EFFECTS OF HABITAT CHANGE ON FOOD AVAILABILITY AND PREFERENCE BY BLACK AND WHITE COLOBUS MONKEY *(C. angolensis)*, AT KIBONGE FOREST ELGEYO MARAKWET COUNTY, KENYA.

BY

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DECLARATION

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Declaration by supervisors

This thesis has been submitted with our approval as University supervisors.

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DEDICATION

I dedicate this work to my husband Mr. Charles Mutai and our children Evans Korir, Daisy Mutai, Judith Mutai, John Kiplagat, my beloved grandson Aron Kigen and to my friends Mr. Josphat Kosgei and Ms. Emmy Kerich for their continous emotional support throughout my study period.

ABSTRACT

Forest disturbances by anthropogenic activities present challenges to animals and lead to feeding behavioural changes. Change of diet may be an important strategy to adjust to forest degradation. This study examines how changes in habitat, impact on feeding behaviour and food preference of folivorous *Colobus angolensis*, in Kibonge forest in Elgeyo- Marakwet County, Kenya. Data were collected between, July 2013 and July 2014. Observations were made on feeding behavior of two groups of *C. angolensis* in two regions of Kibonge forest (Mwen and Segen). Food types and plant species used as food and time taken in feeding were recorded. Amount of canopy cover and nature of disturbance were established using Global-information system (GIS) maps of between years 1976- 2016 and ground field work on 87 sampled vegetation plots each measuring, 20m x 10m. Leaf parts eaten by *C. angolensis*, were collected, identified and analyzed for nutrient content in the laboratory. Data obtained were analyzed using SPSS, xLSTAT and SAS-92 software's for comparing means. Chi square tests were carried out to establish variations between regions and species. Pearson correlation showed a significant reduction of Kibonge forest size between the years 1976-2016 (n=7, r=0.0956, p< 0.001). More tree species were concentrated on altitude 2400m (χ^2=610.95, df =78, p<0.001) and were generally disturbed by cutting (χ^2=44.16 df =20, p<0.001) at all altitudes. There were n=21±15.71 and n=13±4.8 species of *C. angolensis* population in Mwen and Segen regions, respectively. The dorminant tree species in the forest were *Cupressus lusitanica* (3.9%), *Dombeya goetzenii* (24%), *Prunus africana* (11.3%), *Croton macrostachyus* (9.2%) and *Macaranga kilimandascharica* (6.8%). Selection ratio (S.R) was calculated for each eaten plant species in order to determine food preference (species with S.R>10). In dry season tree species preferred were Dombeya goetzenii, *Nuxia congesta*, and *Cupressus lusitanica*. In wet season were *Prunus africana*, *Croton macrostachyus*, *Ficus thoninngii and Polyscias kikuyunensis.* Mineral content and organic compounds in preferred food trees varied significantly between seasons (p<0.05) and among preferred food trees. There was a higher concentration of nutrients in preferred tree leaves during wet season than in dry season. Zinc levels were high in dry season (63.39ug) but Manganese concentration levels were lowest at all seasons (0.01ug). Acid Detergent fibre, Non digestible fibre, Crude Protein, Nitrogen, Zinc, Copper and Iron mineral elements varied significantly between seasons. High levels of flavonoids and alkaloids were present in the leaves of *Ficus spp., Prunus africana, and Croton spp*. in dry season. *Cupressus spp., Dombeya spp*. and *Ekerbergia spp.* had athracin, tannins and alkaloids during wet season but completely absent in wet season. Tree felling and burning of major colobus food trees are the major threats to *C. angolensis* in Kibonge forest. Afforestation, use of legislature and educating the public are possible mitigation measures.

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LIST OF ACRONYMNS

ADF	Acid Detergent fibre
DBH	Diameter of a tree at breast height
DBH	Diameter at breast height
FAO	Food and Agricultural Organization
GPS	Global Positioning System
KFMP	Kenya forest management plan
KIFCON	Kenya Indigenous Forest Conservation Programme
MLC	Maximum Likelihood Classifier
NDF	Neutral Detergent fibre
RCMRD	Regional Centre for Mapping Resources for Development

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CHAPTER ONE

INTRODUCTION

1.1 Background information

1.1.1 Tropical Forest Disturbance and Loss

Habitat degradation and loss are the greatest threats to terrestrial species (Baillie *et al.*, 2004). Estimates of annual loss of tropical forest range from 8.7 – 12.5 M ha (Chapman & Peres 2001; Mayaux *et al.*, 2005). An area between half and equal size to this, is degraded by selective logging, mining, slash and burn agriculture and other exploitative forms each year (Achard *et al.*, 2002; Asner *et al.*, 2005). Loss and degradation of tropical forests are a global concern as more than half of the world's species are found in these forests, despite covering only 7 % of the world's surface (WRI, 1992). Tropical forest loss and degradation also have implications for climate change, hydrology, nutrient cycling, natural resource availability and quality of wildlife (Whitmore, 1998). In fact without serious mitigation measures to forest destruction, the number of species threatened with extinction in tropical forests is predicted to increase (Whitmore & Sayer, 1992).

East African forests such as Budongo Forest Reserve of Uganda, Kakamega forest and Kibonge forest in Kenya, conserves endemic species of trees and shrubs (Howard, 1991 & Dunham, 2011) used as food by primates (Myers *et al.*, 2000; Lovett *et al.*, 2004).They also act as homes for the endemic primate– the black and white colobus (C. *angolensis*) among others (Davenport *et al.*, 2006). However, these forests have largely been disturbed such that their restoration has become one of greatest challenges for ecologists this century (Duncan & Chapman, 2003). The main contributing factor is that most forms of disturbance are undetectable using remote sensing methods (Peres *et al.*, 2006).This leaves ground surveys as the better option for conservation management although full quantification of the effects of disturbance would be tasking given the large area and the species involved. However use of sampling plots assist in making more rapid assessments (Skorupa 1986 & 1988; Landres *et al.*, 1988; Gondard *et al.*, 2003) and give more accurate results. Determining the impact of disturbance on rare species is also applied for determination of habitat requirements for management. However determining of species-habitat relationships is often insufficient (Lindenmayer, 1999) and is more complicated because disturbance is typically unquantified, and disturbed forests are typically humid, unattractive, and difficult to negotiate.

1.1.2 The origin of Black and white colobus monkey (*Colobus angolensis*)

The study species black and white colobus monkey *(C. angolensis) (Plate 1)* are among the last remaining 31 colobine species after a long series of adaptive radiations. Originally, the colobines diverged from the cercopithecis monkeys 15.97 ± 0.05 Ma to 11.608 ± 0.005 Ma (million years ago) in Africa (Oates, 1994a).They are broadly regarded as a diverse group of 5 species; *C. santanas, C. polykomos, C. vellerosus, C.guereza and C. angolensis (Oates, 1994b). Colobus angolensis* is sub-divided into 6 species; *C. a. angolensis, C. a. cordieri, C. a. cottoni, C. a. pallitus, C. a. prigoginei* and *C. a Ruwenzori* (IUCN, 2013). Of specific interest to this research is *C. angolensis* (Plate 1) found from eastern Nigeria through Cameroon, northern Congo, Gabon, Zaire, Uganda, Rwanda, Ethiopia, Kenya, Tanzania, to the Central African Republic (Thompson, 2002).These monkeys are diurnal and arboreal, rarely descending to the ground, unless necessary to clear a gap in the tree which makes them vulnerable to changes in habitat as well as hunting pressures (Oates, 1994a). While colobus monkeys are found in various habitat types, they are endemic to tropical rainforests and are currently confined to small pockets of fragmented forests in Eastern Africa (Kingdon, 2008; Anderson, 2007a). Group composition structure typically comprises approximately 2-20 individuals, including one or more adult males and more than one adult female; this is dependent on the number of offspring within the group (Oates and Davies, 1994a). Ecologically, *C. a. palliates* is a folivorous primate who spends less time feeding and moving and more time resting, in comparison to primates of an insectivore or frugivore nature(Oates and Davies, 1994a). They are therefore vulnerable to the current rate of habitat loss (Anderson, 2004; Oates, 1996) and extinction (Kingdon, 2008) which calls for new conservation efforts.

Plate 1.1: ***Colobus angolensis*** **monkey on the rear** ***Prunus africana*** **tree in Kibonge forest taken in year 2015.**

Source: Author

1.1.3 Effect of forest disturbance on *C. angolensis* food preference

Colobines are primarily arboreal monkeys living in Africa and Asia whose diet is largely affected by nutrient content under which leaf choice is the predominant activity. An estimated 90% of primates live in tropical forests (Rowe, 1996) and are therefore at great risk from the effects of fragmentation and disturbance. An estimated one in four primate taxa are at risk of extinction worldwide, with 30 % of taxa at risk in Africa, primarily due to habitat loss (Mittermeier *et al.,* 2005; Chapman *et al.*, 2006). Primate abundance has also been closely linked to habitat in several species (e.g. Johns &Skorupa, 1987; Struhsaker, 1997) and Loss of habitat has been linked with reduction of colobine population (Cowlishaw & Dunbar, 2000).

1.2 The Study Area

For investigation of the relationships between habitat quality and feeding behavior of colobus, a study site was selected where both anthropogenic disturbance and conservation value are high, whereby Kibonge forest in Kenya was identified. This forest is among the Kenyan tropical forests consisting of indigenous and plantation forests highly disturbed by human activities (Plate 2). The forest extends in a North-South direction along Elgeyo escarpment in Eastern arm of the Great Rift Valley in Kenya (Wass 1995). The region has more endemic tree species per unit area and indigenous black and white colobus monkey among other animals highly threatened due to destruction of their habitat. If not checked, continuous loss of this forest may result in biodiversity loss and extinction risk to flora and fauna (Brooks *et al.,* 2002; Burgess *et al.,* 2004). Forest loss impacts on *C. angolensis* monkey (Plate 1), because it affects food availability and food selection among other factors (Madoffe *et al.,* 2006). As a result, the monkeys being eclectic omnivores, tend to seek for other alternative unusual foods further away from their home range, so as to ensure their survival (Harding, 1981). In the process they get exposed to predation, poaching and to opportunistic diseases thus reduce in population.

Despite the concerns about the threats of anthropogenic disturbance of forests in Kenya, previous published studies on the impacts of habitat loss and degradation on primates have been few but no documentation has been done for Kibonge forest. Most reports have been biased towards the Kenyan coastal forests, Kakamega and Mau forests.These reports documented that the density of colobus in occupied fragments is attributable to forest area, the proportion of forest change over previous years and the basal area of major food trees in Kenyan coastal forests (Anderson *et al.,* 2005). In Kakamega forest, blue monkeys, group densities correlated positively with anthropogenic forest disturbance (Mammides *et al.,* 1986). In other related forests such as the East Usambaras, vegetation plots showed that stem density and variation in species richness differed between mature and formerly disturbed forests (Huang *et al.,* 2003). A separate study made a similar observation for three sites elsewhere in the East Usambaras, where stem density, invasive species density and ground cover varied with anthropogenic forest disturbance, but not with tree species composition (Newmark, 2006). None of these reports have explainedthe monkeys choose on a particular tree among many for food. Lack of documentation on effects of forest disturbance on forest area and feeding behavior of colobus monkey in Kibonge forest therefore, the reason why this forest was selected for this study.

Plate1.2: Effects of anthropogenic activities in the surrounding areas of Kibonge Forest at altitude 2350m above the sea level. Very few indigenous species are seen scattered in the section depicted by the picture of the year 2015.

Source: Author

1.3 Statement of the problem

Kenyan forests are shrinking in size just like other tropical forests in the world at a fast rate of 9% in the past 10 years yet it is a habitat for a wide range of biodiversity (FAO, 2010). The forest conserves the Angolan black and white colobus monkey (*Colobus angolensis*), one of Kenya's most vulnerable primate species (Mittermeir, 2013) by providing shelter, variety of foods and stable climatic conditions. It also harbors, diverse indigenous and exotic tree species which form the diet of these monkeys. These trees are being lost to property developers, slash and burn agriculture, illegal logging, over harvesting and charcoal burning (Kideghesho, 2001) which degrade the habitat. Such impoverished environments may lead to increased competition and disruption of their complex social organization. The social group size of colobines become small (Mammides *et al.*, 2009) since social group size has been closely related to habitat quality in terms of tree density and diversity (Struhsaker, 1997; Dunbar, 1988; Janson, 1988; Janson & Goldsmith, 1995; Struhsaker *et al.*, 2004; Fashing & Cords, 2000; Fashing, 2004) and may further shrink to extinction (Cowlishaw, 1999; Oates *et al.*, 2000). Also, their density will be affected by a decrease in diversity of food trees (Mammides *et al.*, 2009).

Monkeys are often susceptible to habitat disturbance and loss and therefore are potential indicators of ecosystem health because they can migrate or resort to fall back foods (Harris, 2005; Fashing, 2001). They adopt new foraging strategies also, such as feeding on non-preferred tree species or by selecting fallback foods (Harris *et al.,* 2009; Marsh, 2003) and farm crops, which might lead to conflicts with humans (Banana *et al*., 2001; Waiyaki, 1998). As a result the monkeys' habitat and preferred food tree species are lost or reduced.

The may also utilize some indigenous and non-indigenous food tree species, in response to food scarcity (Anderson *et al.*, 2007a*;* Dunham, 2011; Harris, 2005; Fashing, 2001).

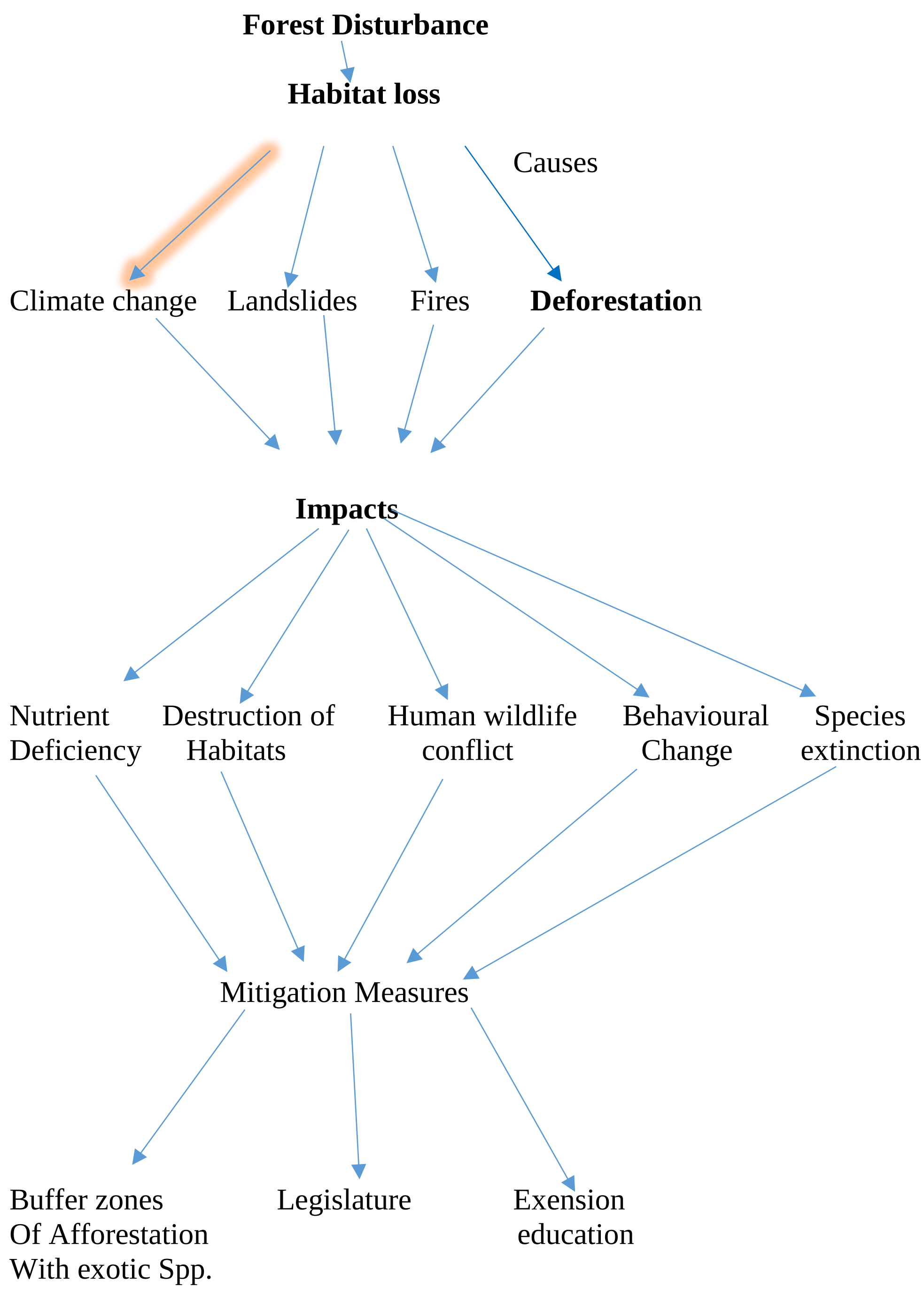
However, these reports do not explain whether the tree species selected by the colobus monkeys were influenced by the species richness of the stand or whether other exotic tree species are utilized by *C. angolensis* at the time of scarcity of usual indigenous foods. These questions need to be answered through such a study by determining the factors influencing the choice of the unusual food trees by *C. angolensis* as a result of change in habitat. This study also, intends to find ways and means of alleviating feeding stress brought about forest disturbance by humans, on *C. angolensis.*

1.4 Justification of the study

Habitat disturbance, fragmentation, and modification are the leading threats to the persistence of primate communities in East African tropical forests (Struhsaker and Siex, 1998). Habitat disturbance comes as a result of conversion of forest and forest grassland mosaics to permanent agriculture including smallholder farming and commercial farming. Also by timber extraction, charcoal burning and unsustainable extraction of minor forest products (Anderson, 2009).

In the past two decades, Kenya’s forests have experienced severe destruction as a result of the above factors as well as forest fires, overgrazing in forest land, landslides, catchment degradation and unsustainable commercial forestry (NEAP, 1994; Environmental draft, 2008).These factors have led to the loss of 5000 ha of forest annually. The main cause of habitat loss, stems from a combination of many factors including inadequate and unharmonized legislative framework, absence or inadequacy of sustainable management and bio-regional scale conservation strategies. Also, uncoordinated land development planning and a financial and human resource deficit for effective mitigation activities.This has come as a result of lack of research and sustainable management by different parties including central, local government and communities. These impacts are predicted to threaten between 17–39% of all endemic primate species with extinction in the next 20 years (Cowlishaw, 1999). The most threatened primate community is colobine species, now surviving only in fragmented forest habitats (Cowlishaw and Dunbar, 2000; Marsh, 2003). They are particularly vulnerable for they are highly arboreal species depending on leaves for most portion of their diet (Davies, 1994; Kahumbu, 1997) and need to be conserved. A research such as this one, was carried out to obtain findings, which will form an important base in the construction of informed conservation or restoration plans for endangered species and degraded environments. Findings on *C. angolensis* nutritional needs, will assist forest managers to pinpoint specific trees and areas to protect, while the human communities will be empowered with conservation needs and methods especially in embracing wildlife as an alternative land use. Also the findings of the study will form a base in establishing the sustainable forest management practices and monitoring such as privatization or use of Community based organization (CBO) in conservation and monitoring process. At the same time, the results will invoke the need for preventing the Angolan black and white colobus monkeys, from invading forest plantations and farmlands through establishment of the preferred trees in between the farmlands and tree plantations in order to act as buffer zones. In so doing the monkeys will be contained within the forest thus human-wildlife conflict will be reduced and consequently the monkey will be saved from human threats. The checklists of the existing tree species and other primates found in the forest obtained from actual field census on line transects, will add information to the library thus bridging gaps in data. Understanding the contributing factors and ecological impacts inflicted by habitat destruction on biodiversity is essential in devising effective mitigating measures and therefore this study is timely.

1.5 Conceptual Framework



Source: Author, 2018

1.6 OBJECTIVES

1.6.1 General objective

To determine the effects of habitat change on food availability and food preference by Black and white colobus monkey *(C. angolensis)*, at Kibonge forest Elgeyo-Marakwet County, Kenya.

1.6.2 Specific Objectives

1. To determine the impacts of habitat disturbance and loss, on feeding behavior of black and white colobus monkey and tree communities in Kibonge forest.
2. To determine the effect of food preference on feeding behavior by *C. angolensis* in Kibonge forest.
3. To determine the influence of nutrients and chemical compounds in preferred food on leaf choice by black and white colobus monkey in Kibonge Forest.
4. To identify suitable conservation and mitigation measures for the preferred food trees by black and white colobus monkey of Kibonge forest.

1.7 Hypotheses

H_{O1}: There is no significant difference in Kibonge forest area between the years 1989 to 2010.

H_{02} There is no impact of habitat loss and disturbance on tree communities of Kibonge forest

H_{03} There is no impact of habitat loss and disturbance on feeding behavior of *Colobus angolensis* monkey in Kibonge forest

H_{04} Food preference has no significant effect on feeding behavior by *C. angolensis* monkey in Kibonge forest.

H_{05} There is no significant variation in nutrients and chemical content in the leaves of food trees between wet and dry season

H_{06} leaf choice by *C. angolensis* is not significantly affected by macro nutrients and secondary compounds.

1.8 Research Question

What are the Mitigation measures suitable for conservation of preferred food trees by *C. angolensis* in Kibonge forest?

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Habitat disturbance is the process in which natural habitat is rendered functionally unable to support the species present. In this process, the organisms that previously used the site are displaced or destroyed, (Sahney *et al.*, 2010; Wright, 2010; Wright, 2005).). Habitat disturbance by human activity is mainly for the purpose of harvesting natural resources for industry production, urbanization and agriculture (Lambin *et al.*, 2003, Foley *et al.*, 2005). Other important causes of habitat disturbance include mining, logging, trawling and urban sprawl (Chapin Iii *et al.*, 2000, Wright, 2005, Bradshaw *et al.*, 2009). Habitat destruction is currently ranked as the primary cause of species extinction worldwide (Pimm & Raven, 2000). It is a process of natural environmental change that may be caused by habitat fragmentation, geological processes, climate change (Sahney *et al.*, 2010) or by human activities such as the introduction of invasive species, ecosystem nutrient depletion and others.

The most important habitat to primates is the tropical rainforests which have received most of the attention concerning its destruction. From approximately 16 million square kilometers of tropical rainforest habitat, that originally existed worldwide, less than 9 million square kilometers remain today (Primack, 2006). The current rate of deforestation is 160,000 square kilometers per year, which equates to a loss of approximately 1% of original forest habitat each year (Laurance, 1999). Cumulatively, countries with primate populations are losing 125, 140 km^2 of forest annually; resulting in the annual loss of 32 million primates (Chapman & Peres, 2001; Mayaux *et al.,* 2005).The loss threatens arboreal primates such as colobus monkeys (Baillie *et al.*, 2004). Kenyan forests are also disturbed.

Kenyan forest covers about 1.7 million ha, which is about 2.6% of the country's total area (UNEP, 2005). This area is composed of 1.22 million hectares of closed indigenous forest and plantation forest and 0.5 million hectares of protective bush and grassland. There are 9.5 million ha of farms, settlement and urban lands which have wooded biomass growing stock of 9.3 m^3/ha (KFMP, 1994). The total indigenous forest cover in gazetted forest areas was estimated by KIFCON (Wass, 1994), to be 1.06 million ha (excluding the mangrove forests along the coastline), while the area of indigenous closed canopy forest outside the gazetted forests was estimated to be 180,000 ha (0.18 million ha). Besides the gazetted forests, the country has a total of about 37.6 million ha of natural woody vegetation consisting of 2.1 million ha of woodlands, 24.8 million ha of bush-lands and 10.7 million ha of wooded grasslands and 54,355 ha (0.54 million ha.) of mangrove forests (Wass, 1994). Plantation forest is comprised of 48.8% was cypress, 34.7% was pines and 8.3% was *Eucalyptus* spp. (KFMP, 1994). Most of the closed canopy forests are concentrated in the high and medium potential zones of Kenya where, incidentally, the human population and agricultural production are also concentrated (Wass, 1995). Within the arid and semi-arid zones, closed forests are fewer and are found concentrated mainly on isolated mountain ranges and along river courses, both permanent and seasonal, with the rest of this zone being composed of woodlands, bush-lands and wooded grasslands where monkeys and other primates inhabit (Oates, 1994a).

2.2 Habitat disturbance and food availability

Habitat disturbance poses the greatest threat to species. It leads to slow degradation and consequently reduced forest health in the long run (Dangwal, 2005). Forest degradation alters ecosystem composition, biodiversity and negatively affect water retention (Bruijnzeel, 2004), natural resource availability, (McDonald *et al.*, 2003; Shanley & Luz 2003), nutrient cycling (Vitousek & Sanford 1986; Villela *et al.*, 2006) and genetic diversity (Lowe *et al.*, 2005; Jennings *et al.*, 2001), contribute to global warming (Reddy & Price, 1999), and increase invasion by non-native species (Brown & Gurevitch 2004).

Habitat destruction causes loss of major food resources, local extinctions of species (Kuussaari *et al.*, 2009, Pimm and Raven, 2000, Vellend *et al.*, 2006) and a decrease in forest fragment area resulting in a decrease in number of monkey species found per unit area (Laurence *et al.*, 2002). Also it increases fragment isolation and total forest edge (Fahrig, 2003). Commercial logging is responsible for the transition of primary forest to poorer quality, secondary forest. Furthermore, logging also reduces biomass, damages soils and other vegetation present, increases vulnerability to fire and conversions to grassland, scrub or agricultural land which may then persist for decades (Shearman *et al.*, 2009). Logging, and the related disturbance, opens remote areas to poaching and hunting (Laporte *et al.*, 2007). Hunting above the species ability to reproduce can lead to species extinction. For example, the result of habitat destruction coupled with hunting in 1999 in west Africa, led to the extinction of the Miss Waldron’s red Colobus monkey (*Procolobus badiuswaldroni*) (Oates *et al.*, 2000). This has further ramifications if the surrounding plant species are dependent on the extinct species for dispersal or pollination. This threat is accelerated by the development of modern hunting equipment such as guns, wire snares and battery powered lamps.

Deforestation can significantly impact *C. angolensis* monkey and other primates, especially because of changes in food availability (Chapman *et al.,* 2006; Felton *et al.,* 2003; Roa & van Schaik, 1997). For example, during a three year study of forest fragments in Uganda, it was found that, on average, logging activities led to a 29.5% decrease in the DBH (diameter at breast height) (Chapman *et al.,* 2006) of available food trees. Orangutan preferred food trees were the most frequently logged species in Gulung Panung National Park, Indonesia (Felton *et al.,* 2003). These logging activities led to fewer and more dispersed trees (Felton *et al.,* 2003) consequently lowering densities of the animal species.

The response of organisms to disturbance is varied and depends on the scale of disturbance. A forest that has had low-to-moderate intensity disturbance generally has higher plant diversity than mature forest due to the presence of both early and late succession species (Toniato *et al.,* 2004). Low intensity disturbance therefore helps to maintain forest diversity and community structure (Denslow, 1987; Schnitzer & Carson, 2001). Conversely high intensity disturbance can cause significant changes in species composition, structure and diversity (Connell, 1978; Silva *et al.,* 1995; Hitimana *et al.,* 2004; Okuda *et al.,* 2003; McLaren *et al.,* 2005; Villela *et al.,* 2006). For the monkeys low species diversity of food trees, cause behavioral changes such as: change of diet (Harding, 1981), an increased competition for food and disruption of the existing complex social organisation (Struhsaker 1975 & 1997; Janson & Goldsmith, 1995; Struhsaker *et al.,* 2004).

2.3 Habitat disturbance and behavioral changes

Behavioral differences associated with habitat quality have been documented in several species of non-human primates i.e baboons (Atlmann & Muruthi, 1988; Eley *et al.*, 1989; Iwamoto & Dunbar, 1983); bearded saki monkeys (Boyle & Smith, 2010; Silva and Ferrari, 2009); black and white colobus monkeys (Wong & Sicotte, 2007); bonnet macaques (Singh &Vivanthe, 1990); gorillas (Watts, 1988); howler monkeys (Marsh, 2003); ruffed lemurs (Ratsimbazafy, 2007); Ruffed lemurs living in degraded habitats diversified their diet compared to those in better habitats (Ratsimbazafy, 2007). Similarly, howler monkeys show differences in resting and foraging time that seem to allow them to succeed in heavily degraded areas (Marsh, 2003, Rodriquez-Luna *et al.,* 2003; Silver & Marsh, 2003). Individuals in disturbed areas may also try to adjust their energy output by reducing any unnecessary behaviors. For example, bearded saki monkeys engaged in fewer social behaviors in disturbed habitats (Silva & Ferrari, 2009). Differences in the quality and distribution of plants, may have a dramatic effect on choice of food types especially when there are many tree species. For instance Fimbel *et al*., (2001) recorded that black-and white colobus (*Colobus angolensis*) in Rwanda largely fed on high quality mature leaves in comparison with other African disturbed forests. Nutritional analyses also reveal colobus use of different plant species and parts in various habitat qualities (Dierenfeld & McCann, 1999).Thus nutritional factors affect leaf choice by *C.angolensis.*

2.4 Conservation status of Black and white colobus monkey (*C. angolensis*)

The IUCN lists *C. a. palliatus* as threatened, though it is vulnerable to extinction (Kingdon, 2008) due to increased rate of deforestation (Anderson, 2004; Oates, 1996). In Uganda complete forest clearings caused a decline of 50% over eight years (Chapman et.al, 2007). The *C. angolensis* is also threatened by hunting for meat and its skin. *C. angolensis* meat sells as bush meat for $4–9 US (Eve's *et al.,* 2000).The skins have been sold for fashion or in the tourist trade (Oates, 1996).

2.5 Ecology and characteristics of black and white colobus monkeys (Colobus *angolensis)*

2.5.1 Ecology

The *C. angolensis* is primarily arboreal, but does sometimes descend on the ground to forage and travel, perhaps more so than most other colobines. It is diurnal and rests for up to half the day. Foraging or travelling is the next most common activity. Sometime after dawn, *C. angolensis* groups leave their sleeping trees and will return to them at dusk. During the day, the *C. angolensis* has long rest periods in between periods of moving and feeding (Bocian, 1997, von Hippel, 1996). Other activities, including grooming, greeting, playing and being vigilant, are performed to a lesser extent (von Hippel, 1996). *C. angolensis* is mostly preyed on by the crowned hawk-eagle, (Struhsaker *et al.,* 1990), Verreaux's eagle (Dunbar *et al.,* 1974), the common chimpanzee (Ihobe, 2001) and the leopard (Schel *et al.,* 2009).

2.5.2 Distribution and habitat

These monkeys are diurnal and arboreal, rarely descending to the ground, unless necessary to clear a gap in the tree which makes them vulnerable to changes in habitat and hunting pressures (Oates, 1994a).

The black-and-white colobus is found in Africa. Common countries include Senegal, Ethiopia, Tanzania, Congo, Malawi, Uganda, and Zambia. The king colobus *(C. polykomos)* is found from Gambia to the Ivory Coast (Landes, 2002). In Kenya, *C. guereza* has only been observed from the Ngong Escarpment, Mount Kenya and the Aberdare Mountain Range (Kingdon *et al*., 2008). The Angolan colobus *(C. angolensis)* is found from eastern Nigeria through Cameroon, northern Congo, Gabon, Zaire, Uganda, Rwanda, Ethiopia, Kenya, Tanzania, and the Central African Republic (Thompson, 2002).

C. angolensis lives in both deciduous and evergreen forests. It mainly inhabits forest and savannah woodlands and often extend into highland and montane forests (Oates, 1994).It can be found in other forest habitats, both primary and secondary, such as riparian (near fresh or brackish water), gallery, and upland forests. It is particularly common in forests close to rivers and lakes and at high elevations (Dunbar, 1987). It can be found in elevations as high as 3,300 metres (10,800 ft) (Dunbar *et al.*, 1974).This species prefers secondary forests and selects them over old-growth forests if given the choice(Lwanga, 2006). It is likely that the *C. angolensis* prefers these forests due to an increased number of food trees and the weaker chemical defenses of the species within (Lwanga, 2006). The *C. angolensis* is sometimes found in swamps (Oates, 1978), as well as human-made habitats such as *Eucalyptus spp*. plantations, which may be eaten when the monkey has nutritional deficiencies (Dunbar *et al.*, 1974).

2.5.3 Characteristics of *C. angolensis*

C. angolensis belongs to Colobinae subfamily, also known as the leaf-eating monkeys, a group of Old World monkeys from Asia and Africa. This subfamily is split into three groups, the colobus monkeys of Africa, the langurs, or leaf monkeys, of Asia, and an "odd-nosed" group. The African colobus monkeys are divided again into three genera, by distinctions in color, behavior, and ecology. The three genera are the black-and-white colobi, the red colobi, and the olive colobi. There are three black-and-white colobi: the mantled guereza (*Colobus guereza*), the king colobus (*C. polykomos*) and the Angola colobus (*C. angolensis*) (Fleagle, (1998). There are 31 colobine species remaining after a long series of adaptive radiations. Originally, the colobines diverged from the cercopithecis monkeys 15.97 ± 0.05 Ma to 11.608 ± 0.005 Ma (million years ago) in Africa (Oates, 1994a). The study species of black-and-white Colobus monkeys are broadly regarded as a diverse group of 5 species; *C. santanas, C. polykomos, C. vellerosus, C.guereza and C. angolensis (Oates, 1994b).* Furthermore, they are sub-divided into 6 species; *C. a. angolensis, C. a. cordieri, C. a. cottoni, C. a. pallitus, C. a. prigoginei*and *C. a Ruwenzorii* (IUCN, 2008).

Physically, *C. angolensis*, is mostly black, with white fringes of silky hair along the sides of its body and tail. The tail is long and ends in a white tuft which varies in how much it covers the tail (Plate 3). Infants are born with pink skin and white hair. The hair and skin darken as they age and by three to four months they attain adult coloration. Male usually gain their coloration before females (Ackerman, 1991).The male (Plate 3) typically weighs 9.3 and 13.5 kilograms (21 and 30 lb) and the female weighs between 7.8 and 9.2 kilograms (17 and 20 lb). The head and body length averages 61.5 centimetres (24.2 in) for males and 57.6 centimetres (22.7 in) for females. Like most colobi, the black and white colobus has a small thumb that is vestigial (Napier, 1985, Oates, 1994a). There is dentition sexual dimorphism among the subspecies. In some, the males have larger teeth than females, in others the reverse is true, and some have no significant difference (Hayes et. al., 1995).

Plate 2.1: **Male *C. angolensis* monkey on a tree found in Kibonge forest**

Source: Author, 2015

2.5.4 Social structure

Socially *C. angolensis* lives in stable social groups usually containing three to fifteen members (von Hippel, 1996). The groups consist of one male, several females and juveniles. In some populations, groups containing several males are common (Dunbar, 1976). In multi-male groups, males tend to be aggressive with one another with one being dominant. Some males may be expelled from these groups (Bocian, 1997). Multi-male groups may contain father-son pairs or unrelated males. Males that are not part of groups either live solitarily or with other outside males in bachelor groups. The females keep the groups cohesive and they are matri-lineally related. They rarely disperse from their natal groups, except possibly when they break apart (Bocian, 1997). Males on the other hand, usually leave when they become sub-adults or adults. They may start out being solitary and or in bachelor groups. They gain entry into a social group either by being on the periphery or displacing a group male (Dunbar *et al.*, 1974). Female guerezas living in a group often have an egalitarian dominance style with no formalized rank relations. Relationships are relaxed and friendly with rare signals of dominance or sub ordinance. Allogrooming is an important part of *C. angolensis* interactions among females (Fashing, 2001).

The adult males rarely groom in the groups. While not strictly territorial, *C. angolensis* groups can be aggressive towards each other. Physical aggression within the group is usually not harmful and rarely escalates into a conflict. In some populations, groups may defend core areas (which exist as a small part of the home range), resources, and mates. During intergroup encounters, males can engage in direct or indirect mate defense, like defending a female's resources. It is the males that participate in agonistic inter-group encounters but female may do so as well (Fashing, 2001). Aggressive encounters between groups usually involve chases, displays and vocalizations rather than physical contact (von Hippel, 1996).

2.5.5 Reproduction and parenting

The *C. angolensis* has a polygynous harem-based mating system (Oates, 1994a, Bocian, 1997). Mating solicitations are made by both males and females, half of the time for each (Harris &Monfort, 2006). To solicit mating, the *C. angolensis* will walk near its potential partner and make low-intensity mouth clicks or tough-smacks. During copulation, the males hold on the female's ankles and body. Most mating take place between individuals of the same group but copulations outside of the group have been recorded (Harris, 2005). In multi-male groups, more than one male may mate with the females (von Hippel, 1996). The gestation period lasts 158 days with a 16-22 month inter-birth interval (Dunbar *et al.*, 1974). Infants are born with white fur and are always carried during the first months of their life. The newborn *C. angolensis* relies on its mother for support and must cling to her. As they grow older, infants can move on their own, but keep returning to their mothers (Horwich &Manski, 1975). The infants take up most of the attention in the groups. The other females in a group may handle an infant although the latter are only comfortable with their mothers (Oates, 1977).The males normally do not pay much attention to infants until they are four to five weeks old (Harris & Monfort, 2006). Infants can eat solid food at about eight to nine weeks and by fifty weeks they are fully weaned and no longer need to hold on to their mothers (Oates, 1977).

2.5.6 Communication

The most notable form of communication by *C. angolensis* is the "roar", which is made mainly at night or dawn by males. The sound of a roar can be carried for up to a mile. It is normally the dominant male who roars when there are multiple males in the group. Roars are used for long distance communication and can regulate inter-group spacing without direct, physical contact while foraging (Schel & Zuberbühler, 2011). When one male starts roaring, neighboring males will start to roar as well. Often, *C. angolensis* will respond to calls regardless of "caller identity," focusing more on the collective vocal displays and not the familiarity of the caller (Harris, 2005, Schel & Zuberbühler, 2011). There is variation in the roars of males which could signal the status of their group and fighting ability. With a roar, a male can advertise his body size; both actual and exaggerated. Other vocalizations forms are making “snorts”, possibly as an alarm call, "Purrs" are made before group movements and "caws" when females and infants are under mild distress. When in more serious distress, like if an infant is in danger, females and sub-adults will squeak or scream (Harris, 2006). "Tongue-clicking" is made during mild aggression. In addition to vocalizations, the *C. angolensis* communicates with several different body postures and movements, displaying of fringe fur, facial expressions, and touches (Oates, 1977).

2.5.7 Anthropogenic related threats to Colobus monkeys

Africa contains a number of the world’s biodiversity hotspots, which include; the Western African forests , the Eastern Arc and Coastal Forests of Tanzania and Kenya, (the latter is listed as the 8th hottest hotspot, in the world) all being crucial habitats of colobus monkeys (Myers *et al.,* 2000). In addition to ongoing deforestation; hunting, diseases and climate change are major threats to colobus monkey populations in these forests (Mc Googan *et al.,* 2007). Particularly for East African tropical forests rapid human population growth has had a drastic effect. These forests are increasingly used as a source of bush meat, fuel wood, poles, timber and charcoal and are leveled for growing crops and exotic trees. This has led to widespread forest fragmentation. Colobus monkeys being highly arboreal, are especially vulnerable to these threats, as they require leaves, fruits and seeds for survival (Anderson *et al.,* 2007a). These activities have reduced the size of colobine habitat and amount of forage while bare pockets in the forest have exposed colobines to predators thus subjecting them to poor breeding, starvation and deaths. If the rate of extraction of forest products continues, colobines will face a status of extinction.

2.6 Influence of nurients and chemical compounds on Colobine foraging behavior

The diet of the *C. angolensis* is predominantly leaves (Fashing, 2006; Kirkpatrick, 2006; Chapman *et al.,* 2004; Harris, 2005; Fashing, 2007), often of only a few tree species based on the positive relationship between the protein-to-fiber ratio in mature leaves and colobine biomass across forests in the Paleotropics (Waterman and Kool, 1994). They also subsist on fall back foods of exotic species during scarcity period (Harris, 2005; Fashing, 2001). Despite its reputation as an exclusive leaf-eater, the *C. angolensis* is not an obligate folivore (Oates, 1994).While it mainly eats leaves and fruit, its diet is quite variable. It may eat bark, wood, seeds, flowers, petioles, lianas, aquatic-plants, arthropods, soil, and even concrete from buildings depending on the availability and nutrients they need at a particular time of the year (Harris *et al.,* 2007).The amount of each food item in its diet varies by area and time of year (Harris *et al.,* 2007). Nutritional factors like protein, tannins, and sodium levels in leaves influence its food choices and may travel for longer distances to access plants with higher levels of nutrition (Fashing *et al.,* 2007).They eat fleshy unripe fruits occasionally depending on the season (Oates *et al.,* 1994; Dunbar *et al.,* 1974) so as to reduce competition with primates that eat ripe fruits (Harris *et al.,* 2007).When foraging for leaves, the *C. angolensis* prefers young ones over old. It consumes a number of plant species but only some make up most of its diet at a specific site (Oates, 1978). *C. angolensis* is able to digest leaves and other plant fibers for they posses a specialized stomach (Fashing *et al.,* 2007) with a large, multi-chambered stomach that contains bacteria in the caecum which can digest cellulose (Milton, 1979; Rogers *et al.,* 1990; Yeager *et al.,* 1997); Food nutrient content mostly influence what the colobine will consume. For instance, energy requirements (Schoener, 1971) is equated to high quality diets (Leighton, 1993; Cowlishaw and Dunbar, 2000; Lambert, 2007) while nitrogen (protein) requirements is associated with proper growth, health, reproduction and survival (Mattson, 1980). Another factor is avoidance or regulation of plant secondary metabolites (PSMs) (Freeland and Janzen, 1974; Glander, 1982), which interrupt with protein digestion and the activity of digestive enzymes (Rhoades and Cates, 1976; Swain, 1979; Haslam, 1989) and limitations of dietary fiber (Milton, 1979; Milton, 1993; Richard, 1985) such that food items high in fiber content (NDF, ADF, and lignin) is difficult to digest and are avoided by many primates (Milton, 1979; Yeager *et al.,* 1997). Nutrient balancing is another fundamental need in food choice by *Colobus angolensis* (Plate 2,) (Davies *et al.,* 1988; Whiten *et al.,* 1991; Raubenheimer and Simpson, 2004). Therefore, for the monkey to meet the required amounts of nutrients in a diet, a wide range of forage is needed which can only be achieved in a forest with diverse tree species.

Food choice among Colobus guerezas, a relative species of *C. angolensis,* has been documented at various sites, namely Kibale (Baranga, 1983; Rode *et al.,* 2003; Chapman *et al.,* 2004; Wasserman and Chapman, 2003), Ituri (Bocian, 1997) and Kakamega (Fashing, 2007) forests, is reported to have been influenced by nutritional factors. At these sites, levels of protein (Bocian, 1997; Chapman *et al.,* 2004); fiber (Chapman *et al.,* 2004); tannins (Oates *et al.,* 1977); and several minerals including zinc, manganese, and sodium (Oates, 1978; Rode *et al.,* 2003) in food items affected food choice. It is also reported that Sodium content exerted a powerful influence on the ranging patterns of guerezas at Kibale, causing them to travel long distances intermittently to access sodium-rich swamp plants and *Eucalyptus sp.* (Myrtaceae) trees believed to make up for sodium deficiencies in their normal diet (Harris,2005; Oates, 1978; Rode *et al.,* 2003). Similarly in Kakamega, guerezas were found to travel long distances to access bark from 2 exotic tree species of Myrtaceae (*Callistemon sp. and Eucalyptus sp*.) in the forest (Fashing, 2001a, b) for sodium supplements lacking in the leaf diet. However, these reports do not explain whether the species selected by the colobus monkeys were influenced by the species richness of the stand or whether other exotic tree species are utilized by *C. angolensis* at the time of scarcity of usual indigenous foods. These questions need to be answered through such a study by determining the factors influencing the choice of the unusual food trees by *C. angolensis* as a result of change in habitat.

2.7 Prevention and conservation of preferred food trees

The protection of land from deforestation and degradation has assisted on conservation of forest over many years (Seabloom *et al.*, 2002). Globally, 18% of all tropical and subtropical moist forests and 9% of all dry tropical forests are protected (Brooks's *et al.*, 2004). Legally protected areas are seen to be the key defence against forest loss and species extinction (Joppa *et al.*, 2008); they have significantly lower rates of land clearing compared to non-protected areas (Nagendra, 2008). With a tree cover threshold set at 10%, the global forest cover is in the region of 39 million Km^2 with only 7.7 % falling within protected areas (Schmitt *et al.*, 2009). However, when the global average forest cover is broken down into WWF eco regions (taking into account differences between forest ecosystems), 65% of the 670 eco regions have less than 10% of their forest cover protected (Schmitt *et al.*, 2009).

A protected area system is only as effective as the governments that protect them; corruption, political instability and economic crises can result in poor protected area networks (Curran *et al.*, 2004). One important protective factor against forest degradation is that of sacred groves (Dudley *et al.*, 2009). These are fragments of forest or stands of trees that local communities conserve primarily because of their associated religious importance (Mgumia and Oba, 2003). They include burial grounds and sites of deity worship (Bhagwat and Rutte, 2006, Chouin, 2002). Sacred groves have been proven to offer a higher form of forest protection than forest reserves (Campbell, 2005; Anderson, 2004). Due to centuries of community protection (Bhagwat and Rutte, 2006); sacred groves have become reservoirs or sanctuaries for biodiversity (Mgumia and Oba, 2003). Human communities found living near a forest are therefore essential in conservation of forest and should, all the time be encouraged to contribute their inherited knowledge towards conservation of a forest ecosystem.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study area is Kibonge forest, located in Elgeyo Marakwet ($0^{o}10^{/}47$–$0^{o}26^{/}37$N and $35^{o}27^{/}12$-$35^{o}41^{/}43$E) *in* the Rift Valley Province of Kenya. It borders Eldoret East district to the West, Baringo central to the East, Eldama Ravine to the South and Keiyo North to the North (Figure 3.1). The district covers an area of 898 square kilometers. The study was carried out in Chepkorio division with a population of 67,062 of which 1000 are in Nyaru town adjacent to the forest. The town is 42 km East of Eldoret town and 56km south of Iten town. The forest covers an area of 8.7 Ha lying on a varying topography. The land falls precipitously in a series of steep uplands Kapchebelel ranges to the south of Nyaru town, which comprise the Elgeyo escarpment.

The study area is made up of two regions, Mwen and Segen. Mwen region had many meanders of the road to fluorspar mines criss-crossing it while Segen being more steep had one main footpath and a few shorter ones criss-crossing it. Both regions are divided into three main agro-ecological zones which run parallel to each other in a North-South direction; highland, the Elgeyo escarpment and the Kerio Valley basin. The highland lies at an altitude of approximately 3000m above the sea level and extends across the constituency from North to South. The Kerio Valley basin is 1000m above the sea level.

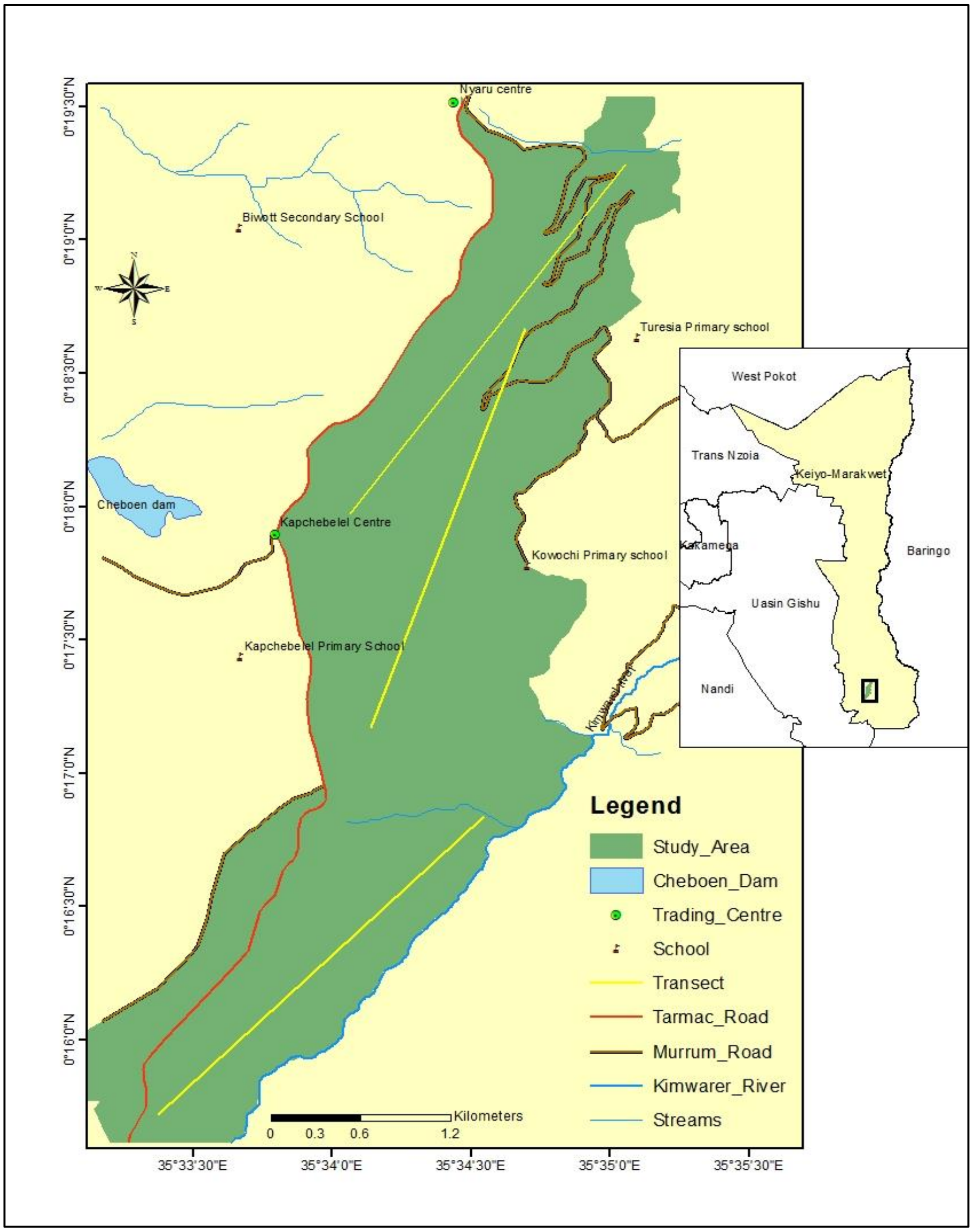


Plate 3.1: **Map of Elgeyo Marakwet County showing the study area and the three marked transects which were used to carry out census for the monkeys in Kibonge forest in the year 2015. (Google maps)**

3.1.1 Climate

Mean annual rainfall in the study area, varies with altitude and ranges between 600–1400mm. The highland, where the study area lies is relatively wet with an annual rainfall of 1400mm while the Kerio basin is drier with an annual rainfall of 600mm. The long rains are received between March to August with the wettest and coldest months being July and August respectively. Short rains are between October and December. Temperatures on the highland vary from, 4^0C during the wet season and 18^0C during the dry season. In the valley the temperatures are higher ranging from 15-28 degrees centigrade respectively.

3.1.2 Soils and Vegetation

The area has a wide range of soils but it is largely dominated by volcanic loam soils. The Kerio basin is covered with sedimentary rocks which comprise of fertile loam soils. The steep slope has thin layers of soil due to increased erodibility of soil.

The study area is covered with indigenous forest of a typical rainforest which is highly concentrated on the steep slopes. Plantation of *Cyprus spp* and *Pinus sp* are concentrated on the gentle sloping area while wattle trees are found along the roads. The forest has greatly been excised due to increased need for more land for grazing livestock and crop farming.

3.1.3 Socio-economic activities

The main economic activity in the study area is agriculture, Transportation of farm produce, fluorspar mining and trade. Mining of fluorite by the Kenya Fluorspar Company is the largest industry in the study area (Muchemi *et al.,* 2008).The area is used by local and foreign athletes for high-altitude training because of the varied terrain and the cool climate attributed to the presence of forests and the steep escarpment. There are several schools and trading centers at the highland which largely depend on the forest for timber and poles for house constructions.

3.2 Selection of sampling points and Research Design Method

An actual field assessment was done in May 2013 to identify sampling stations, for purposes of determining the distribution and abundance of forage trees and Angolan black and white colobus monkeys in Kibonge forest. To be identified also was the suitable research design whereby a Randomized Complete Block Design method was adopted which is good for a rugged terrain and uses line and belt transects. Homogenous blocks were designed using the existing roads meandering along the escarpment and based on altitude, as this determines the type of vegetation of a place.

3.2.1 Preliminary survey and selection of sampling points

A Preliminary field assessment was done to identify sampling stations. Two belt-transects of 3km long were determined using the government topographic maps and were marked to best fit inside the forest habitat. The coordinates of the peripheries of the study area, were established using a Garmin Plus Global Positioning System (GPS). Further, using the determined distance as reference and GPS, the sampling points for disturbance and status of the forest were marked at an interval of 100m along the transects.

Data for the following parameters were sampled;

i) Area covered by vegetation in Kibonge Forest

ii) Tree measurements i.e height, DBH, canopy cover

iii) Disturbances of the forest and key tree species through identification of fires, landslides, logging, pruning etc.

iv) Abundance and Behavior of black and white Colobus monkeys,

v) Population of key tree species (food trees) to obtain the density of trees

vi) Nutritional analysis of samples of food trees frequently utilized by *C. angolensis.*

3.3 Status of Vegetation in Kibonge forest

To establish the status of Kibonge forest, landsat images were taken between January 1978 to March 2016 for path 169 and row 060 covering the study area were downloaded from global land cover facility and earth explorer provided by the Regional Centre for Mapping Resources for Development (RCMRD) in Nairobi, Kenya. Downloads were, MSS (Jan 1978), TMs (Jan 1984), TMs (February 1989), ETM+ image of Jan 2000, ETM+ image of February 1995, ETM+ (March 2006) and ETM SLC off (Feb. 2011) and Landsat TM (March 2016). The scene identity was path 169 and row 069 with 30 m spatial resolution. Dry season images free from cloud cover, humidity and smoke were considered. These images covered an area larger than the study area therefore it was necessary to clip the area of interest which was then classified and studied to determine the land use and land cover change.

3.3.1 Classification of Images

Classification refers to the process of extracting information from remotely sensed images, which can then be developed into interpreted maps of various land use and land cover types. Data of the images acquired were analysed using the false colour composite band (RGB) 4, 3 and 2. Supervised classification using Maximum Likelihood Classifier (MLC) was done based on a method described by Janssen and Huurneman, (2001). In this case, image classification began by creating areas of interest known as training sites and signature names for the various elements in the images used in the study. This involved the identification of the elements, for example plantations forest, shrubland, grasslands and bare ground. Small parts of each element were then digitized in order to come up with the training sites for which signature names were assigned. The digitization of the different scenes was the basis for the development of the vegetation interpretation maps for the years 1973, 1984, 1989, 1995, 2000, 2006, 2011 and 2016. To compute changes, the resulting maps were then compared on pixel by pixel bases and the area queried using raster calculator tool. Ms Excel 2013 table was then used to calculate land cover changes. Regression models will be used to show the trends in forest change for various landuse types. Verification of the findings from imageries on the status of the forest was done by carrying out ground truthing as described below.

3.3.2 Data collection from vegetation plots for quantitative analysis

Data collection was aimed to sample trees equal to or greater than 15cm diameter at breast height (DBH) and determine their canopy cover within systematically located vegetation plots in the survey area and to determine the species composition of the forest under investigation using quantitative vegetation analysis method (Frontier Tanzania, 2001). The method involved marking of three (3) transect lines running on North- South direction; 150m apart in each level of altitude (2300m, 2400, and 2500m) in three sites of Kibonge forest, Kona mbili ($35^0 34^/$ 5E- $0^0 19^/$25N), Kona mboga (35^0 $34^/$ 5E- $0^0 18^/$35N) ,and View point (35^0 $32^/$ 25E- $0^0 15^/$30N). On the transects and using a pre-measured 50m rope, a clinometers , a pair of compass and colored plastic tags, 50 m sections were cut through the forest on a 90 or 180 degree bearing regardless of the vegetation type, two plastic tags were placed at each 50m interval along the transect where the distance along that transect section was written. For example, at 50m along the transect, the tags were marked. After another 50 m, the two tags were marked “100m” etc. This continued to 1000m where three tags were placed to mark the beginning of the next section along the transect. Transects were numbered sequentially and cut as straight as possible, although difficult terrain and irregularly-shaped habitat meant that transects contained many turns. Each section along the transect was given an identification number similar to the identification number given to the 50m x 20m vegetation plot. The, 50m x 20m vegetation plots were marked systematically after every 50m marked on alternating sides of the laid transects using a GPS recorder and pre- measured ropes (2 x 20 m ropes and 2 x 50 m ropes). The 50 m ropes were laid on a 180 or 90 degree (East – West) bearing and the 20 m ropes were laid on 0 or 270 degree (North – South) bearing, the ropes remained laid out while the trees were being measured and marked.

On the plots, all trees and shrubs of 10cm DBH and above within the 50m x 20m plot, were numbered sequentially beginning at “1”. This individual tree identification number was written directly below the DBH line. Above the DBH line, the number of the vegetation plot was marked also.

Multi-stem trees with individual stems of less than 10cm DBH, were recorded if the cumulative DBH was 10cm or over. All stems arising from the central stem at 1.3m and below was added. The stems were marked with paint at the place where the DBH was measured. If the tree had a buttress, its DBH was measured 1.3m above the top of the buttress. Fallen trees but still alive were processed as above. Dead trees were not counted. For trees growing on a slope, the 1.3 m was measured from the uphill side of the tree.

Voucher specimens were collected and pressed for further identification and analysis at Eldoret University laboratories in the school of Natural Resource Management. Figure 3.2 (a and b), shows how to measure depth at breast height (DBH) at various terrains (Miyaura, and Hozumi, 1982)

Figure 3. 1a: Position for diameter measurement at breast height in flat terrain

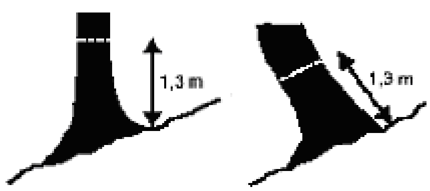


Figure 3: Diameter at breast height measurement position for a tree on steep terrain.

Canopy cover for a sample of trees were determined by measuring the diameter of a tree at breast height (DBH).The sum total would give the canopy cover of the forest. DBH as a measure of tree size was preferred, because inter-observer reliability for this measure is high (Chapman *et al.*, 1992) and the square of DBH as well as the basal area (DBH^2/ 1.273), is a good predictor of leaf biomass (Enquist *et al*, 2002). Also, use of crown volume would be impractical to measure, because the canopy in the forest is often entangled with vines that make crown edges very difficult to see.

3.3.3 Statistical analysis of Data

Basal area was calculated using the formula:

Basal area = DBH^2/ 1.273 (Enquist *et al*., 2002)

Where, DBH is diameter at breast height and 1.273 is a constant.

Estimation of Canopy Cover was given in terms of percentage cover (Enquist *et al*., 2002):

%Canopy cover = Area covered by a species(Basal area) in a line transect divided by the total area covered by all the species multiplied by 100.

Relative coverage = [Coverage (Dominance of a particular species) / the total coverage (Dominance) for all the species in a stand] x 100.

Species Composition was measured using the method by Misra (1989) and Sorensen (1948) where

a) Index of similarity (S)

$$S= 2C/A+B$$

Where, A = Number of species in the community A,
B = Number of species in the community B
C = Number of common species in both the communities.

b) Index of dissimilarity = 1-S

Similarity index suggests that species present in one habitat (line transect) may occur in the other whereas dissimilarity index indicate that some trees species recordered in one line transect are not encountered in only one line transect or in only two line transects but in all line transects.

3.4 Procedure for Human Disturbance assessment

This was aimed to assess the level of human disturbance based on tree cutting, timber extraction and other forms.

On each of the 20m by 50m plots established for vegetation status above, the level of disturbance was assessed in terms of tree cutting, debarking, pruning ,fires and footpaths and even the number of trees cut or left standing in a plot. In this study, trees of interest were those with DBH $\geq$15cm. The procedure followed was as follows:

A team of three people, two observers and one recorder started data collection at the beginning of the transect line. One observer described one side of the transect, while the second observer described the other side, and the recorder noted down all observations made. On each plot, the DBH of every live tree, naturally dead tree, cut tree stump were measured by the observers within the disturbance transect. Any cut, standing and naturally fallen trees were counted and identified where possible and findings recorded immediately on a data sheet by the recorder. Cut trees and poles were described as ‘old cut’ if there was any sign of blackening of the stump, if none, it was recorded as ‘fresh cut’.

Fallen tree trunks or branches were not counted in order to reduce any possible duplicate counts as one does not count a trunk then further along the transect count the base from which it came. Each transect line was surveyed separately.The recorder recorded opportunistic human disturbances such as traps, pitsaws, cleared areas or evidence of fire, seen along the transect. All observations were recorded on prepared data sheet (Appendix 1).

3.5 Abundance and Behavioral sightings of *Colobus angolensis* monkeys

The abundance of *Colobus angolensis* was assessed along straight line-transects according to: Buckland *et al.*, (1993); Struhsaker, (1997) and Plumptre, (2000). Census of *Colobus angolensis* monkey was done aiming to determine the population of Colobus monkeys in Kibonge forest to be related to the amount of food available in the study area. Before the census was undertaken, three personnel, for purposes of only increasing their safety were identified to participate. The Local hunters and guides were preferred to help in locating suitable sites and transect start points. Also equipments such as paint, tape measure, Compass, pair of binoculars, Geo positioning system recorder, recording sheets were assembled. These were used to identify, measure and mark places where transects should begin and the direction in which they should run on the ground. Three transects of 3km long and 5 km apart, running in a N-S direction on an elevation of 2300m to 2600m were marked (Fig 3.1) using a Garmin Plus Global Positioning System (GPS) and compass. Vegetation along it was cut to pave way for data collection. After cutting the line transect they were given distinctive names as corner two in Mwen section and in Segen section were, corner four and view point. Then the study group waited for at least 24 hours before proceeding with the survey so that primates could recover from the disturbance to the area.

Data collection through systematic survey commenced during the dry months of Dec 2012 to Feb 2013. Early in the morning (soon after dawn 7.00- 9.00am) or in the afternoon (after about 15:00 Hrs), surveyors (n= 3) for each transect, walked slowly at a speed of 1km/hr on a calm dry day in order to identify troops of colobus monkeys present, their population and structural composition. Morning and evening hours is suitable time for collecting foraging data since the monkey active feeds in cool hours of the day. Crossing by other survey teams on transects was not encouraged during the survey period since this would disturb troops and as a result may leave the area to be surveyed. A duration of not more than 10 minutes was taken in moving up and down the transect, and left to right, to study the animals. Repeated transect walks were done five times a month giving 15 random replicates for each transect.

At the first encounter with a monkey and using a pair of binoculars to view it, the following information was recorded on a recording sheet: time of day, means of detection such as sighting, branch movement, falling fruit, alarm calls, fleeing animals, etc., the number of different individuals seen (adult males, females, infants), any special marks like bent tails; estimated group size including those heard but not seen and accurate measurements of the distance and perpendicular distance from the transect to all individuals that were seen . Distance was determined either by direct measurement, using a tape measure or by pacing or by estimation on a rugged terrain.

3.5.1 Data collection on seasons and feeding behavior

Using Trail method (Butynski, 1984), Colobus monkey troops were followed all day for feeding behaviour .The trails were conducted in two seasons**,** wet season and dry season partitioned on the basis of mean rainfall and temperature (Nowak, 2007). Rainfall peaks occurred during the long rainy season, March–June and the hottest dry period was between November and February.

Troop observations began in mid-March, the beginning of the long rains period, and ended in mid-June, just at the end of this period for the wet season and in mid-November to mid -March of the following year for dry season. *Colobus angolensis* monkey species have two major feeding bouts, one in the morning from around 6am to 9am and another one in the evening from around 4pm to 6pm. They also have a smaller feeding bout around 1pm. Following this information, identified troops were trailed during the census period, one in Segen section and the other in Mwen section, of the study area. Observations on the focal animals in the troop one at a time were made in morning and afternoon sessions spanning from 06:20am to 09:00am in the morning and 16:00pm to 18:15pm in the evening. Visibility conditions were better at 06:20am as the sun had risen, so this was chosen as a start time. For the first week the troops were observed until 9:15am but this did not provide any more feeding data so 9am was used from then on. Also in the first week the troops were observed until 6pm, but we noticed that they kept feeding until sun set, so after the first week, the evening observation times were extended to 6:15pm as that was as long as visibility conditions allowed.

At the first encounter with a monkey and using a pair of binoculars to view the animal, the following information was recorded on a recording sheet (Appendix 2); tree species fed on by the colobus monkey, part of the tree eaten, and time spent feeding on the tree part and its diameter at breast height (DBH) and height. Samples of the identical plant parts were collected from the tree or the ground and put in a field bag to be transported to the lab at University of Eldoret. Then a field bag was put on the transect at the point from which the first animal was seen, to act as a reference point from which other measurements could be made and where food samples would be collected from. Other information gathered and recorded were behavioral details such as activity of monkey when encountered either feeding, grooming, chasing one another, or the group's reaction upon seeing the observer e.g. wary, curiosity, panicked flight, indifference.

3.5.2 Statistical analysis of Data

In calculating the population density in Groups/Km^2**,** three sets of data were required:

i. The length of transect surveyed (L),

L = (length of the transect) x (the number of surveys)

ii. The numbers of groups encountered include all those groups containing both males and females, while groups which appeared to contain only adult males and solitary groups were noted separately. Using these two pieces of information, the relative abundance of a species (e.g. groups per kilometre walked) was calculated ,Skorupa, (1986) as follows,

Relative abundance = No. of groups encountered/ Distance (km) walked

iii. Forest area = width of the survey strip x distance surveyed

Where Survey strip = distance between belt transects

Therefore,

Population density = group size /unit area.

In determination of Selection Ratios (food preference), all of the feeding behaviors by tree species were compiled and frequencies converted into percentages according to Clutton-Brock, (1975).

Selection ratio (SR) = [(% of total feeding records made on species) / (% canopy cover of tree species in the vegetation sample)] x 10.

Selection ratios larger than 10 suggest a particular species is chosen more often than its abundance would predict if food is chosen at random. Similarly, selection ratios lower than 10 suggest the opposite that a particular species is chosen less often than its abundance would predict if food is chosen at random.

3.6 Sample Collection, Preservation, and Handling

For the two groups of monkeys **(**large and small) food items eaten were identified. Using a tree pruning pole tree leaf parts eaten (either mature leaf, young leaves, bark, flower or fruits) by the monkey were cut and dried and put in labeled bags then transported to the laboratory at university of Eldoret for analysis. All samples were dried at $55^{o}C$ in a cabinet-type forced hair dryer for 12-16 hours and later ground dried samples to pass through a 1-mm mesh screen in a Wiley mill (stainless steel). The samples were analyzed in duplicate for dry matter, crude fiber (ADF), crude protein, secondary compounds and minerals.

3.7 Nutritional analyses

Dry matter was determined by drying a portion of each sample overnight at $105^{\circ}C$. The weight of the dry sample was measured and recorded.

The protein (nitrogen) content of the plant parts was assessed using Kjeldahl procedures (Horwitz, 1970). Samples were digested via a modification of the aluminum block digestion procedure of Gallaher *et al.,* (1975). The digestive mix contained 1.5g of 9:1 K_2SO_4:$CuSO_4$ and digestion proceeded for ≥4h at $375^{\circ}C$ in 6ml of H_2SO_4 and2ml H_2O_2. The nitrogen was determined in the digestate by semi-automated colorimeter (Hambleton, 1977).

For the identified forages parts collected, the following tests were carried out to determine the amount of fibre on the food part following the ADF (Acid detergent fibre) procedure (Van Soest, 1963). ADF measure of cell wall cellulose and lignin was in terms of ADF content, which are refractory components of fiber. ADF has been found to have a strong negative correlation with food selection by primates (Glander, 1982; Oates *et al.*, 1990). The procedure for determining ADF was as follows;

Thirty five grams (35 g) of air dried sample was weighed ground and sieved through a #40 sieve and put into a test tube then 35 ml of ADF solution and 1 ml of decalin was added .A large marble was placed on top of each test tube then they were placed in aluminum block and brought to boil gradually to approximately 124^{O}C for one hour. Feed particles collecting above digestion fluid level were returned to the boiling mass by washing down the sides with a small amount of warm ADF solution. The cooled contents were filtered through a previously weighed sintered glass crucible using a light suction and then washed with hot water. Washing was repeated with acetone until no more color was removed. The residue was dried at 100^{O}C weighed and recorded.

3.7.1 Lignin Procedure

Crucibles containing dried and weighed ADF were placed into a shallow enamel or glass plan containing 1 cm cold water while ensuring that ADF in crucibles remained dry. Then these crucibles were filled half full with saturated potassium permanganate and buffer solution. A short glass rod was used to break lumps and draw permanganate solution up on sides of crucibles. The crucibles were left to stand at room temperature for 90 minutes. To maintain the purple color, more mixed permanganate solution was added where necessary. Crucibles were removed to filtering apparatus and one by one, sucked dry. Again the crucibles were filled half full with demineralizing solution. With a glass rod the contents were moved while taking care that, all feed particles were under the solution and the sides of the crucibles were rid of all color.

After 5 minutes, the crucibles were sucked dry and refilled halfway with demineralizing solution. The sides of the crucibles were re-rinsed. This treatment was continued until the filter was white. Then the crucibles and contents were filled and washed with 80% ethanol. It was suck dried and washed twice with acetone or with ethanol. The residue was dried at $100^{O}C$ weighed and recorded.

3.8 Test for Secondary compounds

Samples were assayed for secondary compounds by, specifically condensing the saponins, anthraquinone derivatives, flavonoids, tannins (CT) and alkaloids, following assay procedures described below by Remis *et al.*, (2001) and Powzyk and Mowry, (2003)).

3.8.1 Frothing test for saponins

Water extract was obtained by boiling respective samples on the water bath. The extract was transferred into a test tube and shaken vigorously then was left to stand for 10 mins and the result noted. A thick persistent froth indicated presence of saponins.

3.8.2 Borntrager's test for anthraquinone derivatives

Chloroform extract of the material was obtained by boiling on the water bath. To 2 mls of this extract, 1ml of dilute (10 %) ammonia was added and the mixture was shaken. Any colour change was recorded. A pink-red colour in the ammoniacal (lower) layer showed anthracene derivatives.

3.8.3 Test for Flavonoids

Water extract of the sample was reduced to dryness on the boiling water bath. The residue was treated with dil. NaOH, followed by addition of dilute HCl, solubility and colour was noted. A yellow solution with NaOH, which turned colourless with dil. HCl confirmed presence of flavonoids.

3.8.4 Ferric chloride solution test for tannins

Water extract was treated with 15 % ferric chloride test solution. The resultant colour was noted. A blue colour indicated condensed tannins, a green colour indicated hydrolysable tannins.

3.8.5 Colour tests/ Spot tests for alkaloids

Five hundred milligrams (500 mg) of plant material was extracted with 500 mls of methanol for 20 minutes, on a water bath. The extract was filtered off and allowed to cool. This extract was dispensed in 2 ml of portions into four different test tubes. Either the Dragendorff's or Hager's or Mayer's or Wagner's alkaloidal reagent was added to each tube and the presence or absence of colours of any precipitates was noted in each test tube.

3.8.6 Test for minerals

To assess mineral content, samples were dried, weighed, ashed, and solubilized samples with hydrochloric acid (Miles *et al.,* 2001). Additionally, a sample of known mineral concentration (Certified National Bureau of Standards Citrus leaves SRM-1572) was run with each set of plant samples to ensure that values obtained from the AAS were accurate (NIST, 1982). Tests were carried out on 10 minerals, 5 macro minerals (Ca, K, Mg, Na,

P) and 5 trace elements (Co, Cu, Fe, Mn, Zn) by atomic absorption spectrophotometry via a Perkin Elmer AAS 5000 (Perkin-Elmer, 1980) and the measurements were reported in mg/kg.

CHAPTER FOUR

RESULTS

4.1 Status of Kibonge forest Resource

Land use/ cover patterns during the years 1978 - 2016 are presented in Figure 3. Land cover included plantation forest, shrubland, grassland and farmland/bare land. The coverage was indicated in terms of kilometre square (Km^2) and percentages coverage of the total area. The percentage coverage of different land use/ cover were derived from the eight images in Table 1 for years 1978, 1984, 1989, 1995 ,2000, 2006, 2011 and 2016 .

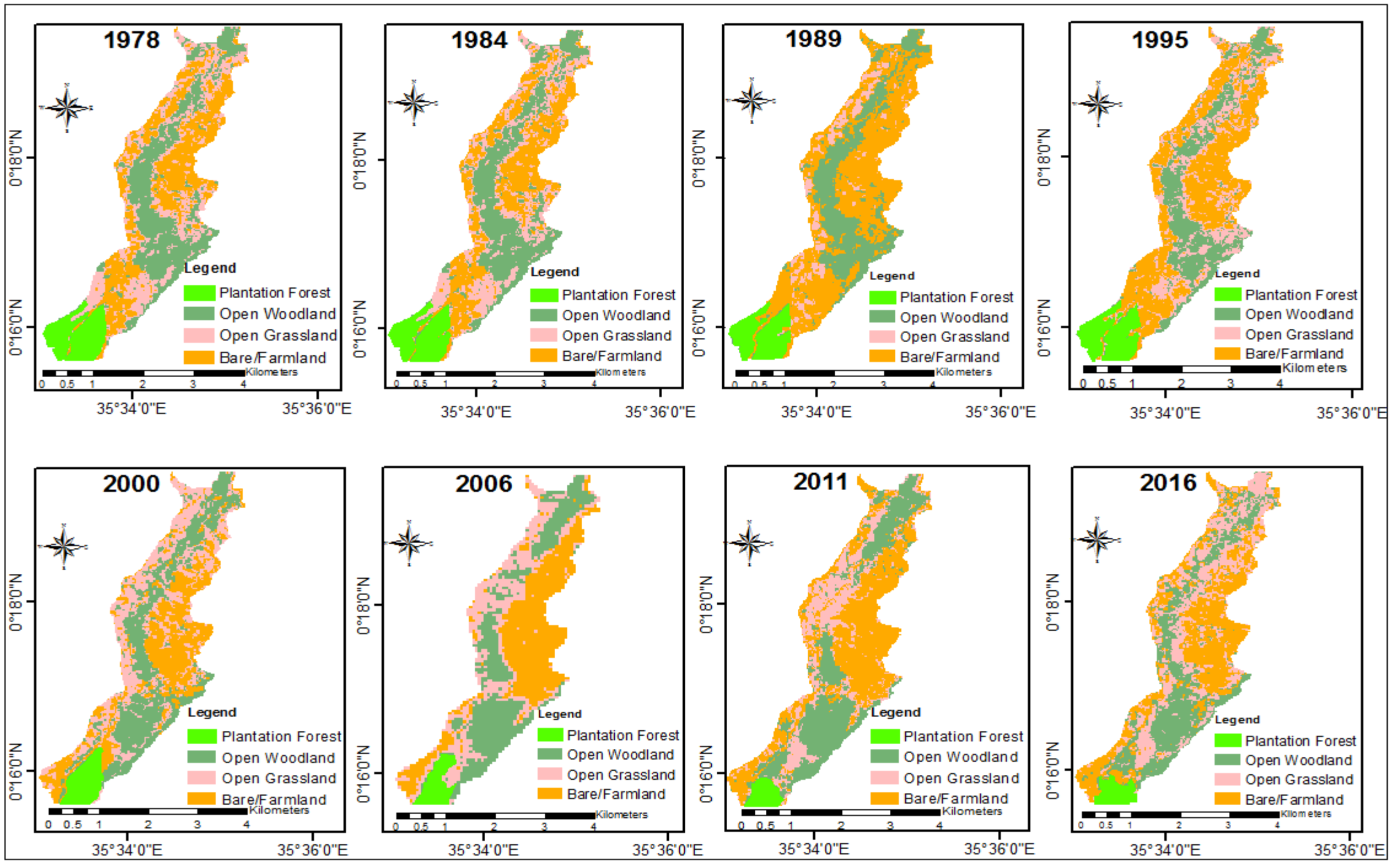


Plate 4.1: Maps showing land use/cover types of Kibonge forest over the years 1978 to 2016.

Source: Author, 2017

4.1.1 Change in area of the various land cover types

Satellite image analyses showed that land use and land cover changes have occurred in the study area between 1978 and 2016. The results from the supervised classification of the images shown in Table 4.1 indicate losses and gains in various land use and land cover types. Bare/farmland (33.1%) occupied much of the land cover in 1978 followed by shrubland (30.1%) and open grassland (27.4%). Similarly, the year 1984 followed the same trend. In 1989, open grassland increased to 32% while bare/farmland decreased to 30.6%. It is apparent that the area covered by open grassland reduced drastically between 1989 and 1995 with an increase in bare/farm land (54.2%). The results from the 2011 and 2016 images indicate a loss of open grassland.

From the percentage change in land use land cover (LULC) estimates in Table 4.2, there has been a loss of Kibonge forest, whose area has shown decreasing trends {1 Km^2 (9.50%), 1 Km^2 (9.1%) and 0.9 Km^2 (8.6%) 0.9 Km^2 (8.9%), 0.6 Km^2 (5.8 %), 0.5 Km^2 (4.6%), 0.3 Km^2 (3.0%) in 1978, 1989, 1995, 2000, 2006 and 2011 respectively}.There was an overall reduction of -6.16% between 1978 and 2016 in Kibonge forests.

Table 4:1: Percentage Area of land use/cover of Kibonge Forest from the years 1978 to 2016.

	% Area of the total study area							
Land use/cover	**1978**	**1984**	**1989**	**1995**	**2000**	**2006**	**2011**	**2016**
Plantation forest	9.5%	9.1%	8.6%	8.9%	5.8%	4.6%	3.0%	3.3%
Shrubland	30.1%	30.3%	28.8%	27.8%	30.2%	32.3%	29.4%	31.4%
Open grassland	27.4%	24.9%	32.0%	9.1%	27.0%	28.7%	31.6%	22.9%
Bare/farmland	33.1%	35.6%	30.6%	54.2%	37.0%	34.5%	36.0%	42.4%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4. 2: Percentage change in land use/ cover sizes of Kibonge forest from the years 1978 to 2016

	Percent change							**Overall**
Land use/ cover types	**1978-1984**	**1984_1989**	**1989_1995**	**1995_2000**	**2000_2006**	**2006_2011**	**2011_2016**	**change 1978_2016**
Plantation forest	-0.32	-0.50	-17.55	-3.13	-1.20	-1.56	+0.29	-6.16
Shrubland	+0.21	-1.48	-56.61	+2.43	+2.06	-2.88	+2.00	+1.31
Open grassland	-2.45	+7.03	-41.02	+17.96	+1.64	+2.96	-8.73	-4.50
Bare/farmland	+2.56	-5.05	-84.82	-17.26	-2.50	+1.47	+6.45	

The regression models in figure 4.2, expresses an evidence that there is a significant increase in bare farmland ($R^2 = 0.0585$) and in open grassland ($R^2 = 0.0016$) over years 1978 to 2016. Also there is a significant relationship (n=8, r=-0.949, p=0.0003), between farmland and open grassland. Thus, as the size of bare/farmland increase the size of open grassland decrease.

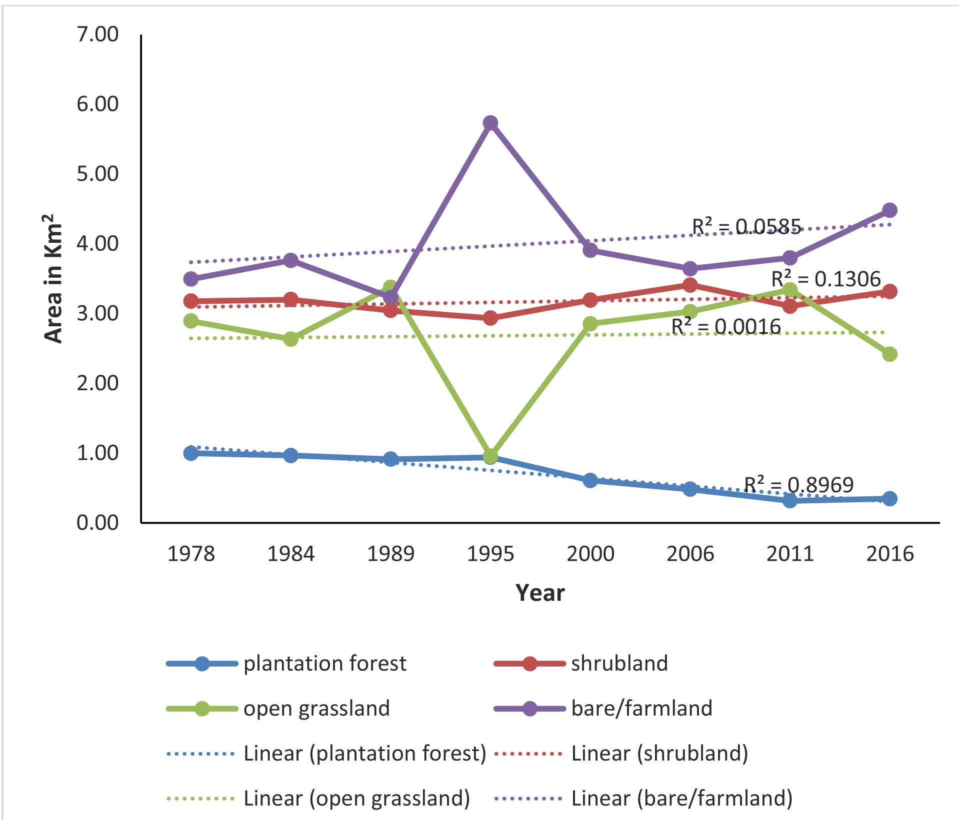


Figure 4.1: Regression model of change in land use land cover area in Kibonge forest region from the years 1978 to 2016.

4.1.2 Status of Black and white colobus monkeys (*C. angolensis*) in Kibonge forest

The black and white colobus monkey (*C. angolensis*) population were higher in Mwen (58%) than in Segen (42%). In Mwen, monkey population had a higher mean (20.6±15.71) than for Segen mean (13.0±4.8) (Table 4.3). There were more females than males and young. Total population of *C. angolensis* in Kibonge had a mean of 33.6± 19.51 (Table 4.3).

Table 4.3: Mean population of C. *angolensis* in Mwen and Segen regions of Kibonge forest during the years 2013-2015

Region	Mwen		Segen		Kibonge population (Mwen +Segen)	
Sex	Population	Mean±SE	Population	Mean±SE	Total Population	Mean±SE
Male	28	5.6 ± 4.83	18	3.6 ±1.67	46	9.2± 5.5
Female	46	9.2 ±8.79	23	4.6± 2.19	69	13.8± 9.98
Young	29	5.8 ±3.19	24	4.8 ±1.3	53	10.6 ±3.49
Total	**103**	**20.6 ±15.71**	**65**	**13.0± 4.8**	**168**	**33.6 ±19.51**

The monkeys devoted most of their time in feeding (56.3%) throughout the study period, while the remaining time was either used for basking (16.8%) or resting (26.8%) (Fig 4.3).

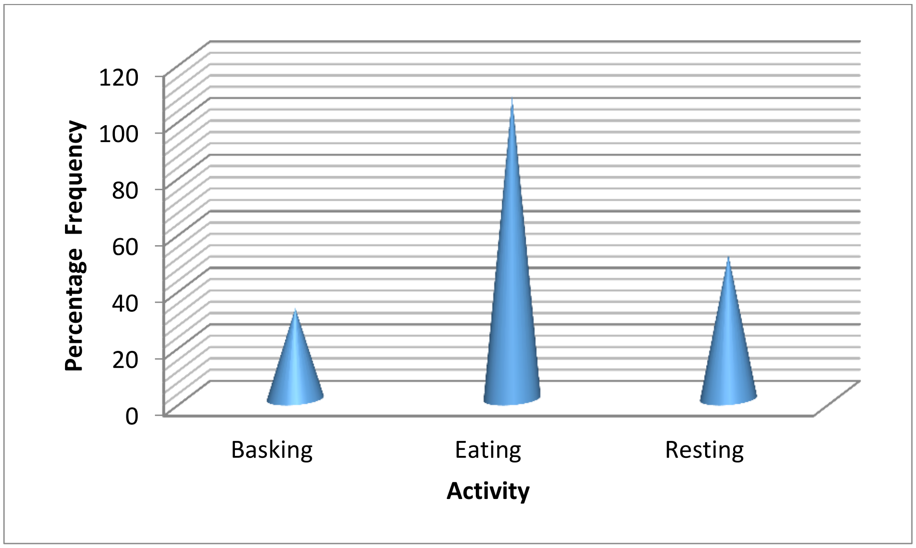


Figure 4.2: Activity budget of *C. angolensis* in Kibonge Forest. The monkey devoted most of its time in feeding than resting and basking during the years 2013-2015.

4.1.3 Field Findings of Vegetation in Study area

From field findings, there were many trees of various species, n= 1124. Segen had the highest percentage frequency (74.8%) occupying a basal area (BA) of approximately 14.3m^2 while Mwen had a lower percentage frequency (25.2%) occupying a BA of approximately 9.55 m^2. In Mwen majority of the tree species were *Dombeya goetzenii* (68%), *Macaranga kilimandascharica* (33%), *Albizia gummifera* (27.8%), *Nuxia congesta* (17.1%), *Cupressus lusitanica* (13.9%), *Croton macrostachyus* (29.2%) and *Prunus africana* (31.3%) Fig. 4.4. Majority of the trees in Segen were *Cupressus lusitanica (57.4%), Macaranga kilimandascharica (6.8%), Dombeya goetzenii (16.8%), Prunus africana (5.2%)* and *Vangueria madagascariensis* (11%). Other trees represented a population of less than 1% (Fig 4.5). Based on altitude majority of the trees n=542 (48.8%), were sampled along altitude 2400m in both regions, followed by those in altitude 2500m, n=413 (36.7%), while the fewest below 10% were in altitude 2300m, n=69 (6.1%) and at 2600m n=94 (8.4 %) (Table 4.4). However , an ANOVA test to find the relationship between canopy cover of tree species in the two regions showed no significant difference in canopy cover of tree species between the two regions (F=1.390, P= 0.239).

Table 4.4: Tree frequency distribution in altitudes 2300m, 2400m, 2500m, and 2600m in Kibonge forest

ALTITUDE(m)	Frequency	Percent
2300	69	6.1
2400	549	48.8
2500	413	36.7
2600	94	8.4
Total	1125	100.0

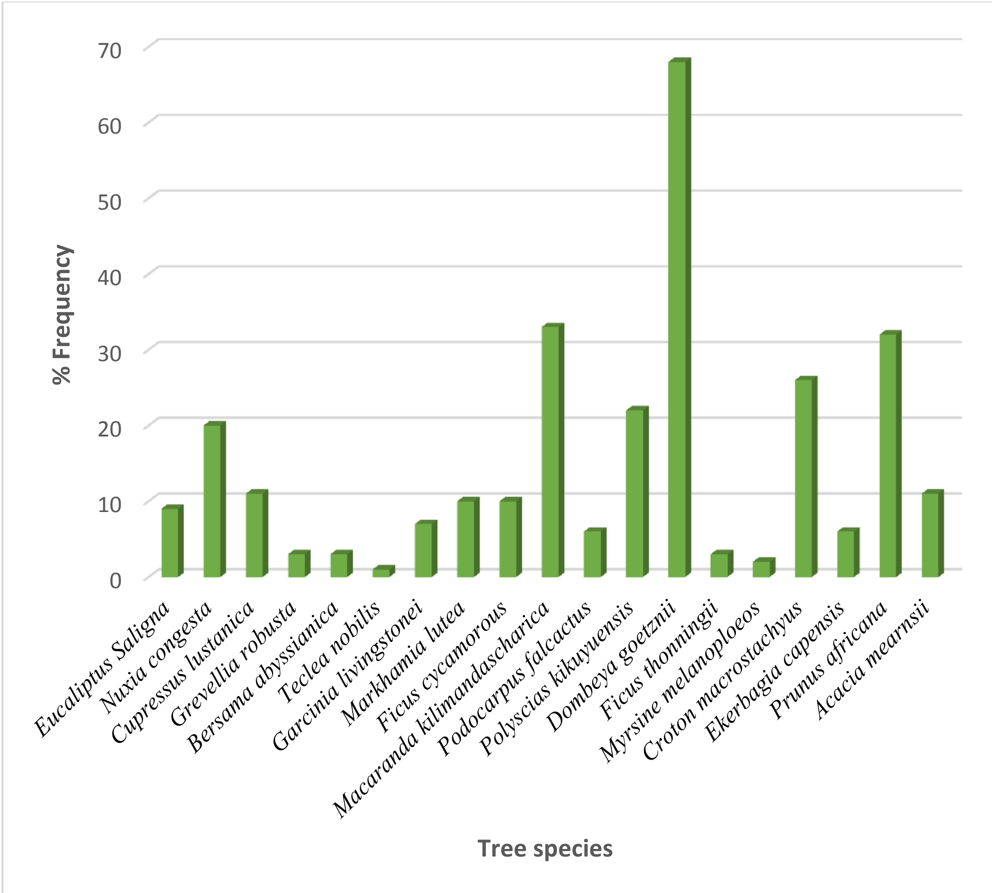


Figure 4.3: Frequency distribution of trees in Mwen region of Kibonge forest. *Dombeya goetzenii, P. africana* and *C. macrostachyus* are the dominant species

From the figure 4.5, it is clear that in Segen majority of trees sampled were *Cupressus lusitanica* n=483, (57.4%) covering (2.64m^2/Ha) of the forest unlike in Mwen were majority of trees sampled were *Dombeya goetzenii* n=68, (24%) with a canopy cover of 2.94m^2/Ha.

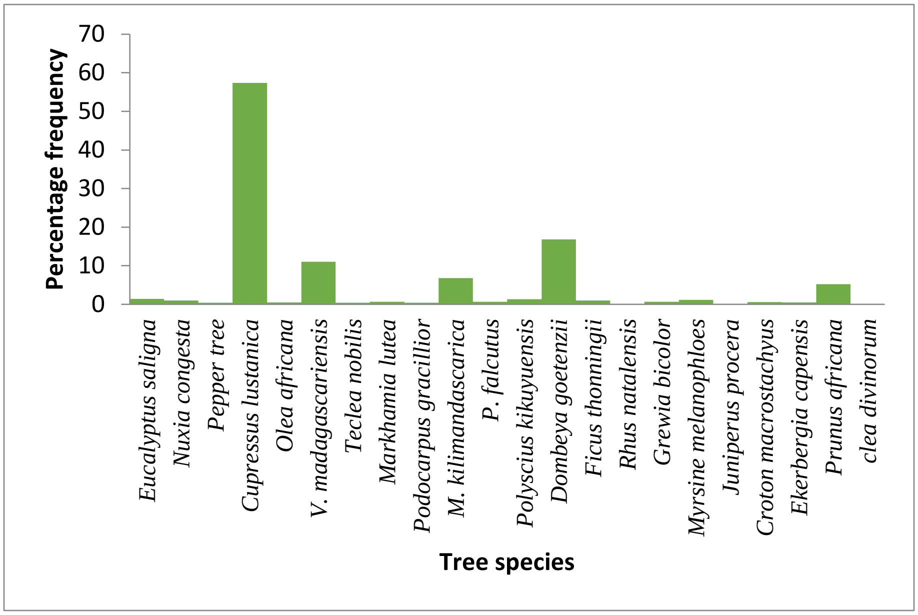


Figure 4.4: Tree frequency distribution in Segen region of Kibonge forest (*C. lusitanica *and* Dombeya goetzenii *are the dominant species) during the year 2013 -2015

4.1.4 Tree species distribution and altitude

A chi-square test showed a significant difference (n=1124, p ≥0.001, df =78) in tree distribution within altitudes. Most of the tree species are distributed along altitude 2400m and 2500m (Table 4.5). For instance *Nuxia congesta, C. Lusitanica, F. cycamore, P. kikuyuensis* and *M. melanoploes*, had a higher population in altitude 2400m. *Macaranga spp* and *Dombeya spp* were evenly distributed in all altitudes. *Junispera procera, Podocarpus gracillior* and *Uclea divinorum* are few n=1 and only found in altitude 2400m. *Cupressus lusitanica, Grivellia spp, Eucalyptus spp*. and *Acacia spp*. are also distributed in altitude 2400m. *Olea Africana* (n=4), are only found in the steep locations of altitude 2300m (Table 4.5).

Table 4.5: Cross tabulation of tree species and altitude in Kibonge forest during study period (2013 -2015)

Tree species	ALTITUDE				Total
	2300	2400	2500	2600	
Eucalyptus spp.	0	21	0	0	21
Nuxia congesta	0	22	5	1	28
Pepper tree	0	0	3	0	3
Cupressus lusitanica	10	227	253	4	494
Olea africana	4	0	0	0	4
Grivellia robusta	0	3	0	0	3
Vangueria madagascariensis	6	3	0	0	9
Bersama abyssinica	0	0	3	0	3
Teclea nobilis	3	0	1	0	4
Garcinia livingstonei	2	0	7	0	9
Markhamia lutea	0	9	2	7	18
Ficus cycamore	0	15	0	0	15
Podocarpus gracillior	0	3	1	0	4
Macaranga Kilimandascharica	5	35	28	22	90
Podocarpus falcutus	2	1	9	0	12
Polyscias kikuyuensis	8	23	0	2	33
Dombeya goetzenii	0	83	83	43	209
Ficus thonningii	2	7	2	0	11
Rhus natalensis	0	0	1	0	1
Grewia bicolor	4	2	0	0	6
Myrsine melanophloes	2	8	0	2	12
Juniperus procera	0	1	0	0	1
Croton macrostachyus	5	26	3	2	36
Ekerbagia capensis	0	5	3	2	10
Prunus africana	15	49	9	3	76
Uclea divinorum	0	1	0	0	1
Acacia mearnsii	0	5	0	6	11
Total	**68**	**549**	**413**	**94**	**1124**

4.2 Tree attributes and values

Diameter at Breast height (DBH) of all trees in Kibonge were grouped at intervals of width 10 are shown in Table 4.6 below. Majority of trees fell within DBH range 30-40cm (37%) while fewer were within range 0-10cm (6%). There was a significant difference in DBH of trees between regions Mwen and Segen (df =1123, F= 4.194, p= 0.041).

Table 4.6: Tree frequency distribution grouped at intervals of 10 in Kibonge forest during study period

DBH group	Frequency	Percent
0-10	6	0.5
10-20	221	19.7
20-30	143	12.7
30-40	416	37.0
Above 40	338	30.1
Total	1124	100.0

From figure 4.6 below, the food trees which fell under DBH range of above 40 cm are *Rhus natalensis* and *Ficus thonningii* with the greatest DBH (>120cm), *Prunus africana*, *P. kikuyuensis* and *Grewia bicolor* had their DBH fall within the range 40-60cm. Other trees had a DBH below 40cm as shown in the figure below.

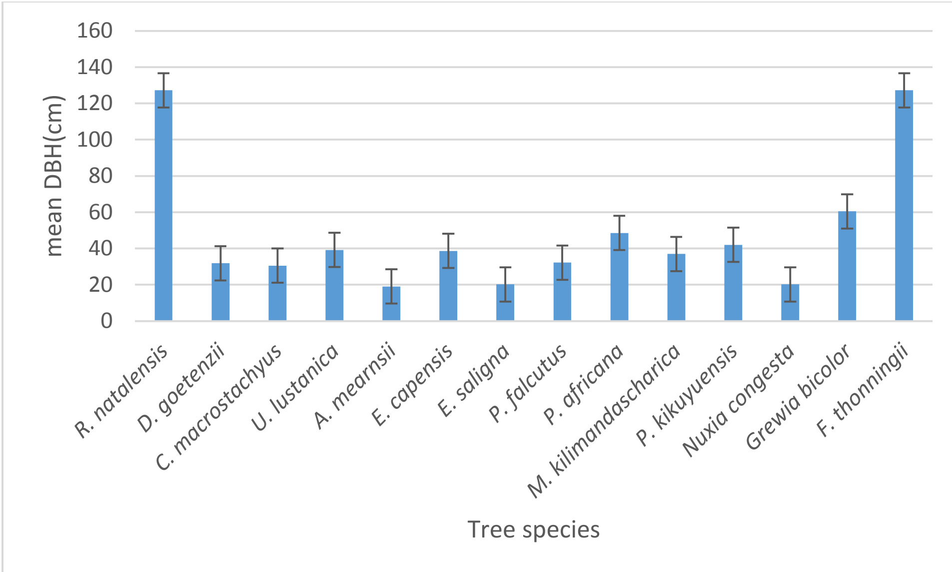


Figure 4.5: Mean ± SE diameter at breast height of tree species utilized by *C.angolensis* during wet season during the study period.

From Figure 4.7 trees utilized by *C. angolensis* for food have a DBH of 40 cm and below. *A.mearnsii*, *Dombeya goetzenii*, *P. facutus*, *E. capensis*, *M. kilimandascharica* and *C. macrostachyus* have DBH 30- 40cm where majority of trees in Kibonge fell. DBH of *N.congesta, E. saligna* and *M. lutea* ranged from 20 – 30 cm.

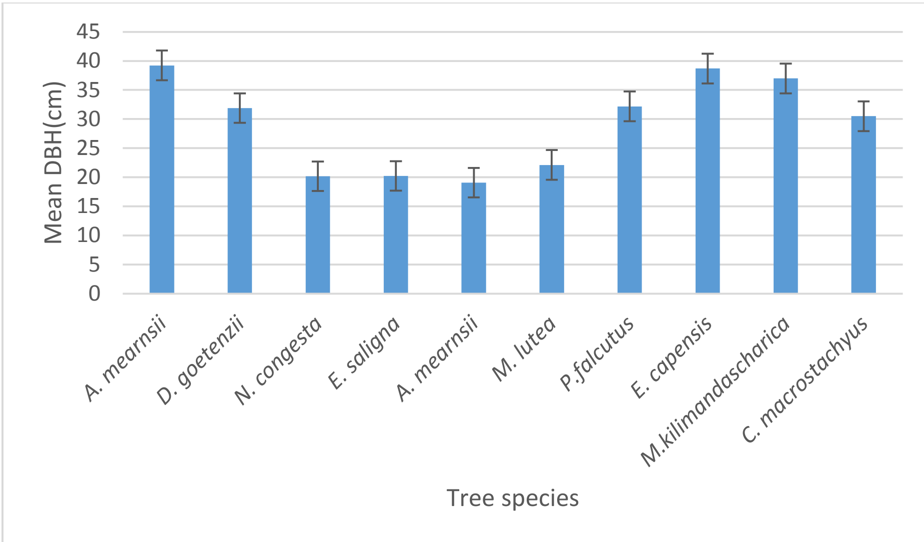


Figure 4.6: Mean ± SE diameter at breast height of tree species utilized by *C.angolensis* during dry seasons over the study period.

4.2.1 Basal area and Canopy cover

Overall resource abundance as measured by basal area (m^2/ha) for all trees in Kibonge forest was 23.7489m^2/ha. The basal area and percentage canopy cover of all the trees are shown in Appendix 2**.** The higher the percentage frequency of trees, the greater the basal area (BA) and subsequently percentage canopy cover.

4.3 Tree disturbance

Data of undisturbed trees and disturbed were collected from 87 vegetation plots for both regions, which amounted to an area of 8.7Ha. A total of 327 trees were disturbed. Of the tree population n=227 (69.4%) were damaged by cutting, then by pruning (16.5%), and debarking (8.9%) (Plate 4) and burning (1.8%) (Plate 5). Other forms of disturbance recorded were firewood collection (Plate 6), pitsaws and by natural disasters such as landslide (Plate 7) which occurred in Mwen region during the study period and accounted for 3.4%.

Plate 4.2: Debarked tree in kibonge forest for purposes of getting bark for harvesting honey and dry tree used for firewood taken during the study period (Year 2013 - 2015). Source: Author

Plate 4.3: Charred tree by fire during fire outbreaks in Kibonge forest during the dry season taken during the study period (Year 2013 - 2015). Source: Author

Plate 4.4: Firewood collection in Kibonge taken during the study period (Year 2013 - 2015). Source: Author

Plate 4.5: Land slide in Kibonge taken during the study period (Year 2013 - 2015)

Source: Author

Chi square test posted a significant correlation between type of disturbance and DBH of trees ($\chi^2 < 48.767$, df =20, $p < 0.0001$). The greatest form of disturbance in Kibonge is by cutting of trees of medium size with range of DBH between 10-40cm (62.1%) (Table 4.7). Burning affected only the small sized trees DBH (10-40cm) whereas debarking was prevalent in the smallest (DBH 0-10cm) and on largest trees DBH (>50cm).

Table 4.7: Cross tabulation of nature of disturbance against tree diameter during study period

Diameter	Type of Disturbance										Total	%
	Burnt	%	Cut	%	Debark	%	Others	%	Pruned	%		
0-10	0	0	26	11.45	6	20.68	0	0	4	7.4	36	11.0
10-20	1	16.67	57	25.11	3	10.34	0	0	15	27.78	76	23.2
20-30	4	66.67	23	10.13	4	13.79	3	27.27	11	20.37	45	13.8
30-40	1	16.67	61	26.87	5	17.24	1	9.09	16	29.63	84	25.7
40-50	0	0	24	10.57	4	13.79	5	45.45	3	5.56	36	11.0
50+	0	0	36	15.86	7	24.14	2	18.18	5	9.26	50	15.3
Total	**6**	**100**	**227**	**100**	**29**	**100**	**11**	**100**	**54**	**100**	**327**	**100**
%Total	**1.8**		**69.4**		**8.9**		**3.4**		**16.5**		**100**	

4.3.1 Tree disturbance and food tree

Percentage Canopy covers of disturbed and undisturbed highly selected foods were compared (Table 4.8). Much of the canopy lost was seen in food trees *Nuxia congesta* by 2.26% , *Ekerbagia capensis* by 15.2%, *Croton macrostachyus* by 2.36%, *Prunus africana* by 16.48%, *Ficus thonningii* by 7.28% and *M.kilimandascharica* by 8.7%. When the percentage canopy cover of food trees disturbed and the undisturbed food trees were correlated, there existed a significant difference (n=9, r=0.788, p= 0.02). The relationship between canopy cover of life trees and disturbed trees in wet and dry seasons were not statistically significant, (n=9, r = 0.492, p = 0.088). This implies that canopy cover of food trees undisturbed is directly proportional to the canopy cover of the disturbed trees such that as more trees are destroyed, canopy cover reduces. This effect has great implications to food supply of *C. angolensis*.

Table 4.8: Percentage Canopy cover of both disturbed and undisturbed highly selected food trees by *C. angolensis* monkey during the study period. Negation represents the percentage loss of canopy

Selected food tree	%Canopy cover Undisturbed trees	%Canopy cover Disturbed trees	Standard Deviation
Dombeya goetzenii	33.4	4.89	28.56
Nuxia congesta	0.3	2.7	-2.26
Cupressus lusitanica	26.6	5.08	21.6
Ekerbergia capensis	0.5	15.77	-15.20
Polyscias kikuyuensis	9.4	6.63	2.77
Croton macrostachyus	2.8	5.27	-2.36
Prunus africana	6.9	23.41	-16.48
Ficus thonningii	15.0	22.29	-7.28
M.kilimandascharica	5.1	13.93	-8.7
Total	**100**	**100**	

4.4 Utilization of forest resource by *C. angolensis*

Trees used as food by *C. angolensis* in Kibonge forest during wet and dry seasons are shown in Table 4.9. During the dry season, trees highly preferred for food measured by percentage feeding time in Mwen in order of merit were *Dombeya spp* (37.57%), *Nuxia congesta* (23.1%), *and Cupressus lusitanica* (18.0%). *Podocarpus falcutus*, *Markhamia lutea*, *Eucalyptus spp.* and *Acacia mearnsi* (Table 9) were not highly preferred. In Segen *Cupressus lusitanica (*78.9%), *Dombeya goetzenii (*20.6%), were highly selected all being indigenous species with a greater basal area (Table 9). During the wet season, *Polyscias kikuyuensis* (34.83%), *Dombeya goetzenii goetzenii (*48.9%), *Croton macrostachyus* (8.3%), were the highly preferred food trees in Mwen, while *Macaranga kilimandascharica* (19.7%), *Polyscias kikuyuensis* (19.1%) and *Prunus africana* (17.8%) were preferred in Segen. There was no correlation between food availability and food preference (n= 9, r= -0.354, p= 0.436) by *C. angolensis* monkey. That is an increase or decrease in food supply does not influence what the monkey will choose to consume at a given time.

Table 4.9: Preferred food trees and their selection ratio (SR) during study period

REGION	SEASON	Tree name	%Feeding record time	%canopy cover	Selection Ratio (SR)
MWEN	DRY	*Dombeya goetzenii*	37.57	31.66	11.87
		Nuxia congesta	23.12	2.87	80.44
		Acacia mearnsii	1.03	1.15	8.96
		Cupressus lusitanica	17.93	1.89	94.94
		Eucalyptus saligna	0.34	0.86	3.95
		Markhamia lutea	0.25	1.33	1.92
		Macaranga kilimandascharica	1.25	11.83	1.06
		Croton macrostachyus	0.79	4.12	1.92
		Podocarpus falcutus	0.17	1.02	1.66
		Ekerbergia capensis	0.45	2.71	1.67
	WET	*Polyscias Kikuyuensis*	34.83	9.4	37.06
		Dombeya goetzenii	48.89	31.66	15.45
		Croton macrostachyus	8.29	4.12	20.12
		Cupressus lusitanica	0.98	1.89	51.67
		Acacia mearnsii	0.43	1.59	2.73
		Ekerbergia capensis	0.72	2.71	2.67
		Eucalyptus saligna	0.58	0.86	6.76
		Podocarpus falcutus	0.14	1.02	1.42
		Prunus africana	5.13	23.753	2.16
SEGEN	DRY	*Cupressus lusitanica*	78.46	60.81	12.9
		Podocarpus gracillior	0.41	0.78	5.23
		Dombeya goetzenii	20.5	8.86	23.14
		Ekerbergia capensis	0.63	0.45	13.91
	WET	*Macaranga kilimandascharica*	19.69	6.66	29.59
		Polyscias kikuyuensis	19.13	2.14	89.56
		Prunus africana	19.77	7.44	26.59
		Nuxia congesta	0.11	0.14	7.69
		Grewia bicolor	1.64	1.78	9.21
		Cupressus lusitanica	20.1	60.81	3.31
		Ficus thoninngii	18.29	2.83	64.65

4.5 Nutrient availability in food trees

4.5.1 Laboratory analysis for nutrients of trees utilized as food by *C. angolensis* in wet and dry season

The nutrient composition of leaves of 9 plant species which were highly selected by the colobus in Kibonge forest regions during the wet and dry season were analyzed (Table 4.10) below. From adhoc statistical computation, leaves eaten by the monkey varied in mineral nutrient content and between seasons (Table 4.10). Minerals Nitrogen and Copper, varied between seasons while other macro and micro nutrients did not.

Nutrient concentration in the food trees were generally at higher levels during the wet season than in dry season (Table 4.10) below. Levels of zinc elements varied significantly between seasons (67.7^{A} µg wet season and 63.39^{B} µg dry season). Also the levels of ADF, Non Digestible fiber (NDF), Crude protein (CP), Nitrogen (N) and iron (Fe) varied significantly between seasons, (Table 4.10). Manganese (Mn) concentration levels were lowest at all seasons while zinc (Zn) concentration were highest (67.7^{A} µg, wet season and 63.39^{B}µg dry season) (Table 4.10).

Table 4.10: Variation of Mineral content in leaves of preferred food trees of *C. angolensis* monkey between seasons. Minerals with the same superscript do not differ significantly at 5% level of significance for the two seasons. All nutrients were measured in micro grams (µg)

SEASON	DM	NDL	ADF	NDF	CP	N	P	K	Ca	Mg	Mn	Zn	Fe
Wet Season	42.03^{A}	23.06^{A}	34.10^{A}	59.50^{A}	21.89^{A}	3.46^{A}	0.29^{A}	3.68^{A}	2.02^{A}	0.26^{A}	0.07^{A}	67.70^{A}	39.05^{A}
Dry Season	39.40^{A}	19.55^{A}	20.44^{B}	41.18^{B}	13.04^{B}	2.09^{B}	0.30^{A}	3.13^{A}	0.68^{A}	0.23^{A}	0.05^{A}	63.39^{B}	34.65^{B}

Table 4.11: Variation of Nutrient content in leaves among preferred food trees of *C. angolensis* monkey.

Minerals with the same superscript do not differ significantly at 5% level of significance among trees. All nutrients were measured in micro grams (μg)

PREFERRED FOOD TREES	DM	NDL	ADF	NDF	CP	N	P	K	Ca	Mg	Mn	Zn	Fe
Dombeya goetenzii	42.70^{E}	31.77^{A}	46.77^{A}	38.6^{H}	7.20^{I}	1.16^{I}	0.26^{E}	2.19^{G}	1.33^{AB}	0.18^{D}	0.12^{D}	68.5^{C}	38.83^{D}
Nuxia congesta	50.20^{B}	28.20^{B}	23.55^{D}	41.83^{G}	12.83^{G}	2.06^{G}	0.31^{BAC}	3.70^{D}	4.33^{A}	0.34^{AB}	0.19^{A}	73.1^{A}	71.0^{B}
Cuppressus lustanica	25.30^{I}	9.20^{G}	31.98^{B}	43.12^{F}	19.09^{F}	3.05^{F}	0.32^{AB}	3.51^{E}	0.42^{B}	0.19^{D}	0.02^{D}	61.5^{G}	71.73^{A}
Ekerbergia capensis	38.20^{G}	19.33^{F}	21.55^{E}	52.47^{D}	20.06^{E}	3.17^{E}	0.32^{AB}	5.15^{A}	0.81^{B}	0.35^{A}	0.02^{D}	62.7^{F}	21.93^{E}
Polycius kikuyunensis	44.37^{C}	19.43^{F}	17.03^{G}	52.33^{D}	28.04^{A}	4.46^{A}	0.30^{BDC}	3.04^{F}	0.15^{B}	0.13^{E}	0.02^{D}	63.9^{E}	15.9^{G}

Croton macrostachyus	52.50^{A}	22.38^{E}	15.77^{H}	61.62^{C}	21.45^{D}	3.38^{D}	0.29^{D}	3.02^{F}	0.50^{B}	0.21^{D}	0.01^{D}	58.9^{I}	15.30^{H}
Prunus africana	34.20^{H}	22.93^{D}	21.47^{E}	65.36^{B}	27.41^{B}	4.33^{B}	0.29^{DC}	3.83^{C}	1.27^{AB}	0.34^{A}	0.02^{D}	59.9^{H}	16.90^{F}
Ficus thonningii	39.43^{F}	25.41^{C}	20.15^{F}	75.5^{A}	23.77^{C}	3.80^{C}	0.32^{AB}	3.97^{B}	0.81^{B}	0.24^{C}	0.04^{C}	64.9^{D}	14.93^{H}
Macaranda kilimandascharica	43.50^{D}	7.80^{H}	26.70^{C}	49.70^{E}	10.58^{H}	1.62^{H}	0.26^{E}	3.08^{F}	1.01^{B}	0.31^{B}	0.18^{B}	69.95^{B}	43.59^{C}

4.5.2: Analysis of Nutrients In non-preferred food trees

The non preferred food trees with S.R <10, were *Acacia mearnsii*, *Eucalyptus saligna*, *Markhamia lutea, and Grewia bicolor* (Table 4.12). They contain secondary compounds as follows: In *Eucalyptus spp*. are high concentrations of formylated phloroglucinol compounds (FPC) which stimulate nausea system and aid animals to recognize and avoid these compounds in foliage (Lawler *et al.,* 1999) or decrease their feeding rates on the tree (Moore *et al.*, 2004c). *Acacia spp*. contain tannins which also deter the colobines from feeding on them while *Grewia bicolor* contain alkaloids, triterpenoids and antibacterial (Jaspers et al., 1986). *Markhamia lutea* has the lowest protein content (Chapman *et al.*, 2002).

Table 4.12*:* Nutrient content of leaves of non selected food trees by C. angolensis Monkey in kibonge forest during study period

Tree spp	DM	ND L	ADF	ND F	CP	N	P	K	Ca	Mg	Mn	Zn	Source
Acacia mearnsii	10.2	6.5	22.3	36.7	18.8	10.3	4.0	1.3	23.05	2.2	65.5	16.7	Rubanza *et al.*, 2007
Eucalyptus saligna	12.8	13.6	28.85	48.2	15.5	9.5	3.8	1.7	14.3	.15	10.11	14.5	Moore *et al.*, 2004c
Markhamia spp.	7.0	10.8	23.8	49.1	12.4	3.47	3.0	2.0	10.5	1.4	15.2	12.7	Dunham, 2017
Grewia bicolor	12.5	10.9	24.5	44.9	13.7	1.52	2.7	1.5	13.7	0.7	20.5	15.8	Jaspers *et al.*, 1986

From the table 4.13, there was a significant (p>0.005) low levels of Dry matter (DM), Phophorus (P), Pottasium (K), Calcium (Ca), Manganese (Mn), Zinc (Zn) in non-preferred food trees as compared to those found in preferred trees (table 4.13).

All the secondary compounds were present in all preferred food trees during the dry season (table 4.14). Flavonoids were absent in leaves of *Cupressus lusitanica* and *Ekerbergia capensis* species in dry season. Athracyanins compounds were absent in dry season in the leaves of species *Ekerbergia capensis, Polycius kikuyuensis, Croton macrostachyus, Prunus africana, Ficus thonningii* and *M. kilimandascharica* but present in *Cupressus lusitanica, Dombeya goetzenii* and *Nuxia congesta* although the other organic compounds were present. However, athracyanins and tannins were present in wet season in the leaves of species *M. kilimandascharica* and *Nuxia congesta* Table 4.14.

Table 4.13: Non- Parametric t- tests of non- preferred foods by *C. angolensis* monkey in Kibonge forest

	DM	NDL	ADF	NDF	CP	N	P	K	Ca	Mg	Mn	Zn
Mann-Whitney U	0.0	6.0	12.0	9.0	;11.0	11.0	0.0	0.0	0.0	8.0	0.0	0.0
Wilcoxon W	10.0	16.0	57.0	19.0	21.0	56.0	45.0	10.0	45.0	53.0	45.0	10.0
Z	-2.78	-1.86	-.93	-1.39	-1.08	-1.08	-2.8	-2.8	-2.8	-1.5	-2.8	-2.8
Asymp. Sig. (2-tailed)	.005	.064	.355	.165	.280	.280	.005	.005	.005	.123	.005	.005
Exact Sig. [2*(1-tailed Sig.)]	.003[a]	.076[a]	.414[a]	.199[a]	.330[a]	.330[a]	.003[a]	.003[a]	.003[a]	.148[a]	.003[a]	.003[a]

Not corrected for ties.

Table 4.14: Presence or absence of secondary compounds between seasons among preferred food trees of Colobus angolensis monkey in Kibonge forest during the study period

Preferred Food Tree	Secondary compounds							
	Athracyanins		Flavonoids		Tannins		Alkaloids	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Dombeya goetzenii	X	√	X	X	X	√	X	√
Nuxia congesta	√	√	X	X	√	√	X	√
Cupressus lusitanica	X	√	X	X	X	√	X	√
Ekerbergia capensis	X	X	X	√	X	√	X	√
Polycius kikuyuensis	X	X	X	√	X	√	X	√
Croton macrostachyus	X	X	X	√	X	√	X	√
Prunus africana	X	X	X	√	X	X	X	√
Ficus thonningii	X	X	X	√	X	X	X	√
M. kilimandascharica	√	X	X	√	√	X	X	√

CHAPTER FIVE

DISCUSSIONS

5.1 Changes in Forest cover

Forest area is the most significant of all habitat variables, strongly affecting number of food trees preferred by *C. angolensis* and its feeding behavior. From this study, there was a significant change in forest area from the time period 1978-2016, where it was apparent that the forest cover in Kibonge decreased by -6.16% as well as open grassland by -4.50% while shrubland and bare/farmland increased by (1.37%) and (9.35%) respectively as shown by the land sat imageries. Decrease in plantation forest area subsequently increased the shrublands and bare/farmland significantly. This study agrees with the study done by (Ministry of Forestry and Wildlife., 2013) on analysis of drivers and underlying causes of forest cover change in the various forest types of Kenya and found out that, while the area under forest has reduced from 46,450 ha in 1973 to 23,850 ha in 2009, the area under farm land has nearly doubled from 49,950 ha to 99,800 ha over the same period (MEMR., 2012). For instance, using aerial Landsat images, the forest cover of Mau forest complex experienced a decline in forest cover from 4695 km^2 in 1985 to 4041 km^2 in 2010 against an increase in area under agriculture (MEMR, 2012). This was partly due to excision of about 35,000 ha of East Mau forest for conversion into settlements in 2010, conversion to small-scale agricultural lands (Baldyga et al., 2008) and logging Nkako et al. (2005). Forests in Upper parts of West Pokot and Kerio Valley characterized by nomadic pastoralism, are also experiencing a reduction in forest cover while crop area is increasing (MEMR, 2012). For Mount Kenya forest, comparison between the Landsat MSS image and ETM+ images, showed that the forest loss was about 12.7 % between 1980 and 2000 (MEMR, 2012). It was close to the study of Ndegwa, (2005) that indicated 10.3 % of forest decrease in Mount Kenya from 1978 to 1987 and 7.2 % from 1987 to 2002. The results also suggested that, forest destruction was mostly due to the development of plantation, especially between 1978 and 1987. Ngigi and Tateishi, (2004) used Landsat images to to determine the magnitude of deforestation in similar study areas in Kenya, in Mount Kenya forest, Mau forest, Aberdares forest and Eburu forest. Their results showed a decreased forest area at the rate of 2 % per year from 1987 to 2000. The results of this study also revealed similar pattern in Mau forest and Gatamaiyo forest during 1980s to 2000s (Ngigi and Tateishi, 2004). Similar forest changes was reported in Kakamega -Nandi forest, in which Landsat imagery reveals reduction of natural forest cover to 25,727 ha, or 34.4% of the 1913 extent (Mitchell *et al.,* 2006) and in Mountain Kilimanjaro (Mbonile *et al.,* 2003 and (Soini, 2005).

The main drivers of forest decline are increasing population pressure agricultural expansion, wood extraction and development of infrastructure (Lambin *et al.,* 2001, Hosonuma *et al.,* 2001, and Ministry of Forestry and Wildlife (2013). The pressure to produce enough food for the fast growing population has resulted to increased pressure on tropical forests, and has imposed irremediable harm to these ecosystems (Fashing et al., 2004). Forest-cover have undergone reduction from six billion hectare to four billion hectare of forest cover worldwide (Fao, 2012). In Kenya, forests are esimated to cover about 6% of the total land cover, below the required 10% threshold (FAO, 2010). The loss in forest cover has been mostly attributed to deforestation fuelled by intense human activities, (Ayuyo and Sweta, 2014) and a rapid growth in population, Ministry of

Forestry and Wildlife (2013). Therefore reduction of forests could obliterate home of endangered animals and plants and in turn cause biodiversity loss (Boahene, 1998), changes the balance of hydrological cycle and decreases rainfall (Boahene, 1998). These reports showing a similar reduction trend of forest cover confirms what is happening in Kibonge forest. All these changes could in turn affect the niches and food preference of the *Colobus angolensis* monkeys in this forest.

5.2 Tree Species Diversity

The 29 tree species documented in the study sites reflects a relatively species-diverse forest, typical of a tropical forests. According to research done by Mutangah et al., (1992), 147 plant species were recorded in Kakamega tropical rainforest, (Mutiso et al., 2015) found 52 species while studying the floristic composition, affinities and plant formations in tropical forests in Mau Forests, Kenya. Omoro *et al.,* (2007) on the other hand captured 58 species in Taita hills forests while in Kakamega forest, Fashing (2004), recorded 64 spp. In Oban forest in Nigeria, Aigbe and Omokhua (2015) found a total of 72 species distributed into 30 families and 65 genera. The highest documented species richness in any of Kenya's indigenous forests was 280 plant species for the Mau Forest Reserve Complex, which covers an area of about 360,000 ha (Mutangah *et al.,* 1993).

From the study it is apparent that, there is a decline in species diversity, probably due to the constant over exploitation of the forest resource such as clearing of forest for human settlement, logging and charcoal making among others. As in most tropical countries where human populations are ever-escalating, forest conservation is a vital issue in Kenya (MEMR, 2012). By the late 1980s/early 1990s only two percent of Kenya remained covered by indigenous forest (Wass, 1995), and 80% of this remaining forest cover occurred in agricultural areas with high human densities (Tsingalia, 1988). In Kibonge forest low species diversity as compared to other region indicate there is a reduction in species density due to conversion of forest into farmlands based on what has been reported on this study. Those animals who may fail to choose from the available foods may naturally get eliminated or move away or seek for an alternative diet from the farmlands. This causes animal human conflict which may endanger the animals' life ()

5.3 Agents of forest disturbances

The significant findings on change in size of the forest and cutting down (deforestation) of trees in Kibonge, is enough evidence to raise an alarm on the seriousness of the activity in Kenya. Deforestation is defined under the Kyoto Protocol as "the direct human-induced conversion of forested land to non-forested land". FAO (2001) defines deforestation as "the conversion of forest to another land-use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold". The main existing anthropogenic drivers of tropical forest loss can be separated into two scales: local and global. Local drivers refer to land use change, wood extraction and hunting whilst global drivers include atmospheric change and climate change drivers (Wright, 2005). The findings of this study are in agreement with what other studies have reported. For instance, according to the UNFCCC, subsistence agriculture in poor countries is responsible for 48% of deforestation while commercial agriculture responsible for 32% and commercial logging responsible for only 14% of deforestation (Schmitt *et al.*, 2009). Furthermore, deforestation caused by land use activities has transformed approximately half of closed canopy tropical forest to other uses (Wright, 2005, Foley *et al.*, 2005). These Land uses include subsistence agriculture, intensification of farmland or expansion of urban centres (Lambin *et al.*, 2003, Foley *et al.*, 2005). Each year, 20 000km of new forest edge in the Brazilian Amazon alone is generated as a direct result of deforestation (Laurance, 2004). In Brazil, Bolivia, Paraguay and Argentina, seasonally dry, high rainfall and flat surfaces are being exploited for soybean production (Fearnside, 2001). Consequently, croplands and pastures have become one of the largest terrestrial biomes globally (Foley *et al.*, 2005); more than 25% of 8 the total land surface is managed through grazing which is a larger geographic extent than any other form of land use (Asner *et al.*, 2005).

There are many reasons for deforestation, such as agriculture expansion, population growth, industrialization and so on. Agriculture expansion was indicated as the main cause for loss of forest areas by FAO, (2010). In Africa, forest is the major source for new agricultural land depended upon by the high human population (Gibbs *et al.*, 2010). Economic development also plays an important role in deforestation in developing countries where people over exploit natural resources to improve on financial incomes. In East Africa, fuelwood use and population growth were important contributors to deforestation (FAO, 2001; Rudel et al., 2009) in 1980s and 1990s and likewise in Uganda and Tanzania (Rudel and Roper, 1996).

Habitat destruction is considered the key cause of species extinction (Pimm and Raven, 2000). Thus, in forests with high rates of deforestation and encroachment, the decrease in forest fragment area will result in a decrease in number of species found (Fischer and Lindenmayer, 2007) and increase in fragment isolation and total forest edge (Fahrig, 2003). A 22 year investigation of ecosystem decay in Amazonian forest fragments found a relationship between species richness and forest fragment size; intact forests contained a higher number of species per unit area than in fragmented forests (Laurance, 2004). The ecological consequences of biodiversity loss are controversial and widely documented in the scientific literature. It has been suggested that a large proportion of species richness is required to maintain ecosystem stability and sustain function (Schwartz *et al.*, 2000). Hooper, (2005) states that ecological experiments, observations and modelling have shown that ecosystem properties depend on the characteristics of biodiversity, the size of the forest and the time in the ecosystem. There is also a concern that local extinctions of species can occur after a time lag following habitat loss or degradation (Kuussaari *et al.*, 2009). For example, Struhsaker, (1976) documented a 10 year lag period after the 90% loss of major food resources and a significant decline in Ververts (*Cercopithecus aethiops*) in Kenya. Habitat fragmentation and its effects on primates have been well documented in conservation science (Chapman *et al.*, 2007, Arroyo-Rodriguez and Mandujano, 2009, Wong and Sicotte, 2006, Wahungu *et al.*, 2005, Anzures-Dadda and Manson, 2007; Murcia, 1995). At edges there is an exchange or flow of energy and organisms across the boundary (Harper *et al.*, 2005). This has severe implications in light of tropical forest loss, death of some primate food tree species which cannot cope with the new prevailing environmental condition or new invasions may colonize the bare land. In the advent of these changes, primates will experience food scarcity and get exposed to predators due to lack of canopy cover.

5.4 Forest biodiversity and Distribution

Tree species composition varied significantly among the different elevations along the Elgeyo escarpment where the forest is located, when traversing from lower elevation through the middle to the top. The results showed that most of the tree species for instance *Nuxia congesta, C. Lusitanica, F. cycamore, P. kikuyuensis* and *M. melanophloes*, had a higher population in altitude 2400m. *Macaranga spp* and *Dombeya spp* were evenly distributed in all altitudes. *Junispera procera, Podocarpus gracillior* and *Uclea divinorum* are few and only found in altitude 2400m. Exotic species, *Grevellia spp, Eucalyptus spp*. and *Acacia spp*. are also distributed in altitude 2400m. *Olea Africana* are only found in the steep locations of altitude 2300m which is similar to findings by Peltorinne, (2004) where the most widespread montane association are the moist and occupied by *Oncotea spp*. and *Polyscias spp.* and in drier slopes are *Podocarpus spp.* and *Cassipourea spp.* while *Junisperus spp*. and *Olea spp.* dominates the upper slopes.

There are multiple theories concerning natural patterns of species richness on elevational gradient and their determinants (Ghazoul and Sheil, 2010). On mountains, area effects have been shown to affect species richness patterns (McCain, 2009). Many studies indicate a so called ‘‘mid-domain effect’’ in which species richness increases and then declines with increasing elevation and that can be seen as a natural consequence of species range patterns and elevation limits as seen in this study (Cardelús et al., 2006). Tree species richness was found to be varied along the valley when traversing from lower elevation through the middle to the top. This result can be attributed to altitude where in our study 48.8% of the trees were sampled along altitude 2400m in both regions, 36.7% in altitude 2500m, 10% in altitude 2300m, 6.1% in altitude 2600m. This study concurs with the findings by Brown, (2001) and Lomolino, (2001) who discovered diverse plant and animal species along elevation gradient on mountainous ecosystem as well as varied climate and soil differentiation. The study also confirms works by (Rahbek, 1995; Austrheim, 2002; Vetaas and Gerytnes 2002) where species richness along elevation gradient across habitats has been established. It can also be deduced from this study that, the habits of the plant species as one travels from lower elevation to upper elevation changes from species of forest ecosystem to that of savannah ecosystem. The middle elevation level comprise species of both forest and savannah ecosystem. These changes may be attributed to two main factors: firstly, the water availability is high and decreases as the altitude increases and secondly, the soil nutrient contents might be high at the lower and the middle elevations than the top elevation. This is because the top soil nutrients at the top elevation might have suffered from erosion and be deposited on the lower elevation. This might also explain why the tree richness was poor at the top elevation and rich at the lower elevation. Similar trend emerged with the sizes of the trees where the basal areas of the trees at the lower elevation were also larger than those of trees found at the higher elevations (Rahbek, 1995; Austrheim, 2002; Vetaas and Gerytnes, 2002). The reason for the low species richness and poor basal area of trees at the middle to top site could be due to the steepness of the mountain side and associated with leaching of nutrients which makes it hard for trees to grow under such conditions.

5.5 Status of Black and white colobus monkeys (*C. angolensis*) in Kibonge forest

Two troops of *C. angolensis* monkey were identified in Mwen (21 members) and Segen (13 members) regions of Kibonge forest. These results agree with the findings by Oates, (1996) that group composition structure of colobus typically comprises approximately 2-20 individuals, including 1 or more adult males and more than 1 adult female; this is dependent on the number of offspring within the group (Oates and Davies, 1994). Colobine prevalence is limited largely by food resources within their home ranges, with limited apparent impacts of disease predation and competition (Oates and Davies, 1994a).

Ecologically, *C. a. palliatus* is a folivorous primate. It spends less time feeding and moving and more time resting in comparison to primates of an insectivore or frugivore nature (Although this means that colobines are successful canopy dwellers), it does make them vulnerable to changes in habitat as well as hunting pressures (Oates, 1994a).

The results of the current study suggest that *Colobus angolensis* at Kibonge forest spend markedly less time resting (26.8%) and spend more time feeding and moving (56.3%). Numerous studies have shown that black and white colobus monkey activity budgets vary greatly across species and forest types (Fashing et al., 2007). Resting is generally the most frequent activity for most black and white colobus monkey groups but ranges from 71% of daily activity in *Colobus vellerosus* (Wong and Sicotte 2007) to 32% in *C. angolensis* (Fashing et al. 2007). Activity budgets of the red colobus populations varied markedly among sites. For example, feeding time ranged among sites from 29% to 55%, and traveling varied from 5% to 20%. When faced with increased foraging demands, red colobus monkeys reduced the time spent resting, while the time spent socializing remained fairly constant (Chapman and Chapman, 1999). This is evident for increased foraging effort and decreased inactivity among the Kibonge colobus. There may be substantial energetic costs to living in large groups at Kibonge. On the contrary some studies done in Kenya's Coastal forests by Anderson, (2007) on resting behavior of *Colobus angolensis palliatus* found that, the colobus monkeys spent 52% of their time resting. Also Teichroeb *et al (*2002) reported that black-and-white colobus spend 44% - 64% of their time resting and others (*C. polykomos* 55%, *C. sananta* 54%, *C. angolensis* 52%, *C. vellerosus* 58% - 60%) spent most of their time resting also especially in areas with abundant food. In this study low resting time was attributed to the low percentage of mature leaves in their diet due to human encroachments into the forest which leaves them, to search for the food for most of their time (Anderson, 2007) thus the longer duration taken in feeding by Kibonge colobuines, as reported in this study.

5.6 Basal area and Canopy cover

Overall resource abundance as measured by basal area (m^2/ha) for all trees in Kibonge forest was 23.75 m^2/ha. Similar to the total basal area (28.7m^2/ha) of Mt. Elgon forest which was reported by Hitimana *et al* (2004). The value was higher than the 15m^2/ ha obtained by Alder and Abayomi, (1994), for a well-stocked tropical rainforest in Nigeria. The high basal area value obtained in this study is attributed to the tropical climate which may have contributed to high tree growth rates and high tree basal area. The high number of an exotic tree species, mainly *Cupressus lusitanica* which had a large DBH and highest population may have contributed to the high density. This tree species was highly preferred by *C. angolensis* at all seasons. The high basal area, is also an indication that Kibonge forest is probably one of the richest of the tropical rainforest left in Kenya. This may also indicate that, the forest reserve is probably well regulated. The higher the percentage frequency of trees, the greater the basal area and subsequently percentage canopy cover (Fashing *et al.*, 2004). The Canopy cover of seasonal food trees, of *C. angolensis* in the Kiboge forest were most generally observed in top canopies. The results from this study may be comparable to the study conducted on a population of *Colobus angolensis palliatus*, in the Kibale district. The population was commonly observed in forests of mixed vegetation with numerous tree species at various heights (Anderson et al., 2007c). *C. angolensis* was generally observed in tall vegetation reaching six meters

(6m) and above (Anderson *et al.,* 2007c) which is a preferred height by the arboreal species of *C. angolensis* (Thomas, 1991).

5.7 Tree species preferred for foraging by *C. angolensis*

Black and white *C. angolensis* are found to spend a large part of their day foraging for food in high to low light conditions (Yamashita *et al.,* 2005). Colobus monkeys are known folivores-frugivores having a diet mainly of leaves, but buds and fruits can also be included. About 35% -75% of their diet consists of young leaves which are easier to digest and are less toxic (Usongo and Amubode, 2001). Trees used as food by *C. angolensis* in Kibonge forest vary during wet and dry seasons. The study showed that during the dry season, the monkey preferred feeding on *Dombeya spp*, *Nuxia congesta*, *Cupressus lusitanica Podocarpus falcutus*, *Markhamia lutea*, *Eucalyptus saligna* and *Acacia mearnsi* tree species in Mwen. While in Segen it preferred *Cupressus lusitanica* and *Dombeya goetzenii*. During the wet season, *Polyscias kikuyuensis*, *Dombeya goetzenii goetzenii*, *Croton macrostachyus* were the highly preferred food trees in Mwen, while in Segen were *Macaranga kilimandascharica*, *Polyscias kikuyuensis* and *Prunus africana* .Tree species preference for *C. angolensis* increased during the wet season, because they had a choice of young leaves but during the dry season they fed on mature leave which were more difficult to digest. However, they possess a multi- chambered stomach with special microbes that break down cellulose over an extended time allowing fermentation to occur (Tovar *et al.,* 2005). Our findings relates to a study done by O'Dwyer, (2012) on the black-and-white colobus monkeys (*Colobus angolensis palliatus*) of Diani forest, Kenya, which showed that in the degraded forest, colobus monkey's troops utilize the following species; *Bougainville spectabilis*, *Adansonia digitata*, *Delonix regia*, *Zanthoxylum chalybeum*, and *Majidea zanguebarica*. Their main protein sources were most likely from the leaves and fruit of *Adenanthera pavonina*, the leaves of *Majidea zanguebarica*, and the fruit (most likely seeds) of *Lecaniodiscus fraxinifolius* and *Lannae welwitschii*. From 72 tree species identified by O'Dwyer, (2012), *Ficus sycomorus*, *Ficus exasperata* and *Delonix regia* are among the tree species utilized by six troops of black-and-white colobus monkeys as food materials. Fashing, (2001) repoted that colobus monkeys spend more time feeding on *Ficus exasperata* from 32 tree species in Kakamega Forest, Kenya. Among 42 trees species present in Diani Forest, the most utilized food trees were *Adansonia digitata*, *Bougainville spectabilis*, *Delonix regia*, and *Lannae welwitschii* (Jansson, 2011). From the above findings and those of studies in Kibonge forest, it can be concluded that, although *C. angolensis* monkey prefers leaves of indigenous trees as food, it is not specific in its diet choice, but is able to utilize the available resources during times of scarcity such as exotic species of *C. lusitanica* and *Eucalyptus spp*. These tree species would be planted at the edges of Kibonge forest to be used to provide alternative food for the monkey and act as buffer zones.

5.8 Forest disturbance

5.8.1 Nature and level of tree disturbance

The greatest significant form of disturbance in Kibonge is by cutting. Trees cut were within the range of DBH > 0-10 cm to 10- 20cm followed in the order, then with DBH=20- 50. Tree-stem density was lower in more intensely exploited plots, but smaller-diameter trees were more affected than larger ones. These results are in tandem with a study done by Borghesio, (2008) where he reported 52% - 73% fewer small trees (diameters < 20 cm) and 15% fewer large trees in plots with high levels of wood collection than in plots with low intensity of wood collection. About 29.1% of trees were disturbed in Kibonge forest. Of the population 69.4% were damaged by cutting, 16.5% by pruning, and 8.9% by debarking. Other forms of disturbance recorded were burning (1.8%), firewood collection, pitsaws and by natural disasters such as landslide which occurred in Mwen region during the study period. The most disturbed trees were *Cupressus lusitanica, Dombeya goetzenii, Macaranga kilimandascharica, Prunus africana, Croton macrostachyus and Polyscias kikuyuensis*, most of which were highly selected by *C. angolensis* monkey for food. A similar study done by Vunyiya *et al.*, (2014) on the impacts of human activities on the tree species richness and diversity in Kakamega forest showed similar results. Human activities noted within the three study site in Kakamega forest included logging, charcoal burning, debarking and grazing and the most exploited trees for logging in the region included hardwood like *Olea capensis*, *Prunus africanus* and *Celtis africana*. It can be deduced that deforestation and logging have the greatest impacts on biodiversity in tropical forests (Sala *et al.*, 2000).

Similarly most Kenyan forests are under pressure from deforestation, forest fragmentation, forest degradation, and over-exploitation of species and the introduction of exotic species. One of the ecological communities that have been most extensively exploited is lowland forest, the first forests to be cleared for agriculture. Because the land best suited for the growth of forests is also good agricultural land, while the remaining forests are highly fragmented (Peltorinne, 2004).

This is because the local community usually fell the smallest trees for firewood, fences, and huts and are less interested in the largest logs, the commercial value of which is nil due to a lack of transportation. Large trees are only occasionally chopped to create glades where livestock are grazed.

5.8.2 Diameter at Breast height (DBH) of disturbed trees in the forest

The DBH of all trees in Kibonge were grouped at intervals of width 10cm, 37% of trees fell within the range 30-40cm, while 6% were within range 0-10cm. There was a significant difference in DBH of trees between regions Mwen and Segen. The findings confirmed work done by Vunyiya *et al.,* (2014) in Kakamega forest. They reported that, there was a difference in stem diameter and height of trees recorded in the three blocks investigated, with the western forest block having the highest percentage (37%) of low size class trees with DBH range from 10cm to 40cm, attributed to the proximity to human settlements. the majority of the trees fell between 30-40cm DBH class. implying that the forest is characterized by high abundance of trees with bigger DBH. For heavily logged-over sites both, stems ha^{-1} and basal area, decreased with increasing DBH classes (for trees between 35 and 95 cm DBH) conforming to the Rollet, (1974) and Dawkins, (1958) models that characterize tropical rainforests (Philip, 1994).

5.9 Nutrient content in preferred food trees

5.9.1 Nutritional composition of food preferred of colobus monkeys in Kibonge forest

The study also focused in determining the feeding habits and food preference, it was observed that colobus monkeys in Kibonge forest feed on leaves. This was recognized when recording feeding activities. Generally, black and white colobus monkeys in this area mainly fed on leaves (Dunbar, 1976). During the dry season, trees highly preferred for food measured by percentage feeding time in Mwen were *Dombeya spp* (52.5%), *Nuxia congesta* (17.6%), and *Cupressus lusitanica* (18.2%), *Podocarpus falcutus, Markhamia lutea, Eucalyptus saligna* and *Acacia mearnsi.* In Segen region *Cupressus lusitanica (*78.9%), *Dombeya goetzenii goetzenii (*20.6%), were highly selected all being indigenous species with a greater basal area. During the wet season, *Polyscias kikuyuensis* (23.96%), *Dombeya goetzenii goetzenii (*66.82%), *Croton macrostachyus* (4.3%), were the highly preferred food trees in Mwen, while *Macaranga kilimandascharica* (21%), *Polyscias kikuyuensis* (20.7%), and *Prunus africana* (21.1%) were preferred in Segen. From 72 tree species identified by O'Dwyer (2011), *Ficus sycomorus, Ficus exasperata* and *Delonix regia* are among the tree species utilized by six troops of black-and-white colobus monkeys as food materials. Similar findings were reported by Fashing, (2007) that colobus monkeys spend more time feeding on *Ficus exasperata* from 32 tree species in Kakamega Forest, Kenya while Jansson, (2011) reported 42 tree species in Diani Forest, Kenya.

The non preferred food trees were, *Acacia mearnsii, Eucalyptus saligna, Markhamia lutea, and Grewia bicolor*. They were not selected by the colobine monkey because, *Eucalyptus spp*. contain low nitrogen content in leaves only essential for maintenance and reproduction (Cork and Foley, 1991) whereas *M. lutea* has the lowest protein content (Chapman et al., 2002). *Acacia species* have high levels of Non digestible fibre (NDF) a component made up of hemicellulose, cellulose and lignin (Rubanza *et al.,* 2007). Lignin is indigestible and so the animal could avoid consuming a food with high concentrations of this component.

5.9.2 Seasonal variation of Nutrients in preferred food trees

The leaves eaten by the monkey varied in mineral nutrient content and between seasons. The dry matter Crude protein, Nitrogen, Phosphorus, Zinc, Iron varied in all tree foods. Non Digestible Lignin (NDL) and Non Digestible Protein (NDP) varied but there was no significant difference in *Ekerbergia capensis* and *Polyscias kikuyuensis* this different in nutrients composition among food trees could be due to sunlight, soil composition, tree phenology, and local rates of microbial activity which can vary locally and can have significant impacts on leaf nutrient concentration (Chapman *et al.*, 2002). The difference in the flux of radiant energy received by a surface per unit area results in difference in leaf nutrient content within trees of a single forest canopy (Marenco *et al.*, 2001; Schlesinger, 1997; Weinbaum *et al.*, 1994). There was considerable variation among species with respect to protein, digestibility, and saponins, there was also variation among individuals of the same species; in fact, individuals may vary by as much as 20%. The average coefficients of variation (CV) among individuals of the same species are 13.4 for protein, 12 for digestibility, and 43 for saponins, while the average CV among species are 35, 31.3, and 82.4, respectively. No species showed a variable response with respect to testing for the presence or absence of cyanogenic glycocides, while 2 of 11 species tested for alkaloids showed a variable response (Chapman *et al.*, 2002). The mean mineral components are higher in wet seasons compared to the dry season. There was significant difference among minerals of dry matter (DM), non digestible lignin (NDL), Phosphorus(P), Potassium (K), Calcium (Ca), Magnesium (Mg), Manganese (Mn), but there was a significant difference in mineral content of Acid detergent fibre (ADF), non digestible fibre (NDF),Crude protein (CP), Nitrogen (N) ,Copper (Cu) and iron (Fe) in two seasons at 5% level of significance. High intra-specific variation in nutritional content may also affect studies of seasonality in nutrient content (Chapman *et al.*, 2002). A study done by Baranga, (1983) on changes in chemical composition of food parts in the diet of colobus monkeys showed that seasonal variation contributes to changes in nutrient composition on ten individuals of *Celtis durandii* and *Markhamia platycalyx*.

5.9.3 Influence of Minerals on Leaf Choice at Kibonge

According to this study on foraging pattern, it appears that *C. angolensis* showed selection for leaves with high levels in Zinc, Copper and Calcium and low in Non digestible fibre, Crude protein, Nitrogen, Phosphorus, pottasium, Manganese and Iron. The fact that Non digestible fibre, digestible fibre, dry matter and Calcium were the only mineral significantly selected for, suggests that Calcium and Zinc were the primary mineral influencing *C. angolensis* leaf choices at Kiboge. This also explains why the non preferred trees were not selected, for all showed significant low levels of macro minerals, calcium and zinc. Also the presence of certain secondary metabolites that may not be palatable or affect taste may deter the monkey from feeding on them. A study done on Kibale guerezas monkeys showed that they select plant food which are high Zinc content (Rode *et al.*, 2003). Fashing *et al.,* (2007) who studied the influence of plant and soil chemistry on food selection, ranging patterns, and biomass of *Colobus guereza* in Kakamega Forest in Kenya, also found that the plant food for *guereza* monkey are rich in Zinc. This finding is of particular relevance to captive managers of guerezas because Zinc is essential to proper metabolic functioning and so its deficiencies can have myriad adverse effects on the monkey including stunted growth, reproductive failure, immune deficiencies, and impaired cognitive function (King and Keen, 1999). On the other hand Calcium plays an important role in signal transduction pathways (Brini *et al.,* 2013a*)* where they act as a second messenger, in neurotransmitter release from neurons, in contraction of all muscle cell types, and in fertilization. Many enzymes require calcium ions as a cofactor, those of the blood-clotting cascade being notable examples. Extracellular calcium is also important for maintaining the potential difference across excitable cell membranes, as well as proper bone formation. Calcium levels in mammals are tightly regulated with bone acting as the major mineral storage sites. Calcium ions, (Ca^{2+}), are released from bone into the bloodstream under controlled conditions (Brini et al., 2013b*).*

5.9.4 Influence of Secondary Compounds on Leaf Choice at Kibonge

The food choices of many animals are controlled by the secondary compounds that plants produce as chemical defenses against herbivory (Bryant *et al.,* 1992; Coley, 1983). Researchers believe colobines are somewhat buffered against the adverse effects of some secondary compounds because of their specialized digestive morphology. For example, microbial flora in the colobine fore stomach are thought to be capable of detoxifying alkaloids that render food items unpalatable for other herbivores (Waterman and Kool, 1994). Still, there are East African forests such as Kibale where alkaloids occur in up to 40% of woody species including some of the same species from which alkaloids were absent at Kibonge (Burgess and Chapman, 2005; Gartlan *et al.,* 1980). Explaining this wide interforest variation in alkaloid prevalence will require more detailed data on soil quality, forest composition, and plant chemistry both across species and among individuals of the same species (Chapman *et al.*, 2003; Gartlan *et al.*, 1980). Tannins influence food choice in some colobine populations, e.g., *Procolobus verus* (Oates, 1978) and *Trachypithecus johnii* (Dierenfeld *et al.,* 1999) but not in others, e.g. *Colobus angolensis* (Bocian, 1997), *Piliocolobus rufomitratus* (Mowry *et al.*, 1996), and *P. tephrosceles* (Chapman and Chapman, 2002). Even within a single species, *Colobus guereza*, Oates *et al.*, (1977c) described a population at Kibale as avoiding tannins while Bocian, (1997) reported another at Ituri to be undeterred by them. This study provided a third site to examine the influence of tannins on *C. angolensis* food choice. As at Kakamega, this study found that, tannin concentrations are significantly lower in the leaves *C. angolensis* consumed than in the leaves they ignored. However, several other pieces of evidence suggest that tannins may not have a particularly strong influence on *C. angolensis* food choice. First, as with Ituri guerezas (Bocian, 1997), there is no relationship between food item selection ratio and tannin concentration for Kibonge *C. angolensis*.

5.10 Forest conservation

Investigating the chemical basis of dietary selection in primates has provided a unique understanding of their foraging strategies (Whiten *et al.*, 1991),understanding determinants of primate abundance is becoming increasingly important as ecologists are asked to apply their knowledge to assist conservation biologists to construct informed management plans for endangered species (Chapman *et al.*, 2002). The study evaluated variation in the nutritional value—protein, fiber, digestibility, minerals, alkaloids, cyanogenic glycocides, and saponins—of leaf material of tree species eaten by black and white colobus (*C. angolensis*) in Kibonge forest during the wet and dry season were studied. The trees would be used as food for *C. angolensis*, provide resting areas and as alternative forest resource for use by the adjacent local communities to the forest. Thus conserve the forest.

CHAPER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Our study highlights the negative impact of tropical forest habitat destruction on *C. angolensis* in Elgeyo Marakwet County, Kenya. Identification of the actual mechanism responsible for the variety of tree foods preferred by primates as reported in many studies is complex especially in reference to the level of disturbance. However the strong correlation in forest size between the year 1978 and 2016, shows a drastic reduction in Kibonge forest size. The increase in farmland and open grassland area by 11.8% is a strong indicator of human encroachment to the forest. The small population size and the many hours spent by the monkey in searching for food is an indicator of low canopy cover and a variety of tree species preferred for food by monkey. The significant Chi square test on level of disturbance elaborates further on effects of human encroachment into forest, to colobus monkeys. There were more tree species concentrated on higher altitude (2400m) which was a steep slope in Kibonge. The majority of these trees were exotic spp. such as *Cupressus lusitanica* and indigenous species (*Nuxia congesta*), highly preferred for food by the monkey. Preference of exotic species gives a conclusion that they can be planted to act as buffer zones between human habitation as well as provide alternative foods for the monkey species. Other exotic species may be tried out to see if the monkey can feed on them and provide a wide variety of foods thus meeting the nutritional demands of the monkey.

The significant difference in mineral content and organic compounds between seasons and among preferred food trees is a strong indicator that colobines will prefer to feed on those tree species that would supply essential nutrients in large quantities during wet season then physiologically conserve them for use during dry seasons .

6.2 Recommendations

Forest loss and ongoing tree extraction in Elgeyo Marekwet County, is a dynamic and ongoing process even in protected government forests such as Kipkabus and Kaptagat forest reserves. There is a high degree of human affinity for extracting the major food trees of colobus, which will affect both availability of food resources and the structure of forest canopy. It is likely that there will be future declines of *C. angolensis* and increased population extinctions, over the coming years. This calls for maintenance of large, closed canopy forests within the study area and to restore degraded habitat through afforestation and establishment of buffer zones. The buffer zone should consist of exotic tree species and will act as refuge zones for *C. angolensis* monkey. This will require improved law enforcement to reduce illegal logging, illegal poaching (Mathews and Mathews, 2002), and enhance proper forest management which allow forests to regenerate and promote availability of alternative human resources.

Further studies may be done to identify other species of exotic trees which would provide high nutrient content required by *C. angolensis*.

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APPENDICES

Appendix I: Record sheet for Investigation of human threats on the forest

Plot number	Number of pole sized trees (DBH=5 cm-15 cm)			Number of timber sized trees (DBH≥15)			Signs of human destructions of trees		
	Live	Cut< 1 year Before survey	Cut <1 year Before Survey	Live	Cut< 1 year Before survey	Cut< 1 year Before survey	Sawing	Use of Axes	Firewood collection
1									
2									
3									
4									
5									
6									

Appendix II: Tree species (DBH=>10 CM) of Kibonge forest

Scientific name	Vernacular name(Kalenjin)	Family name	% Canopy cover
Acacia mearnsii	Wattle	Mimosaceae	0.151
Bersama abyssianica	Kopoymetiet	Melianthaceae	0.019
Croton macrostachyus	tebeswet	Myacea	2.914
Cupressus lusitanica	cypress	Cupressaceae	26.676
Dombeya goetzenii goetzenii	silipchet	Sterculiaceae	33.446
Eucalyptus saligna	Bluegum	Myrtaceae	0.358
Ekerbagia capensis	Teldet	Meliaceae	0.574
Ficus cycamorous	Mogongwet	Moraceae	0.264
Ficus thonningii	simotwet	Moraceae	15.014
Garcinia livingstonei	Merkwet	Clusiaceae	0.365
Grevellia robusta	Grevellia	Proteaceae	0.027
Grewia bicolor	Siteito	Malvaceae	0.89
Juniperus procera	Tarakwet	Cupressaceae	0.0304
Macaranga kilimandascharica	sebesebet	Euphorbiaceae	5.228
Markhamia lutea	mochet	Bignoniaceae	0.443
Myrsine melanoploeos	sitotwet	Myraceae	0.352

Nuxia congesta	chorwet	Sterculiaceae	0.441
Olea africana	Emitit	Oleaceae	0.371
Pepper tree	Chupuchupu	Anacardiaceae	0.05
Podocarpus falcactus	Septet	Podocarpaceae	0.477
Podocarpus gracillior	Penet	Podocarpaceae	1.226
Polyscias kikuyuensis	seyat	Araliaceae	2.379
Prunus africana	tendwet	Rosaceae	6.927
Rhus natalensis	Siryat	Anacardiaceae	0.535
Teclea nobilis	Kuryot	Rutaceae	0.153
Uclea divinorum	Uswet	Ebenaceae	0.035
Vangueria madagasariensis	Komolwet	Rubiaceae	0.266
	Total		**99.9994**