition and dominance in Museve forest but not in Mutuluni forest. Species similarity between the two forests was low (37%) despite the forests sharing similar ecological conditions. The dominant plant species (SIV=16.77%) in Museve forest was *Eucalyptus saligna*, an exotic species. We conclude that human activities impacted on tree density, species composition, richness and diversity in Museve and Mutuluni forests, but were more pronounced in Museve forest. Some human activities have positive impacts while others have negative consequences. Therefore, we recommend that any forest management plan for the two forests or for any other forest in Kenya need to critically evaluate the merit and demerit of each human activity to ensure reduced negative impacts in forest resource conservation. Besides, there is need to initiate further research to investigate how the dominance of *Eucalyptus saligna* in Museve forest impacts ecological processes within the forest.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

ASALs	Arid and Semi-Arid Lands
Ba	Basal Area
CFA	Community Forest Association
cm	Centimeter
ET	Evapotranspiration
DBH	Diameter at Breast Height
FAO	Food Agricultural Organization
FD	Forest Department
GoK	Government of Kenya
GPS	Geographical Positioning System
Ha	Hactare
IEA	International Energy Agency
JIA	Jaccard Index
KFS	Kenya Forest Service
KEFRI	Kenya Forest Research Institute
KNBS	Kenya National Bureau of Statistics
km^2	Square Kilometer
Ln	Natural logarithm
MEA	Millennium Ecosystem Assessment
MENR	Ministry of Environment and Natural Resource
MDGs	Millennium Development Goals
SEKU	South Eastern Kenya University
m	Meter
m^2	Square meter

mm	Millimeter
MoA	Ministry of Agriculture
SIV	Species Importance Value
SSA	Sub-Saharan Africa
UNEP	United Nations Environmental programme
UNFCC	United Nations Framework Convention on Climate Change
UNO	United Nations Organization
W/m^2	Watt per square meter (W/m^2).
^0C	Degrees Celsius

ACKNOWLEDGEMENTS

I am grateful to my supervisors Dr. Mugo J. Mware and Dr. Flora N. Namu for their tireless and invaluable support and guidance during the research work and thesis write up. Special gratitude goes to my work station technical officer Dr. Rose Sirali for her ingenious interventions during the entire period of study. I thank my research assistants N. Vuva, J. Mutuku, M. Mulwa, L. Mululu, the Musekavo Community Forest Association (Musekavo CFA) and the Kenya Forest Service (KFS) Kitui County for logistical, materials and equipment support to undertake this work successfully.

I would like to acknowledge Mr. Festus M. Mutiso; Head of Department, Environment and Forestry, South Eastern Kenya University (SEKU) for his technical assistance. I highly appreciate Mr. M. Luvanda, G. Giathi and E. Macharia who were research scientists at Kenya Forest Research Institute (KEFRI) for their contributions in data collection and analysis.

CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

This chapter presents the background of the study, justification, statement of the problem, objectives of the study, hypothesis and definition of key terms.

1.1 Background Information

Forest ecosystems provide key ecosystem services including provisional, regulative, cultural and supportive services which are important for conservation of the earth's biodiversity and human wellbeing (MEA, 2005). Further, forest ecosystems are closely linked to rural livelihoods improvement, sustainable economic growth and environmental sustainability Gachathi (2012) and Mathu (2011) all of which are key pillars to development in most developing economies (GoK, 2007; Ochola, Sanginga, & Bekalo, 2010).

However, despite these fundamental roles, sustainable forest management continues to be elusive in the Sub-Saharan Africa (SSA) including Kenya (UNEP, 1997). Forested ecosystems continue to lose their ecological integrity from human induced and uncontrolled activities (Morris, 2010; Ochola et al., 2010). According to Sanginga Kamugisha, and Martin (2010), the ever increasing human population is fast leading to over utilization of natural resources. Furthermore, lack of adequate scientific information for development of sustainable management plans complicates the situation even the more (Hitimana, Kiyiapi & Njunge, 2004). Consequently, the forests' structure and species composition are progressively modified as a result of human activities (Omeja, Obua & Cunningham, 2004). Serna (1986) reported that more than 90% of the world's rainforest destruction is attributed to deforestation for agricultural expansion and overgrazing.

In Kenya, forest cover is estimated at 7% below the recommendable 10% of total land area in a country (FAO, 2010a). This can be attributed to the challenges faced by the forest sector in the country like overgrazing, illegal logging, illegal charcoal burning, uncontrolled harvesting of non-timber wood products and land grabbing (FAO, 2010b). Besides, significant forests are found within the Arid and Semi-Arid Lands (ASALs) as forest fragments and woodlands which are vulnerable to degradation (Gachathi, 2012). ASALs cover 82% of the Kenyan land area and are home to more than 25% of the Kenyan human population. Forests within these areas support important production systems to this population (Kigomo, 2003).

Besides, dryland forests are associated with poor density, species diversity and growth rate (KFS, 2012). Thus, increased reduction of tree cover can easily increase their vulnerability to degradation and consequently threating their capability to provide ecosystem services in ASALs (Gachathi, 2012; Kiruki, Zanden, Malek & Verburg, 2016). This is made even worse by the fact that little is known about biodiversity and structure in most dryland forests. Many of the dryland forests have been fragmented into small forest sizes often in hilltops and woodlands which are under immense degradation and desertification pressure from anthropogenic influences (Kigomo, 2003; Kiruki, et al., 2016). This has also subjected forests in ASALs to more vulnerability of climate change and extreme climatic events such as droughts and floods (KFS, 2009a).

To come up with any stop gap measure there is need for current, accurate and up to date data on dryland forests species composition, richness, diversity and tree density for bench marking and development of sustainable management plans. It is for this reason that we undertook a comparative study to investigate the impacts of human activities on dryland forest tree species composition, species richness, diversity and tree density in Museve and Mutuluni forest fragments in Kitui County, Kenya.

1.2 Justification of the Study

Museve and Mutuluni hilltop forests and other adjacent forest reserves play a significant ecological role within Kitui County and beyond. The two forest reserves are key water catchments and biodiversity conservation areas (Gachathi, 2012; Mbuvi, Nahama & Musyoki, 2010). Museve forest is the primary catchment for River Nzeeu on the western slopes, and partial catchment for River Thua on the eastern slopes. Mutuluni forest forms a key catchment of River Thua.

Any human practices that negatively impact forest structure, species composition, richness and diversity within and around the forests are likely to affect the functioning capacity of the forests in provision of ecosystem services such as water provision. The people who are directly or indirectly dependent on the two hill top forest reserves are likely to be affected.

It was therefore important to establish and document presence of human activities within and adjacent to the two hill top forest reserves and determine their possible influences on the forest structure and functioning. Thus, this study aimed to document human activities which occurred in Museve and Mutuluni hill top forests and their impacts on tree species composition, diversity and density.

The findings of this study will provide scientific knowledge that can be used in guiding the local community, managers and policy makers in formulating strategies for sustainable conservation and management of Museve and Mutuluni forests. The study also forms a basis for further research; monitoring and ecological modelling of the forests to understand the intricate forest structure and function, hence enhance sustainable forest conservation and management.

1.3 Problem Statement

Unsustainable human practices are fast reducing forest cover especially in Arid and Semi-Arid Lands (ASALs). Besides, ASALs are fragile ecosystems which are vulnerable to unsustainable land use practices, climatic variability and hence affect their productivity (Kigomo, 2003; Gachathi, 2012). About 482 million hectares of drylands in Africa have suffered desertification as a result of variation in physical factors coupled with human activities (Kigomo, 2003).

Increase in human population around Museve and Mutuluni forests is likely to increase human activity and consequently exerting more pressure in utilization of the forest resources, resulting in ecosystem degradation. For instance, the human population of Kitui

East in 2009 was 123,239 with a population density of 24 people/km^2 while that of Kitui Central was 131,715 persons with a density of 197 people/km^2. It was projected to increase by a rate of 2.1% per year (KNBS, 2010). Human populations adjacent to Museve and Mutuluni forests derive key ecosystem goods and services like water, medicine, fuelwood, timber and pasture from the forests (Mbuvi et al., 2010; SoE, 2013). The pressure expected from such human population growth coupled with climate change impacts on the two dryland forest reserves could be so much that if urgent measures are not taken, they may lead to degradation of the forest resources. This could further lead to loss of the biodiversity therein and ecosystem goods and services derived from them.

Despite the challenges posed by an increasing human population, the vegetation status of Museve and Mutuluni forest reserves were not yet known. Tree species composition, diversity and densities were yet to be fully documented. The human activities which took place in the forest and their influences on the forests were unknown, yet forest managers and policy makers require this information in formulating sustainable forest management plans.

Thus, this study sought to document human activities which occur within Museve and Mutuluni dryland forest reserves and evaluate their impacts on tree species composition, diversity, and density. It is expected that the findings of this study will be useful in sustainable dryland forest management especially development of forest management plans that critically examines each human activity and its role in sustainable dryland conservation. Such forest management plans will ensure good foundation in implementation of participatory forest management as provided for by the Forest Act 2005 (GoK, 2005). Museve and Mutuluni forest reserves would provide good benchmark towards conservation of several dryland forests in Kenya and in other regions.

1.4 Research Objectives

1.4.1 Main Objective

The main objective of the study was to document human activities occurring in Museve and Mutuluni forest reserves and investigate their influences on tree species composition, diversity and density.

1.4.2 Specific Objectives

The study's specific objectives were to:

1. To compare types and frequencies of human activities in Museve and Mutuluni forest reserves.
2. To investigate the effects of human activities on tree species composition, richness and diversity in Museve and Mutuluni forest reserves.
3. To assess the effects of human activities on tree density in Museve and Mutuluni forest reserves.

1.5 Research Hypothesis

Objective 1

1. **H_O**: Types and frequencies of human activities in Museve and Mutuluni forest are not different

Objective 2

1. **H$_O$**: Tree species composition in Museve and Mutuluni forest are similar
2. **H$_O$:** Tree species richness in Museve and Mutuluni forest are not different
3. **H$_O$**: Tree species diversity in Museve and Mutuluni forest are not different
4. **H$_O$:** Human activities do not affect tree species richness and diversity in Museve and Mutuluni forests.

Objective 3

1. **H$_O$:** Tree density in Museve and Mutuluni forest are not different.
2. **H$_O$:** Human activities do not affect tree density in Museve and Mutuluni forests
3. **H$_O$:** Tree diameter-distribution between Museve and Mutuluni forests are not different

1.6 Definition of key Terms

The definition of key terms based on their current usage in this report are as follows:

Alien species: Species, sub-species or member of a lower taxon that has been introduced outside its normal range.

Anthropogenic influences: These are relatively discrete events in time (usually human driven) that influence the ecosystems, communities and populations. Anthropogenic influences change substrates and resource availability, and creates opportunities for new individuals or colonies to become established.

Basal area density: This is expression of the estimated basal area of trees in a given area i.e. basal area/ha.

Biodiversity: Refers to the quantity and variability among living organisms within species (genetic diversity) between species and between ecosystems

Deforestation: Deforestation is the conversion of forested areas to non-forest land through cutting, clearing, and removal of forest or related ecosystems into less bio-diverse ecosystems such as pasture, cropland, plantations, urban use, logged area, or wasteland.

Degradation: Decline in forest productivity or quality or the impairment of the capability of the forest area to assume its role and functions

Desertification: Development of desert like conditions due to alteration of local climate and deforestation

Dominant species: Dominant species are the species with highest basal area or density (>50% contribution to the total forest) and frequency of occurrence (> 80%).

Ecosystem: An ecosystem consists of organisms (plants, microbes, and animals - including people) and their environment, physical and chemical components (atmosphere, soil, water, etc.) with which they interact.

Ecosystem services: Ecosystem services are benefits people obtain from ecosystems (i.e. provisional, regulative, cultural and supportive services).

Effective number of species: The number of equally-common species required to give a particular value of an index. It is the true diversity of the community in question.

Forest: A group of trees whose crowns are largely contiguous and a tree canopy cover of over 10%. This includes natural and planted plantation forests in state and private land.

Forest composition: Taxonomic groups making up the forest as well as their relative importance

Native species: Species that naturally exists at a given location or in a particular ecosystem, i.e., has not been introduced to its present locality by any human interventions

Regeneration: The process of renewal of a forest with young seedlings on removal of tree cover; It may be natural if it takes place on natural self-seeding or sprouting without human intervention or artificial in which case the recovery process is human assisted through direct seeding or planting

Secondary forest: Forest regenerated largely through natural processes after significant human or natural disturbance of the original forest vegetation

Species: Closely related individuals that freely interact and breed to produce viable offspring

Stem density: The number of tree stems per unit area (Number of stems/hactare)

Stocking density: Refers to a quantitative measure of the area occupied by trees in relative to an optimum or desired level of density.

Sustainable forest management: Careful management and use of forest resources to meet the needs of the present generation without compromising the ability of forests to meet needs of future generations.

Tree: A tree is a perennial forest crop attaining at least 5m height at maturity

Tree density: It refers to a quantitative measure trees expressed in a unit area such as Basal Area/Hectare.

Tree species composition: Refers to the number of the living tree species present in a specific area.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter gives an overview of forests ecosystems in Kenya, anthropogenic influences on forest ecosystems, laws and polices dealing with environmental and natural resources management and; effects of human activities on tree species composition, species diversity and tree density and their impacts on provision of ecosystem goods and services with specific attention on drylands.

2.1 Forest Ecosystems in Kenya

Kenya's land mass cover approximately 58,072,800 ha and woody resources are found throughout organized into various ecosystems of varying density, structure and species composition (KFS, 2009a). These include some of the rare and biodiversity rich tropical rainforests and the Afromontane forest like Kakamega forest and South Nandi forest, tropical mountain forests and mountain ranges, woodlands and "other wooded" which include trees on farmlands (Mutiso, Hitimana, Kiyiapi, Sang & Eboh, 2013; Njunge & Mugo, 2011; Omoro et al., 2010). These ecosystems support livelihoods to human population in these areas and given the fact that 80% of the Kenya's land mass lies on ASALs, forest lands and other wooded lands in these areas are very important (Kigomo, 2003). Besides, these forest ecosystems are associated with poor structure, density and species composition hence more vulnerable to degradation (KFS, 2009a). Thus unsustainable exploitation can easily affect them and their capacity in conservation and livelihood support (Kiruki et al., 2016; Omoro, Pellikka & Rogers, 2010).

2.2 Anthropogenic Influences on Forest Ecosystems

Forest ecosystems provide ecosystem goods and services critical for biodiversity conservation and human wellbeing (MEA, 2005). However, these ecosystems depend on the integrity of fundamental ecological processes like circulation of carbon, water, nitrogen and other nutrients which anthropogenic influences have directly or indirectly interfered with (MEA, 2005; Morris, 2010). Human activities have major influences on forest regeneration and they exert greater pressure and control on forests ecosystems than do the bio-ecological obstacles (Sarmiento, 1997; FAO, 2010b). Human activities especially within the tropics are increasingly altering forest cover through deforestation for other unsustainable land uses (Mahbud, 2008). This has led to wide spread fragmentation of forests and significant loss of biodiversity which have adverse effects to functioning of forest ecosystems, their capacity to conserve biodiversity and human development (Morris, 2010). MEA (2005) and Gonzalez (2001) have established that global forest ecosystems are fast changing as a result of human activities and therein affecting biodiversity conservation and human well-being.

2.2.1 Laws and Polices Dealing with Environmental and Natural Resources Protection in Kenya

Various policies and legislations have been put in place to address environmental and natural resources challenges most of which are due to anthropogenic influences. Locally, the Constitution of Kenya 2010 advocates rights to clean and health environment to every citizen (GoK, 2010). Chapter five of the constitution part II section 69-72, advocates for sustainable exploitation, utilisation and management of the environment and natural resources. It further recognises other agreements and legislations geared towards addressing local challenges and sound management of the environment and natural resources such as the forest and water resources. For instance, the Forest policy 2014 and the Forest Act 2005 strongly emphasis the need for sustainable management of forest resources in Kenya (GoK, 2014; GoK, 2005). Water Act 2002 addresses sustainable management of the water resources (GoK, 2002).

Besides, Kenya is party to several regional and international treaties and conventions aimed at enhancing protection of natural resources such as forest resources. Such treaties include; Convention on Biological Diversity (CBD) which ensures conservation and sustainable use of biodiversity to meet the needs of the present and future generations UNEP (2001); the Kyoto protocol UNFCCC (1998), the Sustainable Development Goals (SDGs), UNO (2015) and Agenda 21 which advocates for sustainable development (UNO, 1992).

2.2.2 Anthropogenic Influences in Forest Ecosystems in Kenya

Forest cover in Kenya is increasingly decreasing over the years due to destructive human activities especially in the closed indigenous forests. According to FAO (2010b), the area under closed indigenous forests have reduced from 1,240,000ha in 1990 to 1,140,000ha in 2010 while that under public plantations forests declined from 170,000ha to 107,000ha over the same period. Such huge losses in forest cover have significant influence to biodiversity loss and ecosystem degradation hence affecting provision of ecosystem goods and services (MEA, 2005; Omoro, 2012). According to FAO (2010a), deforestation, over exploitation, invasive species, pollution and climate change are some of the key human activities threatening global forest ecosystems.

Deforestation in particular is responsible for loss of several indigenous forests affecting biodiversity therein and ecological processes (FAO, 2010b; Morris, 2010; KFS, 2009a; MEA, 2005). Clearing of forests destroys wildlife habitats, lead to fragmentation and the associated edge effects, and loss of biodiversity especially diversity of trees within the forest ecosystem (Morris, 2010). According to FAO (2010b), the average annual deforestation in Kenya is estimated at 0.3% of the total land cover. A case in point is loss of 34,000 hectares of primary forest in Mau forest since it's designation as a forest reserve in 1964 (Mullah, Totland & Klanderud, 2011). Such dramatic changes in forested ecosystems may further worsen the already fragile balance (FAO, 2010a).

Rapid land conversion for agriculture, urban development and continued infrastructural expansion are fast changing the earth's natural surface (FAO, 2010a). The ever growing human population has increased deforestation and conversion of natural forests to other land uses like military training grounds and pressure from ethnic conflicts and encroachment (Mahbud, 2008). In Kenya for instance, expansive parts of Mau forest has been opened up illegally for human settlement, agriculture and infrastructure development (UNEP, 2007). This has adverse effects to the forest regeneration, species composition and ecosystem functioning at large (Mullah et al., 2011; Mutiso, Cheboiwo, Mware, Sang & Tarus, 2015). To make it worse, most of these land conversions lack good planning and adequate resource management policies, a fact which further complicates the situation leading to unsustainable land uses and consequently land degradation (FAO, 2010b).

Biological invasion and occurrence of invasive species amplified by human actions is another driver of land degradation and climate change (MEA, 2005). Species introductions beyond their ecological boundaries may lack a predator in the receiving ecosystem and outcompete the native species thereby causing significant structural and functional modifications to these ecosystems (Mutiso et al., 2013; Obiri, 2011). Sustained adverse effects can result in local species extinction (UNEP, 2007) which may change the trophic dynamics and affect ecosystem structure and function. Biological invasions are also associated with new plant and animal diseases in the receiving environment (Obiri, 2011). Other human activities influencing forest ecosystems include over exploitation, overgrazing and soil erosion (Middleton & Thomas, 1997).

2.2.3 Anthropogenic Influences in Dryland Forest Ecosystems

Dryland forests are often fragile ecosystems and human activities easily influence them and adversely affect their capability to adequately support biodiversity found within them (FAO, 2010b). According to Middleton and Thomas (1997), land degradation from overgrazing, deforestation, over exploitation and agricultural activities in drylands account for about 332.3 million ha of land in dryland zones. Overgrazing is recognized as the most notable factor causing de-vegetation and degradation in Sahel countries especially areas falling within the Arid and Semi-arid zones (Table 2.1).

Table 2.1: Extent of Land Degradation due to Deforestation and De-vegetation in Africa (million ha)

	Aridity Zones			
Factor	**Arid**	**Semi-arid**	**Dry sub-humid**	**Total**
Overgrazing	119.9	61.9	12.6	194.4
Agriculture	11.1	33.8	15.5	60.4
Over exploitation	42.0	11.7	1.8	55.5
Deforestation	3.9	7.6	10.5	22.0
Total	**176.9**	**115.0**	**40.4**	**332.3**

Source: Middleton and Thomas, 1997

It has been documented that repeated grazing and soil trampling by livestock expose the land to agents of soil erosion (Mutiso, Mugo & Cheboiwo, 2011). Deforestation and agricultural activities lead to opening up of land initially under vegetation to soil erosion by water especially due to poor farming methods (Middleton & Thomas, 1997). Vegetation removal also exposes soil mantle to further degradation by wind especially in dry zones. It is estimated that erosion by wind and water account for (52%) and (30%) respectively of the total soil erosion in Africa's dry zones while water erosion is more important in sub-humid zones (Middleton & Thomas, 1997).

Similarly, charcoal burning, species introduction, and intensive firewood collections are also recognised as destructive activities affecting drylands (Mbuvi et al., 2010; Mutiso et al., 2011). According to International Energy Agency (IEA) more than 80% of the population in Sub-Saharan Africa depend on fuelwood for energy (IEA, 2006). Tree harvesting for fuelwood has resulted in over exploitation of some tree species in Sub-Saharan Africa leading to significant reduction in land cover and land degradation (Kiruki et al., 2016).

Species introduction beyond their ecological boundaries in drylands has also affected species composition in these areas (Obiri, 2011). Invasive species may out-compete the native species or even bring along new diseases thus affecting the receiving ecosystem (Mutiso et al., 2013; Obiri, 2011).

Fast growing population coupled with inadequate land use policies, poor governance, complex land tenure and inadequate conservation knowledge have also consequential effects on drylands (UNEP, 2007). As a result, there has been increasing vulnerability of the dryland ecosystems to impacts of climate change resulting in disasters (UNEP, 2007).

2.3 Effects of Human Activities on Tree Species Composition, Species Diversity and Tree Density

Human activities may lead to successional changes in forests and significantly influence tree species composition, richness and diversity (Morris, 2010; Mutiso et al., 2015). Large scale, indiscriminate tree cutting especially for mature trees reduce their stem density, seeding capability and open up gaps which again may cause soil erosion that erodes the soil seed bank (Hitimana et al., 2004; Omoro et al., 2010). Such a combination often limit plant regeneration and recruitment in the forest hence influencing plant successional processes (Mutiso et al., 2011). Studies Mutiso et al. (2011), Rita, Mesquita, Kalan, Gislene and Bruce (2001) have indicated that human activities like deforestation can lead to succession of plant species in a forest that is different from the primary vegetation especially if there is low or no viable plant propagules of the primary vegetation.

Nevertheless, moderate selective removal of trees from a forest may be beneficial to the forest composition as it may boost regeneration in some cases (Sapkota, Tigabu & Oden, 2010). However, if not checked selective removal of trees can also affect forest composition. Omeja et al. (2004) and Hitimana et al. (2004) have indicated that selective species harvesting of trees with economic and social significance may adversely affect species composition, richness, diversity and density within a forest. This is true if mother trees of such species are targeted and as a result their distribution is reduced and consequently affecting their regeneration in the forest and may cause local species extinction (Omeja et al., 2004).

Repeated grazing, browsing and trampling by livestock may lead to inhibition of species regeneration and even direct removals thus affecting species composition and regeneration (Mutiso et al., 2011). According to Mullah et al., (2011) tree density and species composition increase from heavily human degraded areas in farmlands adjacent to Mau forest to less degraded areas inside the forest. Thus unchecked anthropogenic disturbances easily affect forest composition and recruitment patterns and can adversely affect forest species richness and diversity compromising the whole ecosystem in the long run.

2.4 Effects of Human Activities on Stem Size Diameter Distribution

Natural forests are composed of un-even aged trees of different species and are expected to have individuals of all diameter size classes (Hett & Loucks, 1976). In addition, their stem density should decrease with increasing diameter sizes representing a smooth reverse J-curve shaped distribution associated with structurally stable natural forests or forests without interferences for long time (Hett & Loucks, 1976; Rouvinen & Kuuluvainen, 2004).

A smooth reverse J-curve of stem density-diameter size distribution is important in conservation as it reflects the balanced, continuous regeneration and recruitment of trees in successive diameter size classes (Hitimana et al., 2004; Westphal, Tremer, Oheimb, Hansen, Gadow & Hardtle, 2006). This balance can be distorted by destructive human activities like indiscriminative or selective tree cutting especially of mature trees which reduce their stem density and thereby affecting rate of change of trees (the quotient "*q*") in successive diameter classes (Krebs, 1989; Hett & Loucks, 1976). Consequently the diameter size class distribution of such species under selective harvesting or of all species pooled together is affected which often lead to poor tree stand structures and interfering with ecosystem functioning (Hitimana et al., 2004; Omeja et al., 2004).

Biological invasion of exotic species due to human activities may result in a robust regeneration of the invasive species and poor regeneration of the native species (Morris, 2010; Obiri, 2010). This may affect diameter size distribution for individual tree species or all tree species pooled together in a forest ecosystem and their inter-relationships (Obiri, 2011).

2.5 Anthropogenic Impacts on Goods and Services Provided by Dryland Forest Ecosystems

Uncontrolled human activities have adversely impacted on provision of ecosystem services in drylands (FAO, 2010b). Human activities have resulted in widespread land degradation, desertification and soil erosion with devastating effects on dryland ecosystems (Kigomo, 2003). As a result, adequate delivery of provisional, regulative, cultural and supportive services of the drylands ecosystems is greatly impaired (FAO, 2010b; MEA, 2005).

As a result of over exploitation, overgrazing and deforestation in ASALs provisioning services like water, food and energy are affected. Supportive services like primary production and soil formation are also affected (FAO, 1999; FAO, 2010b; MEA, 2005). Water catchment areas are constantly diminishing, crop yield decreasing while increased rates of soil erosion are adversely affecting water quantity and quality in drylands (FAO, 2010b; Gachathi, 2012). Besides, over exploitation of forest resources reduce the ability of forests to replenish themselves and support adequate provision ecosystem goods and services thereby threatening the very delicate balance between people and biodiversity (MEA, 2005). Biological inventories have indicated that biological richness is fast declining in drylands from human instigated activities (Gonzalez, 2001). This is likely to have interlinked negative impacts on dryland forest ecosystems hence affecting the ability to provide ecosystem goods and services. Regulative services like climate and diseases regulation and social cultural services like aesthetic and spiritual values in drylands are adversely affected as a result of human activities (MEA, 2005; Middleton & Thomas, 1997).

2.6 Summary

Dryland forest ecosystems support biodiversity conservation and provide ecosystem goods and services key to human well-being. However these ecosystems are fragile and faced with numerous challenges that affect their structure and functioning (FAO, 2010b; MEA, 2005). Threats from human activities such as overgrazing, over exploitation, deforestation, biological invasion and soil erosion easily affect forests in ASALs and result to land degradation (Obiri, 2011; Middleton & Thomas, 1997). Anthropogenic influences alter species composition, diversity and tree density thereby affecting the integrity of these fragile ecosystems (FAO, 2010b; FAO, 1999).

Comprehensive documentation of biodiversity in drylands is not yet done and specific studies in most dryland forests to understand their tree density, diameter distribution, species composition and how anthropogenic activities have impacted them is also lacking. To this end, this study is intended to document anthropogenic influences on species composition, diversity and tree density in Museve and Mutuluni dryland forest fragments in Kitui County, Kenya.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Introduction

This chapter describes in detail the study area, materials and equipment used in the study, the study design, methods of data collection, data collection procedures and methods of data analysis adopted for this study.

3.1 Description of Study Area

The study was undertaken in Museve and Mutuluni dryland hilltop forest reserves located in Kitui Central (667 km^2) and Kitui East Constituencies (5119.7 km^2) respectively; Kitui County (KNBS, 2010; MENR, 2002) as shown in Figure 3.1. Museve forest is located approximately 13km to the East of Kitui town at Latitude 1^0 19’35.94”S and Longitude 38^0 4’17.81” E. The highest elevation recorded in Museve forest is 1294 metres above sea level (Mbuvi et al., 2010). Museve forest reserve covers an area of 48 hectares and is part of the Museve-Kavonge forest reserve in Kitui Central (MENR, 2002). The forest is surrounded by privately owned small scale farmlands whose settlements are densely (197 people/km^2) populated (KNBS, 2010). Since the year 2010, Museve forest is jointly managed by the Kenya Forest Service in conjunction with a local Community Forest Association called Museve-Kavonge Community Forest Association (MUSEKAVO CFA). Museve forest has a management plan which came into force in year 2014 (KFS, 2014).

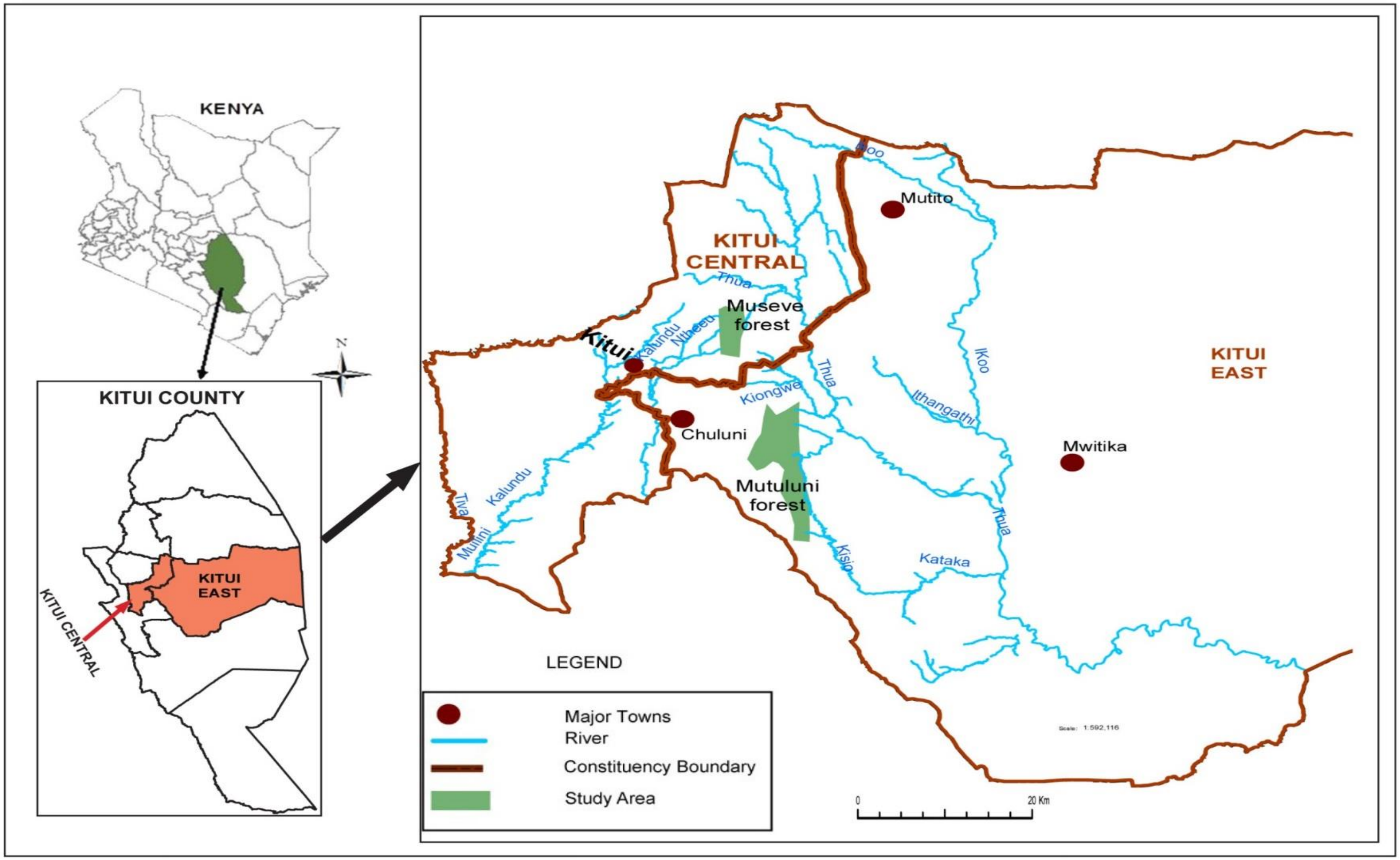

Figure 3.1: Location of Museve and Mutuluni Forest Reserves in Kitui County; Kenya.

Mutuluni Forest Reserve is also a stretch of a hilltop forest located approximately 27km south east of Kitui town at Latitude 2^0 1’0.16”S and Longitude 38^0 17’.64”E.. It covers a total area of 596 hectares and is solely managed by the Kenya Forest Service (MENR, 2002). Mutuluni forest is surrounded by private small scale farms which are less densely populated with 24 people per square kilometer (KNBS, 2010). Culturally, the forest is associated with superstitions by the local community thus perceived with fear. Consequently few people access the forest especially during the rainy season. The forest was a sacred site where sacrifices could be offered, though the practice is fast disappearing. Thus Mutuluni was expected to have less human influences compared to Museve forest.

Both Museve and Mutuluni are secondary mixed forest fragments. The hills were previously owned by the local communities until early 1900’s when people were relocated by the colonial government (Mbuvi et al., 2010). Mutuluni forest was left to recover naturally but large part of Museve forest was put under *Eucalyptus species* by the colonial government to provide fuel wood for tobacco curing, the main cash crop in the area. In 1950s the county council of Kitui took over the management of the two forests and introduced *Cupressus lusitanica* in some sections planted with *Eucalyptus species* in Museve forest for timber production. In 1960s, the Kenya Forest Service (KFS), then the Forest Department (FD) took over the management (Mbuvi et al., 2010). Later the plantations with exotic species in Museve forest were found not suitable in the area as a result of die backs and wind falls. Salvage harvesting was done and the forest left to recover naturally (Mbuvi et al., 2010). As a result, the natural regeneration in Museve forest has remnant of exotic species which are indicators of human interventions. To aid the recovery of Museve forest, there have been enrichment planting efforts by the Kenya Forest Service in conjunction with the local Community Forest Association. Recommendable species for comprised of both indigenous and exotic species with good establishment levels in the region. Exotic tree species like *Senna spp, Acrocarpus flaxinifolius* and *Grevillea robusta* have been recorded within Museve forest (Mbuvi et al., 2010).

The two forests reserves are managed by one forest officer based at Kitui forest station and two forest guards, one in each forest. The Kenya Forest Service management legally allows cattle grazing, firewood collection and forest soil collection on payment of the required fee (KFS, 2010). However, there have been illegal activities reported in both Museve and Mutuluni forests. The activities include; illegal cattle grazing, charcoal burning, logging, fire and firewood collection (Mbuvi et al., 2010; KFS, 2006). Poaching of medicinal plants and extraction of *Osyris lanceolate* for commercial purposes has been reported in both forests (SoE, 2013).

No natural disturbances have been reported in Mutuluni but wind fall and die back of *Cupressus lusitanica* and *Eucalysptus spp* have been reported in Museve forest (Mbuvi et al., 2010). Monkeys, snakes, tortoises and bird life are some of wild animals documented in Museve forest (Mbuvi et al., 2010). No documentation of wild animals and birds was available for Mutuluni forest.

3.1.1 Climate of Museve and Mutuluni forest

The climate in the study area is humid and dry. The total annual average rainfall in the area range from 750mm to 1150mm and is distributed in two rainy seasons (MoA, 1983). The long rains are in October to December while short rains are in March to May. Temperatures range from a minimum of 15.7^{o}C to a maximum of 27.1^{o}C annually. Total radiation is 505 W/m^2 and evapotranspiration is 1571 ET, (Kenya Meteorological services, 2014). The high rate of evaporation, combined with unreliable rains, limit intensive and meaningful agricultural land use and other related development activities (MENR, 2002; MoA, 1983).

3.1.2 Geology and Soils

The geology mainly consists of sedimentary plains which are usually low in natural fertility (MENR, 1994). The soils are rich in sodium and provide best grazing grounds (MENR, 1994). On the hills, the soils are usually shallow and stony and occasionally fertile (MoA, 1983) while on the associated foothills and along the major water courses they vary in fertility from moderate to high fertility (MoA, 1983). Sand is abundant in the region and is exploited on commercial basis SoE (2013) with the major sand harvesting site being Nzeeu and Kalundu Rivers near Kitui town (Mbuvi et al., 2010; MENR, 2012).

3.1.3 Vegetation

Museve forest reserve has both exotic and indigenous tree species. Some of the exotic species include *Eucalyptus spp, Cupressus lusitanica* and *Senna siamea.* Key indigenous tree species include: *Erythrina abyssinica, Rhus natalensis, Combretum molle, Azanza* *gackeana*, *Euclea divinorum* and *Antidesma venosum* (Mbuvi et al., 2010; MENR, 1994). Fruit trees like *Mangifera indica*, *Citrus spp*, *Persia americana* and *Psidium guajava* have been recorded in Museve forest block (Mbuvi et al., 2010). Not much is known about species composition in Mutuluni forest and therefore this study also targets to describe the forest's tree species composition.

Farmlands adjacent to Museve and Mutuluni forest reserves have exotic tree species such as; *Grevillea robusta*, *Senna siamea*, *Eucalyptus spp* and a variety of indigenous tree species such as *Acacia spp, Combretum spp, Commiphora spp, Rhus spp* and *Euphorbia spp.* Kitui Agriculture Project (1997) documented common fruit tree species in the farmlands as mangoes (*Mangifera indica*), *citrus spp*, pawpaws (*Carina papaya*), avocado (*Persia americana*), bananas (*Musa acuminata*) and guavas (*Psidium guajava*).

3.1.4 Demographic and Social-economic Characteristics

Kitui Central constituency has a population of 131,715 people with a density of 197 people/km^2 while Kitui East constituency has a population of 123,239 people and a density of 24 people/km^2 (Table 3.1). Both constituencies have similar percentages of men to women i.e. 48% men and 52% women, with women being more than men (KNBS, 2010).

Table 3.1: Demographic Characteristics of Kitui Central and Kitui East Constituencies

Constituency	**Male**	**Percent age (%)**	**Femal e**	**Total**	**Percent age (%)**	**Area in km^2**	**Population density/km^2**
Kitui Central	63,517	48	68,198	131,715	52	667	197
Kitui East	59,021	48	64,218	123,239	52	5,119.7	24

Source; (KNBS, 2010)

The main economic activities practiced in the area are subsistence agriculture and livestock keeping (MoA, 1983). Key cereal crops grown are maize, beans, cow peas and pigeon peas while root crops are cassava and sweet potatoes (Kitui Agriculture Project, 1997). Limited animal husbandry is also practiced in the area. Other economic activities include trade and mining especially sand harvesting (SoE, 2013).

3.2 Materials and Equipment

Global Positioning System was used to locate points (in degrees) and the elevation of transects corners. A digital camera was used to capture images important in the study area. Ranging rods were used to mark linear distances, linear tapes (30m and 50m) were used to measure distances, wooden pegs to demarcate plot corners, diameter tapes, diameter callipers and one meter ruler were used to measure tree diameters and seedlings height respectively while a direction compass was used to find direction and bearing.

3.3 Methods of Data Collection

The survey and field data collection was done in the months of May and June 2015. The month of May marks the end of the short rain season and the onset of the dry season MENR (2002) in the study area and at this period local residents are mainly not busy with farm work.

3.3.1 Sampling Design and Establishment of the Nested Sample Plots

Four belt transects, two in Museve forest and two in Mutuluni which employed use of nested sample plots were used for the study. Belt transects were preferred due to dense undergrowth vegetation and poor visibility expected within the two mixed secondary forests. Each of the belt transect was 500m long and 20m wide. In each forest, the highest point was identified as the start point of the first transect (Transect 1) that run longitudinally along the forest stretch. From the start point, a distance of 50m was set on the opposite direction to separate the two transects and marked the start of the second transect (Transect 2) which run longitudinally in the opposite direction. Since both forest fragments are strip-like running in the North-South direction, transects were established in such a longitudinal (lengthwise) orientation purposively to collect as much information as possible along the hill (Figure 3.2). A distance of at least 10m was set from the forest edge and transect end point. The direction was determined using a compass while a hand held Geographical Positioning System (GPS) receiver was used to locate points of the transect corners (Appendix I).

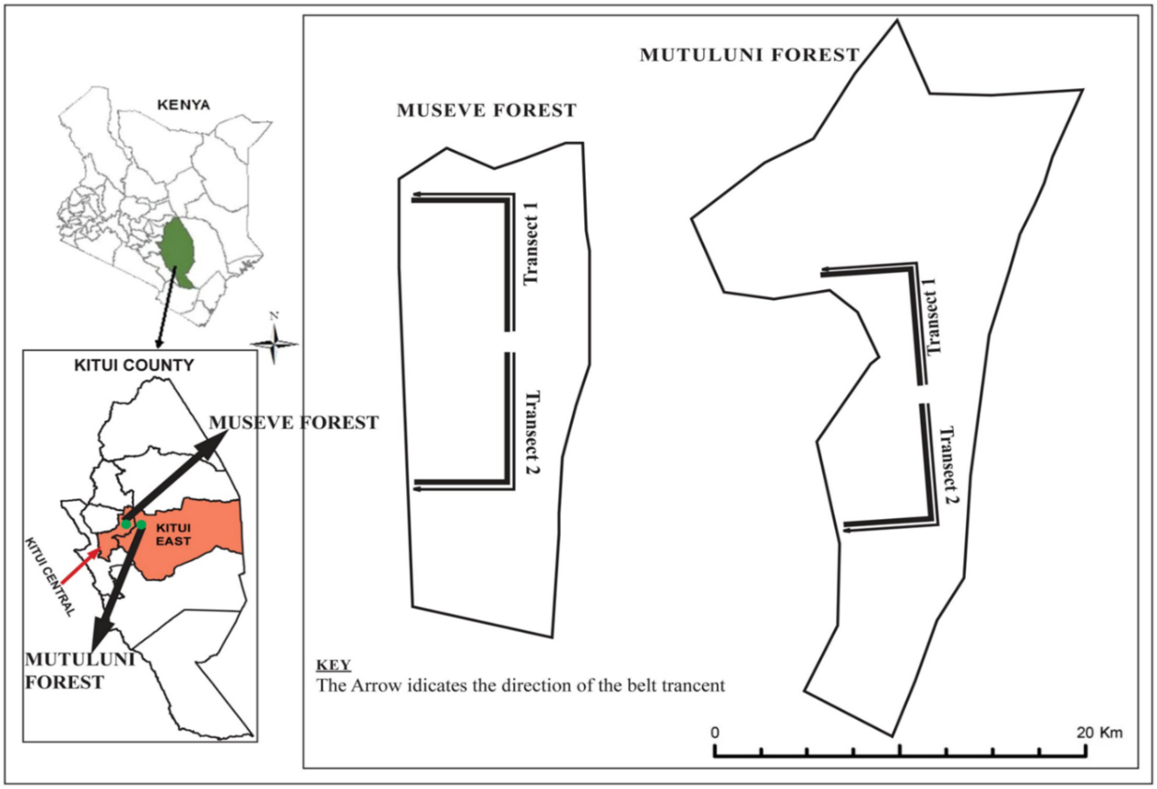

Figure 3.2: Transects' Layout in Museve and Mutuluni Forest Reserves, Kitui County; Kenya

Along each of the four belt transects, twenty five (25) contiguous plots measuring 20m by 20m were established. Using three ranging rods, a straight line was ranged and a 50m linear tape laid to demarcate each of the 20m by 20m plot, along the centerline. Then, using the 30m linear tape, 10m were measured on each side of the ranged centerline, to mark the sides of the 20m by 20m main plots. Wooden pegs were then used to mark the corners of the main plot. A total of 100 plots measuring 20m by 20m were established in both forests with 50 plots in each forest; 25 plots on each belt transect.

Each of the 20m by 20m main plot was further subdivided into four 10m by 10m subplots. Out of the four, one subplot for data collection was randomly selected using random numbers generated from a calculator. Each of the selected subplot was further subdivided into 10 microplots measuring 2m by 5m (Figure 3.3). Again one micro plot was randomly selected. This design referred to as nested plots method was preferred to ensure that different data sets were collected simultaneously.

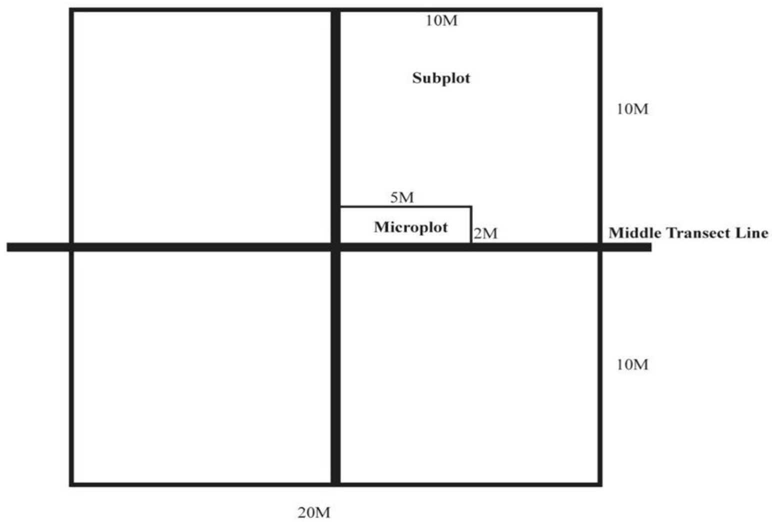

Figure 3.3: Nested Sample Plots' Design

3.3.2 Collection of Human Activities, Tree Species and Bole Diameter Data

In the main plots of 20m by 20m, evidences of human activities, tree species, and diameter measurements at breast height (dbh) of mature trees (≥5cm dbh) were recorded. Evidences of human activities were collected under nine predetermined indicators. The indicators were: signs of charcoal burning, pit sawing, footpaths, grazing, fire, debarking, grass cutting, tree cutting and presence of exotic tree species. For each indicator, absence or presence of human activity was recorded. Codes "0" for absence and "1" for presence were used. In addition, the number of trees cut and number of exotic species present in the 20m by 20m plot were recorded. To establish the number of trees cut, all tree stumps were counted regardless of whether they were old or freshly cut and as long as the cut was evidenced to result from human action. Diameter measurements and species identification for the tree stumps were not done. Where possible photographs were taken for additional information.

Tree species were identified by local and scientific names in the field by help from a local herbalist and expert knowledge. For those trees which could not be identified, specimen samples (leaves, flowers, fruits & bark) and photographs were collected and preserved for further identification using available botanical guides such as "Useful Trees and Shrubs of Kenya" (Maundu & Botengnas, 2005) and "The Kenya Trees, Shrubs and Lianas" (Beenje, 1994). Further identification by expert taxonomist was done at Kenya Forestry Research Institute (KEFRI) Kitui and Muguga. Plant growth characteristics were used to identify tree species and to distinguish trees from other plant life forms such as shrubs, herbs and grasses. Based on description of plant growth characteristic, a maximum height of 5m at maturity was set as a criterion to distinguish trees from shrubs (Kacholi, 2014).

Diameter measurements for all mature trees (≥5cm) within the 20m by 20m plots were taken at breast height (i.e 130cm above the ground level) to the nearest centimeter, using diameter calipers. Trees with multiple stems at 130cm height were measured separately and treated as individual trees while buttressed trees and those with other abnormalities at 130cm height had their diameters taken just above the buttress or the abnormality (Kacholi, 2014). In addition to diameter measurements, all the mature trees were counted and identified. The number of exotic species present in the total count was also determined.

In the 10m by 10m subplots, saplings were identified by their species names and abundance and diameter measurements recorded in appropriate data sheets. Saplings were considered as trees with 1cm dbh and above but less than 5cm, (i.e 1cm ≥ dbh < 5cm). In 2m by 5m micro-plots seedlings species identification and abundance was done and recorded in appropriate data sheets. Seedlings were considered as all tree individuals with less than 1cm diameter reading at breast height or those below 130cm height.

3.4 Methods of Data Analysis

3.4.1 Comparison of Types and Frequency of Human Activities between Museve and Mutuluni Forest Reserves

The frequency of presence of different types of human activities in the 20m by 20m plots was summarized into a frequency table. A two-sided test of equality for column proportions using z-test was used to compare frequencies of human activities between the two forests.

The number of trees cut in each 20m by 20m plots were converted into stems/ha. Data from transect 1 (25 plots) and transect 2 (25 plots) were used to compare density of trees cut (stems/ha) within each forest while data of both transects in each forest was pooled together and used to compare density of trees cut between the two forest reserves. The comparison was preceded by the Kolmogorov-Smirnov test of normality to determine if the data from transects deviated from the normal distribution. Where the distribution of trees cut/ha deviated from the normal curve, Mann-Whitney test was used in the comparison but where it conformed to the normal curve, t-test was used.

3.4.2 Anthropogenic Influences on Tree Species Composition, Dominance Richness and Diversity

a. Influences on Tree Species Composition and Dominances

A list of all the tree species present in each of the two forests was compiled from data on seedlings, saplings and mature trees recorded in each the three nested plots. Jaccard similarity index (Eq. 1) and Species Importance Values (Eq. 2) were employed to examine and compare species similarity and dominances respectively in the two forests (Hitimana, 2000; Spellerberg, 1991).

Jaccard's Index (JI_A) = a / (a+b+c) (Eq. 1)

Where,

a - Total number of species common in Museve and Mutuluni forests

b - Total number of species in Museve but not Mutuluni forest

c - Total number of species in Mutuluni but not Museve forest

JI_A varies from zero (0) to one (1) and is equal to zero if there are no intersecting elements (0% similarity) and equals to one (100% similarity) if all elements intersect (Kent & Corker, 1992). Therefore the closer to "1" the more similar the forests are and the closer to "0" the high the difference in species composition. A critical value 50% (JI_A=0.5) is designated such that above 50% ($JI_A \geq 0.5$) is considered as high and below 50% ($JI_A < 0.5$) as low (Marimon & Felfili, 1997).

Species Importance Values (SIV) also known as species ecological importance (Eq.2) for all mature (>5 cm dbh) tree species were calculated and ranked from the largest to the smallest to show the most dominant species in each forest. Mature trees are expected to demonstrate high dominance due to their large diameters at breast height compared to seedlings and saplings. Further most seedlings are below 130cm height and thus lack diameter at breast height. Therefore seedlings cannot be used in estimating relative dominance which is a key parameter in determining species ecological importance.

$$\mathbf{SIV} = \text{Relative Frequency} + \text{Relative Density} + \text{Relative Dominance} \qquad \text{(Eq. 2)}$$

To get species relative frequency, species relative density and species relative dominance, the following formulae (Eq. 3, Eq. 4 & Eq. 5) were applied in Microsoft excel spreadsheet.

$$\textbf{Species Relative Frequency} = \frac{\text{number of sample units over which the species occurred} * 100\%}{Total\ number\ of\ the\ sample} \qquad \text{(Eq. 3)}$$

$$\textbf{Species Relative density} = \frac{\text{Number of individuals of a species} * 100\%}{Number\ of\ individuals\ of\ all\ species} \qquad \text{(Eq. 4)}$$

$$\textbf{Species Relative Dominance} = \frac{\text{Total Basal Area of a single species} * 100\%}{Total\ Basal\ area\ of\ all\ the\ species} \qquad \text{(Eq. 5)}$$

b. Tree Species Richness and Diversity

Determination of tree species richness and diversity was done only for mature trees (≥5cm dbh) within the 20m by 20m plots. Tree species richness (S) was determined by counting the number of species present (Eq. 6) while species diversity was computed using Shannon-Weiner diversity index, H’ (Eq. 7) (Harris, Milligan & Fewless, 1983; Omoro, 2012). The derived diversity indices were then converted into effective number of species (Eq. 8) to compare species diversity. According to Lou (2006) effective number of species is the true diversity of the community in question and is simply the number of equally-common species required to give a particular value of an index. The Shannon-Weiner's index (H') varies from zero for one species and increases with increase in species heterogeneity (Harris et al., 1983). It was preferred as a measure of diversity in this study over other indices such as Simpson because it provides an account of both the abundance and evenness. It assumes that all species are represented and accounts for them according to their frequency and does not unreasonably favour one species. Shannon-Weiner's index requires a large sample size to minimize biasness (Lou, 2006; Omoro et al., 2010; Hitimana, 2000). Simpson's method on the other hand is a measure of dominance and puts more emphasis on the abundance of the commonest species than species richness (Lovett, 1996). Species richness, Shannon-Weiner's index and effective numbers of species are expressed (Eq. 6, Eq. 7 & Eq. 8) below.

$$\boldsymbol{Species\ Richness\ (S)} = \sum n \qquad \text{(Eq. 6)}$$

Where *n* is number of species in a plot.

$$\boldsymbol{Shannon\ Diversity\ Index}\ (\mathbf{H'}) = -\sum_{i=1}^{R} \boldsymbol{pi\ lnpi} \qquad \text{(Eq. 7)}$$

Where;

$\boldsymbol{pi}$ - Proportion of individuals of species belonging to the ith species in the data set of interest

$$\textbf{Effective Number of Species} = \exp(H') \qquad \text{(Eq. 8)}$$

The number of species present and species diversity in each 20m by 20m plot, within each belt transect, were test for normality. Where significant deviations from the normal distribution were observed Mann-Whitney U test was used to compare species richness and/or diversity across and within forests. Otherwise, t-test was used where the data was normally distributed.

To investigate the effects of human activities on species richness (S) and species diversity(H') in each forest, frequency of human activities in each 20m by 20m plots were recorded and coded "1" and "0" for presence and absence respectively. However, total count for trees cut in each main plot was done and expressed in numbers per hectare. They were further regressed as independent input variables against the dependent tree species richness (S) and species diversity (H') respectively using logistic regression. Results were presented in summary tables and inferences made.

3.4.3 Effects of Human Activities on Tree Density Within and Between Forests

a. Stem Density and Basal Area Density

Tree stocking density (stems/ha and basal area/ha) were computed for main plot within a belt transect using the Eq. 9 and Eq. 10 as indicated below.

Stem Density = Number of Trees/Area (Ha) (Eq. 9)

Basal Area density = Basal Area in m^2/Area in Ha (Eq. 10)

Where;

Basal Area (BA) = $0.00007854d^2$

d = Diameter in cm of a tree at breast height and

0.00007854 is a constant.

Basal area for each tree in the 20m by 20m plot was calculated (Eq. 10). The sum total of basal area for all the trees in each 20m by 20m plot was divided by the plot area (ha) to get basal area density (m^2/ha) for each main plot in both transects 1 and transect 2 in each forest. To compare basal area density within the forest, basal area density of plots in transect 1 were compared with those in transect 2. To compare across the two forests, data from plots in transects 1 and transect 2 in Museve were pooled and compared with those in Mutuluni forest. Mean basal area for every forest was obtained by summing up the mean basal area for every 20m by 20m plots and dividing by the number of plots per forest (50 plots).

Stem density for every 20m by 20m plot was also derived (Eq. 9). This data was used to compare stem density within and between Mutuluni and Museve forest reserves. Kolmogorov–Smirnov test was used to determine if the basal area density and stem density deviated from the normal distribution curve. Mann-Whitney statistic was used for both stem density and basal area density. Mean stem density for each forest was obtained by summing up stem density in each 20m by 20m plots and dividing by the number of plots per forest (50 plots).

To investigate the impacts of human activities on tree density (stems/ha and basal area/ha) in each forest, frequency data of human activities recorded as presence or absence in each 20m by 20m plots were coded "1" and "0" for presence and absence respectively. They were further regressed as independent input variables against the dependent variables; stem density and basal area density respectively using logistic regression. Results were presented in summary tables and inferences made.

b. Tree Stem Diameter Distribution

To compare tree stem diameter distribution between Museve and Mutuluni forests, all recorded stem diameter measurements in each forest were grouped into fifteen diameter size classes. A three centimeter interval was adopted based on the highest and the lowest diameter data collected as most trees had small diameter at breast height at maturity. The diameter classes generated were as follows:

1. below 5 cm
2. 5-8 cm
3. 9-12 cm
4. 13-16 cm
5. 17-20 cm
6. 21-24 cm
7. 25-28 cm
8. 29-32 cm
9. 33-36 cm
10. 37-40 cm
11. 41-44 cm
12. 45-48 cm
13. 49-52 cm
14. 53-56 cm
15. Above56 cm

The diameter class (below 5cm) was for saplings while above from 5cm and above for mature trees. The number of stems/ha in each diameter class in both forests was computed by counting all trees in that diameter size class and then dividing by the total area (ha) sampled in the forest. A graph of stem/ha against diameter classes was plotted to assess if it follows a reverse J-curve diameter distribution. The derived data was further fitted to a power function (Y) model (Eq. 11). Power function (Y) is used for describing diameter structure in natural forests or near natural forests. Regression coefficient of determination was used to assess the model fitness in each forest (Hett & Loucks, 1976). Mann-Whitney u test was used to compare stem density-diameter distribution between Mutuluni and Museve forest reserves.

The power function model is expressed as:

$$\mathbf{Y = YoX^{-b}} \qquad \text{(Eq. 11)}$$

Where;

Y- The number of stems or saplings in any diameter class X

Yo - The initial input into the population at time zero (At the smallest dbh)

b - The mortality or depletion rate with time

The diminution ratio coefficient (the quotient, "*q*") or the *q* factor of trees in successive diameter size classes was calculated according to Meyer (1943). The quotient, "*q*"was plotted against diameter size classes to compare recruitment of trees in successive diameter size classes (Hitimana et al., 2004). The "*q*" values were obtained by the following expression (Eq. 12);

$$\mathbf{q} = \frac{D1-i}{Di} \qquad \text{(Eq. 12)}$$

Where;

D1-$\boldsymbol{i}$- is the density in the lower class

D$\boldsymbol{i}$ -the density in the immediate upper class.

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter presents the results of data analysis and interpretations. Summary tables, figures, and photographs displaying significant data and corresponding brief narrative interpretation are displayed. Summarized data on human activities, species richness, diversity indices and tree densities recorded for Mutuluni and Museve forest reserves are presented in appendices IIa for Mutuluni and IIb Museve. Each of these result categories are discussed in details below.

4.1 Types and Frequencies of Human Activities in Museve and Mutuluni Forest Reserves

Only five out of the nine predetermined indicators of human activities (presence of charcoal burning, pit sawing, footpaths, grazing, fire, debarking, grass cutting, tree cutting & planting of exotic tree species) were recorded in Museve and Mutuluni hilltop forest reserves. The five indicators were: presence of foot paths, grazing, debarking of trees, tree cutting and presence of exotic species. Three indicators; presence of foot paths, grazing and tree cutting occurred in both forests while debarking occurred only in Mutuluni and presence of exotic species only in Museve forest (Table 4.1). A two-sided test of equality for column proportions using z-test indicated significant differences ($p < 0.05$) in frequencies of presence of tree cutting, grazing and foot paths in the two forests. Presence of exotic species and tree debarking were not compared because they only occurred in either Museve or Mutuluni forest but not in both forests (Appendix III).

Table 4.1: Types and Frequencies of Human Activities Recorded in Museve and Mutuluni Hilltop Forest Reserves (May-June 2015).

Types of Human activities		Museve forest	Mutuluni forest
		No of plots out of 50 in which the indicator was present	No of plots out of 50 in which the indicator was present
1	Footpaths	30	11
2	Grazing	32	10
3	Human debarking	0	6
4	Tree Cutting	47	27
5	Exotic species	47	0

The number of trees cut/ha in each of the 20m by 20m plots are as shown in Appendix IIa & IIb. In Museve, Kolmogorov–Smirnov test indicated no significant deviation of the trees cut/ha from the normal distribution (D (50) = 0.12 p > 0.05).However, there was a significant deviation (D (50) = 0.28 p < 0.05) in Mutuluni forest (Appendix IV). Mann-Whitney test statistic for two samples revealed significant (p < 0.05) differences in the number of trees cut/ha between the two forests. No significant (p >0.05) difference was observed within Mutuluni forest (Appendix V) but there was a significant difference (t = 2.69, p < 0.05) in density of trees cut within Museve forest (Appendix V).

a. A freshly cut tree stump in Museve forest

b. Presence of exotic tree species (*Senna siamea*) in Museve forest

Figure 4.1: a) Freshly Cut Tree Stump and; b) An Introduced Exotic Species in Museve Forest

4.2 Tree species composition and species diversity

4.2.1 Tree species composition

A total of 68 tree species belonging to 28 families were recorded in Museve forest appendix (VIa) while 57 tree species belonging to 31 families were recorded in Mutuluni forest (Appendix VIb). The trees in Museve included both exotic and indigenous species while those in Mutuluni were all indigenous species.

In both forests, tree species recorded were at different growth stages ranging from mature trees, saplings to seedlings. In Museve, mature trees comprised forty eight (48) tree species belonging to 23 families, saplings fifty five (55) tree species belonging to 26 families and seedlings fifty four (54) tree species belonging to 28 families (Appendix VI a). This indicated that the tree species composition was more at the seedling and sapling stages compared to the mature trees. On the other hand, Mutuluni forest had mature trees with fifty two (52) tree species belonging to 28 families, saplings with forty three (43) tree species belonging to 27 families and seedlings having thirty two (32) tree species belonging to 21 families (Appendix VIb). This showed that the tree species composition at maturity stage was high compared to the sapling and seedling stage.

4.2.2 Species Similarities and Dominance

a. Species Similarities

A total of twenty seven (27) tree species were common in both Museve and Mutuluni forests. In contrast, twenty one (21) tree species were only present in Museve, while twenty five (25) tree species were only found in Mutuluni (Appendix VII). The computed Jaccard similarity coefficient (JI_A) between Museve and Mutuluni forest was 0.37. A JI_A index of 0.37 is below the critical 0.5 value Marimon and Felfili (1997) implying that tree species composition in Museve and Mutuluni forest was not similar (Appendix VII). Likewise, tree species composition within Mutuluni forest reserve, with JI_A of 0.48, was not similar. However, within Museve forest, the JI_A was 0.67, meaning that the tree species composition within the forest transect 1 and 2 were similar.

b. Species Dominance and Importance Values

The ten most dominant tree species in Museve forest were: *Eucalyptus saligna, Azanza gackeana, Combretum molle, Euclea divinorum, Antidesma venosum, Dichrostachys* *cinerea, Commiphora africana, Terminalia brownii* and *Calodendrum capense* (Table 4.2). These species represent a species importance value of 53.51%. In Mutuluni forest, the ten most dominant species were: *Teclea nobilis, Bersama abyssinica, Croton megalocarpus, Grewia bicolor, Dombeya burgessiae, Terminalia brownii, Diospyros mespiliformis, Bridelia taitensis, Combretum collinum and Euclea divinorum* (Table 4.2) These species represent a species importance value of 58.58%. Therefore, in both forests the ten most dominant species, which were less than 20% of all recorded species, exhibited a dominance value greater than 50% (Table 4.2). Comprehensive list for species dominances for each forest is provided appendices (VIIIa & VIIIb) for Museve and Mutuluni forest respectively.

Table 4.2: Summary of the Ten Most Dominant Species (>5cm dbh) in Museve and Mutuluni Forests.

MUSEVE FOREST			**MUTULUNI FOREST**	
No.	**Species name**	**SIV %**	**Species name**	**SIV %**
1	*Eucalyptus saligna*	16.77	*Teclea nobilis*	9.88
2	*Azanza gackeana*	7.31	*Bersama abyssinica*	8.90
3	*Combretum molle*	5.28	*Croton megalocarpus*	6.42
4	*Euclea divinorum*	4.93	*Grewia bicolor*	6.02
5	*Antidesma venosum*	4.18	*Dombeya burgessiae*	5.95
6	*Dichrostachys cinerea*	3.91	*Terminalia brownie*	4.76
7	*Erythrina abyssinica*	3.25	*Diospyros mespiliformis*	4.70
8	*Commiphora Africana*	3.12	*Bridelia taitensis*	4.56
9	*Terminalia brownie*	2.41	*Combretum collinum*	3.71
10	*Calodendrum capense*	2.35	*Euclea divinorum*	3.68
	Total	**53.51**	**Total**	**58.58**

4.2.3 Species Diversity and Richness

The calculated mean Shannon-Weiner diversity index (H') for Mutuluni forest was 1.50 while for Museve forest was 1.46 equivalent to effective number of species 4.5 and 4.3 respectively (Appendix IV). A normality test indicated that diversity indices in the 20m by 20m plots for both Museve and Mutuluni forest deviated from normal distribution (D (50) = 0.36 $p < .05$) in Museve and (D (50) = 0.32 $p < .05$) in Mutuluni forest respectively (Appendix IV). Further, Mann-Whitney statistics revealed there were no significant differences ($p > 0.05$) in tree species diversity across the two forest reserves but it varied ($p < 0.05$) within each forest (Appendix IX). Tree species richness in Museve forest were normally distributed (D (50) = 0.12 $p > .05$) whereas in Mutuluni they deviated (D (50) = 0.15 $p < .05$) significantly from normal distribution (Appendix IV). Mann-Whitney test revealed there was not significant ($p > 0.05$) difference in species richness between the two forests but it varied within Mutuluni. However, within Museve forest species richness did not vary ($t = 1.80$, $p > 0.05$) significantly (Appendix IX).

4.2.4 Impacts of Human Activities on Tree Species Diversity and Richness in Museve and Mutuluni Forest Reserves

When tree cutting/ha, presence of grazing, foot paths, tree debarking and exotic species were regressed against species richness and diversity, the likelihood chi square statistics for logistic regression for species richness ($\chi 2 = 5.75$, $df = 4$, $p > 0.05$) and diversity ($\chi 2 = 5.92$, $df = 4$ $p > 0.05$) in Mutuluni forest were not significant. However, in Museve forest species richness ($\chi 2 = 29.77$, $df = 4$, $p < 0.05$) and species diversity ($\chi 2 = 30.20$, $df = 4$, $p < 0.05$) revealed significant differences. Thus human activities documented in Museve influenced species richness and diversity while in Mutuluni they did not have significant influence.

Test of parameter estimates indicated that only tree cutting significantly influenced tree species richness and diversity in Museve forest. Regression coefficients for tree cutting ($b < -0.01$, Wald $\chi 2 = 30.00$, $p < 0.05$) on diversity and ($b < -0.01$, Wald $\chi 2 = 26.95$, $p < 0.05$) on species richness were significantly different from zero (Table 4.3). Thus, tree cutting reduced species richness and diversity in Museve forest. Wald $\chi 2$ statistics for grazing, footpaths and introduction of exotic species were not significant ($p > 0.05$) implying that their occurrences did not have significant impacts on species richness and diversity in Museve forest (Table 4.3).

Table: 4.3: Test of Parameter Estimates for Species Richness and Diversity in Museve Forest

Dependent Variable	Parameter	B	Hypothesis Test		
			Wald Chi-Square	df	Sig.
	(Intercept)	0.98	53.09	1	0.00
	Grazing	-0.02	0.05	1	0.82
	Footpaths	-0.09	0.66	1	0.42
	Trees cut/ha	-0.004	30.00	1	0.00
	No. Exotic species/ha	<0.00	2.60	1	0.11
	(Intercept)	2.34	267.86	1	0.00
	Grazing	0.02	0.03	1	0.87
	Footpaths	-0.10	0.69	1	0.41
	Trees cut/ha	<-0.01	26.95	1	0.00
	No. Exotic species/ha	<0.00	0.24	1	0.62

4.3 Basal Area Density and Number of Tree Stems per Hectare in Museve and Mutuluni Forest Reserves

The calculated mean stem densities for Museve and Mutuluni forests were 347.50 stems/ha and 639.50 stems/ha while basal area densities were 5.80 m^2/ha and 6.08 m^2/ha respectively (Figure 4.2; Figure 4.3). Kolmogorov–Smirnov test indicated a significant deviation from normal distribution of scores for both stem density (D (50) = 0.14 $p > .05$) in Museve and (D (50) = 0.17 $p < .05$) in Mutuluni and those of basal area (D (50) = 0.14 $p > .05$) in Museve and (D (50) = 0.24 $p < .05$) Mutuluni forest respectively (Appendix IV). Mann-Whitney statistics indicated that basal area density and stem density were not significantly different ($p > 0.05$) in either Museve or Mutuluni forests. However, when compared between the two forests, stems density differed significantly ($p < 0.05$) while basal area density was not different ($p > 0.05$; Appendix X).

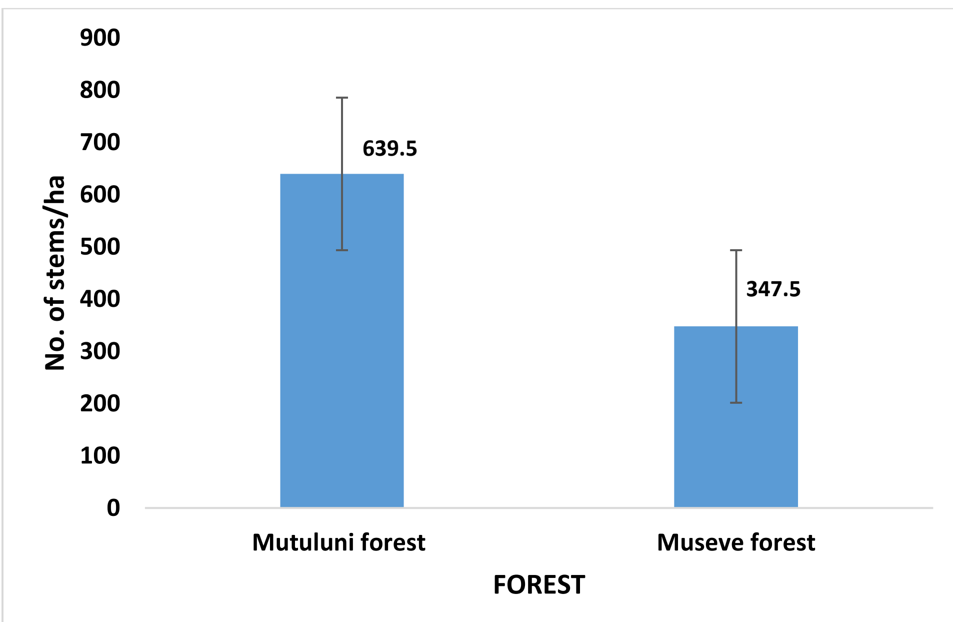

Figure 4.2: Comparison of Stem Densities Recorded in Mutuluni and Museve Forest Reserves in Kitui County.

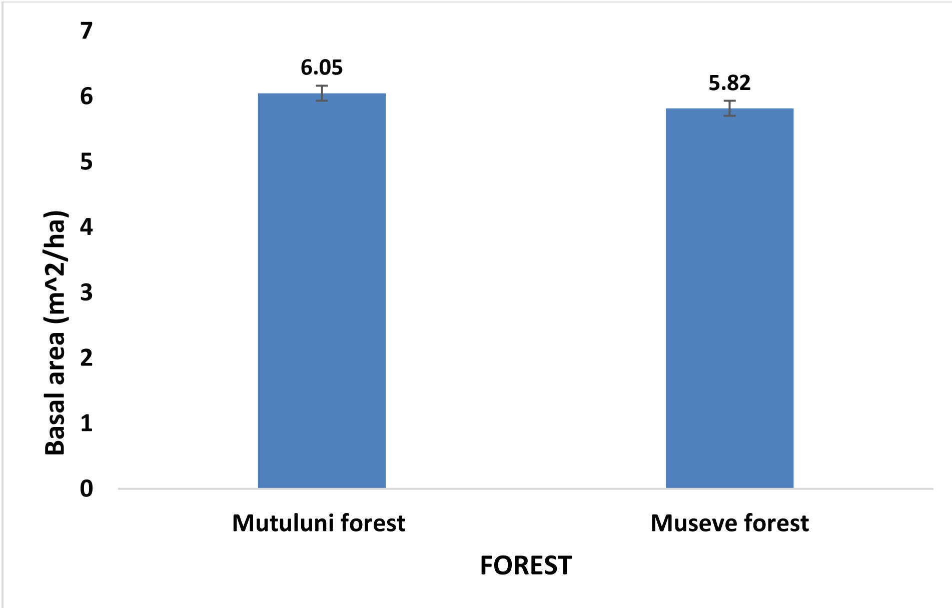

Figure 4.3: Comparison of Basal Area Densities in Mutuluni and Museve Forest Reserves in Kitui County.

4.3.1 Impacts of Human Activities on Tree Density in Museve and Mutuluni Forest Reserves

a. Stem Density

When the frequencies of footpaths, grazing, tree debarking and the number of trees cut/ha and exotic tree species/ha were regressed as predictor variables against stem density, The Likelihood Ratio Chi-Square statistics were significant in both Museve ($\chi2 = 63.00$, $df = 4$, $p < 0.05$) and Mutuluni ($\chi2 = 10.06$, $df = 4$, $p < 0.05$) forest.

A test of parameter estimates indicated that only tree cutting and introduction of exotic species had significant effects on stem density. Cutting of trees significantly reduced stem density in Museve forest ($b = -0.01$, Wald $\chi2 = 48.26$, $p < 0.05$) and Mutuluni forest ($b <- 0.01$, Wald $\chi2 = 4.84$, $p < 0.05$). Introduction of exotic species on the other hand enhanced stem density ($b < 0.01$, Wald $\chi 2 = 19.68$, $p < 0.05$) in Museve forest (Table 4.4). Logistic regression coefficients for grazing, footpaths and tree debarking were not significantly different ($p > 0.05$) and thus they did not have significant effects on stem density (Table 4. 4).

Table 4.4: Test of Parameter Estimates for Stem Density in Museve and Mutuluni Forests

Forest	Parameter	B	Hypothesis Test		
			Wald Chi-Square	Df	Sig.
	(Intercept)	6.45	2594.60	1	0.00
	Grazing	-0.01	0.02	1	0.88
	Footpaths	-0.16	2.45	1	0.12
	Trees cut/ha	-0.01	48.26	1	0.00
	No. Exotic species/ha	<0.01	19.68	1	0.00
	(Intercept)	6.52	294.94	1	0.00
	Grazing	0.03	0.03	1	0.87
	Footpaths	-0.05	0.05	1	0.83
	Human/livestock debarking	0.15	0.31	1	0.58
	Trees cut/ha	<-0.01	4.84	1	0.03

b. Basal area density

When grazing, footpaths, human-livestock debarking, trees cut/ha, number of exotic species/ha were regressed against basal area density, the logistic regression models' Likelihood Ratio Chi-Square for Museve ($\chi 2 = 66.54$, $df = 4$, $p < 0.05$) and for Mutuluni ($\chi 2 = 10.56$, $df = 4$, $p < 0.05$) were significant. Thus the human activities had a significant effect on basal area density

Wald Chi-Square test statistic indicated that tree cutting significantly reduced basal area density ($b = -0.01$, Wald $\chi 2 = 10.79$, $p < 0.05$) while introduction of exotic tree species on the other hand enhanced basal area density ($b < 0.01$, Wald $\chi 2 = 61.61$, $p < 0.05$) in Museve forest (Table 4.5). In Mutuluni forest, regression coefficients for all parameter estimates were not significantly different from zero ($p > 0.05$). Thus, human activities documented in Mutuluni did not influence basal area density significantly.

Table 4.5: Test of Parameter Estimates for Basal Area Density in Museve and Mutuluni Forests

Forest	Parameter	B	Hypothesis Test		
			Wald Chi-Square	df	Sig.
	(Intercept)	1.86	76.57	1	0.00
	Grazing	0.17	2.16	1	0.14
	Footpaths	0.02	0.02	1	0.89
	Trees cut/ha	-0.01	10.79	1	0.00
	No. Exotic species/ha	<0.01	61.61	1	0.00
	(Intercept)	1.24	2.11	1	0.15
	Grazing	0.39	0.78	1	0.38
	Footpaths	-0.20	0.22	1	0.64
	Human/livestock debarking	0.71	1.09	1	0.30
	Trees cut/ha	-0.01	3.14	1	0.08

4.4 Stem Density Diameter Size Distribution between Museve and Mutuluni Forest Reserves

The calculated stems/ha for each diameter size class and *q* factor was presented in a summary table (Table 4.6). Stem densities were high in lower diameter size classes and decreased with increasing diameter sizes. In Museve forest, the uppermost diameter class (above 56cm) was even missing.

Table 4.6: Diameter Distribution and *q* Factor in Museve and Mutuluni Forests

	dbh Class (cm)	Museve Forest			Mutuluni forest		
		density (Stems/ha)	ln (stems/ha)	q factor	density (Stems/ha)	ln (stems/ha)	q factor
1	Below 5	679	6.52		1307.5	7.18	
2	5– 8	208.5	5.34	3.26	375.5	5.93	3.48
3	9– 12	51.5	3.94	4.05	167.5	5.12	2.24
4	13 – 16	15.5	2.74	3.32	49	3.89	3.42
5	17 – 20	23	3.14	0.67	26.5	3.28	1.85
6	21 – 24	9	2.20	2.56	6.5	1.87	4.08
7	25 – 28	12.5	2.53	0.72	4.5	1.50	1.44
8	29 – 32	14	2.64	0.89	4	1.39	1.13
9	33 – 36	3.5	1.25	4.00	1.5	0.41	2.67
10	37 – 40	3	1.10	1.17	1.5	0.41	1.00
11	41 – 44	3	1.10	1.00	1	0.00	1.50
12	45 – 48	2.5	0.92	1.20	1	0.00	1.00
13	49 – 52	0.5	-0.69	5.00	0.5	-0.69	2.00
14	53 – 56	0.5	-0.69	1.00	0.5	-0.69	1.00
15	Above 56	0		0.00	0.5	-0.69	1.00

Stem densities in each forest were plotted against diameter size classes to assess diameter distribution. The shape of the graph for the pooled stem density–diameter size distribution was descending in both forests (Figure 4.4). A fitted line graph revealed a reverse J-curve distribution (Figure 4.4). There was no significant difference in the distribution of tree stem densities across the diameter classes in both Mutuluni and Museve forests (Mann-Whitney U test; $p = 0.68$). The reverse J- curve was an indicator that trees within the two forest reserves varied in age and that most of the trees were in small diameter classes and decreased with increasing diameter size.

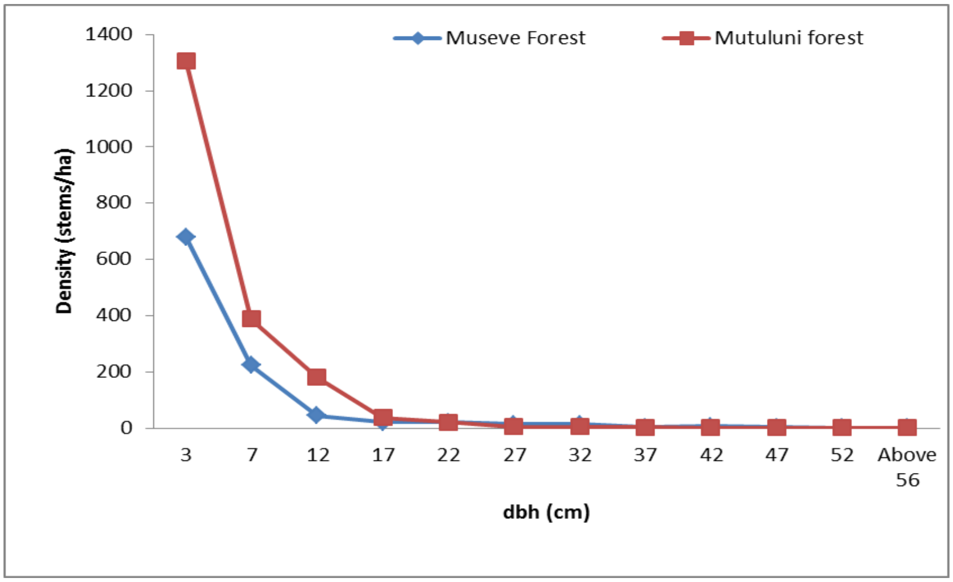

Figure 4.4: Distribution of Stem Densities across Different Diameter Size Classes in Museve and Mutuluni Forest Reserves, Kitui County.

Least squares fit of the power function model on scatter plots of stem density against diameter classes revealed strong goodness of fit (R^2 >0.9) (Figure 4.5). The regression coefficient (*b*) was significantly (*p* = 0.00) different from zero (0) in both forests (Appendix XIa & XIb).

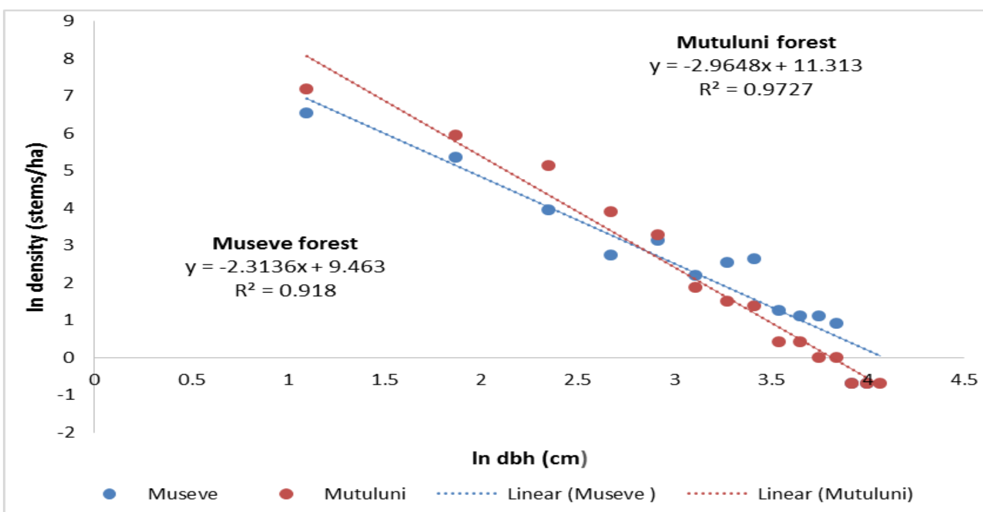

Figure 4.5: Least Squares Fit of the Power Function on Scatter Plots of Stems/Ha against dbh in a Log-Log Scale in Museve and Mutuluni Forest Reserves, Kitui County.

Thus, the model could adequately predict and explain more than 90% (R^2 >0.90) variation in stem density-diameter size distribution in both forests.

The *q* values indicated a fluctuating and irregular curve in both Museve and Mutuluni forests when plotted against dbh size classes (Figure. 4.6). This implies that trees recruitment (birth and death rates) was not balanced in successive diameter classes hence diameter distribution was not balanced. The *q* values were highly irregular and fluctuating in Museve forest compared to Mutuluni indicating that diameter distribution was highly un-even in Museve forest (Figure 4.6).

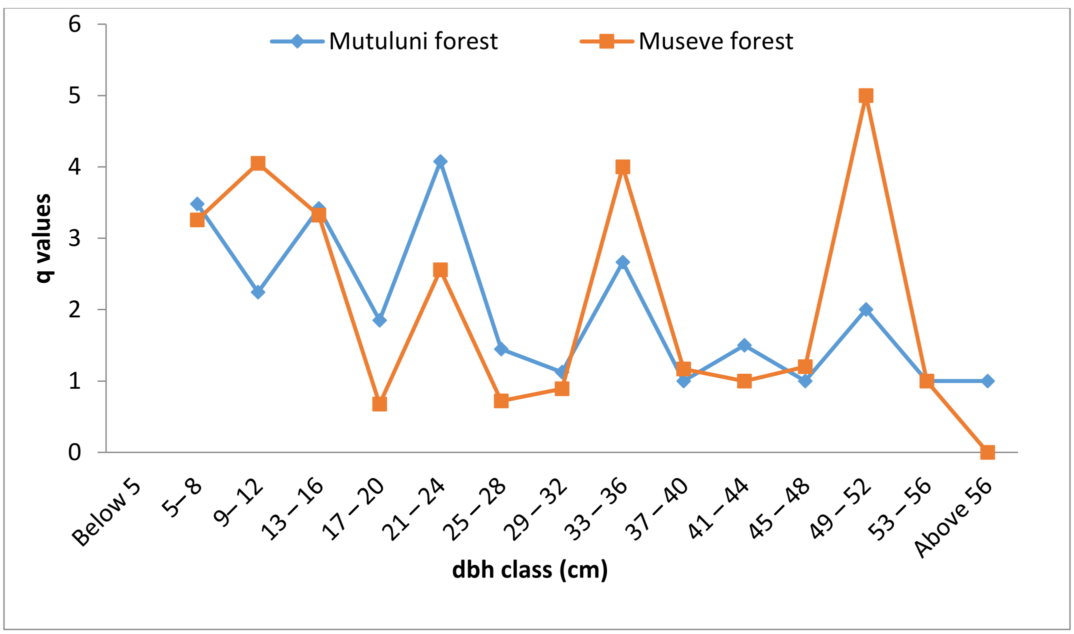

Figure 4.6: Comparison of *q* Values against Diameter Size Classes in Museve and Mutuluni Forest.

CHAPTER FIVE

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter presents a detailed discussion of the study findings and conclusions organized around the formulated objectives. It further provides managerial and research recommendations which are expected to promote conservation of Museve and Mutuluni forests if implemented.

5.1 Discussion of Findings

5.1.1 Human Activities in Museve and Mutuluni Forest Reserves

Presence of human activities was evident in both Museve and Mutuluni forest reserves. However, the frequencies and intensity of human activities was high in Museve forest compared to Mutuluni forest. The two-sided z-test for equality of column proportions revealed significant differences in presence of foot paths, cutting of trees and grazing between the two forests. The findings can be explained by the facts that the two forests had been under different management regimes in the past. Reforestation programmes in Museve forest deliberately targeted introduction of some exotic tree species (Mbuvi et al., 2010). To the contrary, Mutuluni forest underwent natural regeneration and cultural beliefs by adjacent communities hindered people from accessing the forest. In addition, high human population around Museve forest and close proximity to the main trading centre are likely to exert more human influence in Museve forest compared to Mutuluni (KNBS, 2010).

These human activities present challenges to conservation of Museve and Mutuluni forests. Considering that the two forests are located in ASALs which are characterised by fragile ecosystems, human activities can easily affect these forests adversely (FAO, 2010a). Grazing and tree cutting documented in the two forest reserves can easily result into overgrazing, deforestation and consequently result to land degradation in Museve and Mutuluni forests (Middleton & Thomas, 1997). Kiruki et al., (2016) documented that tree cutting for charcoal production in ASALs is major drive to land cover change and degradation. Thus, there is urgent need for appropriate action to control such human activities.

5.1.2 Anthropogenic Influences on Tree Species Composition, Richness and Diversity in Museve and Mutuluni Forest Reserves

Of the five recorded anthropogenic activities in Museve and Mutuluni forest only introduction of exotic species and cutting of trees significantly affected tree species richness and diversity. Grazing, presence of foot paths and tree debarking did not result to significant effects in both Museve and Mutuluni forests. However, their presence in the two forests should be taken into consideration when designing conservation strategies for the two forests since they have potential to affect species richness and diversity directly or through creation of forest edge effects (Mutiso et al., 2013; Omoro, 2012).

Introduction of exotic species in Museve forest may have led to high species richness (68 species) recorded in the forest compared to Mutuluni forest (57 species) which had no exotic species. It was observed that the eight remnant exotic species have integrated well with the natural regeneration in Museve forest and as a result enhanced species richness in the forest when compared to Mutuluni (Omoro et al., 2010). This is also supported by Sovu (2011) findings that species introduction in areas where they were completely lacking enhances species composition, richness and diversity of the receiving ecosystems. Furthermore, presence of footpaths and grazing was higher in Museve forest and may have facilitated higher rate of movement of plant propagules from the surrounding farm lands into the forest (Omoro et al., 2010).

Introduction of exotic species also influenced species dominances in Museve forest. *Eucalyptus saligna,* a remnant exotic species was the most dominant in the entire forest (SIV=16.77%). It is worth noting that *Eucalyptus spp* are known to exudate allelopathic chemicals that inhibit undergrowth and also exhibit high coppicing characteristics and biomass input (KFS, 2009b). Thus they are able to maintain their presence and dominance in the forest. To the contrary, Mutuluni forest did not have exotic tree species. As a result an indigenous species; *Teclea nobilis* was the most dominant (SIV=9.88%) in the forest. Species Importance Value is an important ecological parameter worth determining in ecological research because it puts emphasis on the most dominant species in a forest and which also influence ecosystem functioning (Hitimana et al., 2004). Therefore, the dominance of *Eucalyptus saligna* in Museve forest poses a challenge to the forest given the fact that there is an increasing concern on the effect of the species on the hydrological cycle and biodiversity conservation (KFS, 2009b).

In addition, some exotic species may outcompete and substantially alter the gene pool of local plant materials thereby establishing their dominance and consequently influencing conservation significance of Museve forest (Obiri, 2011). Based on the SIV, only 10 species (< 20%) of the total species in both forests contributed to large proportion (SIV >50%) of the forests indicating that most trees were rare rather than common as it is with most tropical forests (Kacholi, 2014; Njunge & Mugo, 2011). Thus there is genuine need for increased conservation efforts in both forests to avoid a possibility of local species extinction. Kacholi (2014) and Omeja et al. (2004) shares the views that over utilization of rare species or those of social-economic value can result to their local extinction in a forest.

The two forests share same ecological zone and experience similar climatic conditions, thus it would be expected that tree species composition across the two forests would be similar but it was not the case. Introduced exotic species in Museve forest may have led to low similarity in species composition between the two forests. Also, human activities like grazing and footpaths were significantly high in Museve forest and there is likelihood of introducing other tree species from the surrounding farmlands into the forest. Livestock grazing in the forest and movement by people within the forest can introduce propagules of species not present in the forest and end up with increased difference in species composition (Omoro, 2012; Mutiso et al., 2013). This was exemplified by documentation of some fruit trees (i.e *Psidium guajava* and *mangifera indica*) which are usually agricultural fruit trees in the area (Appendix VIa). Rita et al., (2001) shares that human activities may influence succession and result to different species from primary vegetation.

Low species similarity across the two forests implies that, each forest has certain tree species unique from each other. Hence, the need to conserve and protect each forest from likely threats posed by documented human activities so as to minimise risks of local species extinction (Kacholi, 2014). The high species similarity Index (JI_A = 0.67) within Museve forest indicated that similar species where introduced throughout the forest. On the other hand similarity Index (JI_A = 0.48) for Mutuluni indicated low similarity in species composition. Hitimana (2000) and Mutiso et al. (2015) have also shown low species similarity within the same forest as it was the case for Mutuluni forest.

The results further indicated that tree cutting significantly reduced tree species richness and diversity in Museve forest while no significant impacts were evidenced in Mutuluni. This is attributed to high intensity of tree cutting exhibited in Museve forest compared to Mutuluni forest. For instance, the calculated Shannon-Wiener species diversity index; (1.46) for Museve forest reserve which documented high intensity of tree cutting was lower than 1.50 for Mutuluni forest. In 2004, Omeja et al. indicated that selective cutting of socio-economic species reduced their richness and diversity in Uganda. Studies Walters (2004) and Sapkota et al. (2010) have shown that tree cutting may affect regeneration process consequently species richness and diversity to a level of even compromising ecological integrity of a forest ecosystem.

Nevertheless, no significant difference was noted across the two forests despite tree cutting reducing species richness and diversity in Museve forest. This can also be attributed to human activities documented in the forests like tree cutting, grazing and footpaths. On some occasions tree cutting can lead to species richness through gap creations that may trigger high germination of viable soil seed bank or livestock and people movement in a forest facilitated entry of regeneration materials into the forest thus enriching species richness and diversity (Mutiso et al., 2011; Omoro, 2012). It was noted that Museve forest comprised of more species at seedlings and saplings stage compared to mature trees.

5.1.3 Anthropogenic Influences on Tree Density in Museve and Mutuluni Forest Reserves

Introduction of exotic tree species impacted both positively and negatively on tree density while tree cutting only impacted negatively. Results indicated that exotic species enhanced basal area density and stem density in Museve forest. On average, exotic species increased basal area and stem density by < -0.01units (m^2/ha and stems/ha respectively).

It is worth noting that some of the exotic species (*Eucalyptus spp* and *Cupressus lusitanica*) recorded in Museve forest attain high height and large diameter at maturity compared to most of the native species (Beenje, 1994). In particular, *Eucalyptus spp* are known for high efficiency in water use for biomass accumulation compared to most indigenous species (KFS, 2009b). As a result, they are likely to have very large estimated basal area compared to most of the indigenous species which are pole sized at maturity.

Thus, they resulted to increase in basal area in Museve forest, a reason why there was no significant differences across the two forests despite differences in human activities.

Notably the two forests recorded low basal area compared to other forests. As noted by Mbuvi et al. (2010) these are young secondary forests still in succession process. Many trees exhibited small dbh and very few tree individuals recorded large dbh. In addition, the forests are located in ASALs which are characterised of poor tree density and often trees reach maturity at pole size. As a result, they demonstrated low estimated basal area density.

The high stem density observed in Mutuluni forest despite that no positive impacts on stem density were documented can be attributed to post disturbance recovery process. The fact that Mutuluni has recovered naturally for long period of time compared to Museve forest has accumulated high stem density through self-seeding. According to Mutiso et al. (2011) recovery of natural forests usually take long period of time and the recovery process is depended on various natural and anthropogenic influences. Frequencies of human activities were also lower in Mutuluni forest compared to Museve and may have exerted less pressure on stem density in Mutuluni and as a result estimated stem density was high.

To the contrary, cutting of trees led to a significant reduction in basal area density and stem density in Mutuluni and/or Museve forest reserve. Results further indicated that tree cutting had bigger impacts on reduction of basal area and stem density in Museve forest compared to Mutuluni forest a fact that can be linked to high intensity of tree cutting in Museve forest.

It was estimated that tree cutting reduced both basal area and stem density by -0.01 units (m^2/ha and stems/ha) respectively in Museve forest and <-0.01 stems/ha only in Mutuluni forest.

Similar findings have been reported by Kacholi (2014) and Hitimana et al. (2004) who postulated that human activities like tree cutting and intensive fuelwood collections for firewood are major forest destructive activities to tree density. According to Hitimana et al. (2004), uncontrolled tree harvesting with no proper control reduces stem density of mother trees and consequently reduce recruitment potential in that forest. As a result, reduced tree cover and can led to degradation and affect ecosystem functioning (Kacholi, 2014).

Therefore, appropriate measures need to be put in place to control tree cutting especially in Museve forest to mitigate reduction of tree cover, likelihood of land degradation and resulting consequences on biodiversity conservation to adjacent communities. Studies Kiruki et al. (2016) and Kigomo (2003) have shown that tree cutting in ASALs has increasingly resulted to loss of land cover and increasingly amounting to their degradation. These outcomes threaten conservation of biodiversity and livelihoods in these areas.

Stem-density diameter distribution in both forests followed a reverse J-curve as expected of un-even aged mixed forests (Rouvinen & Kuuluvainen, 2004). This distribution was expected because un-even mixed aged or natural forests usually consist of many smaller individuals (regeneration) and relatively few large individuals (mature trees) exhibiting a descending diameter distribution (Hett & Loucks, 1976; Leak, 2002). This can be attributed to several factors like gene pool, age, size, competition, growth rate, herbivore and environmental heterogeneity (Weiner, 1990). Such distribution is important because it demonstrates continuous recruitment of trees into successive diameters size classes over time which is good for forest sustainability (Davis & Johnson, 1987; O'Hara, 1998).

However very many trees belonged to the lower diameter classes (i.e. below 17cm) and thus assumed to be young while very few trees belonged to the upper diameter classes and therefore assumed to be mature indicating that these young secondary forests (Davis & Johnson, 1987). As a result, the gradient was steep at lower diameter sizes and gradually decreased with increasing diameter sizes. It is worth noting that the data in both forests adequately fitted (high and significant regression coefficient of determination) the power function model used in describing diameter distribution in natural or near natural forests (Hett & Loucks, 1976; Appendix Xa & Xb). Studies Hitimana et al. (2004) and Mutiso et al. (2013) have also shown that it is possible for a forest experiencing anthropogenic disturbances to exhibit reverse J-curve diameter distribution. This was the case with Museve and Mutuluni forest although it is important to note that the degree depends on the extent of such disturbances (Leak, 2002).

Even though diameter distribution in both forests followed a reverse J-curve characteristic of structurally stable forests, the *q*-values in successive diameter classes in both forests deviated from the constant *q* factor expected of a structurally stable forest exhibiting a typical reverse J-curve (Davis & Johnson, 1987; Hett & Loucks, 1976). The *q* values were highly fluctuating and irregular in Museve compared to Mutuluni forest indicating that tree recruitment and regeneration was more unbalanced in Museve forest. This is also in line with the findings that the intensity of human activities and their impacts was high in Museve forest. An irregular and fluctuating *q* factor indicate irregular and absence or insufficient regeneration and recruitment while a regular and fluctuating *q* factor indicates good but discontinuous regeneration (Meyer, 1943; Poorter, Bongers, Rompaey & Klerk, 1996; O'Hara, 1998). Tree cutting, grazing and footpaths have potential to influence regeneration of tree hence their distribution in successive diameter classes (Kacholi, 2014; Hitimana et al., 2004; Mutiso et al., 2013). Thus urgent and appropriate protection and reforestation measures should be put in place and especially for Museve to promote tree density as well as enhancing their conservation value.

Nonetheless, it should be noted that diameter distribution modelling has its own limitations. For instance there may be no continuous regeneration in the natural habitats and misinterpretations can arise trying to find causes for deviation in diameter distribution from the expected trends. The deviation may be attributed to natural or human caused forest disturbances which may not be the case (Hitimana et al., 2004; Mutiso et al., 2013; Leak, 2002).

5.2 Conclusion

Five anthropogenic influences were documented in Museve and Mutuluni forest reserves. Cutting of trees, grazing and presence of forest footpaths were present in both forests while presence of exotic tree species and debarking were recorded in Museve and Mutuluni forest respectively. The occurrence of anthropogenic activities was higher in Museve than in Mutuluni.

Tree cutting and introduction of exotic tree species were the most human activities that impacted tree species richness and composition. Presence of grazing, foot paths and tree debarking did not have significant impacts. Introduction of exotic species in Museve forest reserve led to high species composition in Museve and low similarity in species composition between the two forests that share similar ecological and climatic zones. Species dominances were also affected in Museve since *Eucalyptus saligna* an exotic species was the most dominant species and whose effect in conservation and hydrological cycle is a concern exhibited highest dominance in Museve forest. Cutting of trees resulted to reduction on species richness and diversity in Museve but not significant effects were documented in Mutuluni forest. Thus human activities impacted both positively and negatively on tree species composition, richness and diversity.

Tree density was also significantly influenced by species introduction and tree cutting. Introduction of exotic tree species increased basal area density and stem density in Museve forest whereas cutting of trees led to decline in tree density in both forests and possibly affected diameter distribution in the two forests. Thus, anthropogenic activities may be detrimental to forest conservation, but they are can also be important for wood production.

5.3 Recommendations

1. There is need for proper monitoring of the documented human activities in both forests and appropriate regulatory measures taken for control and conservation of Museve and Mutuluni forests.
2. There is need for a well throughout management plan to ensure successful restoration of Museve forest for sustainable provision of ecosystem goods and services.
3. There is need for benchmarking management of Museve forest reserve with management of Mutuluni forest reserve to identify and promote those processes that enhance conservation.
4. Encourage adjacent communities to establish ecological suitable exotic species and /or domestication of high value indigenous species for wood production to easy the two forests form human pressure.
5. Initiate research on the consequences by dominance of *Eucalyptus saligna* in altering tree species composition and ecological processes within Museve forest
6. Historical review of the degradation and alteration of Museve and Mutuluni forest reserves
7. Need for close monitoring and detailed study of presence of footpaths and grazing in both forests in creating an edge effects and their influences on species composition
8. Need for a detailed study on regeneration and forest structure in Museve forest reserve

REFERENCES

Beentje, J. (1994). *Kenya trees, shrubs and lianas*. Nairobi: National museums of Kenya.

Davis, L. S. & Johnson, K. N. (EDs.). (1987). *Forest management*. (3rd ed.). New York: Mc Graw-Hill book. Company.

FAO, (2010b). *Guidelines on sustainable forest management in drylands of sub-Saharan Africa; Arid zone forests and forestry*. Working paper No. 1. Rome: Forest department, FAO.

FAO, (2010a.) *Global forest resource assessment report country report Kenya*. Rome: Forest department, FAO.

FAO, (2001). *State of the world's forests.* Rome: Forest department, FAO.

FAO, (1999). *The role of wood energy in Africa*. Working paper No.1. Rome: Forest department, FAO.

Gachathi, F. (2012). The other water towers. *Better Globe Forestry*, 114, 20-21, Retrieved 6 April, 2016, from www.betterglobeforestry.com/index.php

GoK, (2014). *National forest policy 2014.* Ministry of environment, water and natural resources in Nairobi: Government printer.

GoK, (2010). *The Constitution of Kenya, 2010*. Kenya, national council for law in Nairobi: Government printer.

GoK, (2007). *Kenya vision 2030*. Ministry of state for planning, national development and vision 2030 in Nairobi: Government printer.

GoK, (2005). *Forest Act 2005*. Laws of Kenya in Nairobi: Government printer.

GoK, (2002). *The Water Act 2002*. Laws of Kenya in Nairobi: Government printer.

Gonzalez, P. (2001). Desertification and a shift of forest species in the West African Sahel. *Climate Research*, 17, 217–228.

Harris, H. J., Milligan, M. S. & Fewless G.A. (1983). Diversity quantification and ecological evaluation in freshwater marshes. *Biological conservation,* 27(2)

Hett, J.M. & Loucks, O.L. (1976). Age structure models of balsam fir and eastern hemlock. *Journal of Ecology*, 64, 1029–1044.

Hitimana, J., Kiyiapi J. & L. Njunge, J.T. (2004). Forest structure characteristics in disturbed and undisturbed sites of Mt. Elgon moist lower montane forest, western Kenya. *Forest Ecology and Management*, 194, 269-291**.**

Hitimana, J. (2000). *Structure, composition and regeneration of Mt Elgon moist lower montane forest in Kenya with particular interest in Olea capensis subsp welwitschii*. (Unpublished Mphil thesis). Moi University, Eldoret.

IEA, (2006). *World energy outlook*. Paris: International energy agency organisation for economic co-operation and development.

Kacholi, D.S. (2014). Analysis of structure and diversity of the Kilengwe forest in the Morogoro region, Tanzania. *International Journal of Biodiversity*, 10, 1-8, Retrieved 23 June, 2014, from http://dx.doi.org/10.1155/2014/516840

Kent, M. & Corker, P. (1992). *Vegetation description and analysis*: *A practical approach*. Chichester: John Wiley and Sons.

Kenya Meteorological services, (2014). *Annual report for Kitui county meteorological service station.* (Unpublished report). Kenya meteorological services, Kitui.

KFS, (2014). *Monthly progress report for the month of December*. (Unpublished report). Kenya Forest Service, Kitui.

KFS, (2012). *The forester*. A quarterly magazine of the Kenya forest service. January-March. Karura in Narobi: Kenya forest service.

KFS, (2010). *Kenya forest service general order 2010-2011*. Nairobi: Kenya forest service.

KFS, (2009b). *A Guide to on-farm Eucalyptus growing in Kenya*. Nairobi: Kenya forest service

KFS, (2009a). *Support to forest sector reform in Kenya, miti mingi maisha bora programme report*. Nairobi: Government printer.

Kigomo, B.N. (2003). Forests and woodlands degradation in dryland Africa: A case for urgent global attention. A paper submitted to the XII world forestry congress in 2003 Quebec City Canada. Retrieved 3 December, 2015, from www.fao.org/docrep169-B3

Kiruki, H., Emma, H. Zanden, E., Malek, Z., & Verburg, P. (2016). Land cover change and woodland degradation in a charcoal producing semi-arid area in Kenya. *Wiley Online Library*, Retrieved 11 October, 2016, from wileyonlinelibrary.com

Kitui Agriculture Project, (1997). *Participatory rural appraisal*; Mulundi focal development area, Mulundi sub location, Kyangwithya East location, central division Kitui district. Kitui: Ministry of agriculture, livestock development and marketing.

KNBS, (2010). *The 2009 Kenya population and housing census.* Nairobi: Government printer.

Krebs, C. J. (1989). *Ecological methodology*. New York: University of British Columbia.

Leak, W. B. (2002). *Origin of sigmoid diameter distributions*. Newton Square: U.S. Department of agriculture and forest service.

Lou, J. (2006). Entropy and diversity. *Oikos*, 113(2), 363–375.

Lovett, J.C. (1996). Elevational and latitudinal changes in trees associations and diversity in the eastern arc mountains of Tanzania. *Journal of Tropical Ecology*, 12, 1-22.

Mahbud, U. A. (2008). *Underlying causes of deforestation and forest degradation in bangladesh*. Bangladesh: University of Dhaka.

Marimon, B. & Felfili, J.M. (1997). Structure of a monodominant forest of *Brosimum rubescens* Taub in Nova Xavantina-MT, Brazil; Proceedings of the 1996 international symposium on assessment and monitoring of forests in tropical dry regions with special reference to gallery forests (pp215-230). Brasilia: Brazil.

Mathu, W. (2011). *Forest plantations and woodlots in Kenya*. Nairobi: African forest forum.

Maundu & Botengnas, (2005). *Useful trees and shrubs of Kenya*. Nairobi: World agroforestry centre eastern and central Africa regional programme.

Mbuvi, M., Nahama, E. & Musyoki, J. M. (2010). *Socio-economic report for Kavonge and Museve hill-top forests.* (Unpublished consultancy report). Kalundu and Nzeeu rivers environmental conservation group, Kitui.

MENR, (2012). *County stakeholder's consultative workshop on the development of the national climate change response strategy's action plan.* Kenya, ministry of environment and natural resources in Nairobi: Government printer.

MENR, (2002). *Kitui district forestry master plan.* Kenya, ministry of environment and natural resources and Belgian technical cooperation in Nairobi: Government printer.

MENR, (1994). *Kenya forestry master plan*. Kenya, ministry of environment and natural resources in Nairobi: Government printer.

Meyer, H.A. (1943). Management without rotation. *Journal for Forest*, 41,126-132

MEA, (2005). *Ecosystems and human well-being: biodiversity synthesis.* Millennium ecosystem assessment, Washington, D.C.: World resources institute

Middleton, N. J. & Thomas, D. (1997). *World atlas of desertification*. UNEP, London: Arnold.

MoA, (1983). *Farm management handbook of Kenya.* Natural conditions and farm management information. East Kenya (Eastern and Coast provinces). Nairobi: Government printer.

Morris, R. J. (2010). *Anthropogenic impacts on tropical forest biodiversity*: *A network structure and ecosystem functioning perspective*. Retrieved May 4, 2015, from doi:10.1098/rstb.2010.0273.

Mullah, J. C. Totland, O. & Klanderud, K. (2011). Recovery of plant species richness and composition in an abandoned forest settlement area in Kenya. *A Journal of the Society for Ecological Restoration International*, 10, 1-13, Retrieved 20 January, 2015, from onlinelibrary.wiley.com/doi/10.1111/j.

Mutiso, F. M., Cheboiwo, K.J., Mware, J. M., Sang, F. & Tarus, G.K. (2015). Floristic composition, affinities and plant formations in tropical forests: A case study of Mau forests in Kenya. *International Journal of Agriculture and Forestry,* 5(2), 79-91.

Mutiso, F.M., Hitimana, J., Kiyiapi, J. L., Sang, F. K. & Eboh, E. (2013). Recovery of Kakamega tropical rainforest from anthropogenic disturbances. *Journal of Tropical Forest Science,* 25(4), 56–57.

Mutiso, F., Mugo, J. & Cheboiwo, J. (2011). Post-disturbance tree species regeneration and successional pathways in Mt Blakett and Kedowa forest blocks, Mau ecosystem, Kenya. *Research Journal of Environmental and Earth Sciences,* 3(6), 745-753.

Njunge, J. & Mugo J. (2011). Composition and succession of the woody flora of South Nandi forest Kenya. *Research Journal of Botany,* 6, 112-121.

Obiri, J. F. (2011). Invasive plant species and their disaster-effects in dry tropical forests and rangelands of Kenya and Tanzania. *Journal of Disaster Risk Studies*, (3)2.

Ochola, W., Sanginga, P.C. & Bekalo, I. (2010). *Managing natural resources for development in Africa: A resource book.* Nairobi: University of Nairobi press.

O'Hara K. L. (1998). Silviculture of structural diversity. A new look at multi-aged systems. *Journal of Forestry*, 96(7), 4-1.

Omeja, P., Obua J. & Cunningham, B. (2004). Regeneration, density and size class distribution of tree species used for drum making in central Uganda. *African Journal of Ecology,* 42, 129–136.

Omoro, L. M. (2012). *Tree species diversity, richness, and similarity between exotic and indigenous forests in the cloud forests of eastern arc mountains, Taita hills, Kenya*. Helsinki: University of Helsinki.

Omoro, L., Pellikka, P. & Rogers, C. (2010). Tree species diversity, richness, and similarity between exotic and indigenous forests in the cloud forests of eastern arc mountains, Taita hills, Kenya. *Journal of Forestry Research*, 21(3), 255-264.

Poorter, L., Bongers, F., Van Rompaey & Klerk, M. (1996). Regeneration of canopy tree species at five sites in West African moist forest. *Forest Ecology and Management*, 89, 101-113.

Rita, C.G., Mesquita, Kalan Ickes, Gislene, G. & Bruce, I. (2001). Alternative successional pathways in the Amazon basin. *Journal of Ecology*, 89, 528-537.

Rouvinen, S. & Kuuluvainen, T. (2005). Tree diameter distributions in natural and managed old *Pinus sylvestris*-dominated forests. *Forest Ecology and Management*, 208, 45-61.

Sanginga, P. Kamugisha, R. & Martin, A. (2010). Strengthening social capital for adaptive governance of natural resources: A participatory learning and action research for bylaws reforms in Uganda. *Society and Natural Resources,* 23, 695-710.

Sapkota, I. Tigabu, M. & Oden, P. (2010). Changes in tree species diversity and dominance across disturbance gradient in Napelese Sal (*Shorea robusta* Gaertn. f.) forests. *Journal of Forestry Research,* 21(1), 25-32.

Sarmiento, F. (1997). Landscape regeneration by seeds and successional pathways to restore fragile tropandean slopelands. *Montain Research and Development*, 17(3), 239-252.

Serna, C. (1986). *Degradation of forest resources.* Bangkok: Food and agriculture organization of the United Nations.

SoE, (2013). *Kitui county state of environment*. (Unpublished report). National environment management authority, Kitui.

Sovu, V. (2011). *Forest restoration on degraded lands in Laos*. Alnarp: Swedish university of agricultural sciences.

Spellerberg, I. F. (1991). *Monitoring ecological change*. Cambridge: Cambridge university press.

UNEP, (2007). *Global environment outlook*. Environment for development. Nairobi: united Nations environment programme.

UNEP, (2001). *Global biodiversity outlook.* Nairobi: united Nations environment programme.

UNEP, (1997). *National land degradation assessment and mapping in Kenya*. Nairobi: Kenya government, royal Netherlands government and United Nations environment programme.

UNEP, (1992). *Status of desertification and implementation of the United Nations plan of action to combat desertification*. New York: United Nations

UNFCCC, (1998). *Kyoto protocol to the United Nations framework convention on climate change*. New York: United Nations.

UNO, (2015). *The Millennium development goals report*. New York: United Nations.

UNO, (1992). *Agenda 21*. Rio de Janerio: United Nations.

Walters, B.B. (2004). Ecological effects of small-scale cutting of Philippine mangrove forests. *Forest Ecology and Management,* 206, 331–348. Retrieved 27 March, 2016, from www.elsevier.com/locate/foreco

Weiner, J. (1990). Asymmetric competition in plant populations. *Journal of Tropical Ecology*, 5, 360–364.

Westphal, C., Tremer, N., Oheimb, G., Hansen, J., Gadow, K. & Hardtle, W. (2006). Is the reverse J-shaped diameter distribution universally applicable in European Virgin beech forests? *Forest Ecology and Management,* 223, 75-85.

LIST OF APPENDICES

Appendix I: GPS Location Points in Degrees and Elevation for the Transects Corners; Museve and Mutuluni Forests

Museve T1								
Point								
S	1.32999°	1.32991°	1.32746°	1.32729°	1.32749°	1.32733°	1.32701°	1.32719°
E	38.07272°	38.07284°	38.07239°	38.07243°	38.07259°	38.07257°	38.07075°	38.07073°
Elevation	1276m	1280m	1277m	1274m	1286m	1285m	1238m	1238m
Museve T 2								
Point								
S	1.3308°	1.33035°	1.33289°	1.33303°	1.33301°	1.33281°	1.33308°	1.33291°
E	38.07277°	38.07293°	38.07317°	38.07315°	38.07296°	38.07304°	38.07126°	38.07121°
Elevation	1267m	1270m	1238m	1243m	1240m	1239m	1188m	1198m
Mutuluni T1								
Point								
S	1.47013°	1.47009°	1.46840°	1.46847°	1.46860°	1.46845°	1.46930°	1.46917°
E	38.11106°	38.11124°	38.10994°	38.11007°	38.10988°	38.10982°	38.10832°	38.10825°
Elevation	1150m	1155m	1017m	1032m	1034m	1028m	1002m	993m
Mutuluni T2								
Point								
S	1.47469°	1.47465°	1.47813°	1.47828°	1.47836°	1.47818°	1.47867°	1.47849°
E	38.11204°	38.11198°	38.11193°	38.11198°	38.11184°	38.11180°	38.11034°	38.11033°
Elevation	1208m	1187m	1139m	1144m	1129m	1128m	1049m	1049m

Appendix IIa: Records of Tree Density, Species Richness, Diversity Indices and Human Activities Recorded in Mutuluni Forest Reserve, Kitui County

Transect	Plot	BA/Ha	Stems /Ha	Diversity index	Effective No. of species	Species richness	Trees cut_ha	Presence of Tree Cutting	presence of Grazing	Human_livestock debarking	presence of Footpath	Presence of Exotic species	No. Exotic species/ha
1	1	6.16	925	2.23	9.30	13	0	0	0	0	0	0	0
1	2	2.19	425	0.22	1.25	2	100	1	0	0	0	0	0
1	3	3.79	550	1.04	2.82	3	0	0	0	0	0	0	0
1	4	7.43	575	1.07	2.91	5	0	0	0	0	0	0	0
1	5	4.49	600	1.63	5.11	7	0	0	0	0	0	0	0
1	6	6.58	450	1.98	7.25	9	0	0	0	0	0	0	0
1	7	3.87	525	1.23	3.44	4	125	1	0	0	0	0	0
1	8	2.70	475	2.88	17.78	6	0	0	0	0	0	0	0
1	9	5.51	600	1.89	6.61	9	75	1	0	0	1	0	0
1	10	5.82	725	2.04	7.69	10	0	0	0	0	0	0	0
1	11	2.81	375	1.29	3.62	5	125	1	1	0	0	0	0
1	12	4.65	575	2.03	7.60	9	50	1	0	0	0	0	0
1	13	2.23	500	1.95	7.01	8	100	1	0	0	0	0	0
1	14	2.32	375	1.55	4.72	6	125	1	1	0	0	0	0
1	15	4.22	475	1.56	4.74	7	100	1	0	0	0	0	0
1	16	5.38	650	2.04	7.67	10	75	1	0	0	0	0	0
1	17	6.58	1200	2.31	10.04	15	0	0	0	0	0	0	0
1	18	4.62	550	2.07	7.96	10	125	1	0	0	0	0	0
1	19	9.91	1225	2.38	10.82	13	0	0	0	0	0	0	0
1	20	7.50	1200	2.41	11.09	15	100	1	0	0	0	0	0
1	21	4.44	700	1.74	5.67	7	175	1	1	0	0	0	0
1	22	11.64	1050	1.91	6.77	10	0	0	0	0	0	0	0
1	23	7.74	1000	2.04	7.66	10	50	1	1	0	1	0	0
1	24	6.25	625	2.51	12.32	14	150	1	1	0	1	0	0
1	25	5.73	375	2.25	9.45	11	175	0	1	0	0	0	0
2	1	4.13	1025	0.26	1.30	2	75	1	1	0	1	0	0
2	2	3.73	575	0.64	1.90	4	0	0	0	0	0	0	0
2	3	4.78	550	1.37	3.95	6	100	1	0	0	0	0	0
2	4	1.95	325	1.09	2.98	4	125	1	0	1	1	0	0
2	5	1.51	350	1.81	6.11	7	0	0	0	0	0	0	0
2	6	1.23	200	1.21	3.36	4	175	1	0	1	1	0	0
2	7	3.56	1175	0.14	1.15	3	0	0	0	1	0	0	0
2	8	6.83	1100	0.32	1.38	4	0	0	0	0	0	0	0
2	9	19.02	1400	0.31	1.36	3	0	0	0	0	0	0	0
2	10	1.32	250	0.80	2.23	3	0	0	1	0	0	0	0
2	11	21.10	1550	0.48	1.62	4	0	0	0	0	0	0	0
2	12	2.02	550	0.65	1.91	3	0	0	0	0	0	0	0
2	13	31.61	625	1.15	3.16	5	0	0	0	0	0	0	0
2	14	7.62	400	1.47	4.36	6	0	0	0	0	0	0	0
2	15	2.33	475	1.47	4.35	5	125	1	0	1	1	0	0
2	16	5.82	475	1.72	5.60	7	0	0	0	1	0	0	0
2	17	8.14	575	1.35	3.87	5	50	1	0	0	0	0	0
2	18	7.57	550	1.68	5.37	6	0	0	0	0	0	0	0
2	19	5.20	400	2.10	8.17	9	100	1	0	0	1	0	0
2	20	3.83	425	2.01	7.44	8	0	1	0	0	0	0	0
2	21	2.33	250	1.89	6.60	7	100	1	1	0	1	0	0
2	22	0.37	100	0.56	1.75	2	225	1	0	1	1	0	0
2	23	9.79	900	1.65	5.21	7	25	1	0	0	0	0	0
2	24	7.11	550	1.65	5.20	6	75	1	0	0	1	0	0
2	25	4.80	475	1.71	5.52	6	175	1	1	0	1	0	0

Appendix IIb: Records of Tree Density, Species Richness, Diversity Indices and Human Activities Recorded in Museve Forest Reserve, Kitui County

Transect	Plot	Ba_ha	Stems /ha	Diversity Index	Effective No. of Species	Species richness	Trees cut/ha	Presence of tree cutting	presence of Grazing	Human/livestock debarking	Presence of Footpaths	Presence of Exotic species	No. Exotic species/ha
1	1	27.25	975	2.18	8.88	12	0	0	1	0	0	1	1025
1	2	12.29	875	2.07	7.94	10	25	1	0	0	1	1	550
1	3	7.78	400	2.10	8.14	10	50	2	0	0	1	1	75
1	4	6.33	350	1.87	6.50	7	50	2	0	0	1	1	75
1	5	4.55	525	1.90	6.67	9	100	4	1	0	1	1	50
1	6	13.98	575	1.71	5.54	7	25	1	1	0	1	1	125
1	7	8.97	825	2.30	10.01	13	25	1	1	0	1	1	25
1	8	2.55	175	1.15	3.17	4	175	7	0	0	1	0	0
1	9	3.93	350	1.06	2.89	3	125	5	1	0	1	1	75
1	10	7.64	375	2.30	10.01	11	50	2	0	0	0	1	75
1	11	10.28	600	1.76	5.79	7	0	0	0	0	0	1	100
1	12	4.68	400	1.89	6.62	8	100	4	0	0	1	1	75
1	13	2.17	300	1.98	7.24	8	150	6	0	0	1	1	75
1	14	1.27	250	0.00	1.00	6	175	7	0	0	1	1	50
1	15	2.61	400	1.93	6.87	8	125	5	1	0	1	1	100
1	16	5.76	275	0.99	2.70	3	100	4	0	0	0	1	150
1	17	2.20	450	2.27	9.72	12	75	3	0	0	0	1	125
1	18	2.05	475	1.65	5.20	7	25	1	1	0	0	1	225
1	19	1.38	275	1.54	4.67	6	75	3	1	0	0	1	175
1	20	0.41	125	1.61	5.00	5	200	8	1	0	1	1	25
1	21	1.19	175	1.55	4.71	5	125	5	1	0	0	0	75
1	22	0.78	225	1.74	5.67	6	225	9	1	0	1	0	0
1	23	2.14	225	1.46	4.33	5	75	3	1	0	0	0	0
1	24	4.37	125	0.67	1.96	2	150	6	0	0	0	1	100
1	25	3.95	100	1.04	2.83	3	225	9	1	0	1	1	75
2	1	1.46	425	2.12	8.33	10	125	5	1	0	1	1	200
2	2	4.21	275	2.15	8.55	9	50	2	1	0	1	1	25
2	3	8.55	250	1.50	4.50	5	25	1	0	0	0	1	100
2	4	2.97	400	2.13	8.44	10	75	3	0	0	0	1	125
2	5	1.70	300	2.02	7.56	9	200	8	1	0	1	1	100
2	6	4.03	300	1.82	6.17	7	100	4	0	0	0	1	50
2	7	7.73	475	2.06	7.84	10	0	0	1	0	0	1	225
2	8	4.84	450	2.09	8.09	9	150	6	0	0	1	1	75
2	9	15.46	775	2.16	8.64	11	50	2	0	0	0	1	150
2	10	5.82	200	0.97	2.65	3	200	8	1	0	1	1	100
2	11	2.08	425	2.07	7.91	9	225	9	1	0	1	1	100
2	12	2.50	75	0.00	1.00	1	325	13	1	0	1	1	400
2	13	2.31	175	0.41	1.51	2	225	9	1	0	1	1	350
2	14	1.91	75	1.10	3.00	3	225	9	1	0	0	1	50
2	15	24.36	725	1.19	3.28	5	25	1	0	0	0	1	850
2	16	1.77	150	0.45	1.57	2	275	11	1	0	1	1	25
2	17	7.50	175	0.60	1.82	2	275	11	1	0	1	1	225
2	18	8.44	100	0.00	1.00	1	225	9	1	0	1	1	125
2	19	4.31	150	1.33	3.78	4	225	9	1	0	1	1	125
2	20	13.77	875	1.68	5.35	8	25	1	1	0	0	1	500
2	21	9.27	150	1.01	2.75	3	150	6	1	0	0	1	225
2	22	0.05	25	0.00	1.00	1	300	12	1	0	1	1	75
2	23	6.60	300	1.36	3.89	5	125	5	1	0	0	1	125
2	24	2.86	150	1.33	3.78	4	275	11	1	0	1	1	125
2	25	6.21	150	1.01	2.75	3	175	7	1	0	1	1	75

Appendix III: Comparison of Frequencies of Human Activities in Museve and Mutuluni Forests

Presence or absence of human activity	Forest	
	Museve forest	Mutuluni forest
	Count	Count
0	3_a	23_b
1	47_a	27_b
0	18_a	40_b
1	32_a	10_b
0	50^2	44_a
1	0^2	6_a
0	20_a	38_b
1	30_a	12_b
0	3_a	50^2
1	47_a	0^2

Appendix IV: Tests of Normality for the Trees Cut/Ha, Species Diversity, Richness and Tree Density in Museve and Mutuluni Forests.

Descriptives

Museve forest			**Mutuluni forest**			
	Statistic	Std. Error			Statistic	Std. Error
Mean	130.00	12.637		Mean	60.00	9.258
Std. Deviation	89.357			Std. Deviation	65.465	
Mean	6.26	.467		Mean	6.88	.479
Std. Deviation	3.300			Std. Deviation	3.391	
Mean	1.46	.100	**Diversity**	Mean	1.50	.108
Std. Deviation	.706			Std. Deviation	.763	
Mean	347.50	32.649		Mean	639.50	45.821
Std. Deviation	230.862			Std. Deviation	324.001	
Mean	5.80	.778		Mean	6.08	.765
Std. Deviation	5.500			Std. Deviation	5.409	

Tests of Normality

	Kolmogorov-Smirnov		
	Statistic	df	Sig.
Trees cut_ha	.115	50	.098
Species richness	.118	50	.077
Diversity	.358	50	.000
Stems_ha	.142	50	.014
Ba_ha	.168	50	.001
Trees cut_ha	.280	50	.000
Species richness	.146	50	.010
Diversity	.324	50	.000
Stems_ha	.218	50	.000
Ba_ha	.241	50	.000

Appendix V: Tests of Distributions of Trees Cut/Ha Within and Between Museve and Mutuluni Forests

a. Test between Museve and Mutuluni Forests

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Trees cut_ha is the same across categories of Forest.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Tests within Museve Forest

t-Test: Two-Sample Assuming Equal Variances

Museve forest	*Transect 1*	*Transect 2*
Mean	98.000	162
Variance	4631.250	9537.5
Observations	25.000	25
Pooled Variance	7084.375	
Hypothesized Mean Difference	0.000	
Df	48.000	
t Stat	-2.688	
P(T<=t) one-tail	0.005	
t Critical one-tail	1.677	
P(T<=t) two-tail	0.010	
t Critical two-tail	2.011	

c. Tests within Mutuluni Forest

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Trees cut_ha is the same across categories of Transect.	Independent-Samples Mann-Whitney U Test	.418	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Appendix VIa: List of Trees in Museve Forest Reserve, Kitui County

	FAMILY NAME	SPECIES NAME	MT	SA	SE
1	Mimosaceae	*Acacia hockii*	*	*	*
2	Mimosaceae	*Acacia nilotica*	*	*	*
3	Mimosaceae	*Acacia polyacantha*	*	*	*
4	Mimosaceae	*Acacia Senegal*			*
5	Mimosaceae	*Acacia seyal*	*	*	*
6	Apocynaceae	*Acokanthera oppositifolia*	*	*	*
7	Fabaceae	*Acrocarpus flaxinifolius*		*	*
8	Mimosaceae	*Albizia anthelmintica*			*
9	Annonaceae	*Annona senegalensis*			*
10	Euphorbiaceae	*Antidesma venosum*	*	*	*
11	Malvaceae	*Azanza gackeana*	*	*	*
12	Euphorbiaceae	*Bridelia taitensis*	*	*	*
13	Rutaceae	*Calodendrum capense*	*	*	
14	Apocynaceae	*Carissa spinarum*		*	*
15	Caesalpiniaceae	*Cassia abbreviate*	*		
16	Combretaceae	*Combretum collinum*	*	*	*
17	Combretaceae	*Combretum molle*	*	*	*
18	Combretaceae	*Commelinabenghalensis*		*	
19	Burseraceae	*Commiphora Africana*	*	*	*
20	Burseraceae	*Commiphora habesinica*		*	*
21	Euphorbiaceae	*Croton megalocarpus*	*	*	*
22	Cupressaceae	*Cupressus lusitanica*	*	*	*
23	Papilionaceae	*Dalbergia melanoxylon*	*	*	*
24	Mimosaceae	*Dichrostachys cinerea*	*	*	*
25	Ebenaceae	*Diospyros mespiliformis*	*	*	*
26	Papilionaceae	*Erythrina abyssinica*	*	*	
27	Myrtaceae	*Eucalyptus grandis*	*		
28	Myrtaceae	*Eucalyptus paniculata*	*	*	
29	Myrtaceae	*Eucalyptus saligna*	*	*	*
30	Ebenaceae	*Euclea divinorum*	*	*	*
31	Euphorbiaceae	*Euphorbia candelabrum*	*		*
32	Rutaceae	*Fagara chelybeum*		*	*
33	Moraceae	*Ficus sycomorus*		*	
34	Moraceae	*Ficus thonningii*			*
35	Tiliaceae	*Grewia bicolor*	*	*	*
36	Proteaceae	*Grevillea robusta*	*	*	*
37	Umbelliferae	*Heteromorpha trifoliate*		*	
38	Anacardiaceae	*Lannea schimperi*			*
39	Anacardiaceae	*Lannea schweinfurthii*	*		
40	Anacardiaceae	*Lannea triphylla*	*	*	
41	Capparaceae	*Maerua angustifolia*	*	*	*
42	Anacardiaceae	*Mangifera indica*		*	*
43	Bignoniaceae	*Markhamia lutea*			*
44	Celastraceae	*Mystroxylon aethiopicum*		*	*
45	Ochnaceae	*Ochna holstii*			*
46	Ochnaceae	*Ochna ovate*	*	*	*
47	Papilionaceae	*Ormocarpum kirkii*	*	*	*
48	Papilionaceae	*Ormocarpum trachycarpum*	*	*	
49	Santalaceae	*Osyris lanceolate*	*	*	*
50	Rubiaceae	*Pavetta gardeniifolia*	*	*	*
51	Caesalpiniaceae	*Piliostigma thonningii*		*	*
52	Salicaceae	*Populus ilicifoilia*	*	*	*
53	Myrtaceae	*Psidium guajava*	*	*	*
54	Anacardiaceae	*Rhus natalensis*	*	*	*
55	Anacardiaceae	*Rhus vulgaris*	*	*	*
56	Anacardiaceae	*Sclerocarya birrea*	*	*	
57	Caesalpiniaceae	*Senna siamea*	*	*	*
58	Caesalpiniaceae	*Senna singueana*	*	*	*
59	Caesalpiniaceae	*Senna spectabilis*	*	*	*
60	Apiaceae	*Sterganoteenia oraliacea*	*	*	*
61	Loganiaceae	*Strychnos decussata*		*	*
62	Loganiaceae	*Strychnos spinose*	*	*	
63	Euphorbiaceae	*Synadenium compactum*	*	*	
64	Combretaceae	*Tamarindus indica*			*
65	Combretaceae	*Terminalia brownie*	*	*	*
66	Combretaceae	*Terminalia spinose*	*	*	*
67	Rubiaceae	*Vangueria madagascariensis*		*	
68	Verbenaceae	*Vitex payos*	*	*	*
			48	***55***	***54***

MT *- mature trees* ***SA*** *- saplings* ***SE*** *- seedlings*

Appendix VIb: List of Trees in Mutuluni Forest Reserve, Kitui County

	FAMILY NAME	SPECIES NAME	MT	SA	SE
1	Mimosaceae	*Acacia nilotica*	*		
2	Mimosaceae	*Acacia polyacantha*	*		
3	Mimosaceae	*Acacia seyal*	*		
4	Mimosaceae	*Albizia anthelmintica*	*		
5	Mimosaceae	*Albizia gummifera*	*		
6	Malvaceae	*Azanza gackeana*	*	*	*
7	Melianthaceae	*Bersama abyssinica*	*	*	*
8	Capparaceae	*Boscia angustifolia*		*	
9	Euphorbiaceae	*Bridelia taitensis*	*	*	*
10	Rutaceae	*Calodendrum capense*	*	*	*
11	Apocynaceae	*Carissa spinarum*	*	*	
12	Rhizophoraceae	*Cassipourea celastroides*	*	*	
13	Combretaceae	*Combretum collinum*	*	*	*
14	Combretaceae	*Combretum molle*	*	*	*
15	Burseraceae	*Commiphora Africana*	*	*	*
16	Burseraceae	*Commiphora eminii*	*		*
17	Burseraceae	*Commiphora habesinica*	*	*	
18	Burseraceae	*Commiphora spp*	*		
19	Boraginaceae	*Cordia monoica*	*	*	*
20	Euphorbiaceae	*Croton megalocarpus*	*	*	*
21	Papilionaceae	*Dalbergia melanoxylon*	*	*	*
22	Mimosaceae	*Dichrostachys cinerea*	*	*	
23	Ebenaceae	*Diospyros mespiliformis*	*	*	*
24	Salvadoraceae	*Dobera glabra*	*		
25	Sterculiaceae	*Dombeya burgessiae*	*	*	*
26	Ebenaceae	*Euclea divinorum*	*	*	*
27	Euphorbiaceae	*Euphorbia tirucalli*		*	
28	Moraceae	*Ficus glumosa*	*		
29	Moraceae	*Ficus thonningii*	*	*	*
30	Flacourtiaceae	*Flacourtia indica*	*	*	
31	Tiliaceae	*Grewia bicolor*	*	*	*
32	Rutaceae	*Harrisonia abyssinica*	*	*	
33	Anacardiaceae	*Lannea schweinfurthii*	*	*	*
34	Anacardiaceae	*Lannea triphylla*	*	*	*
35	Fabaceae	*Lonchocarpus eriocalyx*	*	*	*
36	Celastraceae	*Maytenus obscura*	*	*	*
37	Celastraceae	*Mystroxylon aethiopicum*	*	*	
38	Ochnaceae	*Ochna ovate*	*	*	*
39	Papilionaceae	*Ormocarpum kirkii*	*	*	
40	Santalaceae	*Osyris lanceolate*			*
41	Sapindaceae	*Pappea Capensis*	*	*	
42	Rubiaceae	*Pavetta gardeniifolia*	*	*	*
43	Salicaceae	*Populus ilicifoilia*	*	*	*
44	Anacardiaceae	*Rhus natalensis*	*	*	
45	Anacardiaceae	*Rhus vulgaris*	*	*	*
46	Anacardiaceae	*Sclerocarya birrea*	*		
47	Apiaceae	*Sterganoteenia oraliacea*	*	*	
48	Loganiaceae	*Strychnos henningsii*	*	*	*
49	Loganiaceae	*Strychnos madagascariensis*			*
50	Euphorbiaceae	*Synadenium compactum*	*	*	*
51	Caesalpiniaceae	*Tamarindus indica*	*		
52	Rutaceae	*Teclea nobilis*	*	*	*
53	Combretaceae	*Terminalia brownie*	*	*	*
54	Combretaceae	*Terminalia spinose*		*	
55	Rubiaceae	*Vangueria madagascariensis*	*	*	*
56	Rutaceae	*Zanthoxylum chalybeum*	*		
57	Rhamnaceae	*Ziziphus abyssinica*	*	*	*
	Totals		**52**	**43**	**31**

MT*-mature trees* ***SA****-saplings* ***SE****-seedlings*

Appendix VII: List of Tree Species Present Only in Museve and Mutuluni Forest and Those Common in Both Forests

	Tree species common in Museve and Mutuluni forests (a)	Tree species in Museve only (b)	Tree species in Mutuluni only (c)
1	*Acacia nilotica*	*Acacia hockii*	*Albizia anthelmintica*
2	*Acacia polyacantha*	*Acokanthera oppositifolia*	*Albizia gummifera*
3	*Acacia seyal*	*Antidesma venosum*	*Bersama abyssinica*
4	*Azanza gackeana*	*Cassia abbreviate*	*Carissa spinarum*
5	*Bridelia taitensis*	*Cupressus lusitanica*	*Cassipourea celastroides*
6	*Calodendrum capense*	*Erythrina abyssinica*	*Commiphora eminii*
7	*Combretum collinum*	*Eucalyptus grandis*	*Commiphora habesinica*
8	*Combretum molle*	*Eucalyptus paniculata*	*Commiphora spp*
9	*Commiphora africana*	*Eucalyptus saligna*	*Cordia monoica*
10	*Croton megalocarpus*	*Euphorbia candelabrum*	*Dobera glabra*
11	*Dalbergia melanoxylon*	*Grevillea robusta*	*Dombeya burgessiae*
12	*Dichrostachys cinerea*	*Maerua angustifolia*	*Ficus glumosa*
13	*Diospyros mespiliformis*	*Ormocarpum trachycarpum*	*Ficus thonningii*
14	*Euclea divinorum*	*Osyris lanceolate*	*Flacourtia indica*
15	*Grewia bicolor*	*Psidium guajava*	*Harrisonia abyssinica*
16	*Lannea schweinfurthii*	*Senna siamea*	*Lonchocarpus eriocalyx*
17	*Lannea triphylla*	*Senna singueana*	*Maytenus obscura*
18	*Ochna ovate*	*Senna spectabilis*	*Mystroxylon aethiopicum*
19	*Ormocarpum kirkii*	*Strychnos spinose*	*Pappea capensis*
20	*Pavetta gardeniifolia*	*Terminalia spinose*	*Strychnos henningsii*
21	*Populus ilicifoilia*	*Vitex payos*	*Tamarindus indica*
22	*Rhus natalensis*		*Teclea nobilis*
23	*Rhus vulgaris*		*Vangueria madagascariensis*
24	*Sclerocarya birrea*		*Zanthoxylum chalybeum*
25	*Sterganoteenia oraliacea*		*Ziziphus abyssinica*
26	*Synadenium compactum*		
27	*Terminalia brownie*		
Totals	**27**	**21**	**25**

Appendix VIIIa: Importance Values for Tree Species ≥ 5cm Diameter in Museve Forest

	Species name	Species Relative density (%)	Species Relative Frequency (%)	Species Relative dominance	Species importance value	Species importance value %
1	*Eucalyptus saligna*	20.58	82	27.58	130.16	16.77
2	*Azanza gackeana*	7.34	48	1.36	56.70	7.31
3	*Combretum molle*	5.32	34	1.67	41.00	5.28
4	*Euclea divinorum*	5.47	32	0.78	38.25	4.93
5	*Antidesma venosum*	5.32	26	1.14	32.46	4.18
6	*Dichrostachys cinerea*	3.74	26	0.57	30.31	3.91
7	*Erythrina abyssinica*	2.59	22	0.61	25.20	3.25
8	*Commiphora africana*	2.01	22	0.17	24.18	3.12
9	*Terminalia brownie*	1.87	16	0.83	18.70	2.41
10	*Calodendrum capense*	1.58	16	0.65	18.23	2.35
11	*Acacia nilotica*	1.87	16	0.19	18.06	2.33
12	*Acacia seyal*	1.44	16	0.56	18.00	2.32
13	*Rhus vulgaris*	1.73	16	0.20	17.92	2.31
14	*Eucalyptus paniculata*	3.31	10	3.80	17.11	2.20
15	*Diospyros mespiliformis*	2.16	14	0.89	17.05	2.20
16	*Bridelia taitensis*	2.01	14	0.25	16.27	2.10
17	*Sclerocarya birrea*	1.15	14	0.48	15.63	2.01
18	*Acokanthera oppositifolia*	1.44	14	0.17	15.61	2.01
19	*Psidium guajava*	1.15	14	0.08	15.24	1.96
20	*Vitex payos*	2.45	12	0.67	15.12	1.95
21	*Senna singueana*	1.01	12	0.11	13.12	1.69
22	*Eucalyptus grandis*	1.44	10	1.17	12.61	1.63
23	*Maerua angustifolia*	1.87	10	0.47	12.34	1.59
24	*Rhus natalensis*	1.58	10	0.17	11.76	1.51
25	*Acacia hockii*	1.29	10	0.28	11.58	1.49
26	*Grevillea robusta*	2.73	8	0.81	11.54	1.49
27	*Ochna ovate*	1.15	10	0.14	11.29	1.45
28	*Senna siamea*	3.45	6	1.04	10.50	1.35
29	*Terminalia spinose*	0.86	8	0.19	9.06	1.17
30	*Sterganoteenia oraliacea*	0.58	8	0.08	8.66	1.12
31	*Senna spectabilis*	1.73	6	0.70	8.43	1.09
32	*Strychnos spinose*	1.87	6	0.23	8.11	1.04
33	*Dalbergia melanoxylon*	0.58	6	0.08	6.66	0.86
34	*Grewia bicolor*	0.43	6	0.04	6.47	0.83
35	*Cupressus lusitanica*	0.43	4	0.50	4.93	0.64
36	*Pavetta gardeniifolia*	0.58	4	0.22	4.80	0.62
37	*Combretum collinum*	0.58	4	0.22	4.79	0.62
38	*Ormocarpum kirkii*	0.72	4	0.06	4.78	0.62
39	*Lannea triphylla*	0.29	4	0.20	4.49	0.58
40	*Populus ilicifoilia*	0.43	4	0.05	4.49	0.58
41	*Osyris lanceolate*	0.29	4	0.02	4.31	0.56
42	*Croton megalocarpus*	0.29	4	0.02	4.30	0.55
43	*Ormocarpum trachycarpum*	0.14	4	0.01	4.15	0.54
44	*Synadenium compactum*	0.58	2	0.29	2.86	0.37
45	*Lannea schweinfurthii*	0.14	2	0.13	2.28	0.29
46	*Euphorbia candelabrum*	0.14	2	0.07	2.21	0.28
47	*Cassia abbreviata*	0.14	2	0.01	2.16	0.28
48	*Acacia polyacantha*	0.14	2	0.01	2.15	0.28

Appendix VIIIb: Importance Values for Tree Species ≥ 5cm Diameter in Mutuluni Forest

	Species Name	Species Relative density (%)	Species Relative Frequency (%)	Species Relative dominance	Species importance value	Species importance value %
1	*Teclea nobilis*	27.83	48	7.76	83.60	9.88
2	*Bersama abyssinica*	9.54	62	3.73	75.27	8.90
3	*Croton megalocarpus*	5.79	44	4.53	54.32	6.42
4	*Grewia bicolor*	3.75	46	1.14	50.89	6.02
5	*Dombeya burgessiae*	5.16	44	1.20	50.36	5.95
6	*Terminalia brownie*	4.07	32	4.23	40.30	4.76
7	*Diospyros mespiliformis*	3.28	34	2.46	39.74	4.70
8	*Bridelia taitensis*	3.60	34	1.00	38.60	4.56
9	*Combretum collinum*	3.60	26	1.77	31.37	3.71
10	*Euclea divinorum*	2.35	28	0.77	31.11	3.68
11	*Populus ilicifoilia*	4.53	20	1.72	26.26	3.10
12	*Ficus thonningii*	3.05	16	5.62	24.67	2.92
13	*Combretum molle*	2.03	18	1.16	21.19	2.50
14	*Azanza gackeana*	1.56	18	0.72	20.28	2.40
15	*Commiphora africana*	1.25	18	0.52	19.77	2.34
16	*Sterganoteenia oraliacea*	1.33	16	0.51	17.84	2.11
17	*Pavetta gardeniifolia*	0.94	16	0.48	17.42	2.06
18	*Strychnos henningsii*	0.08	16	0.01	16.09	1.90
19	*Lannea schweinfurthii*	2.74	10	1.86	14.60	1.73
20	*Ziziphus abyssinica*	1.02	12	0.46	13.48	1.59
21	*Sclerocarya birrea*	0.86	10	0.84	11.70	1.38
22	*Pappea capensis*	1.25	10	0.35	11.60	1.37
23	*Ochna ovate*	1.02	10	0.15	11.17	1.32
24	*Cordia monoica*	0.55	10	0.10	10.65	1.26
25	*Flacourtia indica*	0.63	8	0.11	8.73	1.03
26	*Synadenium compactum*	0.31	8	0.04	8.36	0.99
27	*Cassipourea celastroides*	1.17	6	0.33	7.51	0.89
28	*Maytenus obscura*	0.78	6	0.09	6.87	0.81
29	*Tamarindus indica*	0.39	6	0.39	6.78	0.80
30	*Lonchocarpus eriocalyx*	0.23	6	0.06	6.30	0.74
31	*Albizia anthelmintica*	1.02	4	0.46	5.48	0.65
32	*Albizia gummifera*	0.55	4	0.68	5.23	0.62
33	*Ficus glumosa*	0.47	2	2.68	5.15	0.61
34	*Commiphora spp*	0.47	4	0.63	5.10	0.60
35	*Acacia polyacantha*	0.23	4	0.41	4.64	0.55
36	*Mystroxylon aethiopicum*	0.39	4	0.21	4.60	0.54
37	*Dalbergia melanoxylon*	0.23	4	0.05	4.28	0.51
38	*Dichrostachys cinerea*	0.16	4	0.02	4.18	0.49
39	*Carissa spinarum*	0.55	2	0.28	2.82	0.33
40	*Lannea triphylla*	0.23	2	0.07	2.30	0.27
41	*Dobera glabra*	0.08	2	0.11	2.18	0.26
42	*Rhus natalensis*	0.16	2	0.02	2.18	0.26
43	*Commiphora habesinica*	0.08	2	0.08	2.16	0.26
44	*Zanthoxylum chalybeum*	0.08	2	0.08	2.16	0.26
45	*Acacia nilotica*	0.08	2	0.03	2.11	0.25
46	*Commiphora eminii*	0.08	2	0.02	2.10	0.25
47	*Acacia seyal*	0.08	2	0.02	2.09	0.25
48	*Rhus vulgaris*	0.08	2	0.01	2.09	0.25
49	*Calodendrum capense*	0.08	2	0.01	2.09	0.25
50	*Ormocarpum kirkii*	0.08	2	0.01	2.09	0.25
51	*Harrisonia abyssinica*	0.08	2	0.01	2.09	0.25
52	*Vangueria madagascariensis*	0.08	2	0.01	2.09	0.25

Appendix IX: Tests of Distributions of Trees Richness and Diversity Within and Between Museve and Mutuluni Forests

a. Test between Museve and Mutuluni Forests

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Diversity is the same across categories of Forest.	Independent-Samples Mann-Whitney U Test	.823	Retain the null hypothesis.
2	The distribution of Species richness is the same across categories of Forest.	Independent-Samples Mann-Whitney U Test	.467	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Comparing Species Richness and Diversity within Museve Forest

Species Diversity within Museve Forest

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Diversity is the same across categories of Transect.	Independent-Samples Mann-Whitney U Test	.031	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Species Richness within Museve Forest

t-Test: Two-Sample Assuming Equal Variances

Museve forest: Species richness	*Transect 1*	*Transect 2*
Mean	7.08	5.44
Variance	9.33	11.51
Observations	25.00	25.00
Pooled Variance	10.42	
Hypothesized Mean Difference	0.00	
Df	48.00	
t Stat	1.80	
P(T<=t) one-tail	0.04	
t Critical one-tail	1.68	
P(T<=t) two-tail	0.08	
t Critical two-tail	2.01	

Appendix IX Continued: Tests of Distributions of Trees Richness and Diversity Within and Between Museve and Mutuluni Forests

c. Comparing Species Richness and Diversity Within Mutuluni Forest

Species Diversity within Mutuluni Forest

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Diversity is the same across categories of Transect.	Independent-Samples Mann-Whitney U Test	.001	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Species Richness within Mutuluni Forest

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Species richness is the same across categories of Transect.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Appendix X: Tests of Distributions of Basal Area and Stem Density within and between Museve and Mutuluni Forests

a. Test between Museve and Mutuluni Forests

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Ba_ha is the same across categories of Forest.	Independent-Samples Mann-Whitney U Test	.456	Retain the null hypothesis.
2	The distribution of Stems_ha is the same across categories of Forest.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

b. Tests within Museve Forest

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Ba_ha is the same across categories of Transect.	Independent-Samples Mann-Whitney U Test	.710	Retain the null hypothesis.
2	The distribution of Stems_ha is the same across categories of Transect.	Independent-Samples Mann-Whitney U Test	.165	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

c. Tests within Mutuluni Forest

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Ba_ha is the same across categories of Transect.	Independent-Samples Mann-Whitney U Test	.572	Retain the null hypothesis.
2	The distribution of Stems_ha is the same across categories of Transect.	Independent-Samples Mann-Whitney U Test	.107	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Appendix XIa: Regression Models for Diameter Size Distribution in Museve Forest

MUSEVE FOREST

Regression Statistics	
Multiple R	0.961632302
R Square	0.924736685
Adjusted R Square	0.918947199
Standard Error	0.586991128
Observations	15

ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	55.03528	55.03528	159.7269	1.11964E-08			
Residual	13	4.479262	0.344559					
Total	14	59.51454						

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	9.47342	0.600126	15.7857	7.34E-10	8.176929649	10.76992	8.17693	10.76992
Ln mid	-2.31788	0.183402	-12.638	1.12E-08	-2.714104573	-1.92167	-2.7141	-1.92167

Rate=

0.0985

Appendix XIb: Regression Models for Diameter Size Distribution in Mutuluni Forest

$R^2 = 0.97$
Rate=0.05157

Mutuluni forest

Regression Statistics	
Multiple R	0.9862565 94
R Square	0.9727020 69
Adjusted R Square	0.9706022 28
Standard Error	0.4408933 51
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	90.0452	90.0452	463.2266	1.5E-11			
Residual	13	2.52703	0.194387					
Total	14	92.57223						

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	11.312926 03	0.450759	25.09749	2.13E-12	10.33912	12.2 8673	10.339 12	12.2867 3
Ln mid	- 2.9648473 94	0.137754	-21.5227	1.5E-11	-3.26245	- 2.66 725	- 3.2624 5	-2.66725

Rate=0.051568338