EFFECTS OF VARIATIONS IN NUTRIENT CONTENT OF WILD FORAGE AND RAIDED CROPS ON FORAGING BEHAVIOUR OF AFRICAN ELEPHANTS (*Loxodonta africana*) IN RIMOI GAME RESERVE, KENYA

BY

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DECLARATION

Declaration by Student

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To my beloved Family: Mercy Chebet, Abigael cherotich, Erick Kipruto, Sheilah Cheptoo, Abel Kiplagat and Selina Jepkemei

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ABSTRACT

African elephants (*Loxodonta Africana*) are known to be crop raiders and feed on large quantities of food. They are also mixed feeders, ingesting both grass and browse in varying proportions. The elephants demonstrate distinct preference for different plant species in the ecosystem. Due to their immense body size, elephants have a key ecological role that is defined by their need for great quantities of food, water and habitat. With continuous loss of habitat, elephants are forced to extend their feeding range depending on the type and quality of available food. Decision to feed on crops outside protected areas was influenced by the nutrients in crops or vegetation outside the protected area. A survey in the conservation area was carried out to find the crop raiding situation. 311 respondents were randomly sampled from the population and snow ball sampling technique used to identify the respondents to be interviewed. Data on preference were obtained by making a systematic record of forage preferred. These data was deduced from records of plants which showed signs of recent elephant use. Debarked, browsed or grazed vegetation were picked with the use of secateurs, identified, tallied and air dried in the field. Twenty five plants were considered for laboratory analysis. Nine nutrients were analysed for, which included: Nitrogen, Phosphorous, Potassium, Calcium, Magnesium, Copper, Manganese, Sodium and Neutral detergent fiber. Three samples of each plant were taken and the procedure of Chapman and Pratt (1961) with slight modification was used in the analysis of macro and micro nutrients, while Kejldahl procedure was used in the analysis of nitrogen. Landsat images were down loaded from the global land cover facility using path 169 and row 060. Bands 2, 3 and 4 were clipped to study the area shape file and false colour composite. The area was classified using the Anderson classification scheme based on three classes: trees, woodlands and shrubs. This was done in Arc GIS 9.3 and processed using Erdas imagine 9.2. Statistical analysis was carried out by use of descriptive, ANOVA and regression analyses. The popular form of conflict in this region arises from crop depredatin (52.4%). Results showed that maize (86.5%) was the most raided crop and the most preferred wild forage were *Acacia tortilis* (22.5%), *Balanites aegyptiaca* (14.8%), *Acacia mellifera* (9.6%), *Zizyphus mucronata* (7.5%) and *Acacia brevispica* (7.1%). There was significantly positive correlation ($R^2 > 0.45$, $P < 0.001$) between the feeding preference and level of nutrients among plant species. Landsat TM trajectories showed vegetation cover to have declined over the years (Cramer's V = 0.3997), indicating that forage availability for elephants was most likely decrease. The major source of human elephant conflict in this region was crop depredation, while Acacia formed the bulk of forage preferred by *L. african Africana*. The most preferred wild forage was *Acacia tortilis*, though the bark had high NDF. The vegetation in the conservation area had declined between 1986 and 2006. In this region, the elephant population should be closely monitored to avoid exceeding the carrying capacity and the local authority in charge should institute measures that would encourage the local community to support elephant conservation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

LIST OF ABBREVIATIONS/ACRONYMS

ANOVA	Analysis of Variance
Ca	Calcium
Cl	Chlorine
Cu	Copper
Co	Cobalt
CO_2	Carbon dioxide
CP	Crude Protein
Fe	Iron
GOK	Government of Kenya
GIS	Geographic information systems
K	Potassium
Mo	Molybdenum
Mn	Manganese
Mg	Magnesium
NDF	Neutral detergent fibre
NDVI	Normalised Difference Vegetation Index
NIRS	Near Infrared Spectro-photometry
O.M.	Organic Matter
PA	Protected areas
P	Phosphorous
ppm	Parts per million
RGRCA	Rimoi Game Reserve Conservation Area
SPSS	Statistical Package for Social Sciences
S	Sulphur

OFT	Optimal foraging theory
Na	Sodium
NaCl	Sodium chloride
N	Nitrogen
UNEP	United Nations environmental programme
Zn	Zinc

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Biodiversity represents the very foundation of human existence. The establishment of protected areas has probably helped prevent part of biodiversity from being destroyed by development and land conversion. However, particularly in developing countries, it is well known that this conversion policy has had some adverse effects. Local people are prevented from eliminating "problem" animals to protect their crops and livestock (Marks, 1984).

The African elephant (*Loxodonta africana* Blumenbach) is the largest extant land mammal, with recorded body mass of up to 6,000 kg for males, and 2,800 kg for females. Accordingly, its dietary intake is considerable (typically 1% (dry weight) of body mass daily) and the resulting effects on vegetation can be dramatic. The diet of elephants is composed of many plant species and plant components (Paley & Kerley, 1998). Its diet is shaped mainly by their large body size and is expected to have a long gut which would translate to a long retention time. In elephants total gut length is shorter than expected and the diameter of components such as the small intestine is greater (19 m), and these together result in a reduced gut retention time (Clause *et al.*, 2003). Clause *et al.*, (2003) further have proposed that, for very large herbivores such as elephants, they would need to evolve adaptations to speed up through put of material through the gut so as to reduce the development of components such as methanogenic bacteria. The very large body size results in absolute daily energy requirements for maintenance, which must be met through extraction of energy from the plant material fed on. The need for an abundant food source is exaggerated by the reduced gut retention time and low digestive coefficient realized in elephant digestion. Indeed elephants spend up to 75% of their time feeding (Whitehouse *et al.* 2002). Pronounced reductions in trees and other woody plants have been experienced due to the elephant feeding behaviour (Pamo & Tchamba, 2001; Jacobs & Biggs, 2002a). As elephants experience human-caused habitat reduction, elimination of migration routes and disturbance (including poaching), previously wide-ranging populations may become confined within reserves inducing sudden changes in feeding behaviour (Mapaure & Mhlanga, 2000; Pamo & Tchamba, 2001). Therefore, conservationists have expressed concern about effects of feeding behaviour of elephants relative to ecological integrity in many environments.

Elephants are mixed feeders, ingesting both grass and browse in varying proportions. Woody plants contain higher levels of crude protein than grasses in the dry season (Cerling *et al.*, 2004), so that browsing allows elephants to maintain body condition year-round. Elephants thus tend to increase the percentage of browse (when available) in their diet, causing most damage to woody plants, in the dry season (Rode *et al.* 2006). Browsing may also be increased as elephants take refuge in woodlands as a response to human disturbance (de Boer *et al.,* 2000). De Boer *et al.* (2000) found that the diet became narrower at the late dry season for elephants. Preferred feeding height tends to be below 2 m, the height of the browsed plants being somewhat greater (Smallie & O'Connor, 2000). Other workers have found a preference for adult trees, which may entail switching from stem and leaf browsing to bark stripping as height increases beyond 4 m (Smallie & O'Connor, 2000). Because of the reduction of the feeding range of elephants as a result of human encroachment of the elephant home ranges, the increased density of elephants, which effectively limit their feeding ranges and the reduction of diversity of species of vegetation, may necessitate a change in the elephant feeding behaviour (Mapaure & Mhlanga, 2000).

While being bulk feeders, elephants still demonstrate distinct preference or avoidance for different plant species, which in turn affects extent and pattern of any vegetation change that may occur with elephant utilization of a habitat. Preferentially utilized vegetation include those that provide shade or fruit and marula, *Sclerocarya birrea* (Duffy *et al.*, 2002), nutritious plants – such as calcium and nitrogen; those nutritious enough to provide energy- *Portulacaria afra*, (Boshoff *et al.*, 2001) and others or simply those individuals that are more exposed or accessible (Pamo & Tchamba, 2001). Bowland and Yeaton (1997) found that elephants had a four- fold preference for trees from later successional stages (*Acacia caffra* and broadleaves) to earlier successional trees such as *A. nilotica*. As a result, elephant damage tends not to be distributed among species in proportion to their relative abundance.

In line with environmental factors, elephants can nonetheless precipitate declines in vegetation populations or marked changes in vegetation community composition. Palatable species such *Acacia tortilis*, *A. xanthophloea*, *A. dudgeoni*, *Brachystegia boehmii*, and *Colophospermum mopane* (Lagendijk *et al.*, 2005). Due to their foraging behaviour, elephants can cause a lot of damage to trees and shrubs when they make their way through the terrain (Chamaille-Jammes *et al.*, 2007; Guldeemond & Van Arde, 2008).

Intensity of elephant feeding behaviour and the emergent patterns of change in vegetation, reflect the distribution of elephants across the heterogeneous savanna landscape (Steyn & Stalmans, 2001). However, it is also widely believed that the decline in the species density in the elephant natural habitat and the preference of crops with high nutrient content both within their home range and outside may influence the feeding behaviour of elephants. Previously it has been demonstrated that elephants have preference for crops due to the species, nutritional content and other factors (Osborn, 2004).

Studies in Africa have demonstrated the diversity of feeding behaviour that elephants exhibit under different environmental conditions (Ruggiero, 1992). In general these studies have examined the daily activity patterns, plant selection and defecation rates. Studies conducted on culled elephants have investigated nutritional variation relating to the condition of animals during the period of collection. Various parameters were measured relating to seasonal differences in body condition (Meissner & Spreeth, 1990). Several studies have attempted to assess the factors that influence diet selection in different habitats (De Villiers *et al.*, 1991; Lindsay, 1994). From the above mentioned studies a number of trends emerge. Elephants spend from 70 to 90% of their time foraging and consume between 100 kg and 300 kg (wet mass) of vegetation per day. Elephants are generalist feeders and tend to eat what is available to them, but they can be very specific about which parts of a plant they eat and when (Osborn, 2004). It was therefore postulated that elephants could avoid feeding on the wild forage and raid crops due to the quality. Yet there are currently very few studies available that have determined the effects of variation in nutrient content of wild forages and raided crops on foraging behaviour of African elephants (*L. africana*). This study investigated on whether changes in nutrient content of food available influence the crop raiding behaviour of elephants.

1.2 Statement of the Problem

Rimoi Game Reserve is a home to about 300 African elephants (*L. africana*), which form part of the elephants threatened globally (Douglas-Hamilton, 1971). Elephants may be sedentary or nomadic (Lindique & Lindique, 1991). Due to the dietary requirements, elephants have a key role in shaping vegetation in their home range. With continuous loss of habitat, qualitatively as well as quantitatively, elephants are forced to extend their range. Encroachment on their ranges therefore has serious implications on their survival, reproduction and management. Elephants show a preference for secondary re-growth and are strongly associated with wet habitats such as swamps, marshes and seasonally inundated forests, but can extend their feeding range to raid crops in the advent of trying to meet their nutrient requirements. The type and quality of food available determines their range of movement. For effective conservation and management of elephant populations, an understanding of their feeding behaviour is important because it is in the course of searching for food by moving between areas that they cause problems.

Many African elephants live outside protected areas (PA), because the PA alone cannot sustain elephant populations. Therefore, elephants depend on areas outside PAs often on a seasonal basis. The decision to feed on crops outside protected areas appears to be driven by their demand for some critical elements in crops or vegetation outside PA, despite the availability of abundant wild forages in the reserves. It therefore remains unknown which critical elements or what aspects of vegetation influence the elephant's preference during foraging. In an effort to identify what triggers or influences the foraging behavior, the study sought to determine the effects of variation in nutrient quality of wild forages and raided crops in the overall feeding ecology of the elephants in Rimoi Game Reserve and Conservation Area.

1.3 Rationale/ Justification of the Study

The preferred habitats of the African elephants are forest edges, woodland, bush land and wooded bush land or bushed grassland, yet they also exhibit crop raiding. An elephants' feeding behaviour therefore results in a hierarchy of selection for plant types, species and plant parts. The elephant should favour food types that permit a rapid rate of nutrient intake; food from which the greatest amount of digestible nutrients can be sequestered within the shortest time possible because it affects its fitness. The grazing/browsing process used to gather food by elephants can best be described as hierarchical system of diet selection which is as a result of physiological needs resulting in a unique pattern of use across a given landscape. Although large populations are found in the southern parts of Kenya a substantial number are also found in the north of rift valley but little effort has been made to study their foraging behaviour and their impacts in the ecosystem. This then calls for the need to investigate their foraging behaviour or preference and try to predict the factors that influence it.

Therefore obtaining baseline data on elephant feeding behaviour was considered essential in this study. The study of nutritional composition of preferred forage by *L. africana* can present insights into the physiology of the species as well as help us in assessing its habitat and formulating management plans.

1.4 Research Objectives

The main objective of this study was to determine the effects of variation in nutrient quality of wild forages and raided crops on foraging behavior of African elephants (*L. africana*). Specifically the study addressed the following objectives:-

1) To investigate the human elephant conflict in Rimoi Game Reserve and Conservation Area
2) To determine forage preference by the *L. africana* in Rimoi Game Reserve and Conservation Area
3) To investigate the level of nutrient elements in forages preferred by *L. africana* in Rimoi Reserve and Conservation Area
4) To establish effects of the level of nutrient elements in forage on feeding preference by *L. africana* in Rimoi Reserve and Conservation Area
5) To investigate the effects of changes in vegetation cover on the feeding preference of *L. africana* in Rimoi Game Reserve and Conservation Area

1.5 Research Questions

To address the above objectives, the study was guided by the following research questions:

1) Are there human elephant conflicts in Rimoi Game Reserve and Conservation Area?
2) Which forages are preferred by the African elephants?
3) How does the level of nutrient elements in forages influence feeding preferences by African elephants?
4) What are the effects of nutrients on foraging preference by African elephants?

5) Do the changes in vegetation cover affect the feeding preferences by African elephants?

1.6 Assumptions of the Study

The assumptions of the study were that:-

(i) The answers given through the research instruments were honest responses.

(ii) That equipment and chemicals were of the correct standards for measuring the nutrient contents.

(iii) That all factors not included in the study remained constant.

1.7 Scope and Limitations of the Study

1.7.1 Scope

The study investigated property damage situation and variation in nutrient content of wild forages and raided crops by an African elephant population in Rimoi Game Reserve and Conservation Area (RGRCA). The study was restricted geographically to areas adjacent to RGRCA.

RGRCA in Elgeyo Marakwet County was chosen as a research site because of the evidence of the increasing problem of human-elephant conflicts despite coping strategies and planning measures being in place. Human-elephant conflicts recorded have had effects on several parts of the study area such as in crop depredation, encounters between people and elephants, damage to property such as farm installations, water reservoirs, fences and houses.

1.7.2 Limitations

The findings were confined to the period of study and samples from communities living around RGRCA in Elgeyo Marakwet County during the year 2010 and may not be exceptionally generalize to all the Counties in Kenya.

1.8 Operational Definition of Terms

Local community involvement - This means the sharing or involvement of the local community in mitigating Human-elephant conflicts in their areas.

Community - A group of people, who have something in common, live in similar conditions and same neighbourhood.

Human-elephant conflicts - Conflict between people and elephants takes several forms. Crop depredation is probably the most common type of conflict. Encounters between people and elephants can lead to deaths and injuries of both people and elephants. Elephants are also known to cause damage to property such as farm installations, water reservoirs, fences and houses. All these forms of conflict are reported to occur in Kenya with varying severity.

Crop depredation - Crop depredation is a major cause of human-elephant conflicts whereby farmers living in the agricultural areas which frequently border forests or areas with bushed, such as RGRCA complex, report high incidences of crop-raiding.

Crop-raiding patterns - Frequency and timing of crop damage around RGRCA complex. Crop-raiding incidents is defined as discrete events where elephants left the game reserve to raid crops and subsequently returned to the game reserve.

Crop loss - Amount of crops damage or suffered due to elephant raiding.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction and Scope of the Review

This chapter gives a general introduction to the African elephant. In describing the lifestyle of a species, it is often convenient to lump all members of the species together and say, for example, "elephants live in families", "elephants prefer to aggregate", "elephants are seasonal breeders", or" "elephants are browsers". But the study of African elephants reveals their social complexity and flexibility, and their ecological adaptability.

Over the last thirty years literally hundreds of studies on African elephants *(L. africana africana)* have been carried out across the continent. Elephants have captured man's imagination and respect for thousands of years. In some ways we can draw close parallels between humans and elephants. Like humans, elephants have the capacity to modify their habitats dramatically (Western, 2006), and their need for space often brings them into direct conflict with expanding human populations. Elephants, like our own species, are noted for their intelligence, close family ties and social complexity (Moss, 2000).

The African elephant is the largest living land mammal with males of the species weighing up to 6,000 Kg (Plate 2.1) and standing 3.3 m at the shoulder (Skarpe *et al.*, 2004, Wiseman *et al.*, 2004). With a trunk weighing 140 kg, an elephant can pick up the tiniest crumb, push over a mature tree, reassure its young, pour 12 litres of water into its mouth or detect a smell from several kilometres away. The elephants spend 16 hours feeding and 4-5 hours sleeping per day. Their two elongated incisors composed of ivory have been coveted by humans for hundreds of thousands of years, and ivory has played a significant role in the art and culture of many peoples (Ross, 1992). Elephants once populated the entire continent and, formerly, within the last three centuries, *L. africana* inhabited all of sub-Saharan Africa in habitats ranging from tropical and montane forests to open grasslands, semi-arid bush and desert (Barriel *et al*., 1999).

Plate 2.1: Savanna African elephants (*L .africana africana*) with their calves moving while foraging(Author, 2010)

In recent years, however, the poaching of elephants for ivory and human population growth and expansion have reduced the species' range and numbers drastically, and the majority of remaining elephants exist in small pockets of protected land isolated by human habitation and development, or in dense forest. Two subspecies of African elephant are recognised: the savanna elephant, *L. africana africana*, and the forest elephant, *L. africana cyclotis*. The savanna elephant is larger than the forest elephant, has sparser body hair, more triangular ears that are larger, and thick, curved tusks as opposed to the straighter, narrower downward pointing tusks of the forest elephant

(Barriel *et al.*, 1999). Elephants intermediate between the two subspecies are found in hybridization zones over large areas of Africa where forests and savannas merge (Roca *et al.*, 2001).

An animal's range of movement increases with greater body size and energy requirement (Giuggioli *et al.*, 2006). Long distance travel during seasonal movement offers clear ecological advantages to elephants. Availability of food, water, barriers to free movement, spatial distribution, and diversity in habitat types may influence the home range size. Though elephants have no seasonally distinct ranges, they move widely to find food patches that are sufficiently rich with habitat resources to support them (Jetz *et al.*, 2004). The more diverse a region, the smaller could be the home range since elephants would be able to meet their varied seasonal requirements within a relatively restricted area. Factors such as nutritive value and toxicity are important in influencing the selection of food plants by elephants (Jetz *et al.*, 2004). As elephants have a digestive system which makes them particularly susceptible to toxins and tannins, they must search for plant parts which contain only small amounts of such chemicals.

Elephants are extremely adaptable, occupying a variety of habitats from desert to savannah to gallery forest (Weins and Graham, 2005). Environmental factors affect elephant population dynamics, home range, migration patterns, diet, group size and composition, all of which can vary tremendously, in turn influencing the dynamics of elephants and their habitats. An elephant's diet may include grass, herbs, bark, fruit and tree foliage. In savannah habitats grass may make up 70% of the elephants' diet in the wet season, with larger proportions of browse contributing to their diet as the dry season progresses. In tropical forest, an elephant's diet may include as many as 230 species with leaves, twigs, bark and fruit constituting over 90% of all items eaten. Trees represent up to three quarters of the species fed upon and, in contrast to savannah elephants, fruit is an important component of a forest elephant's diet (White *et al.*, 1993). Estimates for mean daily intake range from 4% to 7% (Ruggiero, 1992) of body weight, with lactating females consuming proportionately higher quantities. Elephants digest only 40% of what they consume (White *et al.*, 1993).

Elephants are capable of greatly affecting the structure of vegetation (Plate2.2) and perhaps animal communities (Skarpe *et al.*, 2004). At high densities elephants reduce woodlands, converting them to more open grassland (Western 2006). In many areas human expansion and poaching have forced elephants to alter traditional migration patterns and concentrate in protected areas (Tchamba and Mahamat, 1992; Poole *et al.*,1992). At high densities, particularly where they have been compressed into protected areas, elephants can reduce biological diversity and cause economic loss of timber in forests. In some cases the reduction of woody vegetation has been beneficial in opening up tsetse fly infested woodland and transforming bushland to grassland for livestock (Western, 2006). Often fire or logging may initiate change with elephants playing a maintaining role (Dublin *et al.*, 1990).

Studies have also shown the ecological importance of elephants as agents of seed dispersal increasing habitat mosaic in forests and diversifying mammalian communities (Western, 2006). As a keystone species, elephants play a crucial role in maintaining linkages in the food web, and their extermination from some habitats may cause a cascade of change or extinctions in ecosystems (Western, 2006). Evidence suggests that elephants diversify savanna and forest ecosystems when free to move (Western, 2006).

Plate 2.2: *L. africana* using its evolutionary trunk to reach high up forages (Author, 2010)

As with other parameters elephant home ranges vary from population to population and habitat to habitat. Individual home ranges for Asian elephants vary from 15 to 3,700 Km^2 (Kumar *et al.*, 2010). In most areas where they have been studied, females live in predictable dry season home ranges, but migrate over large areas during the wet season. Moving singly or in groups of up to several thousand, elephants may travel as far as 75 Km in a few days. They may live at densities as low as 0.024 per Km^2 or as high as 5 per Km^2. Previously, elephants migrated over long distances throughout their range. The increasing compression of elephants into smaller and smaller protected areas with no allowance for seasonal migration is likely to lead to accelerated habitat destruction and loss of biodiversity in our national parks and reserves. Finding solutions to this problem is one of the most pressing management needs in elephant conservation today.

2.2 Forage preference by *L. africana africana*

The feeding ecology of the largest land mammals has attracted much attention, not only for the sheer quantity of food consumed, but also the variety of plants selected and their impact on vegetation (Sukumar, 2003). Herbivores have long been known to demonstrate preferences for different plant species and individual plants within a species. Also the average food plant quality selected by different herbivores has been shown to be greater than the average found in the environment (Laws & Belovsky, 2010). Large-bodied mammals, depending on the large areas of suitable habitat to meet their dietary demands, are considered to be particularly vulnerable to the effects of habitat transformation (Shannon *et al.*, 2009; Leimgruber *et al.*, 2003). Studies in Africa have demonstrated the diversity of feeding behaviour that elephants exhibit under different environmental conditions (Ruggiero, 1992). Most studies of elephant diets describe elephant forages in general terms, for example, browse, grasses and fruits, instead of assessing the nutritional value of particular food plants (Chiyo *et al.*, 2005; Kabigumila, 1993; Ruggiero, 1992). Food selection can take two forms- plant species (quantity) and plant parts (quality). Selection of plant species results in a characteristic composition of a species diet in a particular habitat, while the selection of plant-parts appears to be aimed at obtaining the component with the highest nutritive value.

Elephants diet consist of a wide variety of plant species that studies on the nutritional content of their food items have collected and analysed only a small fraction. In general these studies have examined the daily activity patterns, plant selection and defecation rates. Feeding behaviour in the short to medium term of days or a few weeks essentially involves food selection within one or a few vegetation communities, while the seasonal changes in diet may involve complete shifts to different vegetation communities (Sukumar, 2003). Studies conducted on culled elephants have investigated nutritional variation relating to the condition of animals during the period of collection. Various parameters were measured relating to seasonal differences in body condition (Meissner & Spreeth, 1990).

Grass and browse have their relative advantages and disadvantages. For grass, intake rates are higher (it is easier to harvest and handle), it is lower in toxins and when its nutrient content is high, its fibre content is low (Lindsay, 1994), it also provides a return per unit time feeding that is higher than browse. It may, however, lack certain essential key nutrients and when it matures its nutrient content becomes very low. Browse offers generally higher levels and diversity of nutrients, but toxin and lignin levels are also higher. The tendency of elephants to shift from consuming mainly grass in the wet season to mostly browse in the dry season has been noted by many researchers (Santra *et al.*, (2008); Lindsay, (1994)). Elephants can fulfil energy requirements from either browse or grass, depending on availability and quality, and switch to consuming crops whenever their forage sources are insecure, as grass availability is highly seasonal. Despite the attractiveness of crops to elephants, Osborn (2004) observed that elephants did not immediately leave protected areas when crops planted along the boundary were mature, which suggests that crop raiding could not be linked to the availability of crops, and thus this behaviour could be related to the quality and availability of wild foods. Hence it is important to establish the particular plant species which elephants eat in the wild, as the availability of these species could diminish the temptation to begin crop raiding. Lindsay (1994) concludes that after ‘a long and rather pointless debate’, elephants are recognized as being both browsers and grazers and can fulfil energy requirements from either browse or grass, depending on availability and quality.

Field observations have highlighted elephant-induced changes in community structure as palatable abundant tree species are selectively reduced (Tafangenyasha, 1997) and savannas become dominated by woody species which are unpalatable or disturbance-tolerant (Ben-Shahar, 1996). Elephants demonstrate distinct dietary preferences for particular species (e.g. marula *Sclerocarya birrea)*(Duffy *et al.*, 2002), while avoiding others such as latex bearing *Euphorbia candelabrum*. It is generally assumed that in the absence of hunting/poaching, habitats with high animal densities (i.e. highly selected habitats) is of high quality, and low densities indicate low quality habitat. Animal populations respond positively to the availability of highly selected habitat types (Railsback *et al.*, 2003).

Bowland and Yeaton (1997) recorded elephants preferring later successional species such as *Acacia caffra* and broadleaved trees, while avoiding early successional species such as *A. nilotica*. Preferences may vary with habitat, location or season. For example, elephant preference for *Colophospermum Mopane* has been recorded (Ben-Shahar 1998, Smallie and O'Connor 2000) whereas others have found relatively low occurrence of *C.mopane* in the diet (Styles and Skinner 2000). *Delonix elata* is not typically eaten but may become heavily utilized in drought conditions.

In the African savannas, there are seasonal fluctuations in plant biomass, nutrient content and digestibility (Pamo and Tchamba, 2001). Past studies on food selection by elephants have focused on leaves rather than other parts. Holdo (2003) noted that elephants feed extensively on the bark of woody plants. Elephants have been recorded to use their tusks to gouge trees and then use their trunks to peel the stringy cortex of the bark off.

The impact of elephants on woody vegetation has led to concern about possible extirpation of plant species and of animal species whose persistence is dependent on forest or woodland habitat (Lombard *et al.*, 2001). The influence of large body size on foraging ecology has the potential to affect the success of some woody species and possibly lead to extirpation of some preferred species (O'Connor *et. al.*, 2007). The percentage of browse in the diet of an elephant is high during the late-dry season and drops off rapidly in the wet season (Osborn, 2004).

Elephants selectively suppress the regeneration of desirable species when they occur in gaps created by falling trees, as they preferentially forage on their saplings (Smallie and O'Connor, 2000). *Acacia tortilis* is easily killed by moderate to high debarking or branch removal (Page, 1995). Selective feeding by mammalian herbivores on the more palatable woody species can result in domination of the vegetation by the chemically defended woody species (Bryant *et al.*, 1992). Due to the constant hedging of preferred species, an area heavily foraged by elephants will show a change in composition with an increase in stem density of less preferred species (Holdo, 2003).

Numerous studies on the feeding habits of African and Asian Elephants have shown that proportions of various food-plant categories in the diet vary widely from one region to another. A feeding pattern established for one area cannot be extrapolated to another area. Selection of forage by African Elephants according to tree species has been reported by several authors in national parks. Likewise, the intensity of damage by elephants has been found to vary among species. Most studies have shown that elephants cause slight damage to short trees more often than expected by chance (Van Aarde *et al.*, 2006) and push over large trees from which leaves could not be reached. In small home ranges, elephants may use specific parts of their ranges more intensely than in large home ranges and therefore impact may be more intense. Thus, it may be more appropriate to define elephant impact in terms of range utilization functions or densities rather than population numbers *per se* (Junker *et al.,* 2008). In the zones close to water, both the frequency and severity of the damage are generally considerable (Calenge *et al.*, 2002). Presence of water is often the best predictor for elephants, especially for females, and particularly during dry seasons and in dry areas. This limits elephants to permanent water sources, including artificial water holes, in the dry season. If it is close enough to water an elephant seeks areas with high vegetation cover. Proximity to water is not merely the most important variable but the one that managers can more easily control (Harris *et al.,* 2008). It would appear then that under optimal conditions, both species show variability in their diet, foraging on herbaceous and woody materials. These factors are of great importance for any consideration in conservation of the elephant.

L. africana are known to migrate according to vegetation changes (Vanleeuwe & Gautier-Hion, 1998). The proximate factor that influences the decision to consume or reject a plant is the palatability of the item as conveyed to the herbivore through the senses of smell, taste, sight and touch. The selection of dietary items obviously depends to a large degree on what is available. In the processing of consuming an ideal diet from a natural environment, an elephant has to select from a changing mosaic of different plant species, phenological stages, structural types, chemical compositions, relative or absolute abundances and dispersion patterns (Sukumar, 2003). On a daily scale, intake rates are limited by digestion and excretion, and the amount of time invested for foraging. On a finer scale, consumption rates are influenced by the morphological properties and spatial distribution of plants (Shipley *et al.*, 1994).

In India, elephants were observed to be feeding on wood and bark of *Acacia catechu* and bark from *Bombax ceiba* (Stenheim *et al.*, 2005). This was also confirmed by large, easily identifiable remnants in the fresh elephant dung, and signs of debarking on a number of these trees. In the Cat Tien National Park, Vietnam, elephants fed on at least 24 species of plants, both wild and cultivated. Of these, stems of 11 species, roots of 7, fruits of 4, and bark of 2 were eaten (Varma *et al.*, 2008). Supporting tissues such as stems, twigs, wood, roots and bark tend to be high in indigestible fibre, while fruits contain stores of soluble carbohydrates and leaves contain photosynthetic enzymes and are high in protein and minerals.

2.3 Level of nutrient elements in plants and their effects on foraging preference by *L. Africana africana*

Evolution of herbivores has followed that of plants and plant interactions with the animals. However, plants also have evolved protection mechanisms against animals that lower availability of forage (Van Soest, 1996). Many herbivores feed on a variety of plants to balance their nutrient uptake and to avoid toxins by consuming too much of any one type of defensive chemical. This involves trade-offs between foraging on many plant species to avoid toxin or specializing on one type of plant that you can (Hawethorne & Parren, 2000).

Biologically regulated whole-ecosystem stores and fluxes of elements and compounds, such as phosphorus, nitrogen, and carbon, are simply the sums of the stores and fluxes of the constituent organisms (Brown *et al.,* 2004). Micro-nutrients have been found to influence food selection by herbivores. Macronutrients for both plants and animals are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), chlorine (Cl) and sulphur (S) (Whitehead, 2000). The N: S ratio in soils is rather constant, typically 7.7: 1, indicating that the stabilization of S in organic matter (OM) is similar to that of N (Nguyen and Goh, 1994).

Sodium and Chlorine are micronutrients for plants but macronutrients for animals. While Cl may accumulate as salts of Na and K in arid areas, it is barely retained for long by soil constituents and hardly any is observed in senescent herbage and was omitted on this basis. Iron (Fe) is a macronutrient for plants and is on the borderline between micro and macronutrients for animals while Manganese (Mn), Zinc (Zn), Copper (Cu), Molybdenum (Mo) and Cobalt (Co) are micronutrients for both plants and animals. The amount of Mo is low in sandy soils and its adsorption is very low under conditions of high pH (≥5); conditions that are characteristic of the reserves. Cobalt after being released by weathering is adsorbed by Mn and Fe oxides or is complexed by OM (Whitehead, 2000).

The adsorption and complexation with some of the oxides reduces cobalt's solubility and availability. Cobalt's availability is increased when the drainage is very poor, which is converse of soils in the study area that have been reported to be well drained. Phosphorus plays an important role in animal reproduction and lactation (Holdø *et al.*, 2002). N, P, Ca and Fe are major constituents of animal body tissues. Na, K and Mg are important for buffering pH and osmoregulation, while the micronutrients Mn, Zn and Cu are major constituents of enzymes (Holdø *et al.*, 2002). The nitrogen content of a plant is only one of the many plant characteristics that are vitally important to herbivores. However, because of its central role in all metabolic processes as well as in cellular structure and genetic coding, nitrogen is a critical element in the growth of all organisms (Chen *et al.*, 2006).

Sodium requirements of elephants have not been directly measured, but rough estimates are possible if extrapolations are made from information available for other species. Daily sodium requirements for mammals vary iso-metrically with body mass. The elephant's strategy of alternating seasonally between grass and browse is related to the plant's Calcium content. Elephant' feeding on bark is not yet fully understood (Plate 2.3). The calcium content of dicotyledonous bark is much higher (18-57mg/g) than grasses (1-5mg/g) (Duane *et al.*, 1997). Although a diet of grasses alone could provide elephants with a sufficient intake of calcium, it is not known how much is physiologically unavailable. Supplementing the diet with bark could increase calcium intake to a safe level. Bark may serve more than one purpose in an elephant's diet (Duane *et al.*, 1997).

Plate 2.3: *L. africana africana* debarking acacia trees probably looking for some specific nutrient element deficient in their body systems (Author, 2010)

Relations between bark consumption and other nutrients in different studies have been inconsistent with some studies showing high debarking intensity to be positively correlated with calcium (Hiscocks, 1999). Duane *et al.* (1997) found leaf sodium concentration to be a major factor determining browse quality for elephants, with the concentration of sodium being related to that of magnesium. Holdo *et al.* (2002) reported that elephants compensate for the low sodium levels in the Kalahari Desert woody vegetation and water sources by geophagy where elephants selectively consume soils rich in sodium. Ungulates show a positive selection of plant species and plant parts with the highest minerals such as sodium (Brown *et al.*, 2004).

Heterogeneity in resource quality, coupled with adaptive response in diet selection, will cause the form of nutritional gain response to deviate from that of intake response. The form of gain response depends moreover on the extent to which digestive capacity is limiting (Nelleman *et al.,* 2002). Ultimately, the diet should provide all the nutrient requirements of the animal (Duane *et al.*, 1997).

Digestion inhibitors consist of fibres and tannin. Fibre (often measured as Acid Detergent Fibre (ADF) is a major deterrent in food selection. The findings of Osborn (2004), explains that the fibre content of grass increases and its moisture content drops as it ages, causing increased wear on teeth and a decline in digestive efficiency. When the fibre content is high and the protein content is low, there is decrease in the digestibility of protein (Osborn, 2004). Therefore the motivation or 'trigger' for crop raiding during any particular wet season may be a decline in the quality of wild grasses as the dry season approaches.

A comprehensive study of the foraging and crop raiding behaviour of elephants in Benin was carried out by Imorou *et al.* (2004). One of the methods employed in the study was the collection of elephant droppings for the purposes of dietary analysis. The study found that elephants invaded community farmlands and increased their home ranges during the May-September rainy season and the October-December crop-ripening season. Through their study, Imorou *et al.* (2004) discovered that the elephants' diet consisted of 71 vegetation species during the rainy season, a figure which shrank to 30 species during the dry season.

Osborn (1998) and Duane *et al.* (1997) have established that foods of wild elephants are lower in protein and minerals than crops, thus crop consumption could be used to supplement deficient diets. However, the authors do not indicate that this difference in quality varies with time, as crop raiding near many habitats is highly seasonal in occurrence. By sampling food items selected by crop-raiding elephants, the study by Osborn (2004) indicated a linkage between the onset of crop raiding and the quality of grass toward the end of the wet season.

Although there is consensus that nutritional deficiency may be the cause for crop raiding, some authors (Osborn 2004) suggest that the nutrients in question are mainly proteins, while others (Rode *et al.*, 2006; McDowell, 1997) suggest that minerals, rather than energy and protein, may be limited in availability, leading to crop raiding. Low mineral availability in tropical environments is well documented in the management of domestic herbivores frequently requiring supplementation to maintain adequate productivity (McDowell, 1997). Copper and sodium, which exhibit low concentrations in elephant foods, are considered to be two of the three most limiting nutrients (along with phosphorus) for herbivores and deficiencies of these minerals are particularly common in tropical environments (McDowell, 1997). This lends credence to the nutritional deficiency explanation of crop raiding, and also opens up further areas for investigation.

In addition, Holdo *et al.* (2002) stress the importance of sodium in elephant behaviour. Their findings suggest that mineral deficiency along with the increased digestibility associated with crops could contribute to crop-raiding behaviour. Masters *et al.* (2001)

concur, stating that higher sodium concentrations in crops may allow elephants to solve the complexities of meeting sodium requirements from wild foods.

2.4 Effects of diversity of forage species on preference of feeding by *L. africana*

Animal reactions that regulate food acceptance have been classified into three systems, one these systems include stimuli within the animal's body which bring on desires for eating, some of them learned. The second system conditions the animals through evolutionary development of feeding habits on a long time scale and through learning on a short time scale. The third system affecting food preference comprises the animal's environment (Vanaraj, 2001). These three systems operate a chain of events that includes recognition of food, movement toward the food, appraisal, eating, and leaving the food source. Preference for a food may be exhibited at any point in this series. One aspect of elephant feeding behaviour that concerns wildlife managers of national parks in savannah ecosystems is their habit of feeding on several species of vegetation (O'Connor *et al.*, 2007).

Several theories have been proposed suggesting that it is a consequence of physiological changes in the elephants and the vegetation. The factors underlying differences in species utilization have not been investigated (Holdo, 2003). Riparian habitats serve as key habitats for elephant by providing forage of adequate quality at the height of the dry season. The fibrous bark of *A. elatior* has a high tensile strength and tends to be ripped off in strips by the elephants. Foley (2002) noted that the most severely damaged trees are the ones for which elephants have developed a predilection; consequently elephants seek out these trees until they become completely girdled and die within two years.

Elephants in East Africa prefer grasses in the wet season turning to browse in the dry season when grass has withered (Holdo, 2003). The crude protein and fibre content in the browse fluctuates less than that of grass (Osborn 2004). Woody parts dominate the diet in dry season but leaves and shrubs are eaten throughout the year (Holdo, 2003). When green grass is less available during drought years, elephants are forced to increase consumption of bark earlier in the season when they are relatively the most palatable (Styles and Skinner, 2000). This results in increased impact on woody plants (Osborn, 2004). Jetz *et al.*, 2004 argued that elephants are dentally specialized towards grass feeding but because of changes in the grass' seasonal availability; they must be able to switch to alternate foods such as browse. Despite its higher lignin levels, browse offers higher levels and diversity of nutrients (Sukumar, 2003). Large-bodied herbivorous mammals survive on food of lower quality owing to their higher absolute metabolic needs, higher digestive efficiency, and lower specific metabolic rate (Belovsky, 1997). Edaphic factors influence diet quality since plants derive nutrients from the soil (Scholes and Walker, 1993).

2.5 Changes in vegetation cover and the feeding preference by *L. africana africana*

Currently large tree cover is decreasing in several African savannas due to high elephant pressure and frequent fires (Echardt *et al.*, 2000). Outside protected areas the situation is often even more dramatic, with most of the trees being removed by local people for production of charcoal (Kituyi *et al.*, 2001; Luoga *et al.*, 2004). At the root of all elephant problems is their effect on the habitat (de Boer, 2000). Reduction in tree cover could have serious consequences if trees have a positive effect on herbivore food quality and availability. Attention in East Africa is invariably drawn to woodland change to open grasslands in the presence of elephants (Duffy *et al.,* 2000). Elephants selectively suppress the regeneration of desirable species when they occur in gaps created by falling trees, as they preferably forage on their saplings. The influence of large body size on foraging ecology has the potential to affect the success of some woody species and possibly lead to extirpation of some preferred species (O'Connor *et al*., 2007).

Human population pressure, change in lifestyle, technological advances, change in land tenure and climatic change are some of the factors attributed with the vegetation change in the rangelands. Livestock and wildlife is a product of a plant growth and their productivity is commensurate with the welfare of plants (Raubenheimer & Simpson, 1998). However, importance of the rangeland is under siege from vegetation change. Increased woody plants and decrease in grass cover has threatened the productivity of such ecosystems. Such changes in the species composition affect the economies of the pastoral communities. Sheet soil erosion, which later develops to rill and gully erosion, always, accompanies such vegetation change due to lack of ground cover. In the long run, removal of the topsoil and uprooting of the trees by flash floods and wind make the land to take long to heal from such perturbations and thus reduced chance of plant regeneration (Higgins *et al*., 2000).

Natural factors such as fire frequency and climatic change bring about vegetation change. However, ecosystems are capable of recovering from such perturbations since they tend to be temporal, irregular and physically separate. In contrast, population increase, sitting and realignment of the political and administrative boundaries, development of forest reserves and national parks, establishment of commercial ranches and agricultural farms, and though the influence of the missions and several other modern institutions like schools, hospital and churches, there has been restriction of movement for the nomadic people and a reduction in the area they formally occupied. As such, the human orchestrated vegetation changes as a result of land use tend to be permanent, regular and concentrated in a given area plants (Raubenheimer & Simpson, 1998).

The migration of people from high potential lands and urban growth in arid and semi arid lands and the short-term benefits of leasing land have contributed to land degradation and have altered natural vegetation. The migrants occupy the more fertile area, which also produce good pasture. When combined with privatization of lands, pastoralists have lost access and left with more marginal pasture that are degraded by unsustainable land use. Studies on rangeland vegetation change have concentrated in single factor analysis such as overgrazing and fire (Kothmonn *et al.,* 1997), atmospheric CO_2 enrichment (Archer *et al.*, 2000) and exotic species introduction (Archer and Brown, 1999). However, the problem of the vegetation change is complex and varies across time and space and thus need to be viewed in temporal, spatial, ecological and human dimension.

2.6 Theoretical Framework

The study was based on the Optimal foraging theory (OFT) by McArthur and Pianka (1966) which states that animals forage in such a way as to maximize their net energy intake per unit time and the theory can be used to investigate the properties of communities. The theory aims to “explain and predict” the pattern of food choice and foraging by animals. It is based on the premise that foraging can be viewed as a process that has been optimized by natural selection to maximise fitness. The focal point of this study is not fitness, but foraging behaviour which is assumed to be a proxy for fitness. The foraging behaviour is influenced by nutrients which determine whether wild animals thrive, how populations evolve and decline, and how ecological communities are structured.

The components of the environment included food and other animal populations in the habitat, and abiotic (for example rainfall and solar radiation) factors, which influence the way organisms, respond to ecological environment at various time scale. Animals behave in such away as to find, capture and consume food that is most profitable, while expending the least amount of time possible in doing so. According to OFT, elephants while foraging have two choices after coming in contact with a forage plant either eat, when the plants shows some profitability, or leaves it and looks for another. This is typically due to habitat and size constraints, but even within habitats, organisms eat only a proportion of what is available. Animals typically eat the most profitable food type more than would be expected by chance, since it will appear in the diet at a higher proportion than it is encountered in most profitable food types.

Many animals attempt to regulate intake of multiple nutrients independently through selection of food and consumption of nutritionally imbalanced food is sometimes inevitable, forcing trade-offs between eating too much of nutrients present in the foods in relative excess against too little of those in deficit. This theory therefore helped us study the foraging behaviour of elephants, and for this reason was relevant to the study.

2.7 Conceptual Framework

During the study, independent variables comprised the environmental factors which included both biotic and abiotic factors. The elephant foraging behaviour was dependent on biotic (plants) and abiotic (Climate, edaphic) factors which influenced the nutrients in the vegetation. The abiotic factors (Climate, edaphic) influenced the nutritional components in the vegetation, through what the plants take up from the soil and photosynthetic products when sunlight is available. (Figure. 2.1)

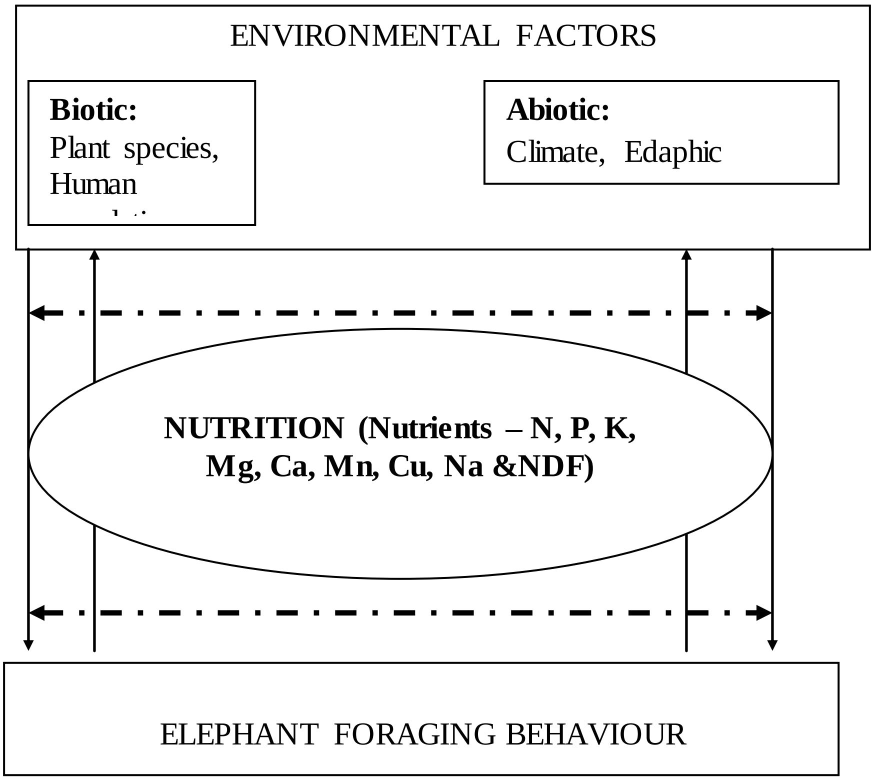

Figure 2.1: Conceptual relationship between the elephant foraging behaviour and nutrients in the plants (Author, 2010).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter outlines the methodology, procedures and modalities used in data collection. It includes the study area, research design,sample size, sampling design, sampling procedure, the instruments of data collection, validity and reliability of data collected, sources of data, methods of data collection and analysis.

3.2 Study Area

3.2.1 Location and Size

This study was done in Rimoi Game Reserve and Conservation Area (RGRCA) situated in Elgeyo-Marakwet County. Elgeyo-Marakwet County is one of the fourty seven (47) Counties in Kenya. The County has a total area of approximately 3,029.8 km^2 (Kenya National Bureau of Statistics (KNBS), 2010). It borders Pokot County to the North, Baringo County to the East, South-east and South, and Uasin Gishu County to the south-west and west, and Trans Nzoia County to the north-west (Figure 3.1). It lies between 35°25' and 35°45' East longitudes and between 0°10' and 0°52' North latitude (Ministry of Finance and Planning (GoK), 2002).

Rimoi Game Reserve is situated in the Kerio valley floor in the Keiyo/Baringo boundary. It is situated between longitudes 35^0 30' and 35^0 40' East and latitude 0^0 40'and 0°50' North. Regionally, it is located in Rimoi and Tambach Divisions of Keiyo District. Rimoi Game Reserve (RGR) is about 404 square kilometres which is approximately 35% of the entire District. Rimoi Game Reserve and Conservation Area (RGRCA) is bounded by the Kerio River in the east which also separates Elgeyo

Marakwet and Baringo County, and the Keiyo escarpment on the western part with the top of the escarpment (the highlands) extending as far as the Uasin Gishu County border (figure 3.1). The boundary of the Reserve, which is the critical zone of RNGRCA, is marked to the northern-end by River Emsos while to the south by River Kessup.

For purposes of integrated development and management, the RGRCA can be divided into three land units. The first is the lower part of RGRCA and the Game Reserve itself, a trust-land area of 66 square kilometres, generally flat and is part of the Kerio Valley basin – locally called *Soin* (or *Tir'ngwon'gwo or Soiwo*), that portion lying adjacent to *Endo* (River Kerio) (Plate 3.1). The official boundaries of the Reserve are delineated on a boundary plan No. 216/46 and were gazetted through legal notice number 13 of 26th January, 1983. The County Council of Keiyo is the local authority that is responsible for the management of the RGR with technical advice from the Kenya Wildlife Service (KWS) as is the case with all other National Game Reserves in the country (RGRCA Integrated Development and Management Plan, 2007).

3.2.2 Topography

Keiyo District can be divided into three topographical zones, which run parallel to each other in a North-South direction. These are highland plateau; the Elgeyo escarpment and Kerio Valley. The highland plateau rises gradually from an altitude of 2,400 meters above sea level on Chebiemit Hills in the North to 2,700 metres above sea level on Metkei ridges in the South. Metkei ridges which are in the South are an extension of the Mau ranges, the highest peak being Timboroa (2,890m) and the land falls in a series of steep scarps and flat plateaus that comprise of the Elgeyo escarpment and falling down into Kerio Valley floor which is between 800-1000 meters above sea level (Keiyo District Development Plan, 2002).

The Kerio Valley is a low-lying stretch of land bounded to the West by the Rift Valley and volcanic activities have played a major role in shaping Keiyo District's landscape. The Elgeyo escarpment illustrates the main features of the rift wall. Part of the process of the rift valley formation has been up warping of the areas on either side of the faults.

3.2.3 Climate

Rainfall distribution in Keiyo District is highly influenced by altitude. In highland plateau where the altitude is high, temperatures are moderate and evaporation rate is low. In the Eastern part of the district, which forms the Kerio Valley and where the altitude is low, low rainfall, high temperatures and high evaporation rates characterize the climate. In between these two extremes, there are variations as one drop from the highlands to the floor of Kerio Valley. The mean monthly temperatures vary between 17^{o} C and 22^{o} C. It is generally hot in the valley, while it is cold in the highlands, mainly in Nyaru and Iten. The rainfall pattern is bi-modal in nature with long rains from March to June and short rains occurring between October and December, though it varies from one area to another within the district.

3.2.4 Soils and rock formation

The Kerio Valley has been formed by several phases of intensive volcanic activities. Most of the extensive rocks include basalts, phonolite, trachylespyroclassic rocks and alluvial deposits. The rock formations in the district can be divided into basement systems (metamorphic), tertiary volcanic (extensive igneous) and quaternary alluvial deposits (sediments). Most of the coarse debris in these sediments is basement material derived from the escarpment. They are derived from pre-existing sedimentary rocks through mineralogical, chemical and structural processes, due to changes in temperature, pressure and chemical environments deep in the earths crust. The sedimentary rocks occur throughout the Kerio Valley. They consist of red and brown silts with numerous irregular coarse debris. Extensive igneous rocks are mainly found in southern part of the district. Soils in the district vary with location and altitude. Along Kerio River runs a zone of fluvisols while there is cambisols in the escarpment zone and luvisols on the foot slopes of Kerio Valley (Kiplagat, 1998).

3.2.5 Vegetation

The vegetation that covers Elgeyo Marakwet County is not homogenous as can be explained by the difference in altitude and the varying climatic condition. The highlands are covered with forests and cultivated land. The western slopes (east facing) are steep and covered with forests and plenty of undergrowth. Shrubs, herbs and trees in some areas cover part of the escarpment between the highland and the plateau. Vegetation cover in the escarpment is sparse. Acacia species, shrubs and herbs cover the Kerio Valley floor. Dry sub-humid climate is found in some parts of the Kerio Valley in Keiyo District area (RGRCA Integrated Development and Management Plan, 2007). Vegetation consists of semi-evergreen bushland and savanna woodland. On the escarpment is sub-humid, forested and with *pennisetum species* dominating the grasslands and bushland. Rimoi National Game Reserve and Conservation Area have a variety of vegetation and habitat types that differ according to altitudes and climatic conditions. Its virgin wilderness is covered by a vibrant biotic community, which consist of thorn bush and woodland.

The vegetation is dominated by Acacia trees (mostly *A. mellifera* and *A. tortilis*), bush lands and cactus, plus other prickly leaved species. Within the Reserve the biotic communities are basically arid thorn bushland and woodland. Grasses in the Reserve are dominated by *Themeda triandra* and *Cynodon dactylon* in the open glades. The vegetation is green and thick during wet seasons but becomes scorched brown and sparse during dry periods. Vegetation progresses gradually from open glades of grassland and scrubland along the Kerio River through open bush lands to thick bushes and forests of Acacias and *Balanites aegyptica*. The vegetation and habitat of RGRCA can be categorized into forest, woodland, bushland and grassland (RGRCA Integrated Development and Management Plan, 2007).

3.2.6 Fauna

Rimoi Game Reserve and Conservation Area had been the home of large herbivores which included rhino, buffalo and carnivores like the lion which no longer exist. The existing fauna are composed of the African elephants (*L. africana*), Waterbucks (*Kobus ellipsiprymnus)*, Bushbucks (*Tragelaphus scriptus*), Blue monkeys (C*ercopithecus mitis*), Dik diks (*Rhynchotragus guentheri*), Bushpigs (*Potamochoerus porcus*), Warthogs (*Phacochoerus aethiopicus*), Baboons (*Papio anubis*), Impala (*Aepyceros melapus*) and the African hare (*Lepus capensis*). The birds include Pigeons (*Columba guinea*), Weavers (*Bubaloruis niger*), Ibis (*Threskiornis aethiopca*) to mention a few (RGRCA Integrated Development and Management Plan, 2007). Other fauna include carnivores such as, civet and genet cats which occupy varied habitats. Aquatic species such crocodiles occur in Kerio River but breed within the neighbouring Lake Kamnarok and later disperse to the Kerio river and its various tributaries.

The domestic livestock include cattle, goats, sheep and recently introduced camels. The camels and elephants share the forages since their feeds are the same i.e they are both browsers. Goats feed on tree leaves and shrubs but at a lower level. Cattle and sheep also feed on the few grass species present, though at times they also browse on shrubs and leaves of trees. The other wild herbivores too are grazers and browsers, for example the bush bucks and water bucks. Traditional bee keeping is also being practiced by the people

3.2.7 Land and Agricultural Activities

The land use around the Game Reserve is dominated by livestock rearing with scattered crop production since it is a rangeland. Wildlife conservation is the predominant land use in the valley floor close to the Kerio River, though honey gathering is common with game hunting also reported. The livelihood of the communities living in areas adjacent to the protected area, are dependent on charcoal burning for cash income, though under restriction by authorities. The average farm size is 3.6 Ha in the district. The main food crops include: maize, beans, finger millet, sorghum, cowpeas, sweet potatoes, groundnuts, Pawpaw's, cassava and horticulture (vegetables, water melon, beans). Kerio valley is dry with erratic rainfall, leading to poor crop production and hence low income. Poverty is therefore rampant and the inhabitants rely on food relief.

3.2.8 Human Demography and Economic Activities

According to the 2009 population and housing census, the division (Tambach) in which Rimoi Game Reserve is located had a population of 18,676 people with a

density of 56 persons per km^2 and an area of 330.8 km^2. Rimoi location had a population of 1,567 people with a density of 54 persons per km^2 and an area of 29.1 km^2 (KNBS, 2010).
The populations on the adjacent areas are mainly dependent on relief food on a year round basis, not because of the low rainfall and poor soils, but they claim to be mainly due to frequent crop raids by wildlife, making them amongst the lowest income per capita in the country. These have been hikened by the conflicts among them and wildlife, especially the elephant.

The Keiyo is part of the Kalenjin speaking people that comprise Terik, Kipsigis, Nandi, Tugen, Pokot, Marakwet, Sengwer, Sabaot, Sebei and Okiek according to Chebet and Dietz (2000). The Keiyo preferred to settle on the Western slopes of Kerio Valley because they were fleeing from various calamities and found Kerio Valley and the hills around it a place of safety and source of food. They preferred living on the escarpment plateau because it is free from mosquitoes and tsetse flies, which were a threat to human and livestock. Most of the natives live on the broken edges at the foot of the main escarpment which is a convenient place for their homes as they are not too far away from their livestock in the highlands while the can easily decent into the valley taking them for salt licks (Kiplagat, 1998).

These communities certainly traded with one another, Tugen often sale honey and poison arrows in exchange for sorghum and millet from Keiyo and Marakwet. Further north the Pokot exchanged milk and dried meat for the Marakwet's grain. The Marakwet traded metal goods from their blacksmiths for elephant tusks, salt and buffalo hides. The Turkana, like the Pokot came to the valley primarily for grain and tobacco, which is grown in the valley for domestic consumption (Kiplagat, 1998).

3.3 Research Design

3.3.1 Survey

A survey was used to gain the insight into occurrence of conflicts as a way of obtaining the basic information in the study area. The survey of the area prone to elephant crop raiding was done and estimated to stretch to about one hundred and forty three (143 Km) kilometres north from Rimoi which is the epi-centre of the elephant activity and had 1,407 households. Kerlinger (1992) argues for the use of surveys in educational fact finding because they provide a great deal of information which is accurate. Based on the 2009 population and housing census, the study area was estimated at 12,000 people residing in 1,407 households. The households covered most of the areas prone to elephant crop raiding. This included Keu, Kamogich, Chepsigot, Kiptuilong and Kokwo locations of Keiyo District.

A sampling frame was based on households in the study area, since the whole population could not be sampled due to time and resource constraints (Kothari, 2005). To determine the sample size, the following formula was used i.e. $n = \frac{N}{1 + Ne^2}$.

Where n = required responses (sample size)

N = Sampling frame (number of households)

e^2 = error limit (Kerlinger, 1992)

Placing the formula for sampling site will yield a sample size of

$$n = \frac{1407}{1 + 1407 * 0.05^2} = 311$$

The sampling of households was done using simple random sampling technique, where a total of 311 households were sampled. After knowing the number of respondents required to participate in the survey, each household was assigned a number, thoroughly mixed in a container, then simple random sampling without replacement was done to identify the respective households to be interviewed. This was preferred because the variance is smaller than when samples are selected with replacement.

Each of the five administrative locations were (Figure 3.1) allocated equal number of households to participate in the survey. The three hundred and eleven households were distributed as follows:

1. Keu location 63 Households
2. Kamogich location 65 Households
3. Kiptuilong location 62 Households
4. Chepsigot location 61 Households
5. Kokwo location 60 Households

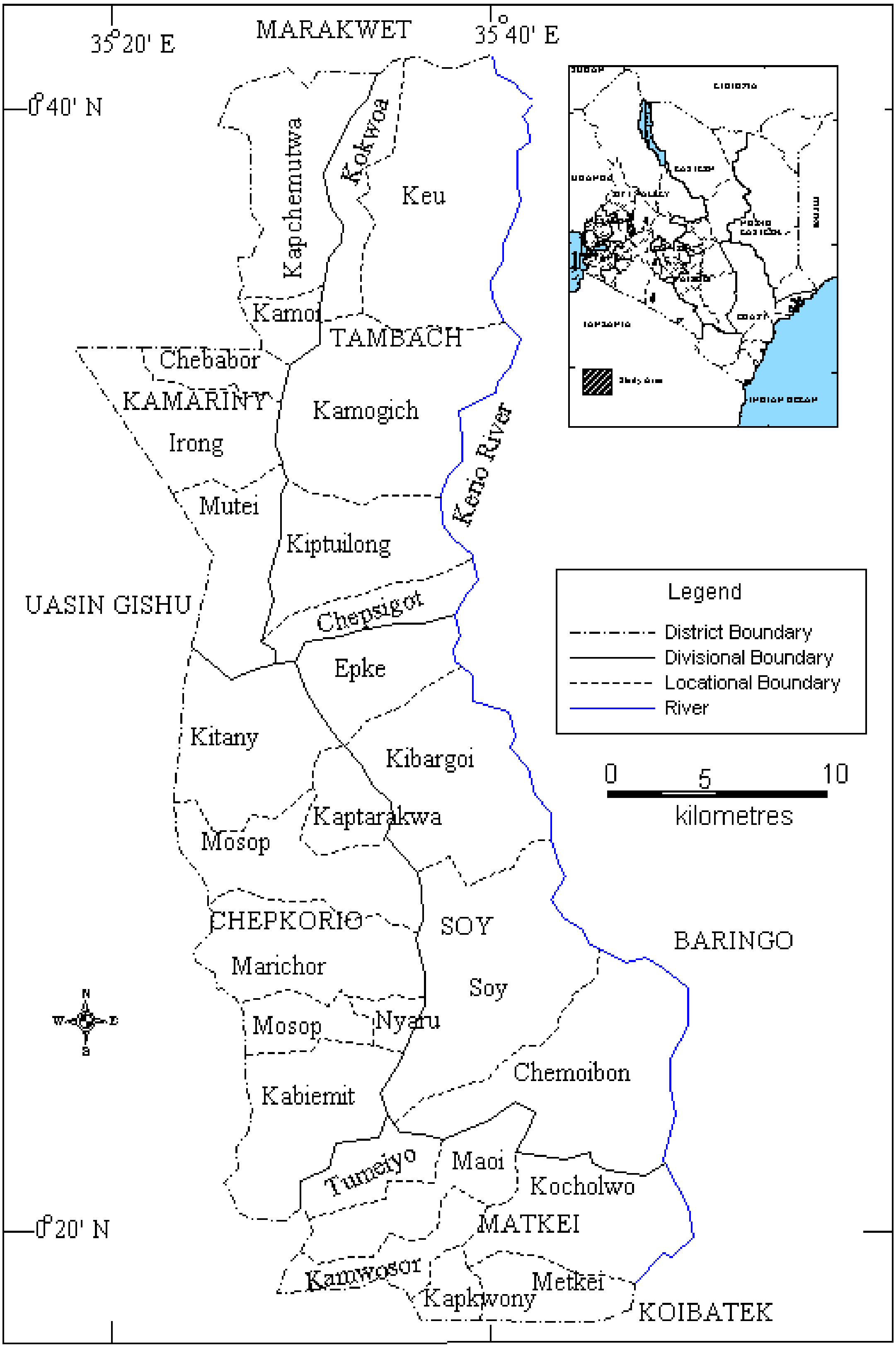

Figure 3.1: Administrative units of Keiyo District (Ministry of Finance and Planning, 2002).

3.3.2 Data Collection Instruments

The study relied on both primary and secondary sources of data. Therefore the data were collected using different methods, namely: questionnaires, interviews, observations and document analysis. Tools for data collection were based on the indicators to be assessed, and the objectives of study.

3.3.3 House hold Interviews

Primary data were collected from a total of 311 respondents who answered the content of the questionnaires in the study area between January 2010 to March 2010. The semi-structured questionnaires were provided to the respondents (Appendix 1).

3.3.4 Observation Check list

The general information on settlement patterns, crop raiding patterns and crops available in the area were gathered through observation. Observation in the field was carried out hand in hand with taking photographs and aiming at collecting information that will not necessarily require interviews.

3.3.5 Document Analysis

Document analysis involved reviewing the contents of target documents with the aim of adducing some relevant secondary data (Oso and Onen, 2005). The document reviewed during the study included: crop production trends, vegetation cover changes from GIS images and information on the elephant demographics from the Kenya Wildlife Services (KWS) records.

3.3.6 Pre-testing of the Questionnaire

The survey tools were tested through a pilot study using thirty households. The researcher sat with each respondent while they were keying in their answers to observe how they coped with and interpreted questions and to answer any queries. In addition they were asked if they felt that any aspect of the questionnaire will be problematic. This piloting was particularly helpful in refining the questionnaires and interview schedules ahead of the actual data collection. Piloting ensured that ambiguities in the questionnaires and interview schedule are ironed out before they are administered to the respondents. Enumerators to help in questionnaire administration were present in every step during piloting.

3.4 Validity and Reliability

To test the validity of the research instruments, the pre-tested questionnaires were corrected and submitted to five researchers for validation and to assess the reliance of the content. The researchers were specialists in the field of social sciences. Three enumerators were part of this activity and participated in the review of questionnaires.

3.5 Field data collections

3.5.1 Determination of Elephant Forage Preferences and level nutrients

Forage preference was deduced from recent feeding trails of the African elephant (*L. africana*). Those plants showing signs of recent elephant browsing/grazing were picked, identified and tallied. The data on preferred forages by elephants were obtained by making a systematic record of the feeding behaviour. Their diet was deduced from records of plants which showed obvious signs of recent elephant use. Debarked, browsed or grazed vegetation were picked with the use of a secateur. For each sampled tree or vegetation, areas showing signs of feeding like the leaves or bark samples were taken at browsing level for nutrient analysis. The picking was done for three hours every two days a week from 7.00 am. Picking was done at the onset of the planting season (start of wet season), harvesting season and dry season.

Each of the collected plant was identified /tagged, tallied and air dried in the field inside a brown 'sugar paper bag' and later transported to the laboratory (at Tea Research Foundation, Kericho and Kenya Agricultural Research Institute, Muguga) for analysis of nutritional content. The sampling regime was that three samples of each plant species in a season were collected and analyzed. Twenty five plants were considered for nutrient analysis (Samples of *Acacia tortilis* and *Ficus spp*. bark were also taken), which was composed of nineteen wild forages and six major crops raided. The start of the planting season was in Apri-May, harvest season was in July-August; and start of dry season was in October-November.

3.5.2 Plant Nutrient Content Analysis

For the plant nutrient content nutrients, laboratory analysis was done at the tea research foundation of Kenya (Kericho) and at the Kenya agricultural research institute (Muguga). Eighty one samples were collected from different plant species. The elements analyzed for were Ca, Mg, Mn, N, K, P, Cu, and Na. Two bark (*A. tortilis* & *Ficus* species) samples were also analysed. The procedure of Chapman and Pratt (1961) with slight modification was used in the analysis of micro and macro nutrients. However, nitrogen was analyzed using Kjehldal methods (N × 6.25). Neutral detergent fiber analysis was also done. All the methods were done according to the procedures detailed in American Public Health Association (APHA, 1998).

3.5.3 Habitat assessment

Landsat TM and ETM+ were used to acquire stored images for the study area. The images acquired were for: 1986, 2000, and 2006. The resulting image subsets were subjected to unsupervised digital image classification into three information classes. An information class entails the spectral signatures that were of interest for this study. The specific spectral peculiarities for this study were trees, woodlands and shrubs which were forages for the elephants in RGRCA. The information classes were labelled with a reference made to Google maps and other study area information.

A spatio-temporal analysis was then done by image differencing and Normalized Difference Vegetation Index (NDVI) calculation. This essentially was a change detection analysis. Change detection process by image differencing was achieved by subtraction of an image from an earlier acquired image to check the extent of changes that have occurred. The aim was to have an over view of the status and dynamics of vegetation across the study area.

3.6 Data Analysis

Once all the survey data had been collected, they were coded in Statistical Package for Social Sciences (SPSS ver. 17.0). All the data were analysed by descriptive statistical analysis. In the survey and habitat change study chi square analysis was carried out to see whether there were any significant differences. In the analysis of nutrients, both analysis of variance and multiple regressions were used to obtain the relationship between preference of forage and the nutrients. The nutrients were subjected to ANOVA to examine the extent of variation within the season so as to make a decision on their influence on foraging preference.

CHAPTER FOUR

RESULTS

4.1 Overview

In this chapter, results of survey and the forage preference study are presented. The section covers: human elephant conflict, crops raided, forage preference, nutrients concentration in the crops, relationships between the nutrients concentration in crops and the vegetation preference, vegetation cover change and the implication of forage preference on food security in this region.

4.2 Human elephant conflict

An examination of the questionnaire responses pertaining to the forms of conflicts revealed that conflicts between people and elephants in RGRCA takes several forms. Crop depredation (52.4 %) was identified as the most common type of conflict. Close to 31% of the respondents stated that encounters between people and elephants often led to deaths and injuries of both people and elephants. A small proportion (16.7 %) of the respondents also stated that elephants tended to cause damage to property such as farm installations, water reservoirs, fences and houses (Figure 4.1).

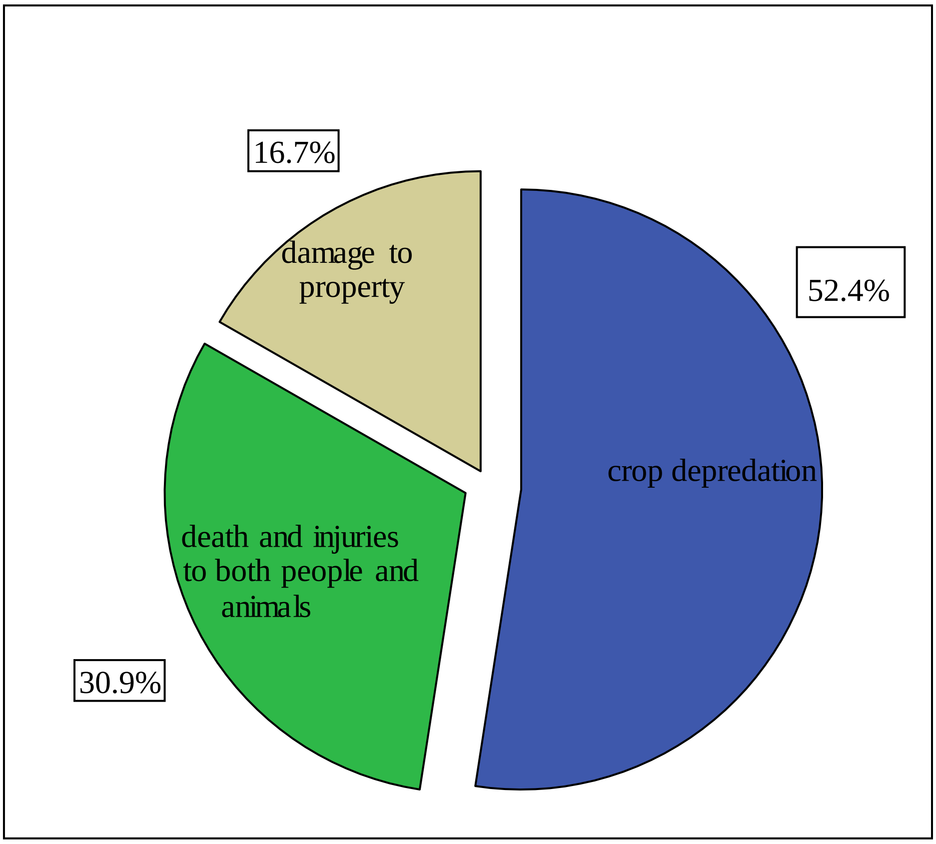

Figure 4.1: Forms of human Elephant conflict in RGRCA, (Field data, 2010)

Respondents reported that crop raiding by elephants was very low in the months of January (2.85%) to March. It however rose steadily in the months of April, May, June, July, and at peak in August (78.42%) before dropping again in the months of September, October, November and December (Figure 4.2).

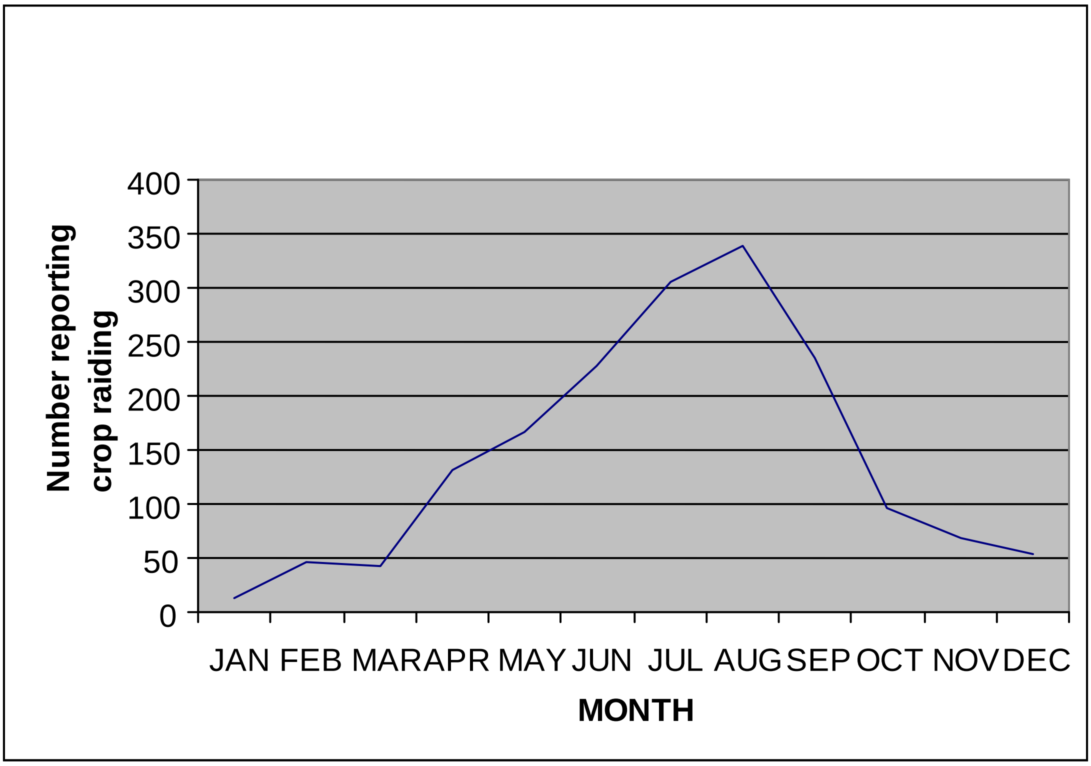

Figure 4.2: Crop raiding trend over the year as reported by community members in RGRCA, (Field data, 2010)

Elephants were reported to eat a wide variety of food crops which included maize, millet, green grams, sorghum, cowpeas, and groundnuts, among others. Maize (44.3 %) most reports, followed by millet (20.0 %), sorghum (14.4 %) and green grams (11.4 %) respectively. Other food crops (6.7%) such as bananas, pumpkins, cabbages, carrots and onions were also reported to be raided by elephants.

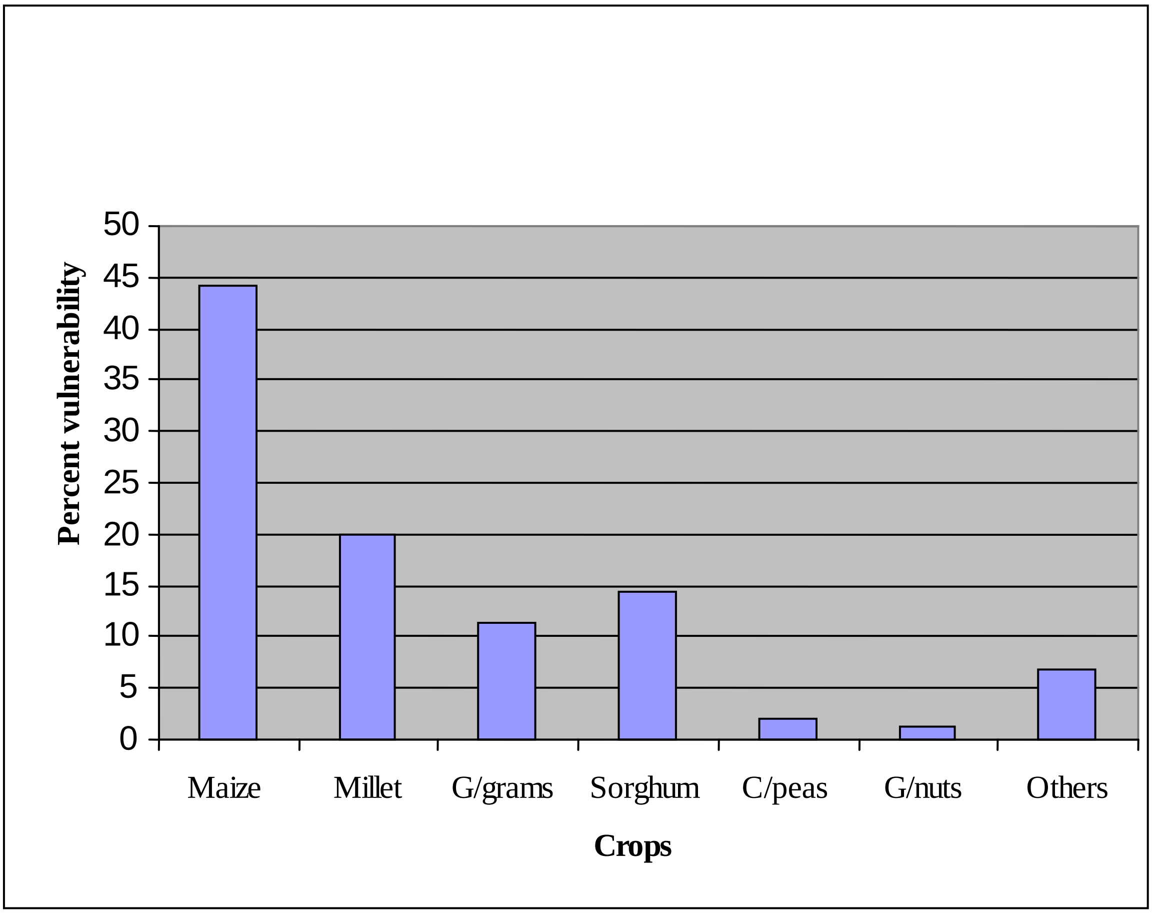

Figure 4.3: Crops Reported to be Vulnerable to raiding by *L. Africana* in RGRCA, (Field data, 2010)

4.3 Forage Preference by the Elephants

The first objective of this study was to determine the forage preference by the *L. africana*. Preference of the wild vegetation by *L. africana* is provided in Figure 4.31. According to the results from the feeding trail, analysis showed the five most preferred wild forage were *Acacia tortilis* (23%) followed by *Balanites aegyptica* (14.8%), then *Acacia mellifera* (9.6%) and *Zizyphus mucronata* (7.5%) and Acacacia brevispica (7.1%). The other components of the elephant diet in this region were: *Acacia hamulosa* (6.1%), *Acacia abyssinica* (6%), *Compretum spp* (5.3%), and *Grewia* *bicolour* (3.5%). Further field observations showed that, both the leaves and bark of the *Ficus* spp. and *A. tortilis* were also consumed by the *L. africana* (Plate 4.3).

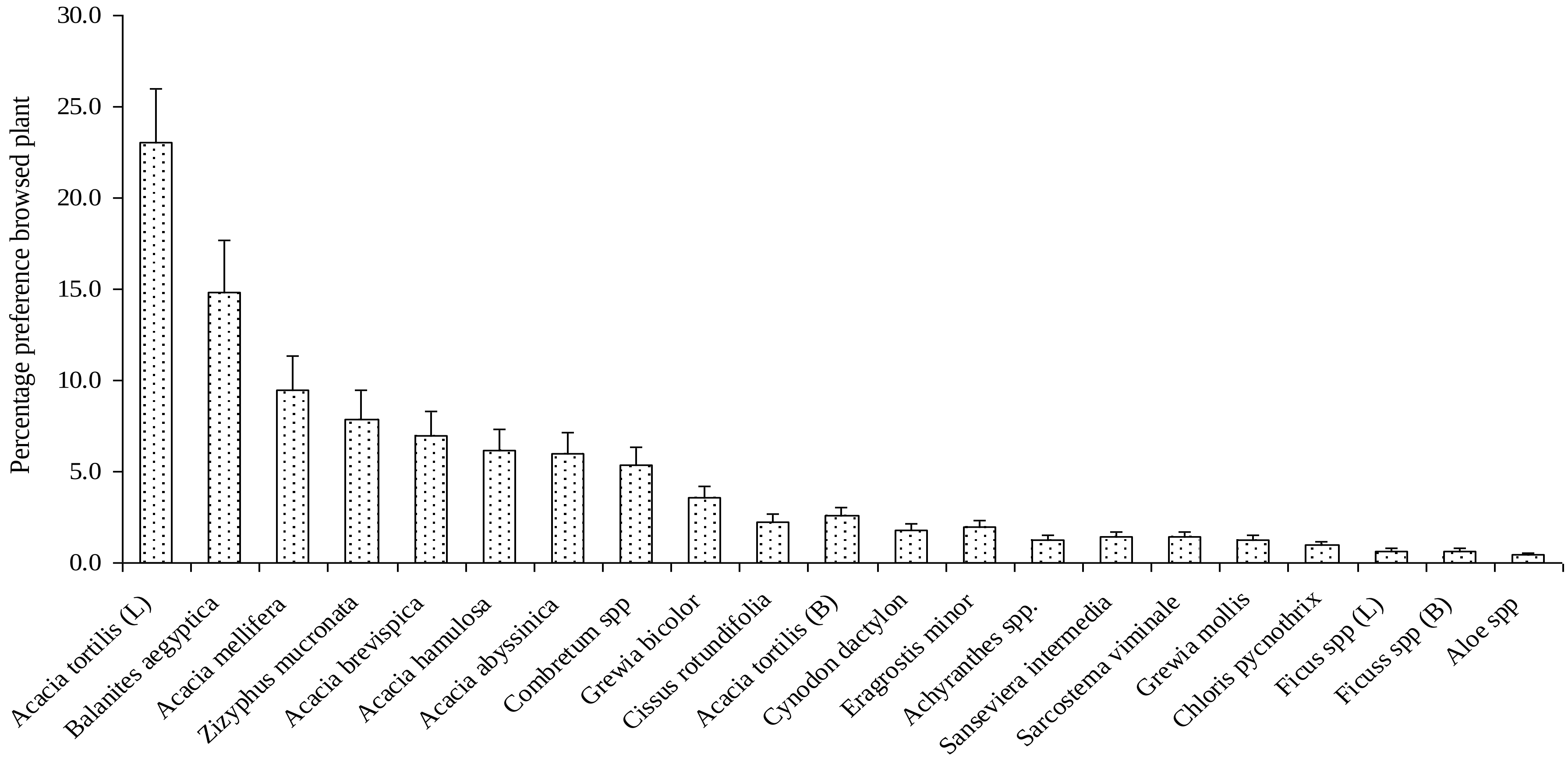

Figure 4.4: Wild vegetation preference by *L. africana africana* in Rimoi Conservation Area based on counts along the feeding trails (Field data, 2010)

PLATE 4.1*: Browsed and debarked *Acacia tortilis* by *L. africana african* in Rimoi Conservation Area (Author, 2010)*

The preference of crop raiding by the African elephant is shown in Figure 4.5. There were significant differences in the crop raiding patterns of the crops (χ^2 = 36.443, df = 5, p = 0.0003). Based on the findings, the most preferred crops and therefore most raided was maize (86.5%) followed by millet (51.4%) and green grams (34.8%), while the least raided crops were cowpeas (16.8%) followed by millet (7.3%).

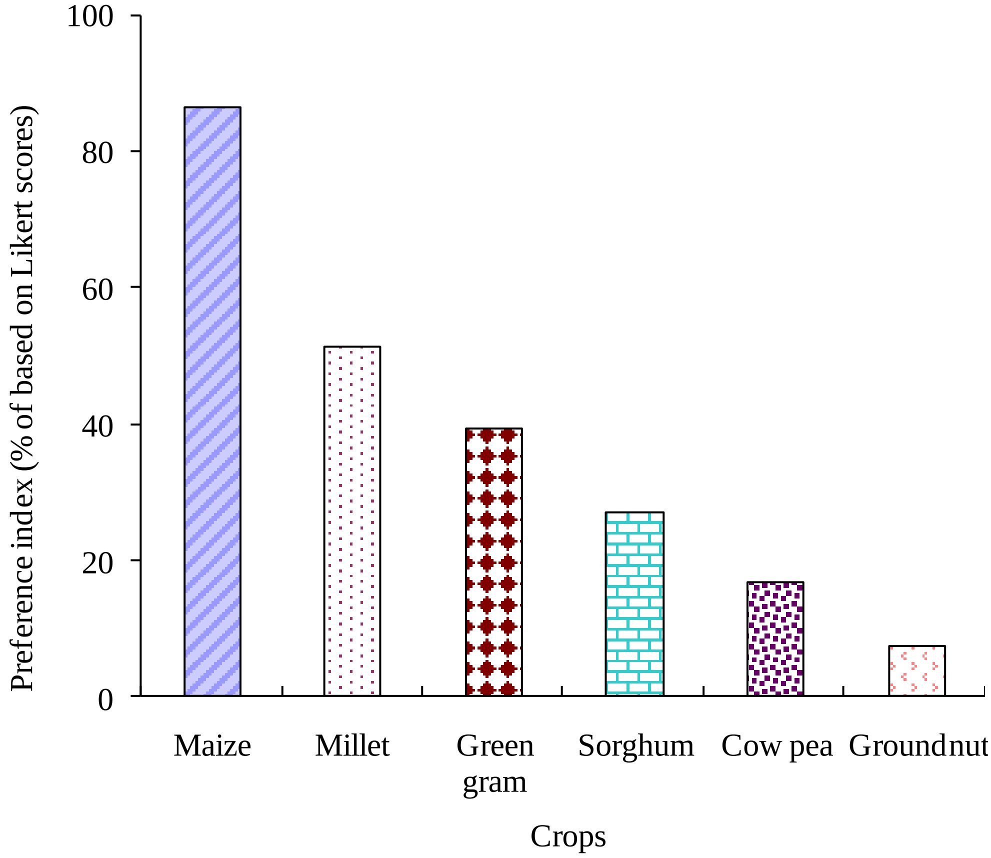

Figure 4.5 Crop preference by L. africana africana in areas adjacent to Rimoi Conservation Area based on Likert scores from data on the questionnaires (Field data, 2010)

4.4 Level of nutrient elements in preferred wild vegetation and raided crops

The levels of nutrient elements were also determined in the wild forages and raided crops by *L. africana africana*. The levels of nitrogen and phosphorus content in the wild forages are shown in Figure 4.6. There were significant differences in the levels of nitrogen among the plant species (ANOVA, F = 23.133, df = 20, p = 0.002) similarly to phosphorus (ANOVA, F = 112.137, df = 20, p = 0.000). Plants that contained high nitrogen contents were: *Acacia mellifera* (2.77 mg/Kg), *Acacia hamulosa* (2.75 mg/Kg), *Achyranthus aspera* (2.65 mg/Kg) and *Chloris pycnothrix* (2.51 mg/Kg). On the other hand, plants containing the highest phosphorus among the plant species were: *A. aspera* (4.22 mg/Kg), *Aloe spp*. (2.92 mg/Kg), and *Sanseviera intermedia* (2.51 mg/Kg).

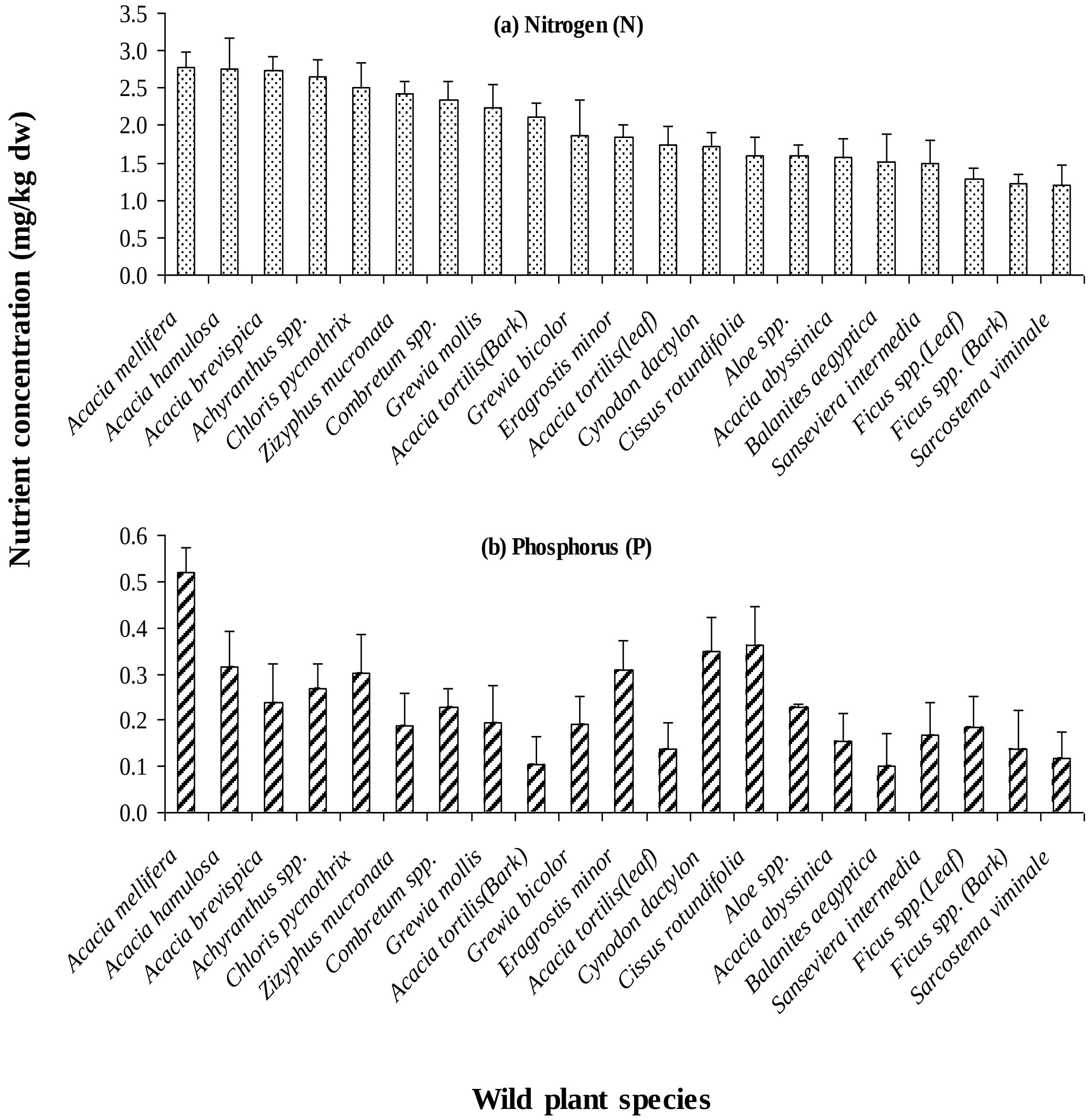

Figure 4.6: Concentration of (a) nitrogen and (b) phosphorus in wild forage browsed by L. africana africana in Rimoi Conservation Area (Field data, 2010)

The nitrogen and phosphorus concentration was also determined in the raided crops (Figure 4.7). There were significant differences in the levels of nitrogen among the raided crops (ANOVA, $F = 11.134$, $df = 5$, $p = 0.0325$) and significant differences were also shown in phosphorus concentrations. (ANOVA, F = 11.137, df = 5, p = 0.0052). Crop plants that contained high nitrogen level were green grams (2.12 mg/Kg dwt) and groundnuts (1.44 mg/Kg dwt), while cowpeas (0.30 mg/Kg dwt) and millet (0.35 mg/Kg dwt) contained systematically higher phosphorus concentrations than other crops.

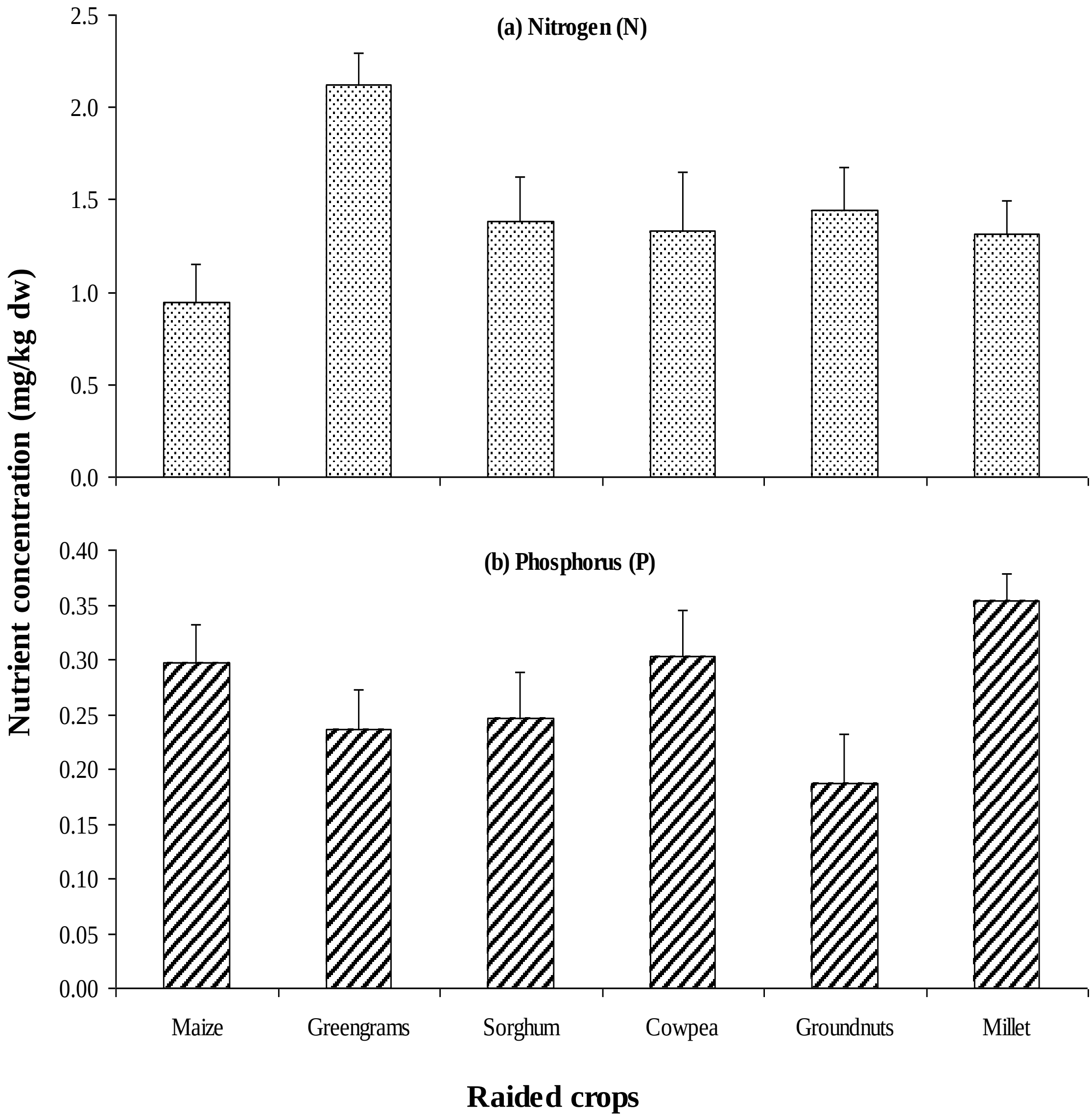

Figure 4.7 Concentration of (a) nitrogen and (b) phosphorus in raided crops by *L. africana* a*fricana* in Rimoi conservation area (Field data, 2010)

The concentration of Neutral Detergent Fiber (NDF) in wild forages was also determined (Figure 4.8). The differences in NDF levels in plants were significant (ANOVA, F = 18.137, df = 20, p = 0.0025). High NDF were shown by *A. tortilis* bark (B) (84.5 %), *Cynodon dactylon* (75.4 %) and *C. pycnothrix* (72.96 %).

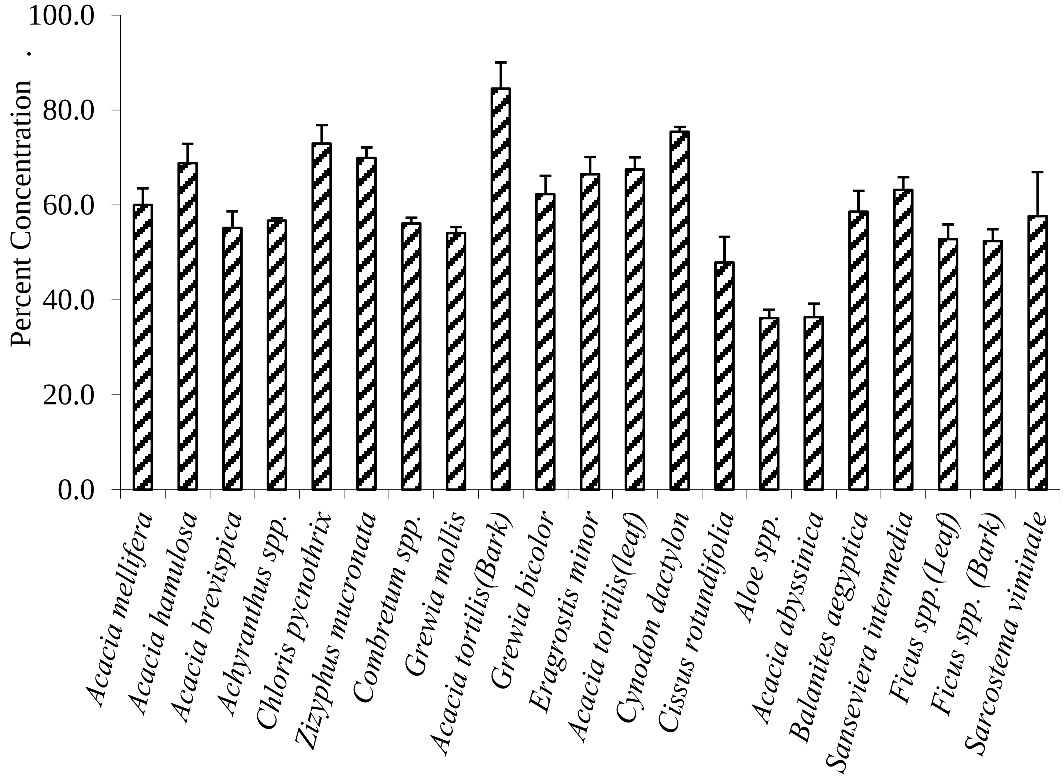

Figure 4.8: Percent concentration of NDF in wild forage browsed/grazed by *L. africana africana* in Rimoi Conservation Area (Field data, 2010)

Results also showed differences in the concentration of NDF in the raided crops by *L. africana africana* in Rimoi Conservation Area (Figure 4.9). There were significant differences in the levels of NDF among raided crops (ANOVA, F = 19.009, df = 5, p = 0.025). Maize (65.43 %), sorghum (74.4 %) and cowpea (63.17 %) contained significantly higher concentration of NDF than millet (52.81 %), and green grams (26.4 %) which had low concentration of this element.

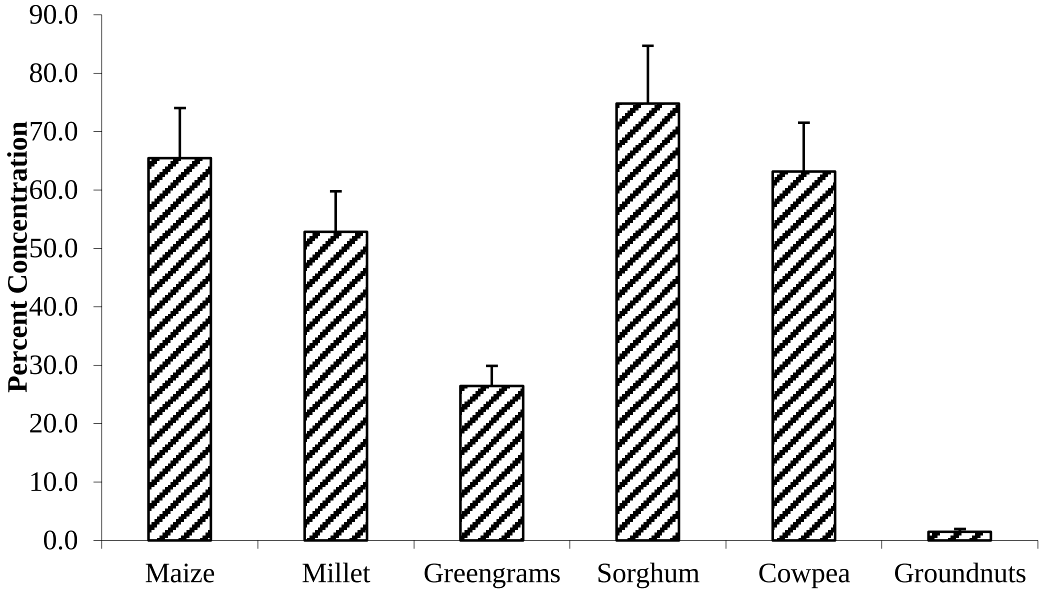

Figure 4.9: Percent concentration (%) of NDF in raided crops by *L. africana africana* in Rimoi Game Reserve and Conservation Area (Field data, 2010)

Levels of sodium (Na) and potassium (K) in the browsed plants are shown in Figure 4.10. Differences in sodium was significant among the plant species analyzed (ANOVA, F = 34.553, df = 20, p = 0.0000). *A. aspera* (0.92 g/Kg dwt), *Aloe spp* (0.83 g/Kg dwt). and *S. viminale* (0.75 g/Kg dwt) had systematically higher concentration than other plant species. Similarly, there were significant differences in the concentration of potassium among forage plants (ANOVA, F = 23.222, df = 20, p = 0.0001). There were higher concentrations in *A. aspera* (4.22 g/Kg dwt), *Aloe spp.* (2.92 g/Kg dwt), and *S. intermedia* (2.51 g/Kg dwt) than other species.

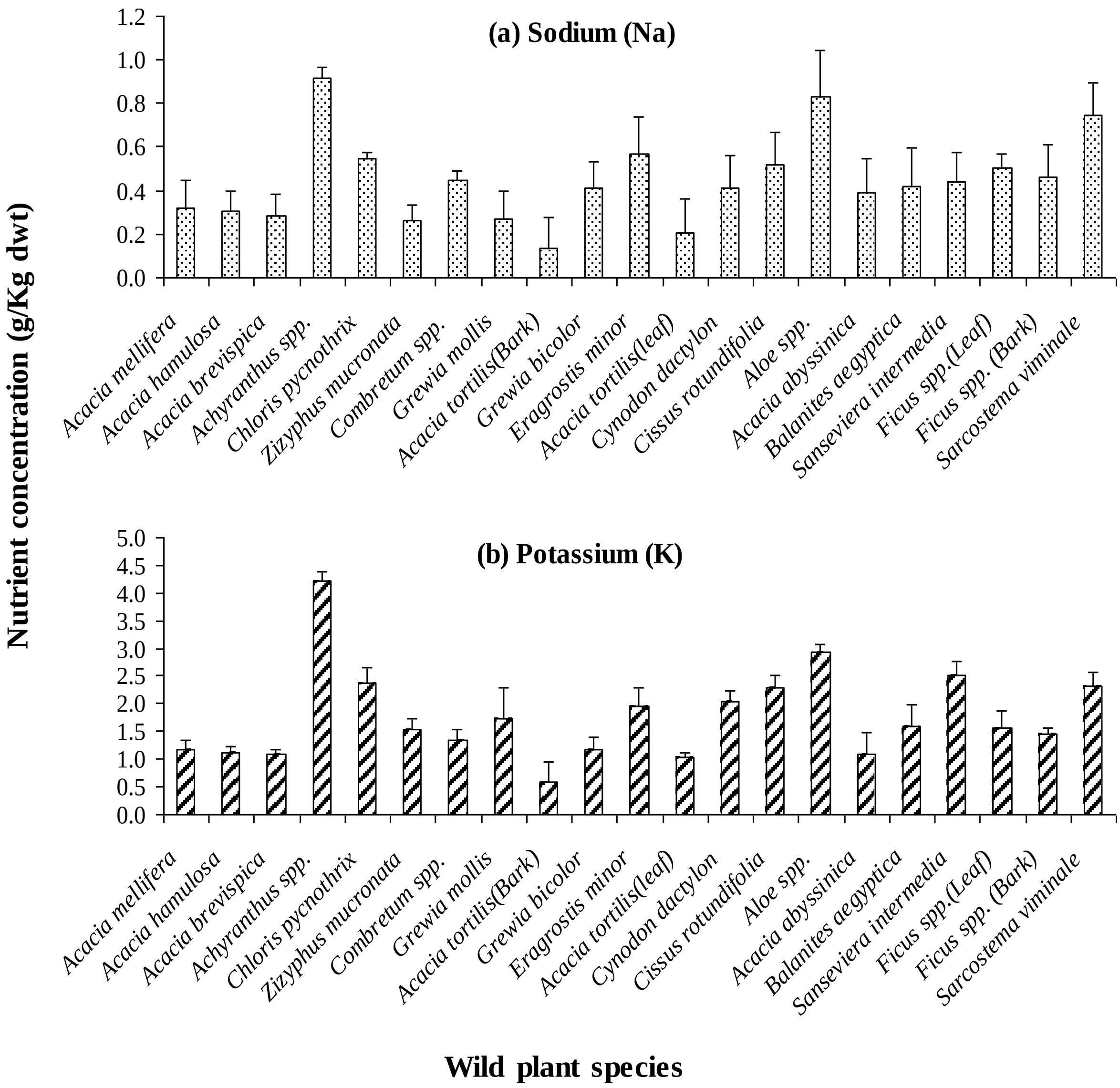

Figure 4.10: Sodium and potassium in wild forages browsed by *L. africana africana* in Rimoi Conservation Area (Rimoi, 2010)

In the raided crops, there were also differences in the concentrations of Na and K in crops (Figure 4.11). There were significant differences in the levels of sodium and potassium among raided crops (ANOVA, F = 11.134, df =5, p = 0.0325). Groundnuts (0.26 g/Kg) showed high sodium levels, while potassium was shown to be high in green grams (0.25 g/Kg).

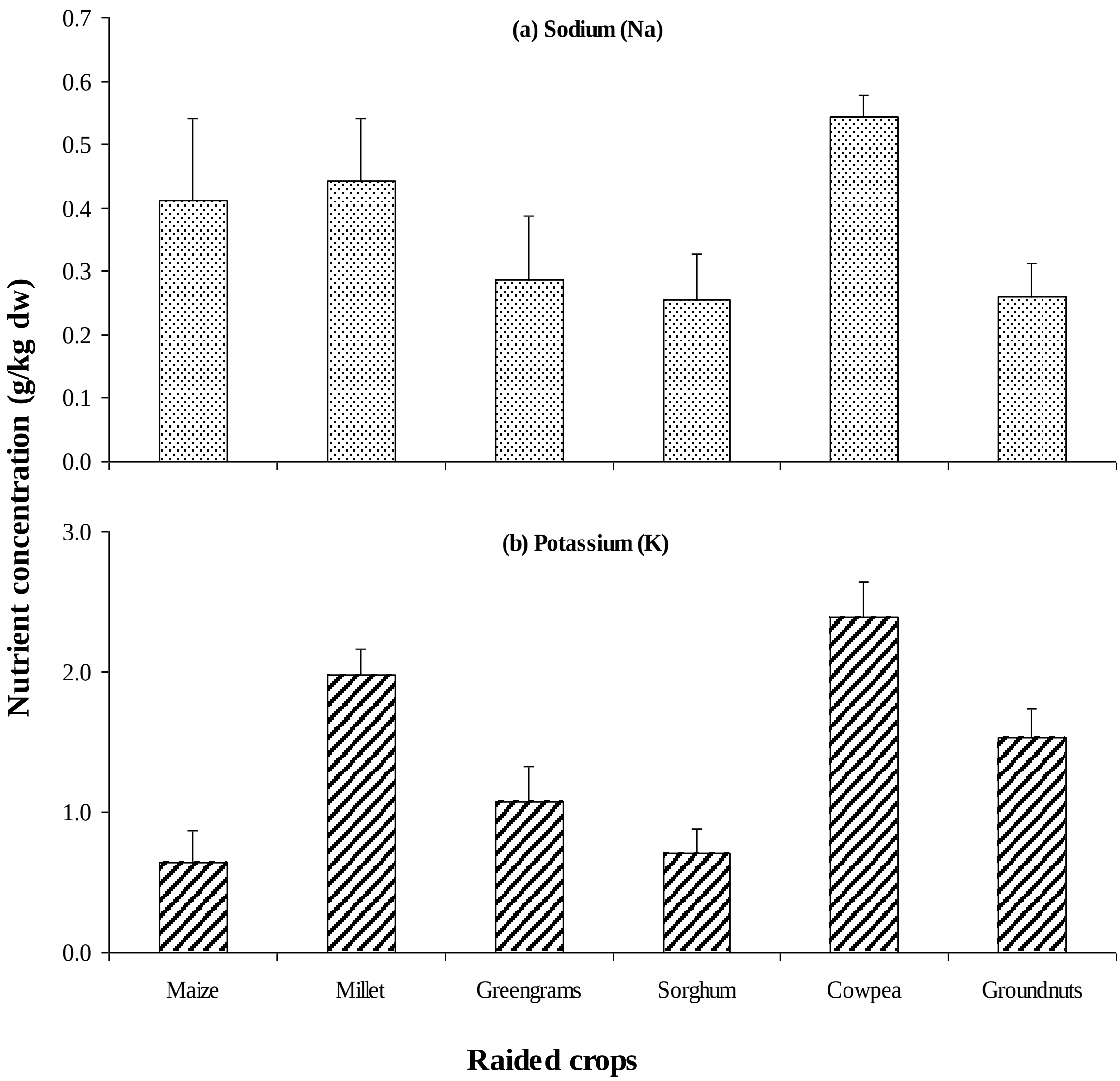

Figure 4.11: Sodium and potassium in crops raided by *L. africana africana* in Rimoi Conservation Area (Field data, 2010)

Levels of calcium and magnesium in the browsed plants are shown in Figure 4.12. Differences in Ca was significant among the plant species analysed (ANOVA; F = 34.553, df = 20, p = 0.0000). *A. tortilis* (B) (3.45 g/Kg), *Fiscus spp.* (L) (3.25 g/Kg). *Ficuss spp.* (B) (2.82 g/Kg), *Aloe spp.* (2.53 g/Kg) and *G. Mollis* (2.36 g/Kg) had the highest concentration of Ca than other plant species. Similarly, there were significant differences in the concentration of Mg among plants (ANOVA; F = 23.222, df = 20, p

= 0.0001). The highest concentration of Mg occurred in *Aloe* spp. (1.42 g/Kg dwt) and *A. aspera* (0.99 g/Kg) than other species.

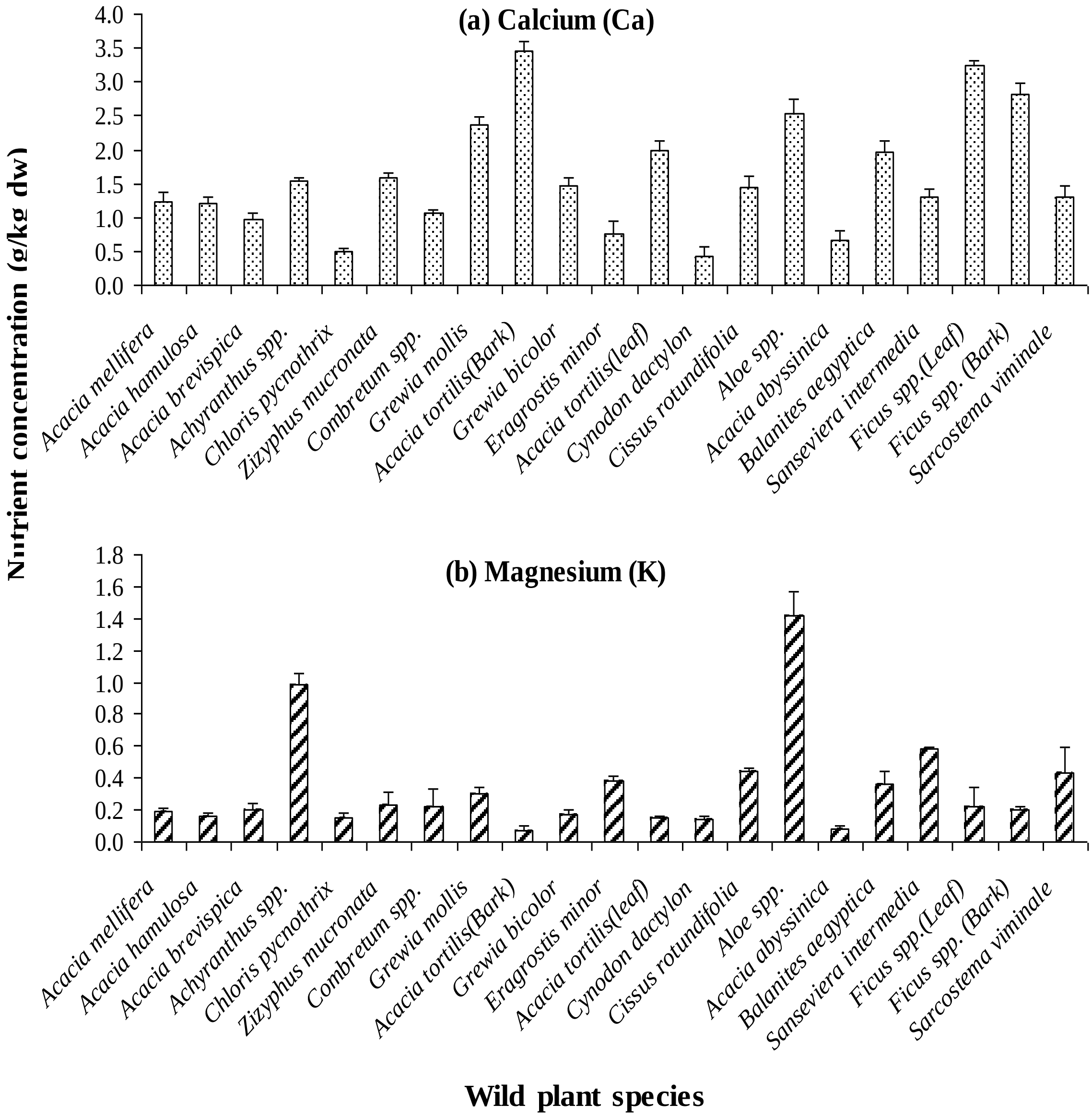

Figure 4.12: Calcium and magnesium content in plants browsed by *L. africana africana* in Rimoi Conservation Area (Field data, 2010)

In the raided crops, results showed that there were differences in the concentrations of Ca and Mg (Figure 4.13). There were significant differences in the levels of Ca and

Mg among raided crops (ANOVA; F = 11.134, df = 5, p = 0.0325). Ca was shown to be high in Cowpeas (1.95 g/Kg dw), while Mg was high in Groundnuts (0.45 g/Kg dw).

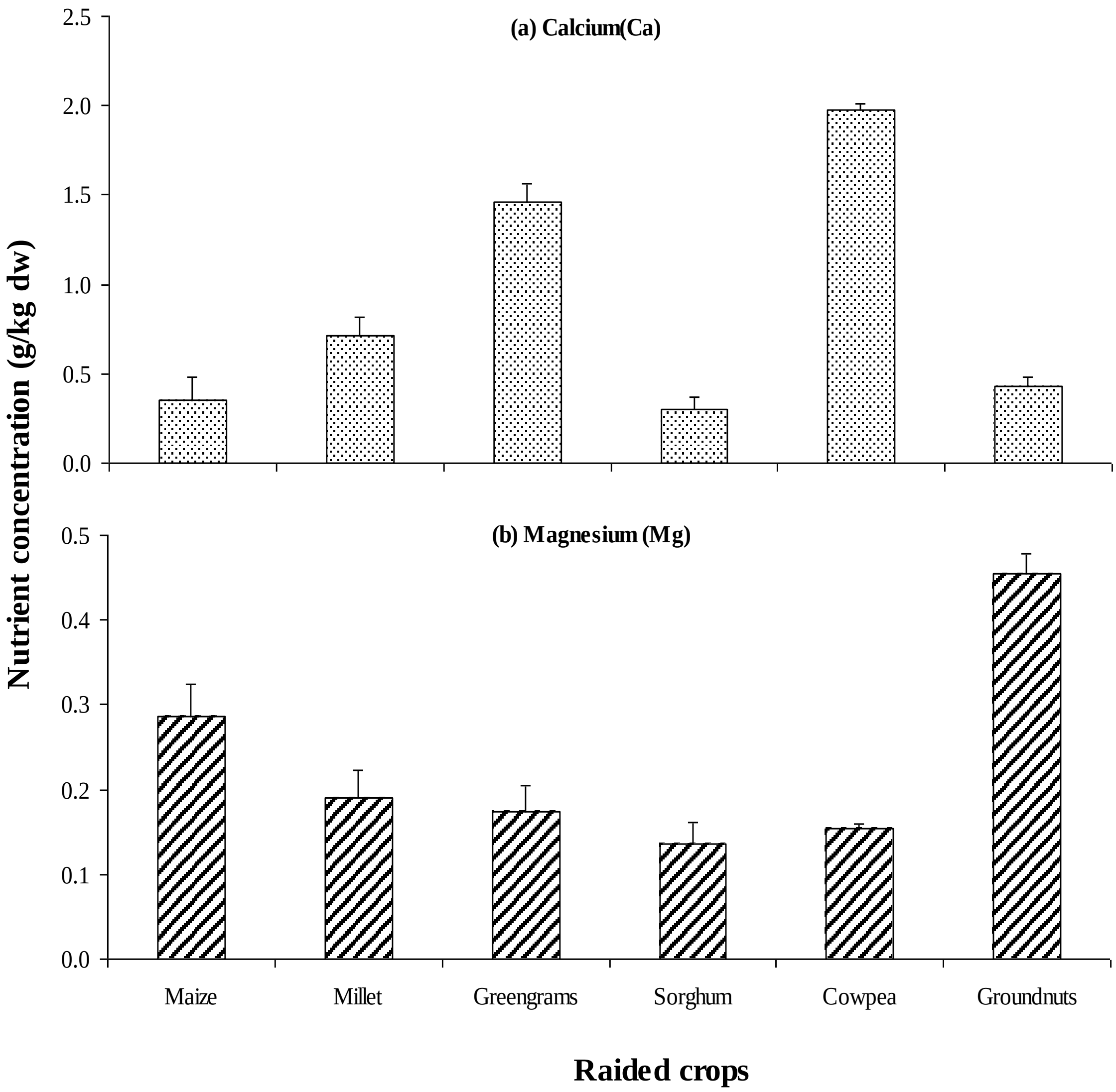

Figure 4.13: Calcium and magnesium in crops raided by *L. africana africana* in Rimoi Conservation Area (Field data, 2010)

Finally the levels of Mn and Cu in the wild forages were also determined in the samples (Figure 4.14). Differences in Mn was significant among the forage plants analysed (ANOVA; F = 34.553, df = 20, p = 0.0000). *C. pycnothrix* (1.07 mg/Kg dw), *C. rotundifolia* (0.98 mg/Kg dw) and *E. Minor* (0.87 mg/Kg dw) had higher concentration of Mn than other forage plants. Similarly, there were significant differences in the concentration of Cu among forage plants (ANOVA; F = 23.222, df = 20, p = 0.0001). The highest concentration of Cu was shown by *C. pycnothrix* (7.1 mg/Kg dw), *E. minor* (6.7 mg/Kg dw) and *G. Mollis* (6.1 mg/Kg dw) than other species.

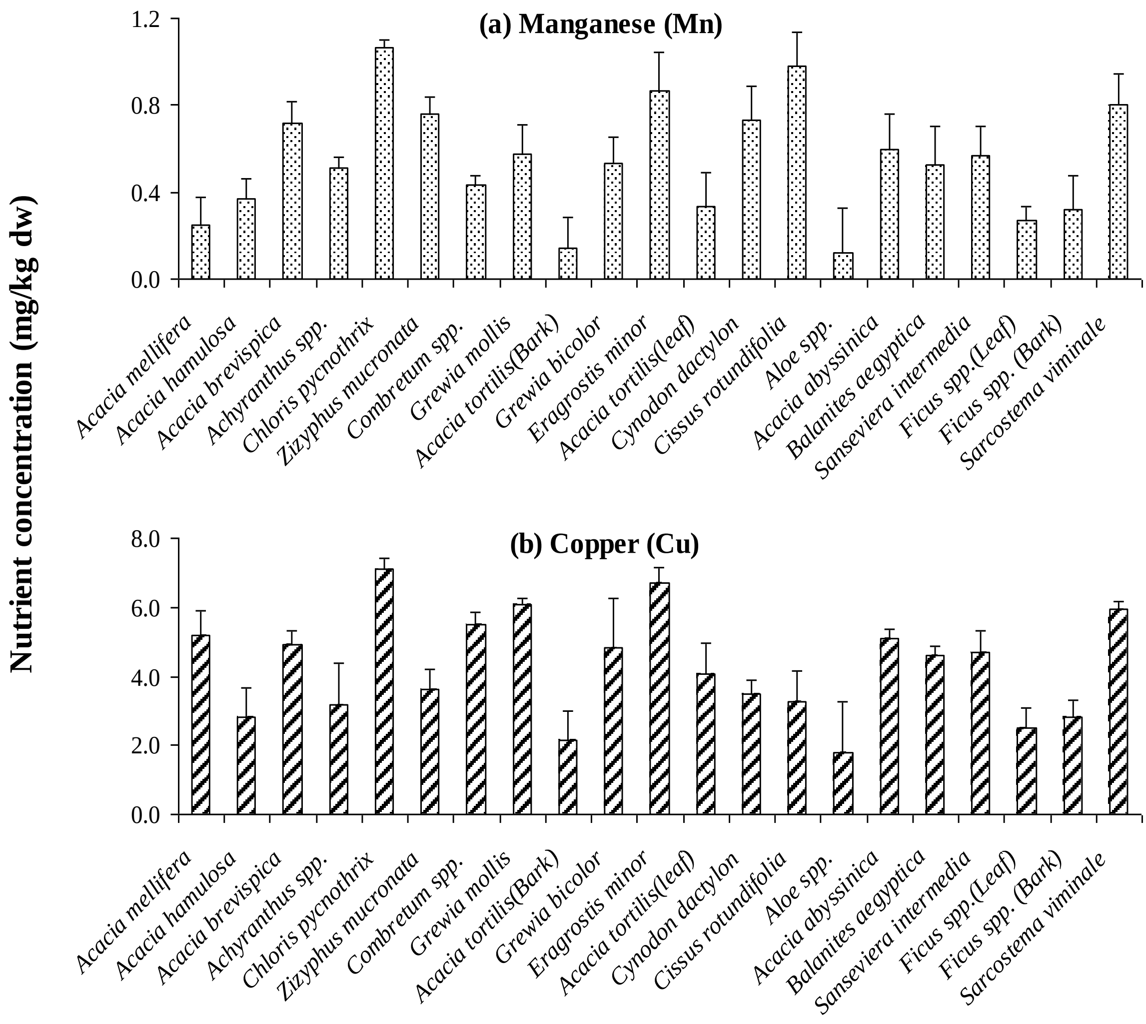

Figure 4.14: Manganese and copper (Cu) in the forages and crops browed/grazed by L. africana africana in Rimoi Conservation Area (Field data, 2010)

In the raided crops, results showed that there were significant differences in the concentrations of Mn and Cu (Figure 4.15) in crops. Mn was shown to be high in Maize (0.9%), Groundnuts (0.867%), and Green grams (0.433%), while Cu was high in Groundnuts (6.7 pm), Millet (6.167 ppm) and Green grams (5.5 ppm)

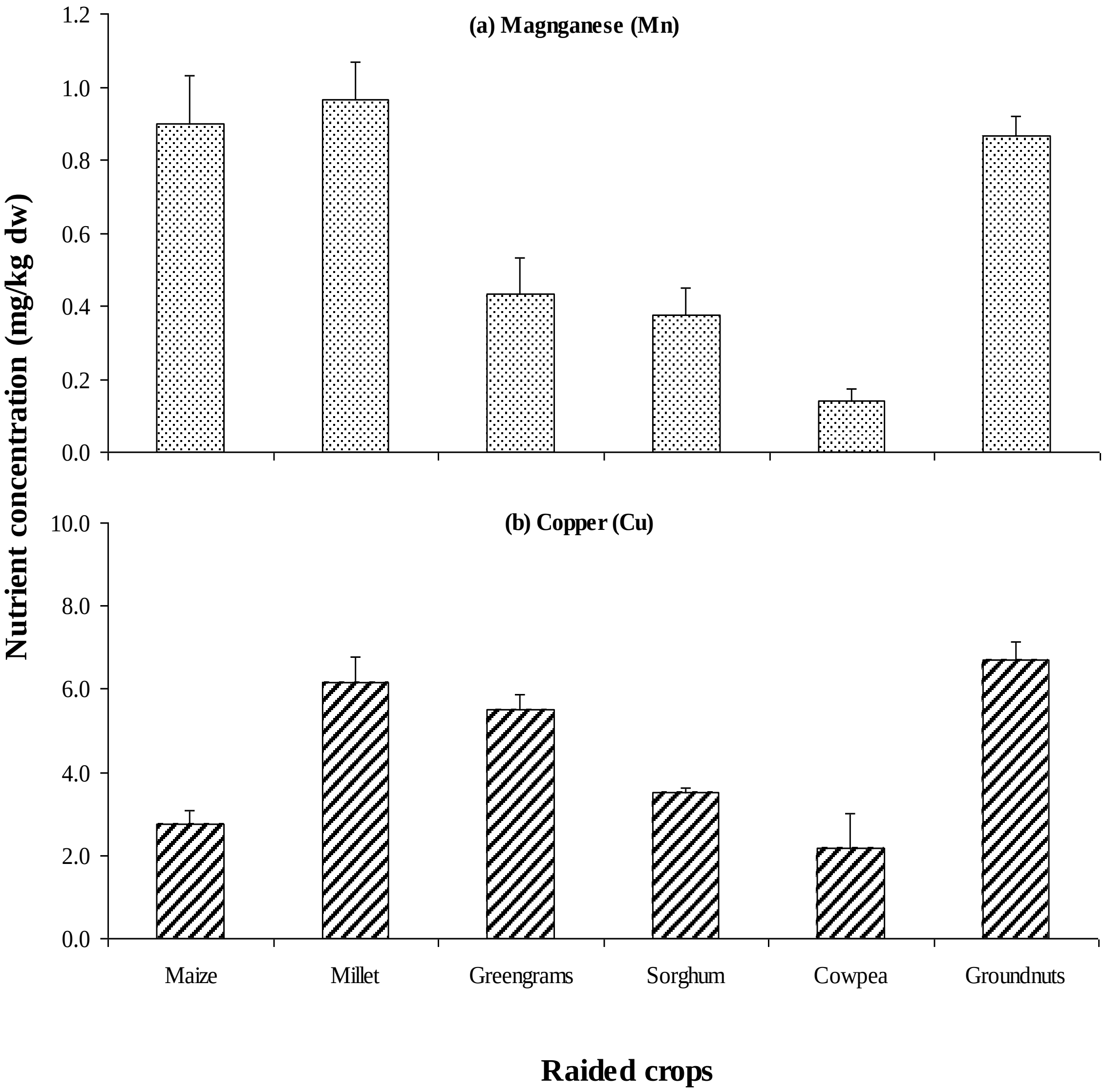

Figure 4.15: Manganese and copper in crops raided by L. africana africana in Rimoi Conservation Area (Field data, 2010)

4.5 Nutrient Elements and Foraging Preference by Africa Elephants

Multiple regression results show that the proportion of variation in the preference can be attributed to the plant nutrients (R^2 = 0.596). It thus shows that 59.6% of the preferences of plants foraged by the elephants were accounted for by the variation in the nutrients found in the plants in the month of April (Table 4.1). R = 0.772 indicates that about half the variance of preference is associated with the nutrients. R^2-Adjusted, R^2 = 0.772 - 0.383 = 0.389, the shrinkage means that if the model were derived from the population rather than a sample, it would account approximately 38.9% less variance in the outcome. Results of the month of April indicates that the preference for a specific plant by elephants was statistically significant (p-value, p=0.033<0.05), indicating that the variations were due to the differences in nutritional content of the plants (Table 4.2).

Table 4.1: Model Summary for the month of April

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.772(a)	.596	.383	6.237

a Predictors: (Constant), % NDF, %K, %Ca, %N, %P, %Mn, ppm Cu, % Na, %Mg

Table 4.2: ANOVA for the month of April

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	976.710	9	108.523	2.790	.033(a)
	Residual	661.290	17	38.899		
	Total	1638.000	26			

a Predictors: (Constant), % NDF, %K, %Ca, %N, %P, %Mn, ppm Cu, % Na, %Mg
b. Dependent Variable: Plant preference

Multiple regression results in the month of August, showed that 82.8% of the variation in preference was accounted for by the nutrients in plants (Table 4.3), indicating that this model had a better fit than in April. R = 0.910 shows that over half the variance in preference is associated with the nutrients. R – Adjusted: R^2 = 0.910 - 0.743= 0.167, the shrinkage means that if the model were derived from the population rather than a sample at this time of the year, it would account approximately 16.7% less variance in the outcome. Results at this time of the year indicates that the preference for a specific plant by elephants was highly significant (p=0.000<0.05), indicating that preference was due to variation in nutrition (Table 4.4).

Table 4.3: Multiple regression model Summary for the month of August

Model Summary				
Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.910a	.828	.743	4.172
a. Predictors: (Constant), % NDF, %Ca, PPM Cu, %K, %N, %Mn, %P, %Mg, % Na				

Table 4.4: ANOVA for the month of August

ANOVAb						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1513.625	9	168.181	9.660	.000a
	Residual	313.375	18	17.410		
	Total	1827.000	27			
a. Predictors: (Constant), % NDF, %Ca, PPM Cu, %K, %N, %Mn, %P, %Mg, % Na						
b. Dependent Variable: Plant type						

Multiple regression results of October show that 65% of the variation in preference was accounted for by the nutrients in plants (Table 4.5), indicating that this model had a better fit than that of April but poorer than in August. R = 0.806 indicates that about half the variance in preference is associated with the nutrients. R-Adjusted: R^2 = 0.806 - 0.0.65 = 0.156, the shrinkage means that if the model were derived from the population rather than a sample, it would account approximately 15.6% less variance in the outcome (Table 4.5). Results at this time of the month indicate that the preference for a specific plant by elephants was significant (p=0.037 <0.05), indicating that preference was influenced by variation in nutrition (Table 4.6).

Table 4.5: Multiple regression model Summary for the month of October

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.806(a)	.650	.425	1.76905

a Predictors: (Constant), %NDF, ppm Cu, %N, %K, %P, %Ca, %Mn, %Mg, %Na

Table 4.6: ANOVA for the month of October

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	81.450	9	9.050	2.892	.037(a)
	Residual	43.813	14	3.130		
	Total	125.263	23			

a Predictors: (Constant), %NDF, ppm Cu, %N, %K, %P, %Ca, %Mn, %Mg, %Na

b Dependent Variable: Plant preference

When logistic regression was performed to determine the relative contribution of the nine nutrients to the model of the feeding preference of *L. africana* on the wild forages, results showed that, the determinants of feeding preference were N, Mg, Mn, Cu and NDF. Among the analyzed nutrients, Mn, Cu, Ca, Mg, N and NDF were the highest contributors to the feeding preference due to their high coefficients (Figure 4.16).

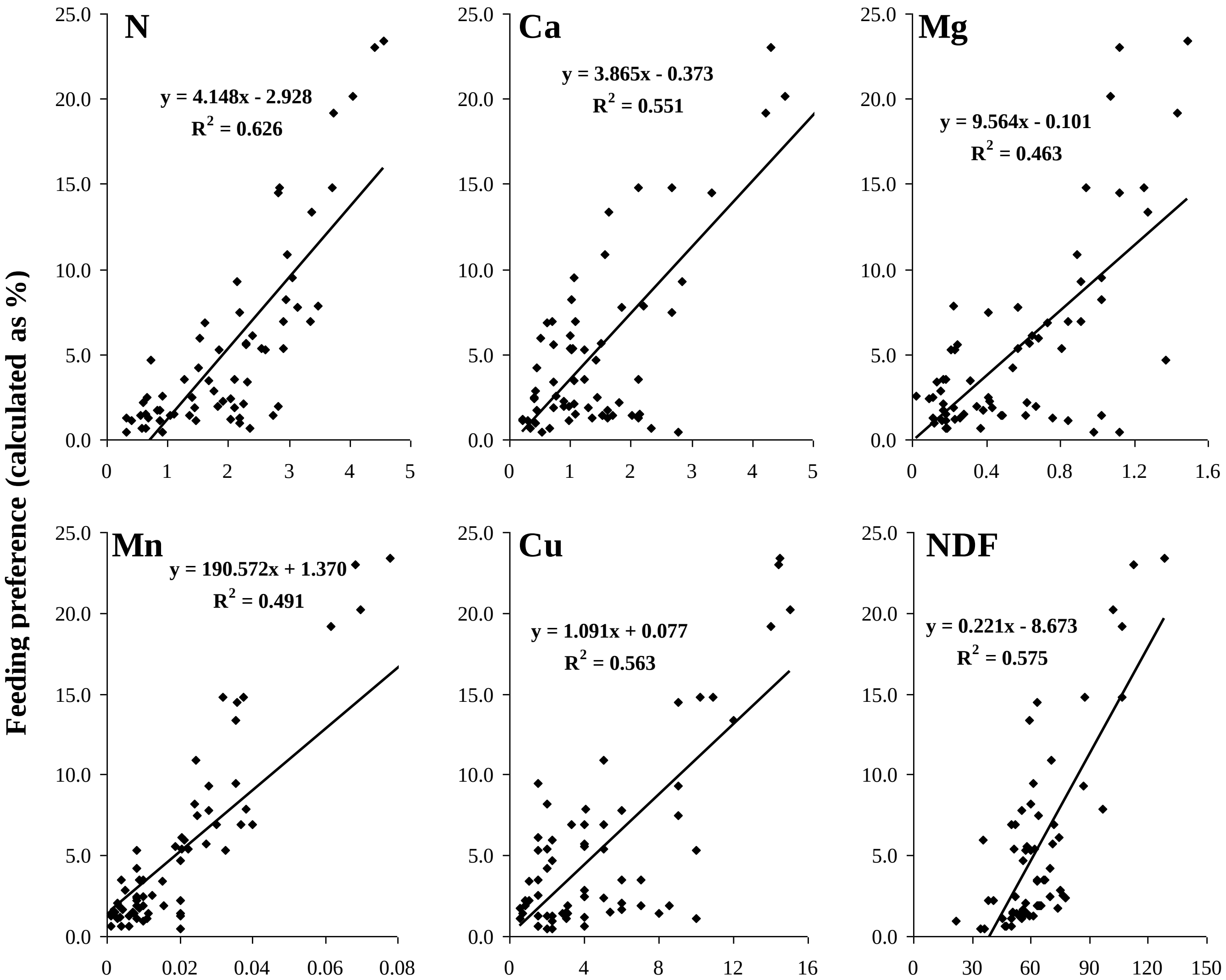

Figure 4.16: Nutrient contents in the wild forages (Field data, 2010)

Regression plots showing the relationships between the food preference and levels of nutrient elements in forages preferred by *L. africana* a*fricana* in Rimoi Conservation Area. The regression fit using linear regression and the regression coefficients are also indicated in the figures.

Results showed that, the relationships between the feeding preference and element concentrations in the food crops were highly influenced by N, Mg and NDF as shown by the model (12.8 %, p = 0.0000; 12.87 %, p = 0.0000; 11.10 %, p = 0.0000 respectively), while Mn and Cu still had a significant contribution to the model (29.56 %, p = 0.0634; Cu (15.55 %; p = 0.0312 respectively) (Table 4.7).

Table 4.7: Relative contribution of nine nutrients to the regression model of the feeding preference by *L. africana africana* on the wild forages in Rimoi Conservation Area

	Coefficients	Contribution to the model	Standard Error	P-value
Intercept	-7.5354	-	1.3487	0.0000
N	1.4692	12.7977	0.3229	0.0000
P	0.7624	2.4338	2.6964	0.7784
K	-0.4673	1.4917	0.3682	0.2097
Ca	0.5532	13.9275	0.3412	0.1106
Mg	4.0311	12.8682	0.8583	0.0000
Mn	34.6568	29.5563	18.2922	0.0634
Na	-0.0842	0.2688	0.4603	0.8555
Cu	0.2163	15.5545	0.0978	0.0312
NDF	0.0913	11.1017	0.0173	0.0000

4.6 Changes in Vegetation Cover and the Feeding Preferences by Elephants

This was done using landsat image, which was downloaded from global land cover facility using path 169 and Row 060.The downloaded image was projected using projected coordinates WGS 84 Zone 36N. The bands used are bands 2, 3 and 4 because vegetation reflects better in NIR band. These bands were clipped to study area shape file and false colour composite which were prepared using bands 2,3 and 4. To enhance detail legibility during classification, the area was classified using Anderson classification scheme based on three classes: Trees, woodlands and shrubs. This was done in ArcGIS 9.3 and processing using Erdas imagine 9.2. so as to get the classified maps, NDVI and change maps.

From the images, visual appearances and the NDVI result of 1986 (0.67) indicate that there was dense vegetation with few areas of bare soil. The larger area without vegetation in the game reserve was the dam within in the Game Reserve. The buffer zone shows lighter vegetation as compared to the Game Reserve (Figure 4.17).

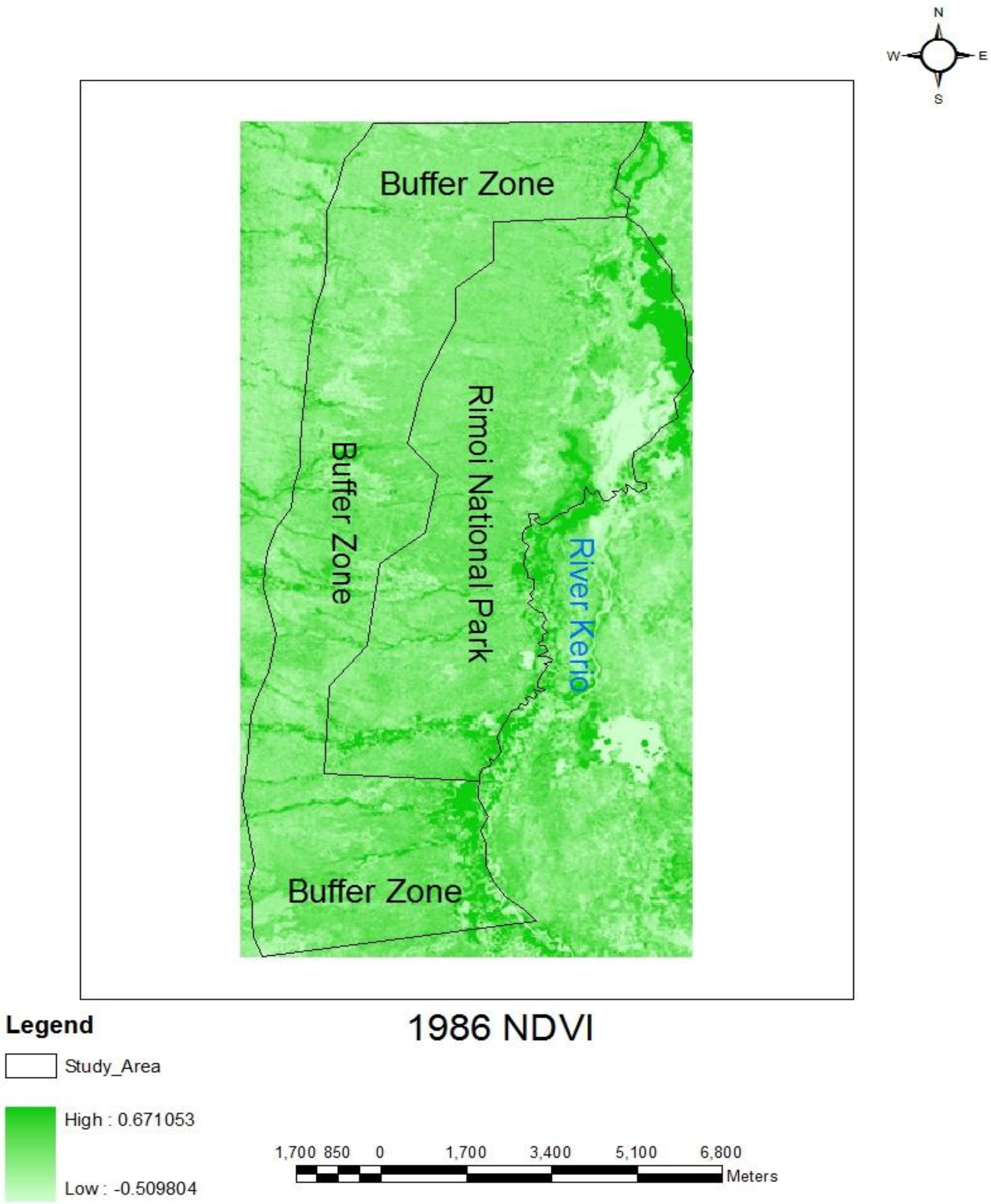

Figure 4.17: NDVI of RGRCA showing dense vegetation along Kerio river and its tributaries (www.global land cover facility.com, 1986)

In the year 2000, NDVI results shows that there has been change towards a more sparse vegtation (0.54) (Figure 4.18).The only places showing some dense vegetation was along Kerio river and it tributaries especially those within the Game Reserve. Area under bare soil (-0.6532) was increasing as compared to the previous years, for examples 1986(-0.5098) , indicating that there was a decrease in vegetation cover of thesoil.

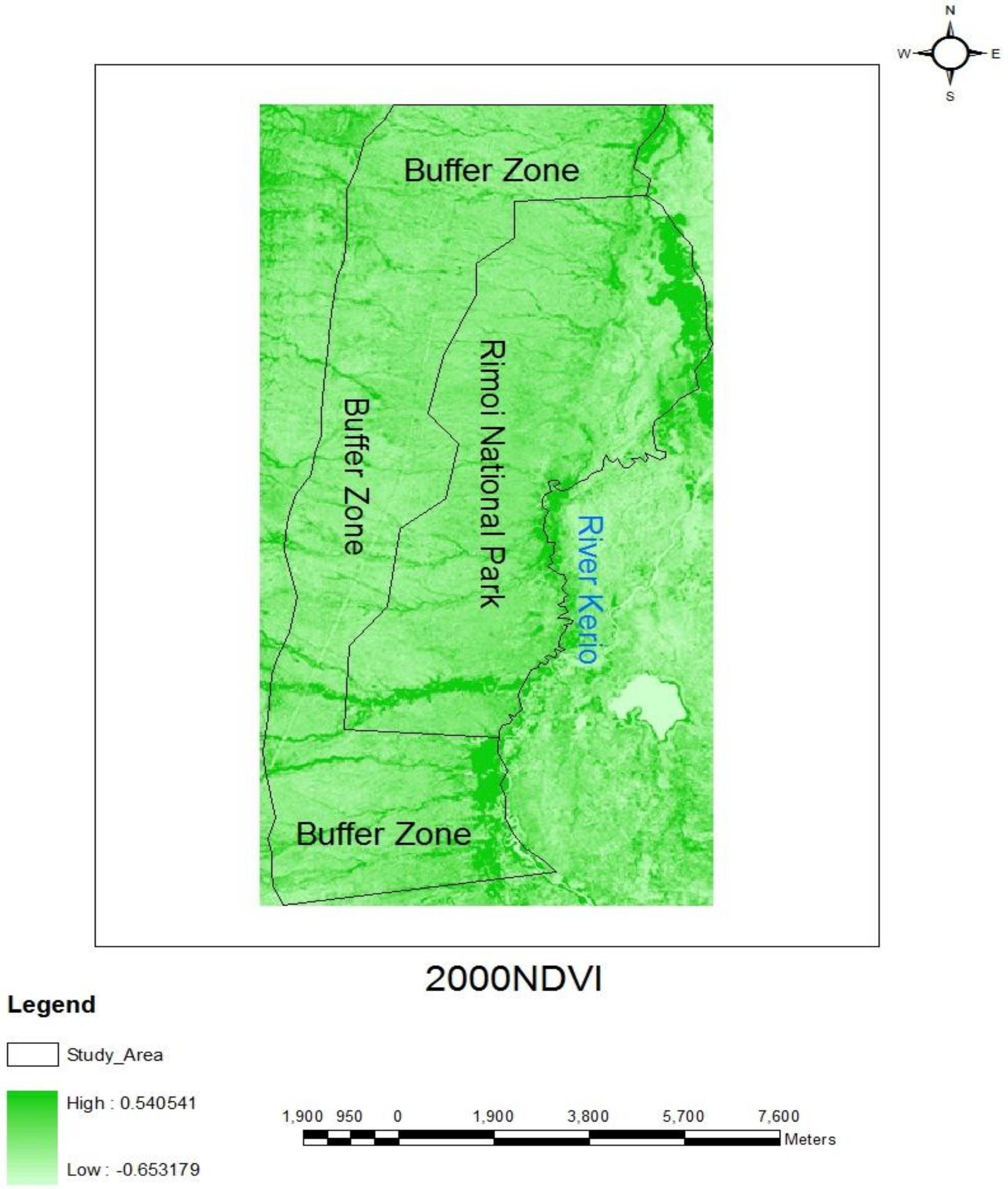

Figure 4.18: NDVI of RGRCA showing the change in vegetation cover (www.global land cover facility.com, 2000).

It is indicated here that there is more bare soil, especially in the buffer zone and part of the Game Reserve towards the buffer zone.

NDVI results of 2006 show that, the vegetation was becoming more and more sparse (0.4615) as compared to the previous years. (Figure 4.19).This indicate that more land was being coming exposed and remained without cover (-0.5752). This is seen especially in the buffer and along the fence of the Game Reserve.

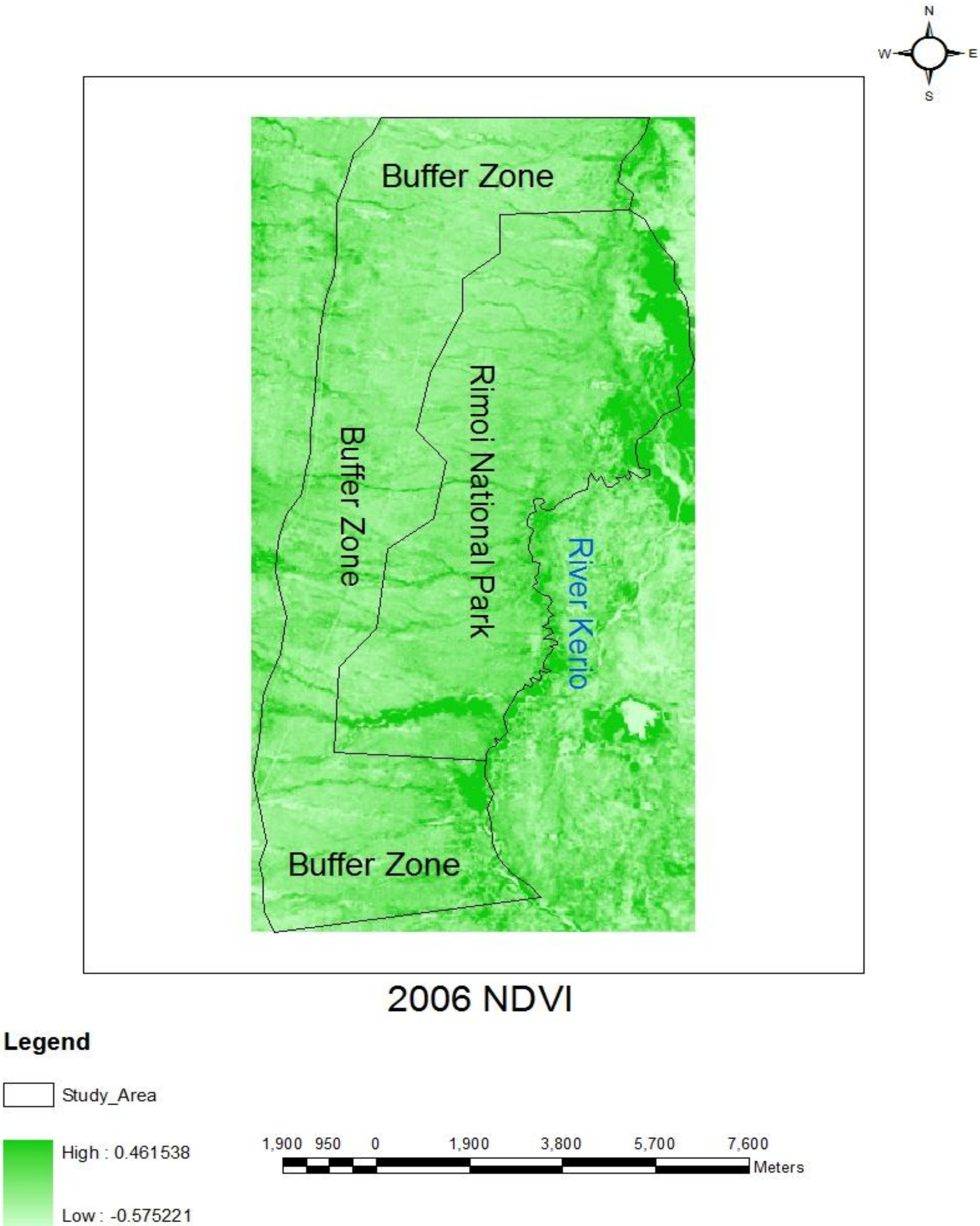

Figure 4.19: NDVI of RGRCA showing change in vegetation cover (www.global land cover facility.com, 2006).

Still areas of better vegetation cover are arround Kerio River and its tributaries. The area under tree cover was 32.18%, shrubs 31.92% and woodlands covered 35.91% in 1986 (Table 4.8), this means that the tree and shrub area was relatively equal and woodlands covered a slightly larger area (Figure 4.20).

Table 4.8: 1986 classified area

Category	Hectares	Legend
1	118.6200000	Trees
2	117.6300000	Shrubs
3	132.3900000	Woodlands

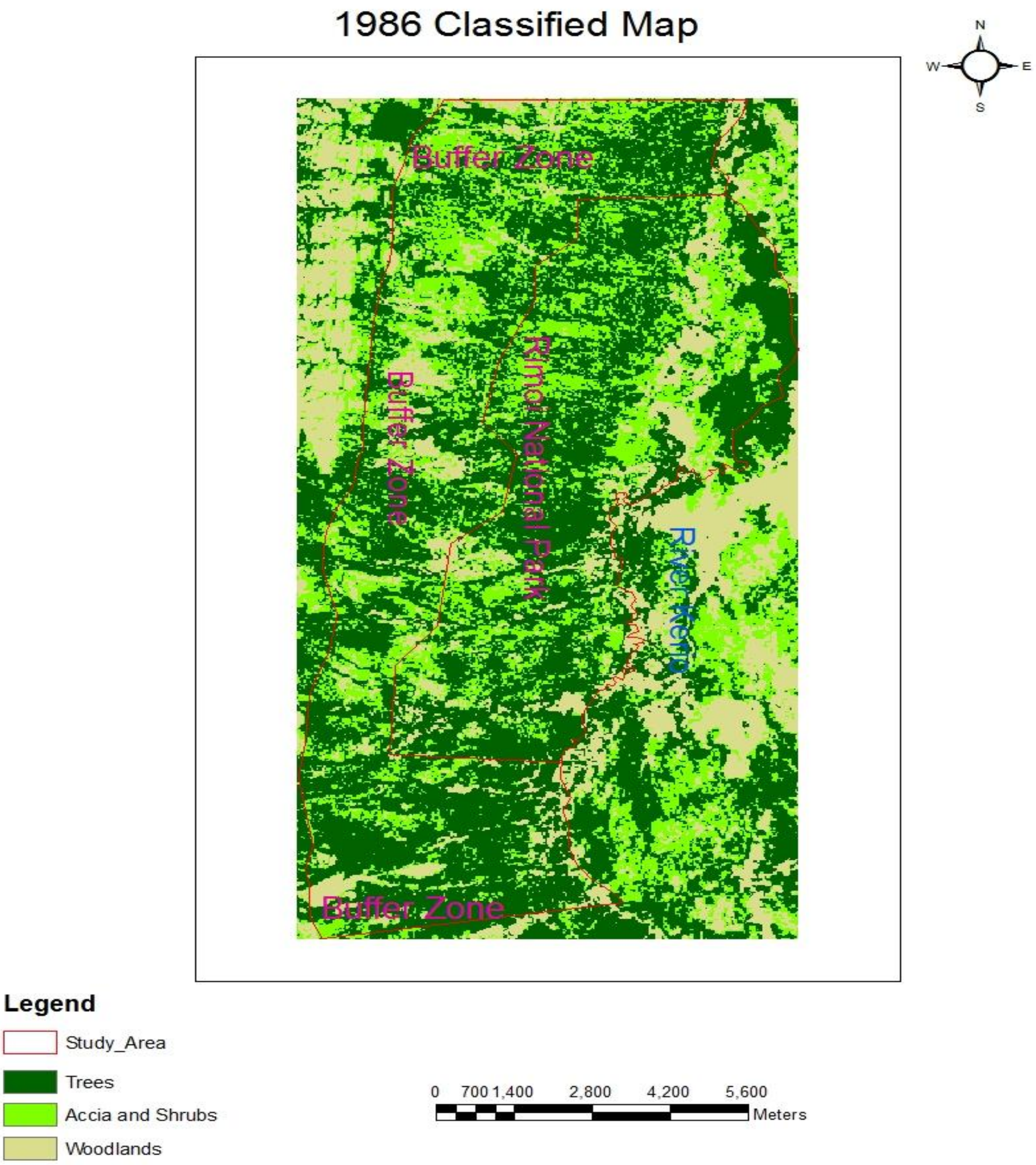

Figure 4.20: classified area of RGRCA showing tree, shrub and woodland cover (www.global land cover facility.com, 1986).

The area under tree cover was 8.13%, shrubs 70.80% and woodlands 21.07%. This result show that since 1986 to 2000, tree cover had dropped to 8.135 while the shrubs had increased covering an area of 70.80% and area under woodlands had dropped to 21.07% (Figure 4.21).

Table 4.9: 2000 classified area

Category	Acres
1	74.0585673
2	644.9544900
3	191.9295603

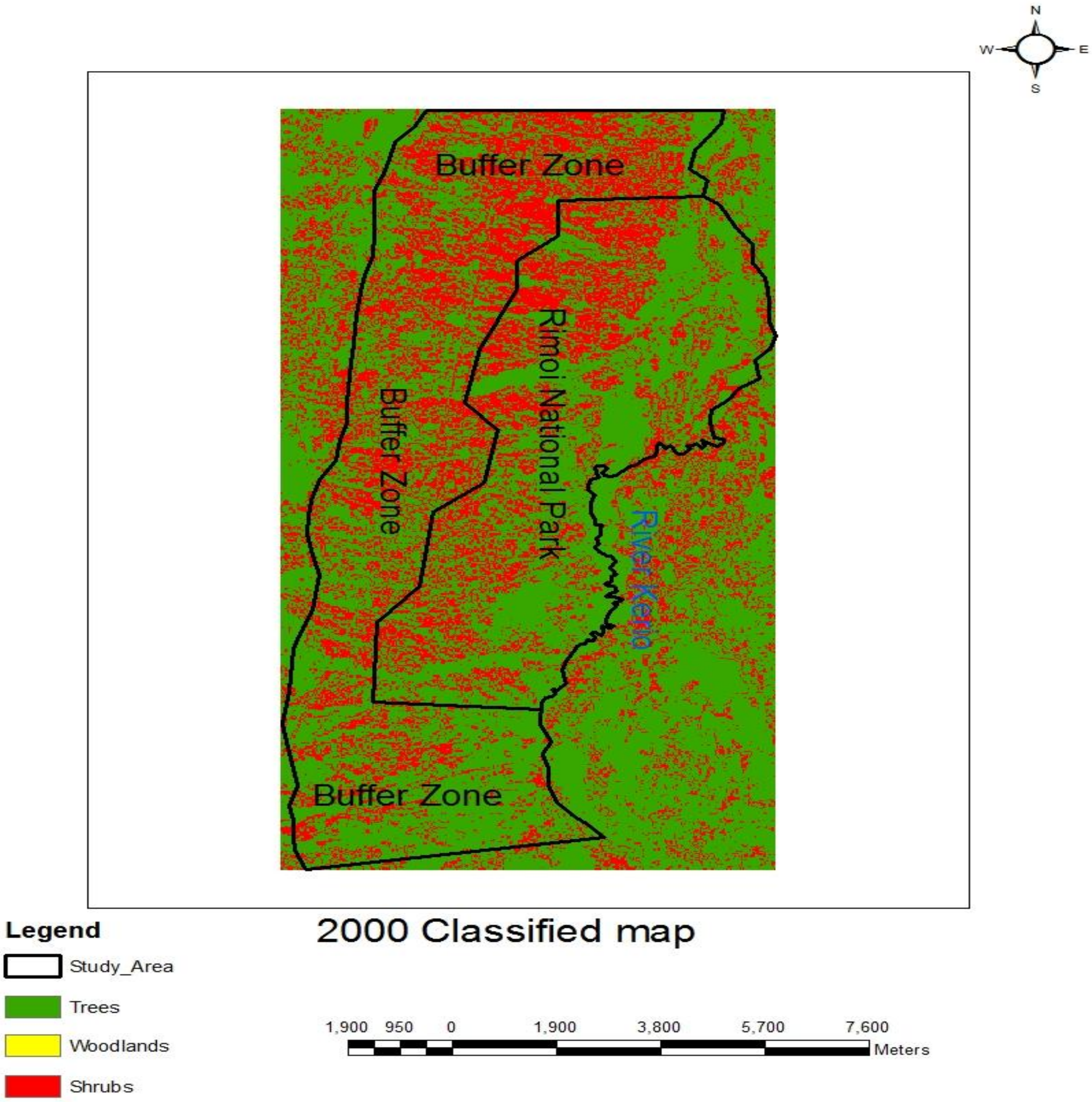

Figure 4.21: Classified area showing tree, shrub and woodland cover in RGRCA (www.global land cover facility.com, 2000).

Area under tree cover was 35.35%, shrubs 24.37% and woodlands 40.28% (Table.4.10). This indicates that there were flactuations of vegetation cover over the years. From the year 2000 to 2006 the tree cover had improved by about 27.22%, while shrubs had dropped by 30.62% and woodlands improved by3.3% (Figure 4.22)

Table 4.10: 2006 Classified area

Category	Hectares	Legend
1	148.5000000	Woodlands
2	130.3200000	Trees
3	89.8200000	Shrubs

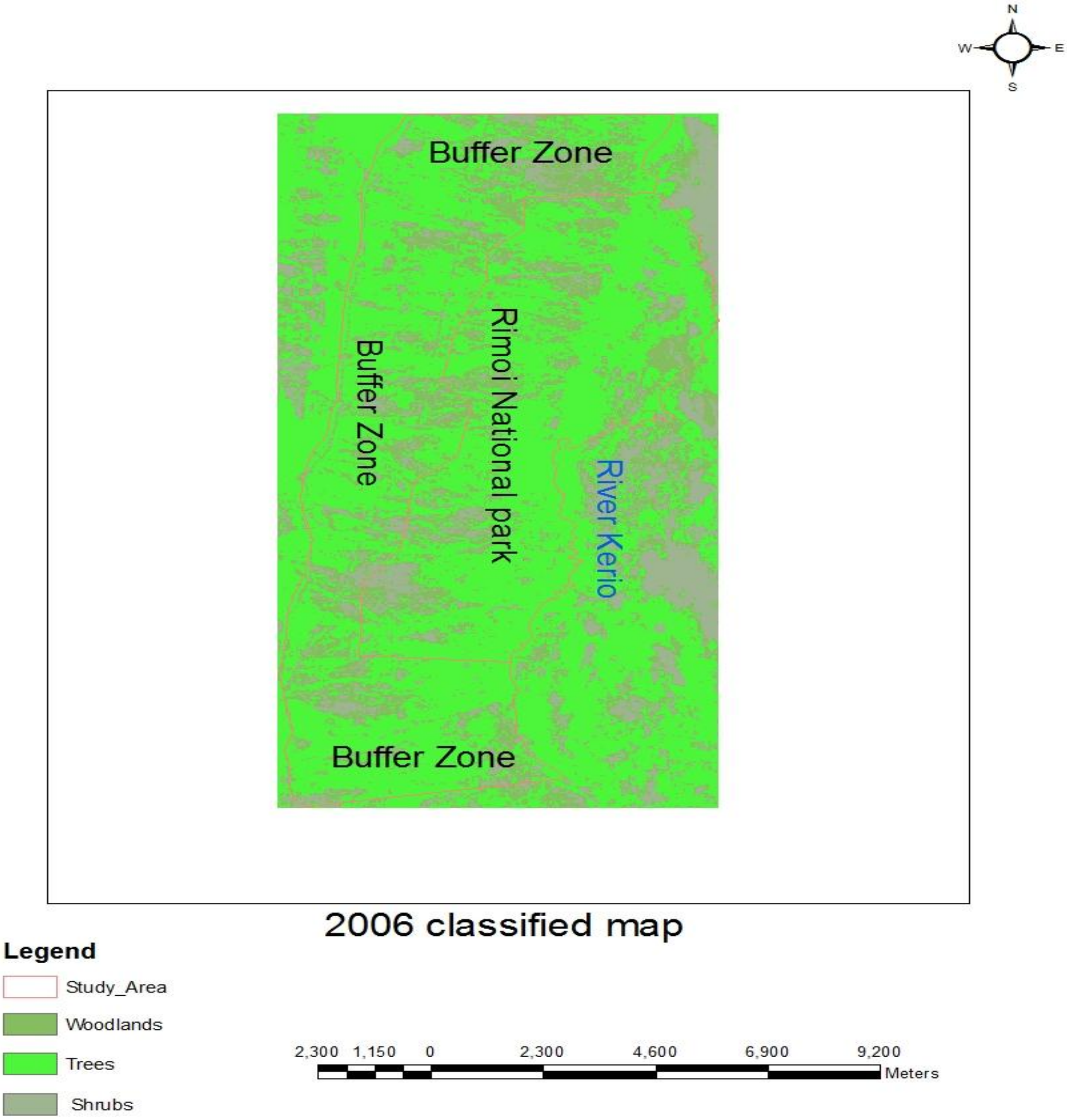

Figure 4.22: Classified area showing tree, woodland and shrub cover in RGRCA (www.global land cover facility.com, 2006)

Generally the change between 1986 and 2000 was moderately strong (Cramer's V= 0.3248) (Table 4.11). This shows that there was change in vegetation in the conservation area (Kappa = 0.0648), indicating that the vegetation wasundergoing some change (Figure 4.23).

Table 4.11:Cross-tabulation of 1986classified (columns) against 2000 classified (rows)

	1	2	3	Total
1	47	6	280	333
2	1066	1184	650	2900
3	205	117	541	863
Total	1318	1307	1471	4096

Chi Square = 864.26703
df = 4
Cramer's V = 0.3248

Proportional Crosstabulation

	1	2	3	Total
1	0.0115	0.0015	0.0684	0.0813
2	0.2603	0.2891	0.1587	0.7080
9	0.0500	0.0286	0.1321	0.2107
Total	0.3218	0.3191	0.3591	1.0000

Overall Kappa 0.0648

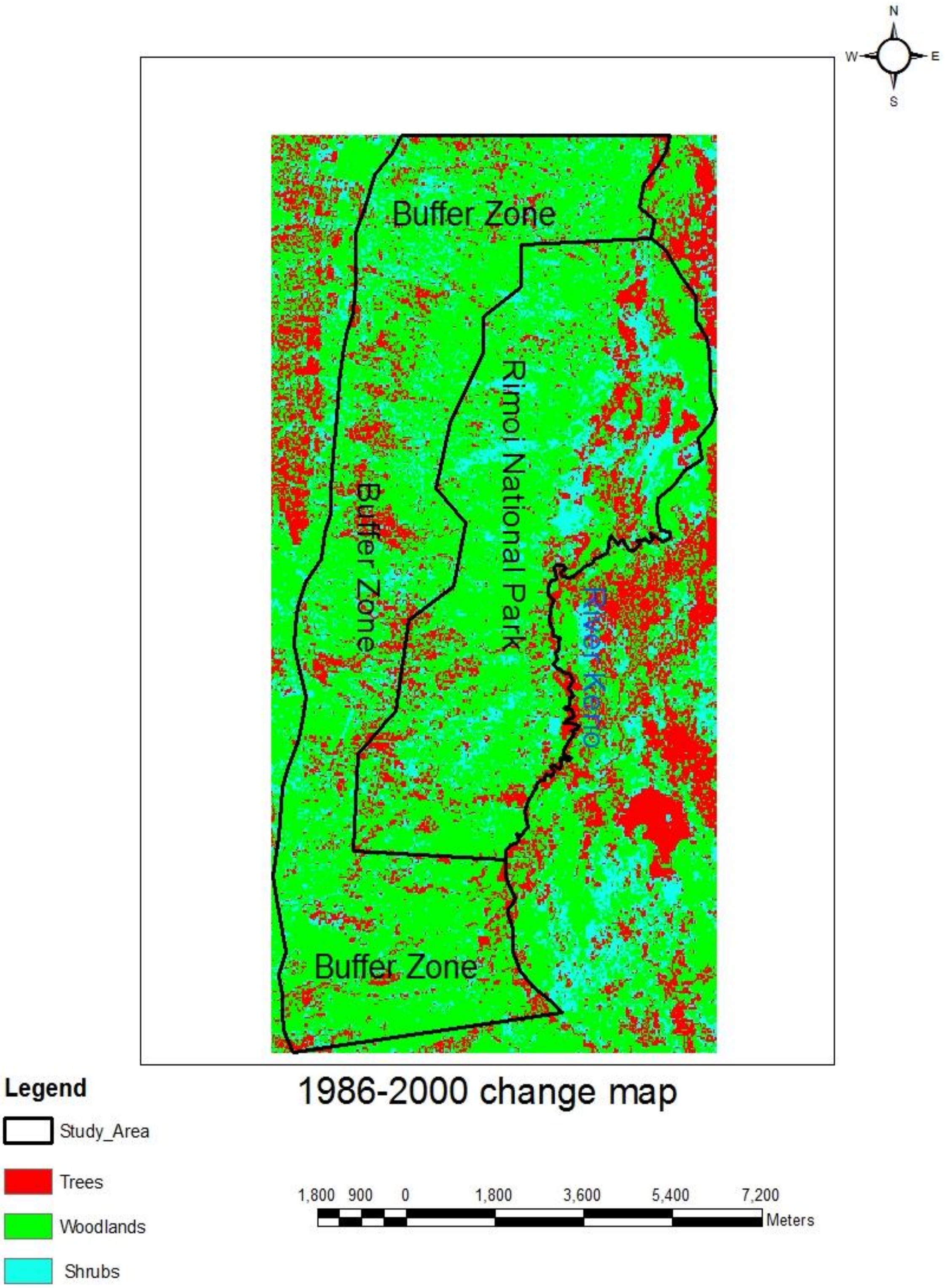

Figure 4.23: Cross tabulation 1986 classified against 2000classified maps, showing the status and dynamics of vegetation in RGRCA (Author, 2010).

Generally the change between 2000 and 2006 was strong (Cramer's V = 0.3579) (Table 4.12), indicating that there was some relationship between change in 2000 and 2006 (Kappa =-0.1874). This indicates that there was change in status and dynamics of vegetation in the conservation area (Figure 4.24).

Table 4.12: Cross-tabulation of 2000classified (columns) against 2006classified (rows)

	1	2	3	Total
1	21	1477	152	1650
2	292	588	568	1448
9	20	835	143	998
Total	333	2900	863	4096

Chi Square = 1049.10730
df = 4
Cramer's V = 0.3579

Proportional Crosstabulation

	1	2	3	Total
1	0.0051	0.3606	0.0371	0.4028
2	0.0713	0.1436	0.1387	0.3535
9	0.0049	0.2039	0.0349	0.2437
Total	0.0813	0.7080	0.2107	1.0000

Overall Kappa -0.1874

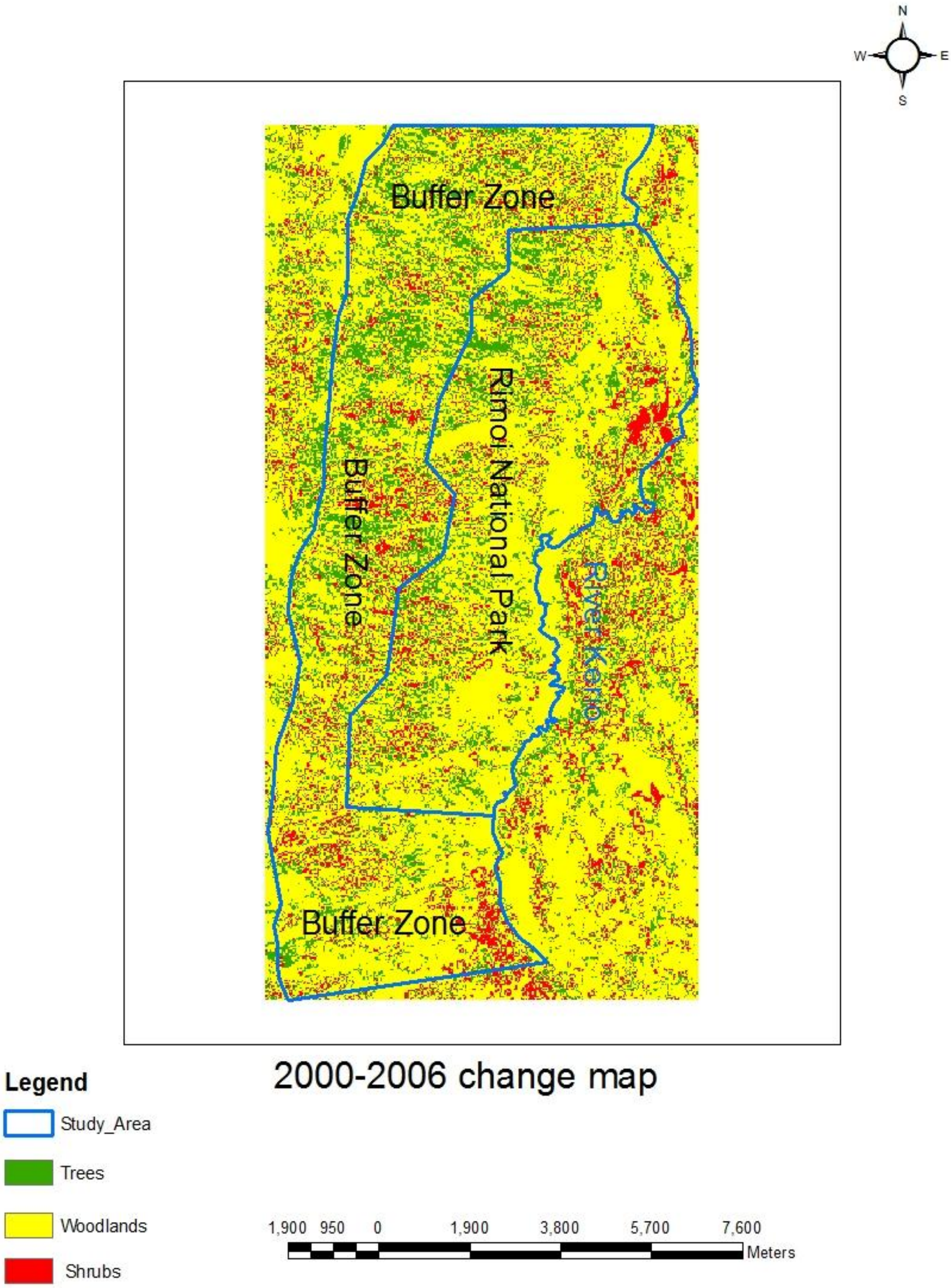

Figure 4.24: Cross-tabulation of 2000classified map against 2006 classified map, showing the status and vegetation dynamic in RGRCA (Author, 2010).

The change in vegetation between 1986 and 2006 show that it was very strong (Cramer's V = 0.3997), indicating that there was some agreement in association between changes (Kappa = -0.15561) (Table 4.13). This indicates that there was change in status and dynamics of vegetation in the study area (Figure 4.25).

Table 4.13: Cross-tabulation of 1986classified (columns) against 2006classified (rows)

	1	2	3	Total
1	524	913	213	1650
2	337	126	985	1448
3	457	268	273	998
Total	1318	1307	1471	4096

Chi Square = 1308.62036
df = 4
Cramer's V = 0.3997

Proportional Crosstabulation

	1	2	3	Total
1	0.1279	0.2229	0.0520	0.4028
2	0.0823	0.0308	0.2405	0.3535
3	0.1116	0.0654	0.0667	0.2437
Total	0.3218	0.3191	0.3591	1.0000

Overall Kappa -0.1561

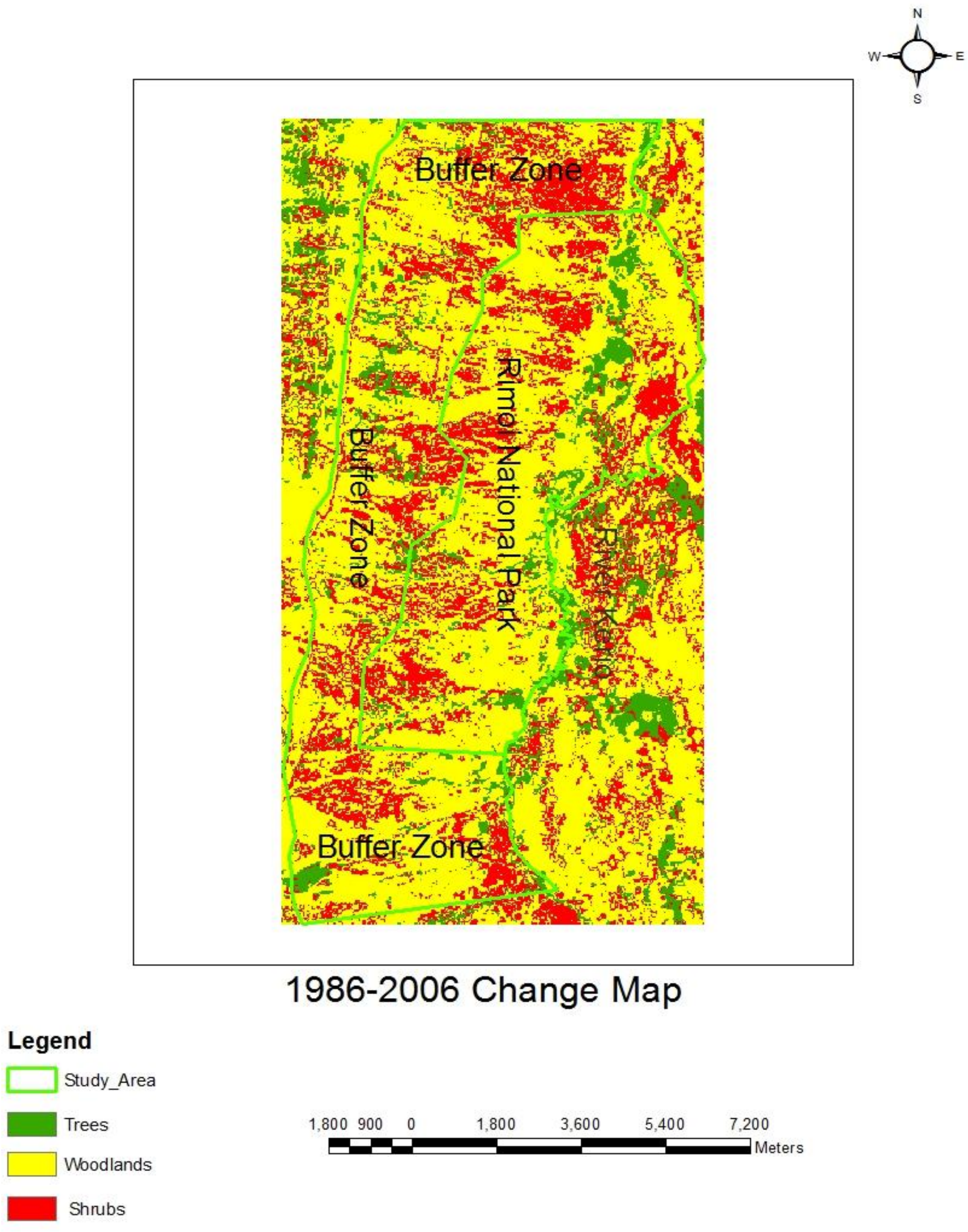

Figure 4.25: Cross-tabulation of 1986classified map against 2006classified, showing the status and dynamics of vegetation in RGRCA (Author, 2010).

CHAPTER FIVE

DISCUSSION

5.1 Introduction

Results showed that selection of dietary food items of elephants in Rimoi conservation area were dependent on the nutritional status of the forage. Hence, elephants in the study area followed the patterns of phenology across the season in order to obtain optimal forage. Results showed that forage preference was more skewed towards the Acacia species and other components. The variation in forage preference by African elephants showed to be accounted for by the variation in nutrients, indicating that there were significant positive correlations between the feeding preference and level of nutrients among plant species. There were significant differences in crop raiding patterns in the study area. Classified images showed that there were changes in vegetation cover, except in areas near rivers. This indicated that most parts of the ecosystem seem to be undergoing change in vegetation cover showing less ground cover. Survey results showed that peak period of crop raiding was during crop harvest season (August), while the most raided crop was maize.

5.2 Forage preference by the elephants

Elephants consumed different plant species with varying degree of preference. Nineteen wild plant species *viz., A. tortilis, B. aegyptica, A. mellifera, Z. mucronata, A. brevispica, A. hamulosa, A. abyssinica, Combretum spp., G. bicolor, C. rotundifolia, C. dactylon, E. minor, A. aspera, S. intermedia, S. viminale, G. mollis, C. pycnothrix, Ficus spp.* and *Aloe spp.* were consumed by elephants at varying degrees, which agree with the findings of Joshi & Singh (2008) where they found elephants feeding extensively on a large number of food resources. The study showed that elephants in Rimoi National Game Reserve preferred Acacia plants than other plants, which deviated from the findings of Varma *et al.*, (2008), where it was indicated that the diet was dominated by grass. The most preferred species was *A. tortilis,* which was also the most debarked. Other Acacias included *A. mellifera, A. brevispica, A. hamulosa*) and *A. abyssinica*.

The Acacia plants were preferred because they remained leafy and offered forage during dry season because of their ability to conserve water and hence nutrients required by the elephants. Observation showed that, the fibrous parts were not consumed, for example in *S. viminale* and *S. intermedia.. B. aegyptica* constituted an important part of the elephant diet, because of its nature of offering green vegetation during dry periods, when no other plants do the same. This has been brought about probably by the elephant feeding strategies where by tree browse sustained green leaves by stimulating re-growths if the plants do not die. *Ficus* species and *A. tortilis* bark were shown to be consumed by *L. africana* because this part of the plant shows little fluctuation of nutrients unlike other parts. These results agree with the findings of Pamo and Tchamba (2001) where they found that Acacia topped the list of preferred species when debarking.

Observations made in this study indicated that foraging behaviour of elephants may probably bring about dramatic changes in vegetation due to the increased damage of vegetation through debarking. This in turn may suppress recruitment and regeneration of vegetation. From the results it is indicated that the preferred or more palatable species of vegetation will be exterminated by elephants as their population increase and the demand of food goes up. The elephants will switch to new food items so as to continue their survival especially the cows which normally forage diversely on vegetation due to the demand in nutrients for milk synthesis to feed the calves. The less preferred food items will become more dominant in the habitat due to their physiological growth habit which may tend to concentrate phytochemicals which are unpalatable or adversely affect the animal's physiology.

The complex ecological interactions of elephants with their environment will lead to changes in species and structural diversity of plants forcing the elephants to look for food outside their home ranges. Therefore when outside their natural home ranges, elephants are capable of feeding on a variety of food items that it comes into contact with which includes the crops. In this study, the elephants were found to exhibit diet preferences for the crops too. The study showed elephants to exhibit diet preference for maize, millet and green grams. Among the crops, maize was the most frequently raided followed by millet and then green grams while groundnuts and cowpea were the least raided, despite the local people's effort to protect their crops using diverse means.

5.3 Level of nutrient content in preferred wild vegetation and raided crops

5.3.1 Nitrogen concentration

Acacia plants had high nitrogen (N) levels than other plant species indicating that it may be the main drive in forage preference. These results concur with findings of Foguekem *et al.*, (2011) which indicated that protein concentration influence animals to select food of desired nutritive value. The animals probably use their nutritional wisdom to identify plants rich in protein. This probably may be the reasons why results show elephants to utilize more of the Acacia plants in this region than any other plant species. Observation made in this study shows that elephants most likely may change vegetation composition due this influences, which agrees with the findings of O'Connor *et al*., 2007 which showed that elephants were responsible for the decline in Acacia plants.

Total nitrogen had the strongest positive correlation with elephants debarking behavior. Bark of *Acacia tortilis* and *Ficus species* offers a diet that is less variable in quality as the results of this study showed, which do agree with studies made by Wanderi (2007), where he found that crude protein in the bark did not vary significantly over the seasons. Results too indicated that shrubs contain high N than the grasses which probably may be influencing the elephant forage preference. The nutritional value of grass declines steadily as leaves age over the growing season (Georgiadis and McNaughton, 1990). In this region, grass is limited probably because of the climate which is mainly dry or the large livestock population numbers which graze on them. The mean CP of elephant diet in this region was comparable with the findings of Dierenfeld (1994), which range from 10-12 % based on captive elephants. Crops in this region showed a low level of N than the browse plants. Results showed that there were significant differences in nutrient levels among the crop plant species raided, with green grams showing the high N content in its tissues followed by Cow peas and Maize. This result indicates that elephants probably selected nutritious food, as opposed to selecting the most available. Crops maintain their nutrient quality after they mature, which probably may explain why results show peak period of crop raiding appearing during crop harvests, which also is the late wet season. This preposition may help in predicting the crop raiding period and thus take measures to prevent crop damage.

5.3.2 Phosphorous Concentration

Phosphorous (P) is considered as one of the three (Copper and Sodium) most limiting nutrients in elephant food within the tropical environments. Results from this study showed that there were significant differences in P concentration among the preferred plant species (figure 4.3). The preferred diet of elephants in Rimoi National Game Reserve showed a mean diet of 0.21±0.03%, which is consistent with Wanderi (2007) detailed study of Kenyan elephant forage items showing P to be between 0.5% and 0.25%. This result deviates from that of McDowell (1997) in other tropical environments where by forages exhibit low concentrations.

5.3.3 Calcium Concentration

Calcium (Ca) drives has properties common to other appetitive drives and most likely have an effect on the animal's behavior. Results showed debarking, indicating that the animals may have been under stress for this particular element, especially in situations where the herd is composed of animals with high demand for Ca, for example lactating or in calf elephants. The utilization of this particular plant species (*A. tortilis* and *Ficuss* species) may be as a result of low presence of alkaloids in the plants. Hindgut fermenters such as elephants, allows consumption of food items containing high levels of secondary plant compounds like alkaloids, oxalates, tannins and terpenes. From the results Ca was within the requirements based on captive elephants (1.5%) as indicated by Dierenfeld (1994).

5.3.4 Magnesium Concentration

Results of the study showed that Magnesium (Mg) in both crops and preferred elephant diet were consistent with Dierenfelds (1994) study where requirements was 0.1% based on captive elephants. As an important element Mg forms part of chlorophyll in green plants, part of many plant enzymes needed for growth and must be bound to ATP in order to be biologically active. Preferred forage plants in RGRCA had good amounts of Mg which agree with elephant food items in Kibale National Park which had 0.25±0.15% against requirements of 0.6% (Rode *et al.,* 2006)

5.3.5 Copper Concentration

Copper (Cu) is a vital component of protein structure of a range of enzymes involved in electron transport, redox reactions in mitochondria, chloroplasts, cell walls and cytoplasm of plant cells. It was shown by results to be high in grasses than browse plants in this region. Cu concentrations were low in RGRCA (3.73±3.54%) as compared to the result (10.7±5.3 ppm) found by Rode *et al.,* (2006). This may be as a result of formation of complexes with both soluble and insoluble organic compounds which could lead to its deficiency to plants (Whitehead, 2000).

5.3.6 Manganese Concentration

Forage plants were rich in Manganese (Mn), which agree to the findings of Rode *et al.,* (2006) in elephant food items. Among crop plants, green grams showed higher level (Fig 4.12) of concentration. Mn is an essential trace element because it is an activator of several Mn metalloenzymes and in excess may inhibit iron absorption.

5.3.7 Sodium and Potassium Concentrations

Results showed variations in levels of Na with respect to seasons, with low levels in wet season un like food items of Kibale elephants which showed moderate concentrations (139.0±79.3 ppm) (Rode *et al.*, 2006). Probably the elephants compensated the variations by browsing on shrubs which contained high Na than other plants (Fig. 4.7). Sodium chloride (NaCl) is important in the maintenance of osmotic potential that drives into the cells, though most plants use K rather than Na for osmotic adjustments (Wang *et al*. 2004).

Though it has been documented that elephant diets are deficient in Na, results of this study indicated that Rimoi elephant diet had a mean of 0.45±0.62% Na content, which was above what Dierenfelds study in 1994 found with captive elephants who required 2000 ppm. Deficiencies of Na has been associated with a drive to seek alternative sources, such as soil and well water (Holdo *et al*. 2002) and these are indicated by congregations of elephants at mineral licks.

Shrubs in the study area showed high Potassium (K) levels in plants (Fig.4.7). Probably the elephants in this region compensate for the deficiencies by foraging on this particular plant showing high levels. The study showed that Rimoi elephant diet had 1.76±0.24% K, which was well within suggested amounts of 0.6% by Dierenfeld (1994) based on captive elephants, though Zhang and Wang (2003) had suggested that studies have indicated this element is widely deficient in elephant foods. The food items of Kibale elephants as shown by Rode *et al.*, (2006) had K (1.5±0.7%) to be well within that of elephants in RGRCA.

5.3.8 Neutral Detergent Fibre

The high Neutral Detergent Fibre (NDF) values exhibited generally indicate that there would be low intake of these forages by elephants. NDF as one of the nutrients shows to contribute to the forage preference by elephants and probably its behaviour. As the forage moisture content drops it becomes more fibrous resulting in a lowered digestive efficiency which will bring about an increase in consumption of available food. The study showed that NDF was high in both crops (Fig.4.6) and preferred wild vegetation (Fig.4.5). Crops showed a high mean fibre content, though they showed variations over the seasons, which are consistent with studies carried out by Chapman *et al*., (2003). In this study, NDF did not fluctuate greatly from season to season in the wild vegetation indicating that the nutritional value did not change greatly, unlike crops which showed a lower NDF in the month of April, August and October.

5.4 Effects of nutrient content on foraging preferences of Africa elephants

Nutrient variations in food consumed by elephants in this study suggest that they could be influencing the behaviour of elephants. Vanleeuwe *et al*., (1997) suggested that congregations of elephant populations at mineral licks indicate that there is an attraction of specific nutrients which could be playing a role in crop raiding behaviour which corroborates with Foguekem *et al.,* (2011) findings. The variation in preference was associated with nutrients and may be one among many other factors in the crop raiding behaviour of elephants.

According to this study, forage preference was influenced by nutrients, which agree with the findings of Sukumar (2003) which showed that the proximate factor that influences the decision to consume or reject a plant is the palatability of the item as conveyed to the herbivore through the senses of smell, taste, sight and touch. In this study, it is likely that elephants meet their nutritional requirements from the forage available during the year, as the nutritional content of most of these plants was within that threshold required by elephants as indicated by Dierenfeld (1994) based on captive elephants. Results of this study indicated that variance on preference was shown contribute over 50% of the variations in preference which could be explained by the linear relationship between forage preference and nutrients.

The study showed also that, it is most likely that Ca influenced the behaviour of elephants towards crop raiding. Ca drive has properties common to other appetitive drives and has an effect on the animal's behaviour. Though geophagy has been associated with acquisition of minerals (Holdo *et al.*, 2002; Krishnamani and Mahaney, 2000), there was no evidence that elephants in this region consume soils. The bark consumed by elephants contained high levels of Ca, which is similar with other studies with studies by Holdo *et al.*, (2002) and Sukumar, (1990). Debarking may have indicated that the animals were under stress for this particular element and also it may have been used by the elephants to enhance digestion since it was high in fibre. From the feeding habits one could conclude that the herd may have lactating or in calf elephants.

The study showed that Cu was generally low in plants in this region, as compared to those in literature. This could be partly explained by genotypic differences, vegetative parts, stage of maturity, levels of Cu available in soil and soil pH. In forages, Cu declines with maturity, and is higher in leafs verses stem fractions (McDowell, 1996). The study showed that NDF was high in both crops and preferred wild vegetation.

Crops showed a high mean fibre content, though they showed variations over the seasons, which do agree with studies carried out by Chapman *et al.*, (2003). NDF, the cell wall components, are digested more slowly and less completely.

Digestion of the cell wall fraction is performed almost exclusively by microbial hydrolysis and fermentation in the colon and/ or caecum of elephants. The high NDF values exhibited, generally indicated that, there would be low intake of these forages by elephants, indicating that the quality was low. As the NDF levels of forages increases the digestibility of its fiber will decrease, which results in low preference.

5.5 Effects of changes in vegetation cover on the feeding preferences of elephants

Generally there was a decline in vegetation cover in this region exposing most parts of the soil as shown by the classified images (Fig. 21, 22, 23). The elephant species density in Rimoi Conservation Area stood at about 0.75per Km^2. In concert with environmental factors, elephants can nonetheless precipitate declines in tree populations or marked changes in community composition.

The study showed the most preferred plant species in this region was *A. tortilis* and for this reason, it is likely this type of Acacia may in future get decimated by elephants in this region, especially when combined with human activities such as charcoal burning which were prevalent. This do agree with findings of Jachmann and Croes (1991) , Weyerhaeuser (1995) and Mwalyosi (1990) in Lake Manyara National Park, Tanzania, where they noted that these selective browsing have been noted to have little structural change even though there was pronounced impacts effecting a shift towards an older population structure.

Rimoi conservation area is undergoing some vegetation cover change. Change in land cover results in modified climate and land use. These will have serious consequences for the environment and biodiversity. Results indicate that there has been some change in the plant species structure and composition in this area. Plants are the foundations of rangelands worth. Wildlife and livestock is a product of plant growth and their productivity is commensurate with the welfare of plants. The habitat is undergoing vegetation change, which will threaten the productivity of the ecosystem. Landsat image results indicate that the soil cover is decreasing hence soils are being exposed to intense heat. These changes indicate that there are vegetational disturbance in this study area. All these changes are being brought about by the human migrant population. These migrant human populations tend to occupy the more fertile areas, which also produce good forages for animals like elephants. These migrant population activities combined with the elephants heavy use of vegetation will reduce the available forage material, resulting in low animal productivity.

CHAPTER SIX

SUMMARY OF FINDING, CONCLUSION AND RECOMMENDATIONS

6.1 Finding and Conclusion

The following findings and conclusions were derived from the study:

1. The main source of human elephant conflict was crop raiding. This crop depredation arises as a result of increased agricultural activities which have moved closer to or within elephant foraging zone or the forage available to elephants are not enough, so they are forced to forage on a wider area to meet their demands.
2. The most preferred wild forage by African elephants was Acacia plants and the most raided crop was maize. It has been found that elephants do feed extensively on a large number of food plants. This study found out that elephants preferred Acacia plants which deviated from other findings that the diet was dominated by grass. This study too showed elephants to exhibit diet preference for maize.
3. The nutrient elements in preferred wild forages varied. *Acacia tortilis* (Bark) showed high NDF, though there was variation over the season, which were consistent with other findings.
4. The variation in forage preference was explained by the nutrient concentrations, indicating that it influences the foraging behaviour of elephants on whether to select a plant or not.
5. There is a general decline in vegetation cover in RGRCA indicating that there is vegetation disturbance in the study area. This disturbances are from anthropogenic activities and elephant feeding behaviour.

6.2 Recommendation

The following recommendations were born out of this study:

1. The inhabitants of Rimoi area should grow alternative crops that are not appealing to elephants e.g. Cotton. They should venture into enterprises that auger well with the presence of elephants e.g. tourism activities.
2. The administrative authority should control the burning of charcoal so as to save the acacia plants preferred by elephants.
3. The authority should exercise more caution due to increased area of movement by elephants when there is disappearance of acacia plants which are rich in nutrients, for example *Acacia tortilis* (bark) has both high NDF and Ca, and its disappearance has great impacts to elephant behaviour.
4. The community should improve protection of their crops especially in the month of August, since forage preference by elephants at this of the year is influenced by variation in nutrients of vegetation.
5. Expansion of farming activities should be regulated to reduce vegetation decline. Also elephant population should be regulated to reduce damage on vegetation.

Areas for further Research

There is need for research in the following areas:

1. To establish the specific carrying capacity of elephants in the conservation area so as to make informed management decisions on elephants and other browsers /grazers present in the ecosystem.

2. To determine in depth the factors responsible for the general decline in vegetation cover in this conservation area and the possibility of opening up the north and south migratory corridors.

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APPENDICES

APPENDIX I: QUESTIONNAIRE (MEMBER OF COMMUNITY)

I am a PHD student at Moi University. It is a requirement for the course to carry out a research project. I am thus currently soliciting for information on the topic "The effects of variation in quality of preferred wild forages on crop raiding by an African Elephant population in Rimoi National Game Reserve, Keiyo District, Kenya". The purpose for this proposal is purely academic and that any information provided by respondent shall be treated with confidentiality. This questionnaire is therefore intended to help me collect information relevant to the aforementioned topic. Please kindly participate and respond appropriately. Your contributions are highly appreciated.

Thank you very much in advance.

SECTION A: PERSONAL DATA

Gender of Respondent

Male [ ]

Female [ ]

2. Age of Respondent

15 – 24 [ ]

25 – 34 [ ]

35 – 44 [ ]

45 – 54 [ ]

55 – 64 [ ]

65 – Above [ ]

3. Marital status of Respondent

Single [ ]

Married [ ]

Widowed [ ]

Separated [ ]

Divorced [ ]

4. Education level of Respondent

Illiterate [ ]

Basic formal education [ ]

Primary [ ]

Secondary [ ]

College [ ]

University [ ]

5. Household Religion

Traditional Belief [ ]

Orthodox [ ]

Protestant [ ]

Muslim [ ]

Others (Specify)...

6. Family Size

0 – 4 [ ]

5 – 9 [ ]

10 – 14 [ ]

15 – 19 [ ]

20 – Above [ ]

7. Land holding per household in hectares

0 – 0.4 [ ]

0.5 – 1.4 [ ]

1.5 – 2.0 [ ]

2 – Above [ ]

8. Occupation

Casual labourer [ ]

Civil servant [ ]

Farmer [ ]

Pastoralist [ ]

Others (specify)..

10. Length of stay in current location, years

0 – 10 [ ]

20 – 39 [ ]

40 – 59 [ ]

60 – 79 [ ]

80 – above [ ]

11. Language spoken

Native local language [ ]

Neighboring language [ ]

Exotic/foreign language [ ]

12 Approximate distance of your farm from the game reserve boundary

0-3 km ( ) 3.1-6 km ( ) 6.1-9 km ( ) 4. > 9 km

SECTION B: LAND USE ACTIVITIES:

(1) Ownership of land Private ( ) Communal / Trust ( ) Government ( )

(2) What activities have you been practicing on your land since you settled on it?

Rearing Livestock ( ) Growing Crops ( ) Mixed farming ( )

(3) What is the size of your land (acres)? 0-2 ( ) 2.1-4 ( ) 4.1-6 ( ) > 6 ( )

(4) How long have you settled in this land/area (years)?

0-10 ( ) 10.1-20 ( ) 20.1-30 ( ) >30 ( )

SECTION C: PROPERTY DAMAGE

(1) Have you experienced any property damage? Yes ( ) No ( )

(2) If yes, what type of property has been damaged? Crops ( ) Livestock ( ) both crops and Livestock ( ) Farm structures ( ) others Specify……………..

(3) If Crops, list the type by ranking them from the most vulnerable first and least appearing last Maize ( ) Millet ( ) Green grams ( ) Sorghum ( ) Cow peas ( ) Ground nuts ( ) Others, specify……………….

4. How bad were the crops damaged? Low ( ) Medium ( ) High ( )

5. State the names of wild animals involved in crop damage

Elephants ( ) Porcupines ( ) Baboons ( ) Wild birds ( )

Antelopes ( ) Warthog ( ) Squirrels ( ) Monkeys ( )

6. Rank starting with the most problematic animal involved in crop damage

Elephants	Porcupines	Baboons	Wild birds
Antelopes	Warthog	Squirrels	Monkeys

7. Where do problem animals come from? Game reserve ( ) Other places (specify)……………. ( )

8. Which month(s) of the year is the problem worst?

January ( ) July ( )

February ( ) August ( )

March ( ) September ( )

April ( ) October ( )

May ( ) November ( )

June ( ) December ( )

9. Do you take any measures to protect your crops from these attacks?

Yes ( ) No ( )

(a) If yes, what control measures do you take to keep wild animals away?

Use scare grow ( ) Guard day and night ( ) Use fire sticks thrown at the animals ( )

Others, specify…………………….

(b) Have you reported any incident of elephant attacks to KWS staff?

Yes ( ) No ( )

(c) If yes, what measures have they taken?

Return them to the reserve ( ) Compensation ( ) No action ( )

(d) Which wild animal (s) is problematic to livestock?

Baboons ( ) Hyena ( ) Wolfs ( ) Elephants ( ) Pythons ( ) Leopards ( ) Monkeys ( )

(e) Rank wild animals from the most to the least problematic to livestock.

Baboons Hyena Wolfs Elephants

Pythons Leopards Monkeys

(10) Have you, or your friend or relatives had any problems with elephants?

Yes ( ) No ( )

(a) If yes, what kind of problem(s)?

Crop damage ( ) Cause death of people ( ) Kill livestock ( )

Damage farm structures ( )

(b) Have the problems you have mentioned above been:

Increasing ( ) Decreasing ( ) Don't know ( )

(c) How long has this problem(s) been there in this area?

Less than 1 year ( ) 1 to 5 years ( ) 6 to 10 years ( ) Over 10 years ( )

(11) Which group/ type of elephants raid crops?Bull elephants ( )

Cow elephants ( ) Sub adults/calfs ( ) Mixed groups ( )

(12) What are the estimated numbers of the raiding elephants?

1-5 ( ) 6- 10 ( ) 11- 15 ( ) > 15

(13) Do the elephants damage your farm structures?

Yes ( ) No ( )

(a) If yes, which structures?

Granaries ( ) Fences ( ) Houses ( ) Water pipes ( )

(b) What is the extend of damage?

Low ( ) High ( ) Medium ( )

(c) How many times in a year do you experience this damage?

Once ( ) Twice ( ) Thrice ( ) others specify……………….

(14) From your own observation do you think the elephants are the real cause of food insufficiency in this region?

Yes ( ) No ( )

(a) If yes, what makes them contribute to this problem?

Food crop destruction ( ) Destruction of food stored in granaries ( )

Injury /death of productive population ( )

Others, specify……………………….

(15) Have you seen / herd of elephant deaths?

Yes ( ) No ( )

(a) If yes, what might have been the cause?

Natural deaths ( ) Poaching ( ) Killed by irate people (after destruction/deaths) ( )

Others, specify……………………….

(b) How can the cause(s) be controlled to stop elephant deaths?

Increased surveillance/patrols by K.W.S. ( ) Fencing of Game Reserve ( )

Education/awareness on importance of conserving elephants ( )

Others, specify…………………………….

(16) Do people here eat elephant meat?

Yes ( ) No ( )

(17) What do the local communities do with tusks from elephants?

Making ornaments ( ) Sold to middlemen ( ) Taken by K.W.S. ( )

Others, specify…………………………….

(18) From your opinion is the elephant population

Declining ( ) Increasing ( ) Don't know ( )

(19) What are the causes of the elephant population change?

Migration ( ) Encroachment ( ) Scarcity of water and food ( )

Deaths caused by man ( )

Others, specify…………………….

(20) Do elephants share forages with livestock?

Yes ( ) No ( ) Don't know ( )

(a) If yes, list those forages (where you do not know the English/scientific names give Local name) they share above and type of livestock

1……………………………..type of livestock…………………..

2……………………………..type of livestock…………………..

3……………………………..type of livestock………………….

4………………………………type of livestock………………….

5………………………………type of livestock…………………

6………………………………type of livestock…………………

(21) To the best of your knowledge, how can the problems brought about by the elephants be solved: Fencing ( ) Increase security personnel and patrols ( )

Policy formulation compensation and sharing of benefits ( )

Provision of water within the game reserve ( )

Create awareness on the importance of conserving the Elephant ( )

(22) In what way do you think these elephants would/have been beneficial to the Community living along the game reserve

1…………………………………………

2…………………………………………

3………………………………………….

4…………………………………………

In what way do you think we can earn income from elephants ?

APPENDIX II: ANALYSIS OF NITROGEN BY KJELDAHL PROCEDURE

Apparatus

Block-digester.

Distillation unit.

Automatic titrator connected to a pH-meter.

Vortex tube stirrer.

Reagents

The chemicals used here are the same as for soil Kjeldahl-N.

A. Catalyst Mixture (K2SO4-Se), 100: 1 w/ w ratio

B. Sulfuric Acid (H2SO4), concentrated

C. Ethylene Diaminetetraacetic Acid Disodium Salt (EDTA), M.W. = 372.2

D. Sodium Hydroxide Solution (NaOH), 10 N

E. Boric Acid Solution (H3BO3), saturated

F. Sulfuric Acid Solution (H2SO4), 0.01 N

G. Standard Stock Solution: 1.2 g $NH4^{+}$-N per Litre

PROCEDURE

A. Digestion

1. Mix and spread finely ground (Cyclone mill) plant sample in a thin layer on a sheet of paper until it looks uniform.

2. Select representative sub-samples of about 1 g by taking at least 10 small portions from all parts of the sample with a spatula, and put them into a plastic vial.

3. Dry the sub-sample at 60°C in an oven (overnight), and then cool in a desiccator.

4. Weigh 0.25 g (grain) or 0.50 g (straw) of dry plant material, and transfer quantitatively into a 100-ml digestion tube.

5. Add a few pumice boiling granules, and add about 3 g catalyst mixture using a calibrated spoon.

6. Add 10 ml concentrated sulfuric acid using a dispenser, and stir with Vortex tube stirrer until mixed well.

7. Place tubes in a block-digester set at 100°C for 20 minutes, and remove the tubes to wash down any material adhering to the neck of the tube with the same concentrated sulfuric acid. Thoroughly agitate the tube contents, and then place the tubes back on the block-digester set at 380°C for 2 hours after clearing.

8. After digestion is complete, remove tubes, cool, and bring to 100-ml volume with DI water.

9. Each batch of samples for digestion should contain at least one reagent blank (no plant), and one chemical standard (weigh 0.1 g EDTA standard digest), and one standard plant sample (internal reference).

B. Distillation

1. Set distillation and titration apparatus and steam out the apparatus for at least 10 minutes.

2. Prior to distillation, shake the digestion tube to thoroughly mix its contents, and pipette 10 ml aliquot into a 100-ml distillation flask.

3. Carefully add 10 ml 10 N sodium hydroxide solution, and immediately connect the flask to distillation unit and begin distillation.

4. Collect about 35 ml distillate in the collecting dish.

5. Remove distillation flask and connect an empty 100-ml distillation flask to the distillation unit. Drain water from the condenser jacket and steam out apparatus for 90 seconds before connecting the next sample.

6. Titrate the distillate to pH 5.0 with standardized 0.01 N H_2SO_4 using the Auto-

Titrator; record titration volume of acid.

7. Each batch of distillations should include a distillation of 10 ml ammonium-N standard with 0.2 g MgO and 10 ml DI water with 0.2 g MgO. Recovery of ammonium-N standards should be at least 98%. Recovery of EDTA, corrected for reagent blank, should be at least 97%.

CALCULATIONS

Percentage recovery of Ammonium-N standard:

% Recovery = (V- B) × N × 14.01 × 100 / C × D

Where: V = Volume of 0.01 N H_2SO_4 titrated for the sample (ml).

B = Distillate blank titration volume (ml)

N = Normality of H_2SO_4 solution.

C = Volume of NH_4-N standard solution (ml)

D = Concentration of NH_4-N standard solution (µg/ml)

14.01= Atomic weight of N.

Percentage recovery of EDTA standard:

% Recovery = $(V – B_1) \times N \times R \times 186.1 \times 100 / Wt_1 \times 1000$

Percentage Nitrogen in plant:

% N = $(V - B1) \times N \times R \times 14.01 \times 100 / Wt_2 \times 1000$

Where: R = Ratio between total digest volume and distillation volume.

B_1 = Digested blank titration volume (mL)

Wt_1 = Weight of EDTA (g)

Wt_2 = Weight of dry plant (g)

186.1 = Equivalent weight of EDTA.

APPENDIX III: ANALYSIS OF MACRO- AND MICRO-NUTRIENTS BY DRY ASHING

Apparatus

Spectrophotometer or colorimeter, 410-nm wavelength.

Flame photometer.

Atomic absorption spectrophotometer.

Porcelain crucibles or Pyrex glass beakers (30 - 50 ml capacity).

Reagent

Hydrochloric Acid (HCl), 2N

Dilute165.6 ml concentrated hydrochloric acid (37%, sp.gr.1.19) in DI water, mix well, let it cool, and bring to 1-Litre volume with DI water.

Procedure

The procedure is that of Chapman and Pratt (1961) with slight modifications.

1. Weigh 0.5 - 1.0 g portions of ground plant material in a 30 - 50 ml porcelain crucibles or Pyrex glass beakers.

2. Place porcelain crucibles into a cool muffle furnace, and increase temperature gradually to 550°C.

3. Continue ashing for 5 hours after attaining 550°C.

4. Shut off the muffle furnace and open the door cautiously for rapid cooling.

5. When cool, take out the porcelain crucibles carefully.

6. Dissolve the cooled ash in 5-ml portions 2 N hydrochloric acid (HCl) and mix with a plastic rod.

7. After 15 - 20 minutes, make up the volume (usually to 50 ml) using DI water.

8. Mix thoroughly, allow to stand for about 30 minutes, and use the supernatant or filter through Whatman No. 42 filter paper, discarding the first portions of the filtrates.

9. Analyze the aliquots for P by Colorimetry (by Ammonium Vanadate-Ammonium Molybdate yellow color method), for K and Na by Flame Photometry, and for Ca, Mg, Cu, and Mn by Atomic Absorption Spectroscopy.

Note

For Ca and Mg measurement, the final dilution should contain 1% w/v lanthanum (La) and the determinations should be against standards and blank containing similar La concentration to overcome anionic interference.

CALCULATIONS

For Micronutrient Cations in plant:

Cu or Mn (ppm) = (ppm in extract - blank) × A / Wt

For Alkaline Earth Cations in plant:

Ca, Mg, Na or K (ppm) = (ppm in extract- blank ×A / Wt

Where: A = Total volume of the extract (ml)

Wt = Weight of dry plant (g)

APPENDIX IV : RESPONDENTS' DEMOGRAPHIC INFORMATION IN RIMOI CONSERVATION AREA, RIMOI 2010

Demographic Factor		**Number of respondents**	**Percent of respondents**
Gender	Male	259	83.3
	Female	52	16.7
	Total (N=311)	**311**	
Age	15-24 Years	22	7.1
	25-34 Years	85	27.3
	35-44 Years	74	23.8
	Over 45 Years	130	41.8
	Total (N=311)	**311**	
Occupation	Farmer	270	86.8
	Employed	22	7.1
	Business	19	6.1
	Total (N=311)	**311**	
Education	University	1	0.3
	College	32	10.3
	Secondary	37	11.9
	Primary	157	50.5
	None	84	27.0
	Total (N=311)	**311**	