# EFFECTS OF CATTLE GRAZING AND TRAMPLING ON HERBACEOUS VEGETATION QUALITY IN SEMI ARID RANGELANDS OF LEWA WILDLIFE CONSERVANCY, LAIKIPIA, KENYA.

**By**

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**A thesis submitted to School of Biological Sciences, University of Nairobi in partial fulfillment of the requirements for the degree of Master of Science (Biology of Conservation).**

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## DECLARATION

I Rebecca W. Kariuki do hereby declare that this is my original work and has not been submitted to any other University for examination.

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Date------11/08/10------------

## BY THE SUPERVISORS

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

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## DEDICATION

To my beloved mother, Ngami Kariuki and my dear brother, Mutiga Kariuki.

Thanks for your unfailing support in ensuring that I always achieved what I desired in life and for setting the stage that challenged me to seek further education.

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## ABSTRACT

This thesis aims to assess the effects of intensive but controlled cattle grazing and trampling as tools used to improve moribund grasslands of Lewa Wildlife Conservancy located in Laikipia region, Kenya. These moribund grasslands are mainly dominated by *Pennisetum stramineum* and *Pennisetum mezianum* grass species which are nutritionally poor to plains game (Lewa Wildlife Consevancy, 2007). The objectives of this study were to assess and quantify the effects of intensive but controlled cattle grazing and trampling on vegetation quantity, diversity and productivity and to investigate the utilization of different grazing treatments by wild mammalian herbivores.

Changes in vegetation diversity and productivity were compared statistically between cattle grazed areas and non-cattle grazed areas from September 2008 until April 2009. Vegetation survey was done in the cattle corrals (bomas), controlled grazing areas and non-cattle grazing areas (controls) of the black cotton and the mixed soils. Vegetation quantity and diversity were measured using the pin frame method while the crude fibre and the crude protein content of the vegetation were used to estimate vegetation quality. Data was collected during the dry season and the wet season. Vegetation productivity and off-takes by grazers were measured by recording the growth or non – growth of vegetation inside and outside of metal enclosure cages. Dung counts were done in each of the 60 plots.

Vegetation quantity was highest ($500.32 \pm 40.84$ g/m$^2$) in the non-cattle grazing zones, moderate in the controlled grazing zones ($392.0 \pm 33.52$ g/m$^2$) and lowest in the bomas ($241.32 \pm 27.68$ g/m$^2$). There was a significant difference ($F_{2, 657} = 14.304$, $p<0.05$) in standing crop of grass in the three zones. Species diversity was higher in the non-cattle grazing zones than in the controlled grazing zones or the bomas and one way ANOVA established significant differences ($F_{2, 117} = 3.398$, $p<0.05$) in species diversity in the three zones. There was a significant difference ($F_{2, 81} = 12.248$, $p<0.05$) in dung piles among the three grazing zones while off-takes by mammalian herbivores were highest at the bomas (mean±SE, $37.82 \pm 3.43$ g/m$^2$, n=138) and lowest at the non-cattle grazing zones ($5.5 \pm 5.65$ g/m$^2$, n=140).

Vegetation quantity, productivity and off-takes by mammalian grazers were higher in the black cotton soils compared to the mixed soils. However, crude proteins, crude fibres, species diversity and dung density were higher in the mixed soils compared to the black cotton soils. Productivity in the black cotton soils was significantly higher ($t_{(2), 138} = -3.227$, $p<0.05$) than in the mixed soils.

Results suggest that: the intensity of cattle grazing and trampling affected vegetation quantity but did not affect plant species diversity. Most plains game prefer to graze in bomas as opposed to the controlled grazing and non-cattle grazing zones probably because the bomas have lower biomass, and low amounts of crude fibres. They also prefer to graze in mixed soils and this could be because of the high plant species diversity of mixed soils, high amounts of crude protein contents and low biomass of grass.

***Key-words***: bomas, controlled grazing zones, control zones, vegetation quantity, vegetation quality, off-takes by mammalian herbivores, dung density.

**TABLE OF CONTENTS** **Page**

**LIST OF FIGURES** **PAGE**

**LIST OF TABLES** **PAGE**

**LIST OF APPENDICES** **PAGE**

# CHAPTER 1

## INTRODUCTION AND LITERATURE REVIEW.

### 1.1 INTRODUCTION

Rangelands are extensive tracts of arid/semi-arid lands with a mixture of two-plant life forms, trees and grasses (Belsky, 1990; Scholes & Walker, 1993) and are essentially unsuited to rain fed cultivation, industrial forestry, protected forests or urbanization (World Research Institute, 1992; 1994). In Kenya, rangelands house almost all the wildlife as 63% of the national parks and other protected areas are located here.

Some threats that face rangelands are: overgrazing by livestock, human encroachment, agricultural encroachment and changing weather patterns. Pastoral communities knew that the local vegetation had natural defense mechanisms for combating long spells of drought and other climatic patterns. For many years, they were able to prevent the extinction of their livestock herds and to maintain biodiversity of the local breeds by following cyclic and migratory strategies (Sidahmed, 1996).

Lewa wildlife conservancy, a rangeland, located in northern Kenya consists of five extremely diverse ecosystems: open savannah, Acacia forests, rocky gorges and ravines, mountain forests and the Lewa swamp (Botha, 1999). The grassland in Lewa Wildlife Conservancy has become moribund over time due to under utilization by the wild mammalian herbivores which occur at low densities (Chege, personal communication). These moribund grasslands of Lewa Wildlife Conservancy are overgrown with more than 5000kg/Ha biomass; they have very low species diversity, are coarse and are mainly dominated by *Pennisetum stramineum* and *Pennisetum mezianum* grass species which are nutritionally poor to plains game thus are not preferred by wild mammalian herbivores (Lewa Wildlife Consevancy, 2007). Prescribed burning is the treatment that has been used in this wildlife conservancy to reduce and control moribund grasslands and it has detrimental effects upon invertebrates, reptiles, woody vegetation and small mammals.

Intensive but controlled livestock grazing and trampling is an alternative treatment that can be used to reduce and control moribund grasslands. It is also beneficial as it causes minimal damage to woody vegetation, small plains game, invertebrates and reptiles. Livestock grazing and trampling is also assumed to have the potential of significantly improving the diversity and productivity of grassland vegetation (Lewa

Wildlife Consevancy, 2007). Grazing animals and grasslands co-evolved, unfortunately the large numbers of wild grazers and their predators has declined. Movements of these large numbers of grazers was necessary to improve the vegetation quality of savanna areas due to the trampling and grazing effects of the grazers on the plants and soil (Savory & Butterfield, 1999).

Domestic animals can be managed in ways that mimic nature: animals are concentrated and moved according to a plan that causes the animals to till packed soil with their hooves, distribute fertilizer and seed in their excreta, and move from one area to another before they can overgraze any one spot. By maximizing the healthy impacts of grazing cattle, the need for the standard practice of burning crop and forage residues could be eliminated. Use of cattle grazing and trampling as opposed to burning could ultimately result in the removal of carbon in the atmosphere since burning sends carbon directly into the atmosphere. This could offer a natural solution to the problem of global warming (Strang, 2008).

If vegetation is improved, it is often assumed that such improvements will benefit other grazing species. Due to the need of improving moribund grasslands using a treatment that would favour all kinds of flora and fauna, I undertook a project aimed at surveying the effects of intensive but controlled cattle grazing and trampling upon moribund grasslands at the Lewa Wildlife Conservancy in Laikipia, Kenya.

The goal of the study was to determine changes in biodiversity and productivity of grasslands in three zones with different intensities of cattle grazing and trampling. The cattle corrals (bomas) had the highest intensity of cattle grazing and trampling, the controlled grazing zones had moderate intensities of cattle grazing and trampling while the non-cattle grazing zones (controls) had zero effects of cattle grazing and trampling. Lewa Wildlife Conservancy is host to a range of grazing wildlife species including the endangered Grevy's zebra, *Equus grevyi* and improvements to grazing should lead to significant benefits for these species.

## 1.2 LITERATURE REVIEW

### 1.2.1 Rangelands

For a particular landscape–soil combination, the essential components of a rangeland ecosystem are communities of annual grass, perennial grass, woody shrub populations, and the external factors that drive them; rain, fire, and herbivory (Noy-Meir, 1973; Anderies, *et al.,* 2002)**.** Rangelands can occupy multiple stable states depending on the external drivers of fire, rainfall or grazing. They can occupy a stable configuration dominated by shrubs with little grass or by perennial grasses with few shrubs (Anderies *et al*., 2002). While grasses and shrubs compete for scarce water resources, grazing and fire exert differential selective pressure on grasses and shrubs. Fires, which consume dead grass shoots and woody vegetation as fuel, cause significant shrub mortality and thus select against them while grazing selects for shrubs by suppressing grass growth. Rangeland ecology is characterized by shifting balances between these competing forces. Savanna species are adapted to withstand high variability in these determinants (Hudak, 1999). For example, Danckwerts and Stuart-Hill (1988) found that when grazing livestock were withdrawn for six months after a drought ended, palatable grasses quickly recovered to their former abundance.

Rangeland health - the degree of the integrity of the soil, vegetation, water, air as well as the ecological processes of the rangeland ecosystem – needs to be balanced and sustained (Pyke *et al*., 2002). Integrity is defined as the maintenance of the functional attributes characteristic of a locale, including normal variability (Pyke *et al*., 2002). Rangeland managers should therefore decide when to apply or reduce grazing pressures to allow a system to improve and if and when to use fire management to remove moribund grass material.

### 1.2.2 Management of Rangelands.

Some of the treatments accorded to moribund grasslands to improve their quality include: prescribed burning, rest, rotational grazing and rotational trampling (Savory & Butterfield, 1999). Prescribed burning is the treatment that has been used in Lewa to reduce and control moribund grass material.

#### 1.2.2.1 Prescribed Burning

Africa has the most extensive area of tropical savanna in the world, characterized by a grassy under storey that becomes extremely flammable during the dry season. As a result, Africa is known as the "Fire Continent" (Komarek, 1965) and prescribed burning is practiced as a widely recognized and essential ecological factor for managing its grassland and savanna ecosystems. The primary reason for prescribed burning in areas with high loads of fuel is to reduce fire intensity, thus reducing the negative effects of fire. Other reasons as shown by the Forest Resources Assessment Program (FRA), (2001) for burning rangelands as in nature conservation are: to remove moribund grass material, to prevent encroachment of undesirable plants, to encourage wildlife to move to less preferred areas and to create or maintain an optimum relationship between herbaceous and woody vegetation where necessary.

Fire can enhance or suppress vegetation depending on its intensity and severity (Hoffmann & Solbrig, 2003; Zida *et al*., 2008) and the ability of the species to tolerate burning. Burning early in the dry season tends to produce low intensity fires because of high moisture in the fuel thus enhancing colonization process by inducing a flush of germination (Danthu *et al*., 2003).

In African grasslands and savanna areas used for nature conservation and game ranching, there is general consensus that fire has occurred naturally since time immemorial and that it is often essential for the ecological well-being of these ecosystems (Trollope, 1990; Thomson, 1992; Bothma, 1996; Trollope & Trollope, 2004). Experience gained through research on the effects and use of fire in south and east African grasslands and savannas has led to the conclusion that the broad groups of grasses and trees generally react similarly to the different fire regime components and, therefore, general guidelines can be formulated for prescribed burning (Trollope, 1983; 1989; Trollope & Trollope 1999, Van Wilgen *et al.,* 1990).

Further research investigating fire regime effects on the biotic and abiotic components of the ecosystem has led to a general understanding of the effects of type and intensity of fire and season and frequency of burning on the grass and tree components of the vegetation. This in turn has clarified the use of fire as a range management practice (Trollope & Trollope, 1999). The need to retain or restore a mosaic combined with concern for restoring natural processes has also led to conservationists tolerating or encouraging fires (Sutherland, 2000). Burning, however, has negative effects on amphibians, reptiles, small mammals, invertebrates and woody vegetation. Burning is also costly if a large team is needed to extinguish the fire.

#### 1.2.2.2 Grazing

Plants are the foundation of rangelands worth and the productivity of livestock and wild animals depends with the welfare of plants. The Serengeti ecosystem in southern Kenya and northern Tanzania is characterised by large herds of migrating ungulates, and also by high concentrations of large predators (Sinclair & Norton - Griffiths 1979; Sinclair & Arcese 1995; Grange *et al*., 2004).

Questions about proper stocking rate and the effect of livestock grazing on long-term forage productivity are basic to range management (Walker, 1995) and answering them is complicated by the effects that variations in weather, primarily precipitation and temperature, have on forage production (Smoliak, 1986; Sala *et al*., 1988; Lauenroth & Sala 1992; Patton *et al*., 2007).

Herbivores can shape the structure and dynamics of the community and act as agents of natural selection in the evolution of plants (Jefferies, 1988). However, the possibility that herbivory could have a beneficial effect on a grazed plant is a highly debated topic (Belsky, 1986; McNaughton, 1993; Painter & Belsky 1993; Biondini *et al*., 1998).

Herbivores can enhance the colonization process through long distance dispersal of seeds (Miller, 1995; Zida *et al*., 2008) and enhancement of seed germination through gut action (Traveset, 1998; Razanamandranto *et al*., 2004). Moderate levels of livestock grazing reduce the herbaceous layer as well as the intensity and frequency of fire that could otherwise be detrimental to seedling recruitment (Zida *et al*., 2008). Other direct effects of livestock grazing as shown by Environment Waikato Regional Council (2004) include: the consumption of plant biomass, trampling of plants including below-ground parts and soil, nutrients inputs and bacterial contamination from dung and urine.

The effects of the removal of plant biomass depends on how species respond with some increasing biomass and reproductive output, others decreasing both and some decreasing biomass but increasing reproductive output. These changes to vegetative and reproductive output can alter species population dynamics, with frequent changes in species composition that may lead to changes in the structure and function of vegetation communities (Environment Waikato Regional Council, 2004; English Nature, 2005).

Removal of biomass usually in combination with the trampling of plants and soil could have deleterious effects on the fauna. This can be due to damage of reproductive habitats - for example burrow trampling, exposing spawning sites to desiccation, removal of mating perches and decreasing the spatial heterogeneity of vegetation which reduces habitat diversity. However, in areas that are densely vegetated particularly by only a few species, grazing may increase habitat diversity resulting in an increase in the abundance and diversity of flora (Environment Waikato Regional Council, 2004). This could be applicable in Lewa as species diversity of grasses is very low with *P. stramenium* and *P. mezianum* dominating more than 70% of the area. Trollope & Trollope (1999) categorized *P. stramenium* and *P. mezianum* in Lewa as increaser I grass species. They placed them within the first level as they are critical in this grassland and they tend to increase when the range is underutilized or selectively grazed. The low densities of wild herbivores in Lewa could be responsible for this, however, intensive but controlled cattle grazing and trampling might be able to improve the species diversity of grasses in this conservancy.

Trampling is also known to affect species composition, with some species being better adapted to compact soils (Wardle, 1991) or requiring bare patches created by trampling to establish such as annuals or stoloniferous species (Grevilliot & Muller, 2002). This ensures a variety of species continue to flourish. Hoofed animals such as cattle tend to compact the soil, as at every step they concentrate a big weight on a small foot (Savory & Butterfield, 1999). They can also break soil crusts and disturb vegetation when bunched together. Periodic high levels of animal trampling promote the advancement of biological communities on bare, gullied and eroding ground. In dense grassland, such as the one in Lewa, high levels of animal trampling tends to maintain the biological community at the grassland level preventing a shift to woody communities. Low levels of animal trampling tends to produce bare ground as it disturbs algal communities but does not stimulate the establishment of more complex communities. Under low levels of animal trampling, dense grassland with close spacing may proceed toward woody communities and forbs, but these will give way to a landscape of scattered shrubs and much bare or algae- covered ground unless rainfall is sufficient to sustain a full woody cover (Savory & Butterfield, 1999).

To ensure that wildlife habitats are managed for greatest environmental benefit, it is important that the type, number and timing of livestock grazing is tailored to the needs of an individual site. Different livestock types graze in different ways and this influences their suitability for grazing individual sites. Cattle use their tongues to pull tufts of vegetation into the mouth, thus they do not graze vegetation too close to the ground and often leave tussocks of grass which are used by insects and small mammals. They also have wide mouths thus they do not graze selectively and as a result they do not target flower heads and herbage which are important for botanical diversity (English Nature, 2005). They can create their own access into rough areas and can be an important way of controlling shrubs. Proper grazing however is essential to maintain adequate forage condition as cattle grazing can affect the quantity and quality of forage available for other herbivores.

#### 1.2.2.2.1 Holistic Management

Rangeland degradation has been observed on every continent where arid and semi-arid savannas occur (Archer, 1995). Because they are usually too dry to support most crops, rangelands are predominantly used for cattle grazing. Livestock grazing is however; known to be the primary cause of rangeland degradation globally (Mabbutt, 1984) as it has been known to result to shrub encroachment which is a wide spread form of rangeland degradation. Climate change and the increasing atmospheric carbon dioxide concentration have been suggested as other causes for bush encroachment, but much stronger evidence implicates livestock grazing as the cause (Archer *et al.*, 1995). Many studies have suggested that heavy grazing reduces the productivity of semi-arid rangelands (Acocks, 1953; Talbot, 1961; Downing, 1978; Huntley, 1978; Roux & Vorster, 1983). Bush encroachment decreases grazing capacity, increases transpiration - thus lowering the soil moisture available for grass growth - (Donaldson, 1967), and decreases weaner calf production all of which lead to economic hardship for cattle farmers (Hudak, 1999).

Vast areas of Africa which were used for centuries by nomadic herders are being degraded. A growing number of commercial ranches in Mexico, USA, Zimbabwe, Namibia and South Africa suggest that this kind of land degradation can be stopped if holistic management methods which were first advocated by Allan Savory in the early 1960s were applied (Neely & Butterfield, 2004). Savory & Butterfield (1999) state that natural resources could be regenerated only if all interacting ecological, economic and social factors were taken into account in the management process.

Grasslands evolved with the large grazing herbivores that lived on them (Savory & Butterfield, 1999). These immense herds grazed hard for a short time and moved on, leaving grass with adequate time to recover. This relationship can still be seen in the Serengeti ecosystem with the vast migrating herds of wildebeest and plain zebras moving through the landscape. This migratory behavior of ungulate species in the Serengeti and Yellowstone National Parks in response to spatio - temporal gradients of plant productivity and nutrient content has been implicated as a key mechanism maintaining the functional properties of grazing ecosystems (Frank *et al*., 1998; Augustine & McNaughton, 2006). This conclusion is supported by the long term declines in primary productivity, nutrient retention, and secondary productivity that some savanna ecosystems have experienced in response to increased densities and reduced migratory behavior of domestic livestock (Sinclair & Fryxell 1985).

Overgrazing, which has been faulted for degrading lands, occurs when a plant is re-grazed too soon before its root system has had time to recover. Overgrazing results from the amount of time a plant is exposed to a grazing animal and not from the numbers of grazing animals on the land (Grevy's Zebra Trust, 2009). When animals are allowed to roam at will, they will indeed revisit plants before the plants can recover. However, when animals are herded so as to ensure that they do not re-graze plants before they have recovered, then overgrazing is no longer an issue. Time governs the effects of trampling too. Animal hooves enhance soil health when they chip sealed soil surfaces, and knock down dead plants so they can decay more quickly (Savory & Butterfield, 1999). But they cause damage if animals remain in one place too long or return to it too soon. If grazing is managed for recovery periods of plants then overgrazing and over trampling can be avoided.

By combining small groups of animals into larger herds and planning their daily moves, herdsmen maximize forage production and the benefits of animal trampling – the hoof action of the animals - as well as the dung and urine that fertilize the soil (Strang, 2008). Necessary conditions for seeds to take root in soil cracks and indentations are created since livestock is moved off so quickly that their hooves and mouths do not have sufficient time to destroy new seedlings or to damage existing grass butts. By mimicking the wild herds that roamed these lands in the past and keeping livestock moving, they minimize overgrazing of plants, which over time leads to increased ground cover (Neely & Butterfield, 2004).

Livestock also play an important role in breaking down moribund vegetation. In an arid zones during long, dry periods there is not sufficient moisture to cause the rapid recycling of plant nutrients into the soil, so animals are crucial tools for mechanically breaking down old stands of overgrown vegetation and grasses, and then using the microbes in their gut to further break down that vegetation in an environment where there is insufficient moisture to support soil microbial activity during dry spells (Strang, 2008). Plenty of evidence from previous experiments where animals have been removed and an arid area has been 'locked up' shows that regenerating a sustainable environment is impossible instead shrub encroachment or desertification results (Savory & Butterfield, 1999).

### 1.2.3 Lewa Wildlife Conservancy.

Several areas on the Lewa Wildlife Conservancy have high biomass of moribund grass material that has accumulated in the past several years due to under-utilization by wild herbivores which occur in low densities. The low density of wild herbivores is as a result of the conversion of Lewa Wildlife Conservancy to a wildlife sanctuary from a cattle ranch in the early 1990s. To date the numbers of these herbivores has never increased to a point where they can reduce and control the grassland (Chege, personal communication).

Large herds of cattle were required to lower the high biomass grass material in Lewa. To acquire the right numbers; cattle from communities that neighbour Lewa to the east, west and northern sides were allowed to graze on designated blocks. There were two cattle corrals (bomas) which had six hundred head of cattle each. Cattle were kept in a boma for seven nights during the dry season and for two nights during the wet season ensuring there was no overgrazing and over-trampling in one area. During the day, they were left to graze and trample on other secluded areas in a strictly controlled and rotational manner (Lewa Wildlife Consevancy, 2007).

## 1.3 JUSTIFICATION

Past research by the Lewa Research Department has demonstrated that grassland within Lewa whose biomass is greater than 5000Kg/Ha are usually moribund and nutritionally poor thus are not preferred by plains game (Lewa Wildlife Consevancy, 2007)

Prescribed burning, the treatment that has been used to reduce and control the moribund grasslands in Lewa has destructive effects on invertebrates, reptiles, woody vegetation and small plains game. In addition, burning can be costly if a large team is necessary to control the exercise. Due to this non-selective nature of fire and unreliable rainfall in semi-arid grasslands, it was important to introduce another management practice that would not have any negative results on both vegetation and animals in semi-arid grasslands**.**

Intensive but controlled cattle grazing and trampling is assumed to improve the diversity and productivity of moribund grasslands. If vegetation is improved, it is often assumed that such improvements will benefit wildlife grazing.  A study on the moribund grasslands of Lewa Wildlife Conservancy was necessary in order to establish whether cattle grazing and trampling would provide effective tools in improving vegetation quality as opposed to prescribed burning which the conservancy has been using. A study on the effects of intensive but controlled cattle grazing and trampling, would also help in understanding the effects of holistic management and this would go a long way in facilitating the development of effective management and monitoring programs for African rangelands.

One of the key objectives of Lewa Wildlife Conservancy, a stronghold for Grevy's Zebra, is to use its' Grevy's zebra population to improve existing Grevy's zebra populations residing elsewhere in northern Kenya and to restock their former range (Lewa Wildlife Consevancy, 2007). An assumption of improving grassland quality through intensive but controlled livestock grazing is that it may lead to establishment of new sites with improved quality of diverse grass species. Improved conditions of the rangeland would then increase the survival rates of the Grevy's zebras hence an overall increase in their numbers (Sundaresani *et al.,* 2007). In order for Lewa Wildlife Conservancy to achieve this objective, it was important to conduct a study on how herbaceous layer improvement could be part of improving the range of wild mammalian grazers particularly the Grevy's zebra.

To acquire the right numbers of cattle to lower the moribund grass material, cattle from the local communities that neighbour Lewa are allowed to graze on selected blocks. Using cattle from these local communities would demonstrate the sustainable co – existence of livestock and wildlife. As cattle from the local communities feed in a protected area, their bodily conditions improve and so will their demographic rates. An increase in the number of cattle would improve the economic status of the local communities when the animals are converted into financial benefits. This would help to increase the tolerance of the local communities to wildlife and this would be beneficial to the wildlife particularly those that use community areas as migratory routes to other protected areas.

### 1.4 Main objective

The overall objective of the study was to assess the effects of intensive but controlled cattle grazing and trampling as management tools in semi-arid grasslands.

#### 1.4.1 Specific objectives

1. To assess and quantify the effects of intensive but controlled cattle grazing and trampling on vegetation quantity, diversity and productivity at the Lewa Wildlife Conservancy.
2. To investigate the utilization of different grazing treatments by wild mammalian herbivores.
3. To investigate vegetation quantity and diversity in relation to boma ages in semi-arid rangelands.

### 1.5 Hypothesis

Intensive but controlled cattle grazing and age of bomas does not affect vegetation quality, diversity, productivity and rangeland use by wildlife herbivores.

# CHAPTER 2

# THE STUDY AREA

## 2.1 Geographical Location

The study was carried out in Lewa Wildlife Conservancy which is located immediately north of the equator on the northern slopes of Mount Kenya, between latitudes $0^0$ 06' and $0^0$ 17' North and longitudes $37^0$ 21' and $37^0$ 32' East (Figure 1). It is situated in the Laikipia plateau about 65km North East of Nanyuki town. It is approximately 24,600 hectares (ha) in size (Botha, 1999).

## 2.2 History

According to Botha (1999), the Laikipia Plateau of central Kenya has been the home of wildlife and Maasai livestock long before the arrival of the first Europeans. It has since become one of the most important livestock areas in Kenya. It is also one of the remaining areas where considerable numbers and species of wild animals are found outside the protected areas. The long term utilization of the study area has not been recorded; however, according to Botha (1999) ranching first began in Lewa in 1952 with 1800 head of cattle and 3000 sheep on 3300 ha of the current study area. In 1980, some adjacent land was bought increasing it to 15600 ha. All except a few sheep held for domestic use were sold leading to Lewa being primarily considered a cattle ranch with Zebu and Boran crosses.

In 1984 Lewa began as the Ngare Seregoi Rhino Sanctuary and was declared a national conservancy in 1994 concentrating on the conservation of wildlife. It has always served as a dry season retreat for a large number of herbivores and as a migratory route for elephants to the Ngare Ndare and Mt Kenya forests.

Lewa Wildlife Conservancy is one of the few wildlife sanctuaries in Kenya with a viable black rhinocerous breeding population as well as a healthy population of Grevy's zebra. Limited numbers of domestic livestock are also kept for commercial purposes but the primary income of the conservancy is from ecotourism and Lewa is regarded as one of the leading international tourists' destinations in East Africa.

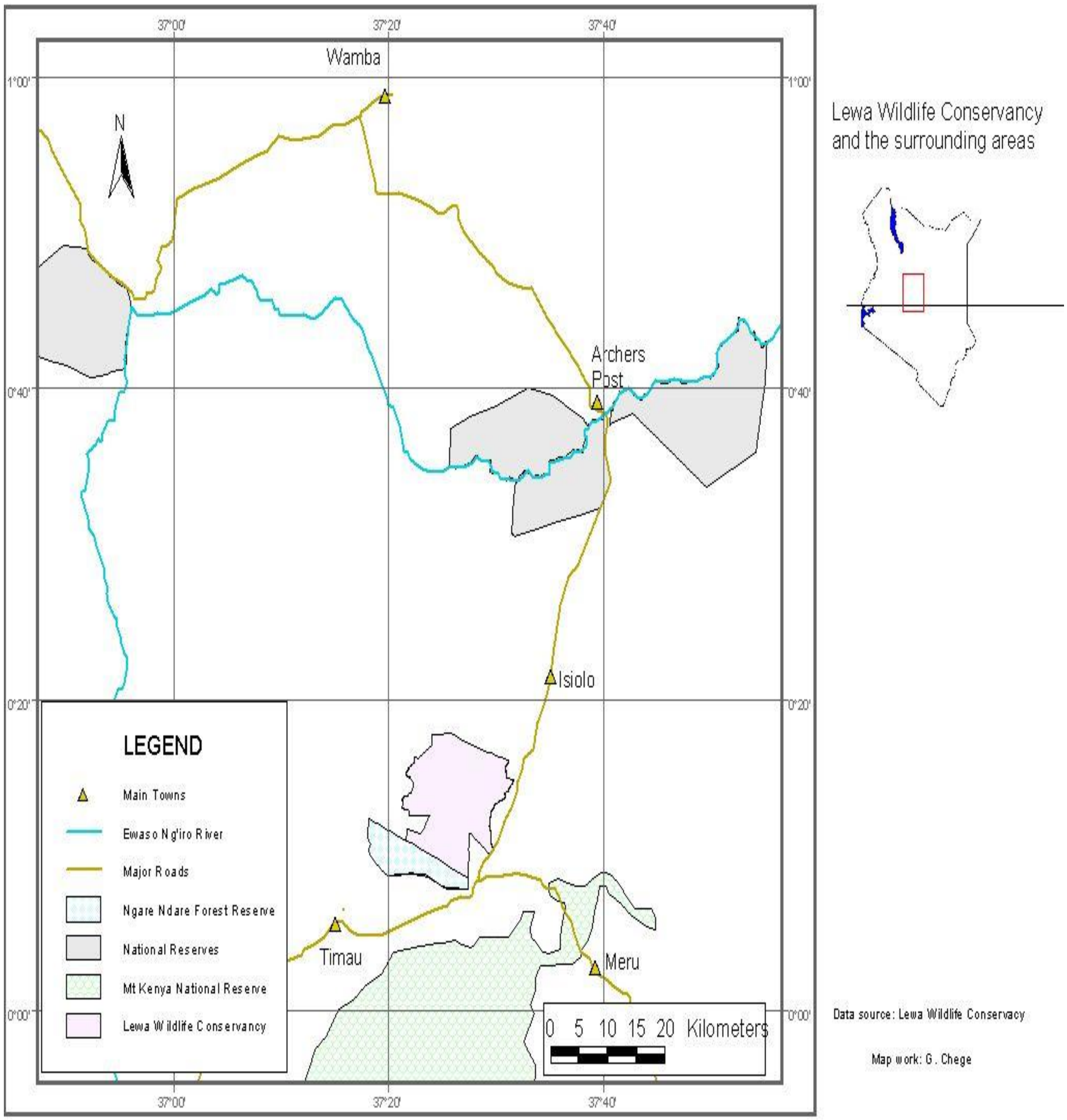


**Figure 1**: Location of Lewa Wildlife Conservancy and the neighbouring areas (From Research Department, LWC, 2010)

### 2.3 Climate

Linsen and Giesen (1983) described the climate of Lewa as transitional between that of eastern Kenya Highlands and the northern Kenyan Lowlands. The daily maximum temperatures in Lewa range from $24^0$ C to $32^0$ C and the daily minimum temperature from $8^0$ C to $16^0$ C (Linsen and Giesen, 1983). According to Botha (1999) the daily maximum temperatures during the wet season are lower than during the dry season. Conversely, the daily minimum temperatures during the wet season are higher than during the dry season. There is a marked temperature difference along an altitudinal gradient, being warmer in the north than in the south.

There are two main rainy seasons. The short rains which fall from March to May and long rains fall from October to December. Mean annual rainfall is 517mm. Periods of prolonged drought are relatively common. Figure 2 shows the amount of rainfall received during the study period while Table 1 shows the amount of rainfall received in the study area for a period of four years.

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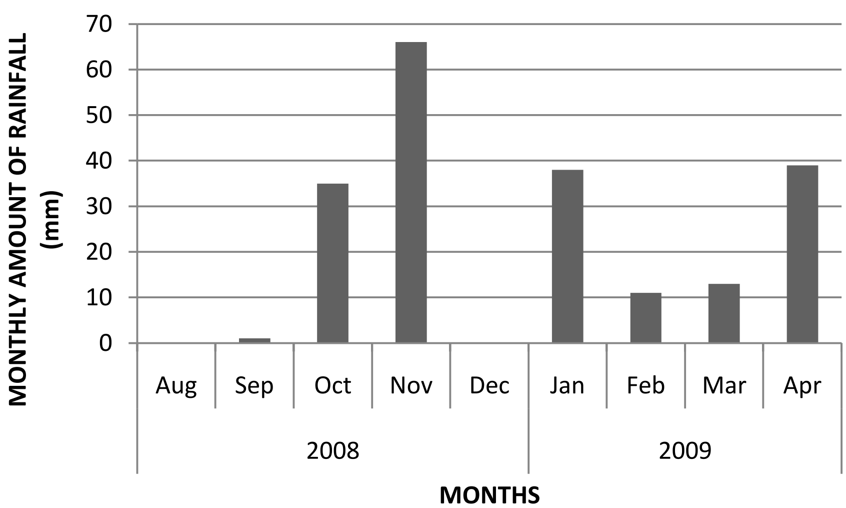


**Figure 2**: Amount of rainfall received in the study area during the study period.

**Table 1:** Mean monthly rainfall (mm) received in Lewa Wildlife Conservancy from 2005 to 2008.

| | 2008 | 2007 | 2006 | 2005 |
|---|---|---|---|---|
| Jan | 50 | 64 | 26 | 48 |
| Feb | 4 | 13 | 17 | 3 |
| Mar | 45 | 37 | 52 | 39 |
| Apr | 73 | 91 | 85 | 60 |
| May | 6 | 54 | 7 | 50 |
| Jun | 0 | 44 | 0 | 0 |
| Jul | 0 | 42 | 0 | 7 |
| Aug | 0 | 6 | 45 | 0 |
| Sep | 1 | 0 | 4 | 14 |
| Oct | 35 | 78 | 112 | 9 |
| Nov | 66 | 146 | 222 | 45 |
| Dec | 0 | 45 | 188 | 10 |

## 2.4 Topography

Lewa is located on an altitudinal gradient, varying from 1450m above sea level in the north, to 2300m above sea level in the south. As a result, the area contains many different topographical and geomorphological units (Botha, 1999). The topography can be described as broken, with steep valleys in the south, gradual slopes tending to flatter volcanic plains in the central part and undulating hills with occasional steep river valleys in the north.

The Ngare Ndare Forest, which forms the southern boundary of the study area, is part of the foothills of Mt. Kenya and is mainly mountainous with many steep valleys. The geology of the forest is mostly volcanic sediment. In the central part of the study area, the altitude decreases more gradually. The slopes are more gradual from 1900 m to 1780 m above sea level. Slopes in the central, western (1780m to 1680m above sea level) and eastern (1780m to 1620m above sea level) parts tend to be more flat. (Botha, 1999).

The difference in altitude and topographical units is not as pronounced when one moves from west to east of the study area.

## 2.5 Geology and Soils

Two distinct geological rock formations occur in Lewa (Botha, 1999). They include the basement system rocks and the volcanic rocks and subordinate sediments of the Mount Kenya volcanic series. The basement system rocks are sedimentary deposits that form the floor upon which the remaining rocks of the area rest. The system consists of schists, granulites and heterogeneous gneisses (Linsen & Giesen, 1983). The volcanic rocks consist of upper basalts, overlying lower basalts of the Mount Kenya volcanic series. Some areas are covered by superficial Pleistocene deposits which are chiefly volcanic ash or basement system gneisses.

Dominant soils found on Lewa, include; nitisols, vertisols, solonetz, luvisols, fluvisols and gleysols. The soils are mainly derived from the erosion of geological formation. Much of Lewa is underlain with black cotton type of vertisol which is a characteristic of impeded drainage. Vertisols form wide cracks because of their swelling and shrinking characteristics. They have a clay content of higher than 60 percent and consist mainly of the clay mineral biotite. They have a high water holding capacity with poor drainage. Solonetz soils are deep, red soils and are characterized by extreme erodibility, low resilience and poor recovery potential. Cambisols are relatively young, shallow, and red to dark brown soils with moderate water holding capacity and fertility. Nitisols consist of stable deep red soils with a strong block structure, and clay content of 30 percent and higher. They are highly fertile with high water holding capacity. Gleysols are found in the Lewa swamp and riverine areas where there are permanent wet conditions. They are deep soils with a blue-grey colour, yellow mottles and a high to extremely high clay content greater than 55 percent. Luvisols occur as a complex of well drained, shallow to deep, red to dark red, friable to firm sandy clay loam to sandy clay soils (Botha, 1999). Fluvisols consist of a stratification of sand and silty sedimentary deposits and they vary from sandy to clay loams depending upon their locality, parent material and depth in profile.

### 2.6 Drainage

Kenya has a simple drainage network. The main rivers radiate either from the central dome formed by the Kenyan highlands, or from the southern foothills of the Ethiopian highlands. Lewa borders the northern outskirts of the Kenyan highlands. Consequently, Lewas' drainage network forms part of the Ewaso Ngiro river basin which is situated north of the study area. All drainage lines through the study area flow from the south to the north since the highest elevations are found in the southern boundary of the study area at the forest and the lowest elevations are found in the north. This drainage network includes the Ngare Ndare River, Ngare Sergoi River and Western Marania River. These three rivers are permanent and both the Ngare Ndare and the Ngare Sergoi Rivers originate from Mount Kenya. The Western Marania River originates as a spring in the central parts of the study area and flows through the Lewa swamp. There are several seasonal rivers; among them is the Eastern Marania River which joins the Western Marania River at Isiolo town to form the Keromet River, which in turn flows into the Ewaso Ngiro River. A single dam that is reliant on rainfall alone is also found on the study area (Botha, 1999).

### 2.7 Vegetation

Most of the study area can be physiognomically described a grassland with a tree and a shrub cover of more than 20 % (Pratt & Gwynne, 1977). The vegetation of Lewa has been divided into 11 plant communities (Figure 3).

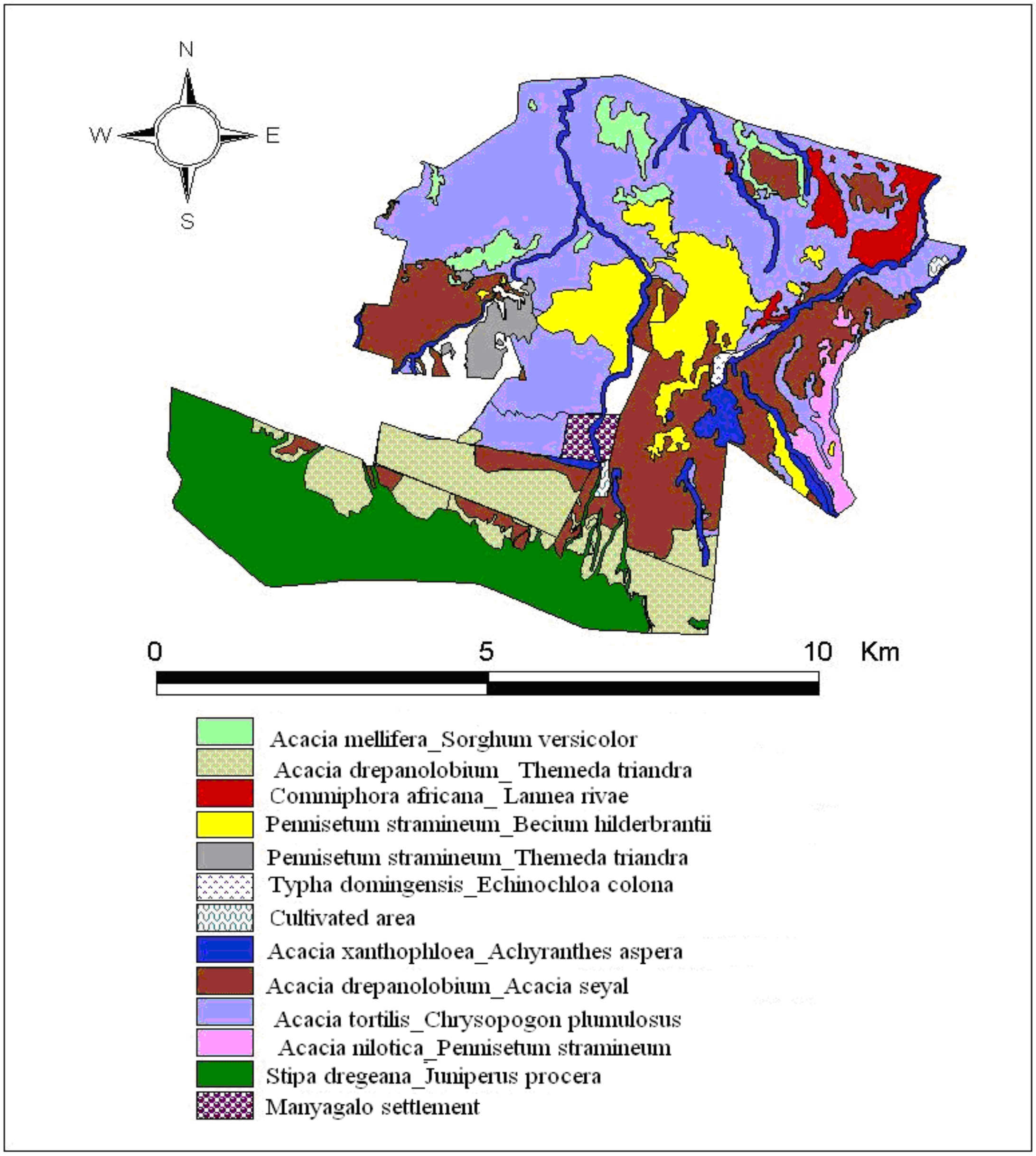


**Figure 3**: Vegetation types in Lewa Wildlife Conservancy. (From the Research department, LWC, 2010)

The *Stipa dregeana– Juniperus procera* tall forest community covers 22.0 percent of the study area. It occurs at altitudes ranging from 1860 – 2260 m above sea level and constitutes the southern boundary of the study area. This community is found in the Ngare Ndare forest and consists largely of closed canopy forest similar to those found at higher altitudes on Mount Kenya.

The *Acacia drepanolobium – Themeda triandra* low thicket community covers 6.6 percent of the study area and ranges from 1900m to 2100 m above sea level. The community is limited to the forest edges and foothills of the Ngare Ndare forest in the southern parts of the study area. This community is characterized by a high cover abundance value and the diagnostic plant species found in this community include: *Themeda triandra, Andropogon schirensis, Bothriochloa insculpta, Hibiscus flavifolius* and *Indigofera brevicalyx*.

The *Acacia nilotica– Pennisetum stramineum* low open woodland community is found in the south east of the study area and covers 2.7 percent of the study area. It ranges from 1660m to 1780m above sea level and is characterized by flat to gradual slopes with varying aspects. The diagnostic species for this community include: *Carissa edulis, Commiphora africana, Euphorbia candelabrum, Hibiscus cannabinus, Klenia abyssinica, Monsonia longipes, Phyllanthus suffrutescens and Thunbergia alata.*

The *Acacia drepanolobium-Acacia seyal* low open woodland community covers 19.2 percent of the study area. It occurs at the centre of the study area at elevations ranging from 1500m to 1960m above sea level. This community has high cover abundance values for *Acacia drepanolobium, Acacia seyal, Pennisetum stramineum and Pennisetum mezianum.*

The *Acacia mellifera – Sorghum versicolor* tall sparse shrubland community is approximately 4.5 percent of the study area. It occurs at the western and northwestern parts of the study area at elevations ranging from 1560m to 1760m above sea level. This community has high cover abundance values from *Acacia mellifera, Chrysopogon plumulosus, Pennisetum mezianum and Pennisetum stramineum*.

The *Pennisetum stramineum – Themeda triandra* short closed grassland covers 2.2 percent of the study area. It occurs in the southwest of the study area from 1700m to 1720m above sea level. No diagnostic species are found in this community. The only woody species are *Acacia drepanolobium,* and *Acacia mellifera.* The grasses include: *Chrysopogon plumulosus, Pennisetum mezianum, Pennisetum stramineum* and *Themeda triandra.*

The *Commiphora africana – Lennea rivae* low thicket covers 3.3 percent of the study area and it occurs from 1520m to 1760m above sea level. It is characterized by *Acacia nilotica, Aristida kenyensis, Commiphora africana, Lannea triphylla, Maytenus senegalensis, Pennisetum stramineum, Sehima nervosum* and *Themeda triandra.*

The *Acacia tortilis– Chrysopogon plumulosus* low thicket communities is the largest plant community in the study area covering 27.1 percent. It occurs from 1510m to 1760m above sea level. Some of the woody plant communities found in this vegetation type include: *Acacia mellifera, Acacia tortilis, Acacia nilotica Commiphora africana,* and *Maytenus senegalensis* while the herbaceous species include*: Aristida kenyensis, Chrysopogon plumulosus, Pennisetum stramineum,* and *Themeda triandra.*

The *Acacia xanthophloea –Achyranthes aspera* tall closed woodland covers 3.3 percent of the study area. It covers all riverine vegetation of the LWC except those of the forest and the swamp. Some of the plant communities found in this vegetation type include: *Acacia xanthophloea*, *Achyranthes aspera, Leonotis nepetifolia* and *Cynodon nlemfuensis.*

The *Typha domingensis*- *Echinocloa colona* swamp is found at the centre of the study area at an altitude of 1690m above sea level. Species found in this community include: *Cyperus papyrus, Crassocephalum picridifolium, Polygonum setulosum, Sphaeranthus napierae* and *Typha latifolia.*

*The Penniseum stramineum – Becium hildebrantii* short closed grassland is located in the centre part of the study area and it covers the remaining part of the study area. Being a grassland, it has widely scattered *Acacia drepanolobium* and A*cacia mellifera* trees. The grass species with the highest cover abundance values include: *Chrysopogon plumulosus, Pennisetum stramineum* and *Pennisetum mezianum* while some forbs found in this grassland community include: *Becium hildebrantii, Hibiscus flavifolius* and *Indigofera volkensii*.

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1 Research Method

The study was carried out in the grasslands of Lewa Wildlife Conservancy between September 2008 and April 2009. Sampling occurred in two habitat types based on soil types; black cotton soils and mixed/sandy soils. There are three dominant soil types in Lewa: Black cotton soils, mixed soils and red soils. However, the proportion of black cotton soils and mixed soils is greater than that of the red soils and most of the abandoned cattle corrals (bomas) were situated on the black cotton and mixed soils making it impossible to get enough replicates of abandoned bomas on the red soils.

To determine the effect of time on vegetation quantity, diversity and productivity of abandoned bomas, the age of abandoned bomas was classified into seasons, based on the dry and wet seasons. Records at the Lewa research department showed that, at the time of this study, the oldest boma was twelve months old and the youngest was a month old. Consequently, the oldest boma considered for this study was six seasons old and the youngest was one season old.

The study was conducted on vegetation quantity, quality, diversity, productivity, off-takes by mammalian herbivores and dung density. The pin frame, quadrats and the disc pasture meter were the main instruments used for vegetation survey while enclosures were used to give estimates of vegetation productivity and off-takes by mammalian herbivores.

### 3.1.1 Sampling Points

Vegetation survey was established in five sites in each of the two soil types making ten replicates in total. At each site, vegetation was surveyed in three zones. The first zone was the boma where cattle were kept overnight for seven nights during the dry season and two nights during the wet season. This zone had the highest levels of cattle grazing and trampling. The second zone was the controlled grazing zone. This was an area surrounding the boma where cattle were grazed during the day in a strictly rotational manner. The intensity of grazing and trampling in this area was lower than in the boma. The third zone was the non-cattle grazing zone (controls) and this area was beyond the controlled grazing zone where no cattle grazing or trampling occurred. At each site six vegetation plots were established, two in the bomas, two in the controlled grazing zones and two in the non- cattle grazed zones resulting in a total of thirty vegetation plots in each soil type where vegetation survey was carried out.

GPS (Global Positioning System) coordinates of sampling points in the bomas, controlled grazing zones and non-cattle grazing zones were randomly selected from GPS coordinates of a digitized map of Lewa by Microsoft – excel. In the controlled grazing and the non-cattle grazing zones, one 100m transect was established from the initial sampling point and the pin frame was dropped after every ten metres. The plant parts that made contact with the pins were then recorded. Boma shapes were irregular and 100m transects could cut right out of the boma. To take care of this, random points equal to the number of sampled points in the controlled grazing zones and the non-cattle grazing zones were taken in the bomas based on GPS coordinates chosen randomly by Microsoft – excel. This resulted in equal numbers of points sampled in each of the three zones in every site.

The pin frame method was used to measure vegetation quantity and diversity at each plot. The pin frame has been found to be a useful tool in studying herbaceous and dwarf vegetation between 20cm and 50cm high by measuring the species composition, plant part proportions and biomass of these plant communities (Githaiga, 1991). The pin-frame used in this study consisted of a one metre horizontal bar supported on two legs. The bar had ten holes along its length, drilled at regular intervals of 10cm, through which the pins were passed while the supporting legs were stuck into the ground so that the bar was leveled. The number of contacts the pins made with the vegetation were recorded thus the frequency of a plant part coming into contact with a pin depended on its abundance. The probability of contact with the different plant parts is a function of pin diameter and size of plant parts, both of which contribute to sampling error. A large sample was taken to minimize the sources of error that could be inherent in this technique.

Two sets of vegetation data were collected: dry and wet season data. Dry season data were collected in September 2008 just before the rainy season while wet season data were collected in November 2008, during the long rains.

### 3.1.2 Vegetation Quantity.

The standing crop of grass, percent estimated vegetation ground cover, the proportion of plants parts biomass were used as estimates of vegetation quantity. These measures gave an estimate of vegetation quantity in the three different zones during the dry and wet seasons in both the mixed and the black cotton soil.

Estimation of the standing crop of grass was done by quantifying vegetation using the pin frame and a $0.25m^2$ quadrat. The quadrat was dropped at some points where pin frame readings had been taken and vegetation was harvested from these points. The dry weight of harvested vegetation from the $0.25m^2$ quadrats from each grazing treatment in both soil types during both the dry and wet seasons was then regressed against readings from the pin frame giving an equation, $Y = a + bx$ (Zar, 1984). This equation was used to give an estimate of the standing crop of grass where 'Y' = Standing crop of grass and 'x' = average hits of a species per pin.

Different equations showed significant relationships between the standing crop of grass and pin hits during the dry and wet seasons in both soil types. From these equations, the standing crop of grass for each transect was calculated from the number of pin hits.

Vegetation ground cover was established by estimating percent vegetation ground cover inside a $0.25m^2$ quadrat in several points where the pin frame had been used. Percent estimated vegetation ground cover was then regressed against pin hits establishing a significant relationship using a regression equation, $Y = a + bx$ (Zar, 1984) where 'Y' = percent estimated vegetation ground cover and 'x' = average hits per pin. This equation was used to give an estimate of percent estimated vegetation ground cover for each grazing treatment in each soil type during both the dry and wet seasons.

The numbers of leaves, stems and seed heads that touched each pin were converted to biomass using a regression equation that established a significant relationship between the number of hits of a given plant part per pin and the dry weight of the harvested biomass. This was then used to estimate the biomass of different plant parts available for consumption.

### 3.1.3 Vegetation Quality.

The crude proteins and the crude fibre content of the forage were used as measures of vegetation quality. They were determined by collecting herbaceous grass from the bomas, controlled grazing zones and non-cattle grazing zones in some of the ten sites where vegetation survey was done. These samples were analyzed for crude proteins and crude fibre contents at the Animal Production Laboratory in the School of Animal Sciences, University of Nairobi using the Kjedahl method to give an estimate of crude proteins and the van Soest method to give an estimate of crude fibres content of the forage (Githaiga, 1991).

The proximate analysis system of food and animal feed consists of the van Soest and Kjedahl methods that are used for analyzing the crude fibre and crude protein content of the forage respectively. This method is the basis for everyday chemical description of forage involved in calculations of food digestibility and utilization of all animal species. Crude fibre is that portion of the carbohydrates that resists digestion when boiled for thirty minutes in dilute potassium sulphate, filtered, and the residue boiled in dilute potassium hydroxide. It includes cellulose and a portion of some of the other polysaccharides (araban, mannan, galactan, but no glycogen or starch). It also contains some of the hemicelluloses and some lignin (Maina, 2008).

Crude protein analysis involves the principle of transforming nitrogen or protein and other organic compounds into a sulphate by acid digestion with concentrated sulphuric acid and a catalyst. When digestion is complete, the acid sample solutions are cooled, diluted with water and made strongly basic with sodium hydroxide. Ammonia is released and distilled into a boric acid solution which is titrated with standardized hydrochloric acid. From the titrations, the amount of nitrogen in the samples is determined and multiplied by 6.25 which is the conversion factor of nitrogen to proteins. This method includes nitrogen of amino acids and amines. It gives no information of the kinds and amounts of amino acids (Maina, 2008).

### 3.1.4 Species Diversity

Species diversity of the herbaceous layer for each grazing zone in both soil types during the dry and wet seasons was estimated by counting the number and abundance of each vegetative species that hit a pin.

### 3.1.5 Vegetation Productivity

Vegetation productivity was measured by recording the growth or non – growth of vegetation inside a 10 x 10m metal enclosure that was established in the controlled grazing zone in each of the two soil types. Vegetation productivity was measured only in the controlled grazing zones due to inadequate funds needed to put up other replicates. A quadrat of $0.25m^2$ was randomly dropped ten times in the 10 x 10m enclosure. The initial standing crop of grass in the ten randomly established points was measured using a disc pasture meter. The standing crop of grass in these points was then taken and recorded after every fortnight from December 2008 to March 2009.

The disc pasture meter, developed by Bransby and Tainton (1977) and calibrated for use under rangeland conditions in South Africa by Trollope and Potgieter (1986) is used to determine the biomass for the herbaceous layer (Trollope & Trollope, 1999). Using the procedure developed by Trollope and Potgieter (1986), Botha (1999) calibrated the disc pasture meter for use in the Lewa Wildlife Conservancy. The disc pasture meter consists of a 45.8cm diameter base plate sliding over a 180cm long calibrated aluminium rod. The mean settling height (cm) of the base plate on the grass sward is recorded. This resultant mean disc height (cm) is converted into an estimate of the standing crop (kg/ha) of the herbaceous layer using a regression equation developed for this purpose. Estimations of the standing crop of the herbaceous layer by the disc pasture meter may compare closely with traditional methods of estimating yield, however the disc pasture meter is found to be more convenient due to its non-destructive nature and its rapidity of use.

The disc pasture meter was calibrated by dry weight of harvested vegetation from $0.25m^2$ quadrats. This was done by regressing disc pasture meter height readings (cm) against the dry weight of harvested vegetation from some of the areas where both the disc pasture meter and the pin frame had been used. This gave an equation, $Y = a + bx$ (Zar, 1984) which was used to give an estimate of vegetation productivity where 'Y' = Vegetation productivity (biomass in $g/m^2/wk$) and 'x' = disc pasture meter height readings (cm). This was done for each soil type during both the dry and wet seasons.

### 3.1.6 Off-takes by Mammalian Herbivores.

To assess which grazing treatment was preferred by mammalian herbivores and to establish how vegetation data would relate to animal data, it was necessary to measure off-takes by mammalian herbivores. This was done using movable 1 x 1m metal cages where consumption rates were measured by recording the growth or non – growth of vegetation inside and outside of 1 x 1m enclosure cages using the disc pasture meter. There were two cage units placed within the boma once cattle were moved, two cages in the controlled grazing zone and further two cages in the non-cattle grazing zone of each site. The initial biomass of grass inside and outside of the cage was taken and vegetation growth or non-growth inside the cages as well as outside the cages was recorded after two weeks. The cages were then moved to a different location and the process done all over again. This was done from the last week of November 2008 to March 2009.

Biomass ($g/m^2$) from the calibrated disc pasture meter height readings were used to give an estimate of off-takes by mammalian herbivores by recording the differences in biomass inside and outside the 1 x 1m cages and running statistical tests on them to establish whether there were any significant differences in off-takes between the mixed and black cotton soils and among the grazing treatments.

### 3.1.7 Dung Density

Besides measuring off-takes by mammalian herbivores, it was necessary to do dung counts in every zone at each of the ten sites which would give an index of abundance of the wild animals. This was to establish the grazing treatment most preferred by mammalian herbivores thus relating plant data to animal data. At the controlled grazing and the non-cattle grazing zone of every site, two belt transects of 100 x 2m were used while in each boma, four belt transects of 50 x 2m were used. The belt transects were shorter in the bomas because the bomas were circular and it was impossible to put up long transects otherwise they would cut out of the bomas. To minimize any error in the differences found in transects length among the zones, the dung piles per animal were standardized to numbers per hectare. The number of dung piles along transects were identified to the source species based on the identification by Chris and Stuart (1994). The dung piles per animal were then recorded and used to give an estimate of the number of wild animals utilizing a particular zone.

### 3.1.8 Vegetation Survey in Abandoned Bomas

To establish if there were any differences in vegetation quantity, vegetation species diversity, off-takes by mammalian herbivores and dung density in different ages of the bomas, the bomas were classified into seasons. This classification was based on the four seasons that occur in Lewa every year, two dry seasons and two rainy seasons. The dry seasons fall from January to February and from June to September while the wet seasons fall from March to May and from October to December. The age of the bomas was determined from the time the bomas were abandoned by cattle to the time the study was being conducted making the oldest boma considered for this study six seasons old while the youngest was one season old.

## 3.2 DATA ANALYSIS

Data was entered, organized and managed using Ms – Excel for Windows Vista while SPSS (Statistical Package for Social Scientists) version 11.5 was used for all statistical analysis. All tests were considered significant at $p < 0.05$.

### 3.2.1 Vegetation Quantity

One way analysis of variance was used to test for differences in the mean standing crop of grass among the bomas, controlled grazing zones and the non-cattle grazing zones while an independent samples t-test was used to test for differences in the mean standing crop of grass between the mixed and the black cotton soils. Data for detecting differences in the mean standing crop of grass between the dry and wet seasons was heteroscedastic and skewed and was therefore log - transformed before analysis. An independent samples t-test was then used to test for differences in the standing crop of grass between the two seasons.

Since percentages had been used, percent estimated vegetation ground cover data was arc-sine transformed before being statistically analyzed. One way analysis of variance test was used to test for any differences in the means of percent estimated vegetation ground cover among the bomas, controlled grazing zones and the non-cattle grazing zones. Independent samples t-tests were done to detect any variations in the means of percent estimated vegetation ground cover between the mixed and the black cotton soils and between the dry and wet seasons.

Two way ANOVA tests were used to establish differences in the mean biomass of leaves, stems and seed heads among the three grazing treatments as well as between the soil types and between the two seasons.

### 3.2.2 Vegetation Quality

Independent sample t-test and one way ANOVA tests were conducted to detect any variations in the crude proteins and crude fibre content in the vegetation found between the two soil types and among the three grazing treatments.

### 3.2.3 Species Diversity

Species diversity of the herbaceous species was analyzed using the Shannon - Weiner index, $H' = -\sum p_i \ell n p_i$ (Shannon & Weiner, 1963) which is an effective measure of diversity as it accounts for species richness and abundance.

Where: $H'$= index of species diversity

$p_i$ = proportion of total sample belonging to the ith species

$\ell n$= natural logarithm of the proportion

To test whether there were any significant differences in species diversity among the three grazing treatments, one way ANOVA test was done while an independent samples t-test was done to test whether there was any difference in species diversity between the mixed soil and the black cotton soil. Data for testing the differences in species diversity between the dry and wet seasons was heteroscedastic and thus it was log - transformed and a two tailed equal variance t-test used to compare the means of the two groups.

### 3.2.4 Vegetation Productivity

An independent samples t-test was used to establish whether there was any difference in mean productivity between the mixed and black cotton soils while one way ANOVA compared the means of the different groups whose biomass were taken after an interval of two weeks.

### 3.2.5 Off-takes by Mammalian Herbivores

An independent samples t-test was used to test whether there was any difference in off-takes between the mixed and black cotton soil while one way ANOVA was used to test whether there were any differences in off-takes among the three grazing treatments. These tests were done on data that had undergone log - transformation as it was not distributed normally and the variances were heterogeneous.

### 3.2.6 Dung Density

Dung census data was not distributed normally and thus was log – transformed. One way ANOVA test was used to establish whether there were any differences in dung piles found among the three grazing treatments while an independent samples t-test was used to establish whether there was any difference in the dung piles between the mixed and the black cotton soils.

To establish which type of feeders utilized a given zone, dung piles were grouped into two categories; mixed feeders and grazers based on the classification by Chris and Stuart (1994) and an independent samples t-test done to establish whether there were any differences in dung density between the mixed feeders and the grazers.

### 3.2.7 Vegetation Survey in Abandoned Bomas

One way ANOVA test was used to establish differences in the mean standing crop of grass, percent estimated vegetation ground cover, species diversity, off-takes by mammalian herbivores and dung densities among bomas aged between one and five seasons old.

# CHAPTER 4

# RESULTS

## 4.1 Regression Equations used for Calibration

Regression equations that were used to calibrate the pin frame, the disc pasture meter and to estimate percent vegetation ground cover during the dry and wet seasons for both soil types were as shown in Appendix 1. The p-values for all the regression results were significant and the x-variables were used to estimate the y-variables.

## 4.2 Vegetation Quantity

### 4.2.1 Standing Crop of Grass Estimation

The numbers of pin hits per transect increased between the three zones and between seasons. Collectively the mean standing crop of grass was higher in the non-cattle grazing zones (500.32 ± 40.84 $g/m^2$) than in the controlled grazing zones (392.0 ± 33.52 $g/m^2$) and the bomas (241.32 ± 27.68 $g/m^2$) (Figure 4). A significant difference ($F_{2, 657} = 14.304$, $p<0.05$) was established in mean standing crop of grass among the three grazing treatments and a sequential Tukey's test was used for pair wise comparisons (Dytham, 2003). Tukey test done to compare the three grazing treatments showed that the difference in the mean standing crop of grass occurred between the bomas and the controlled grazing zones as well as between the bomas and the non-cattle grazing zones. However, there were no differences ($p>0.05$) in mean standing crop of grass between the controlled grazing and the non-cattle grazing zones.

Mean standing crop of grass was not significantly higher ($t_{(2), 658} = -1.255$, $p>0.05$) in the black cotton soil (404.64 ± 30.56 $g/m^2$, n = 330) compared to the mixed soil (353.76 ± 26.68 $g/m^2$, n = 330). The standing crop of grass during the wet season (518.32 ± 31.6 $g/m^2$, n = 301) was significantly higher ($t_{(2), 598} = -10.981$, $p<0.05$) than that of the dry season (303.64 ± 29 $g/m^2$, n = 299).

Standing crop of grass among the three grazing treatments was significantly different in the mixed soils ($F_{2, 357} = 6.720$, $p<0.05$) and in the black cotton soils ($F_{2, 357} = 7.95$, $p<0.05$). During the dry season, the standing crop of grass among the three grazing treatments was significantly different ($F_{2, 297} = 16.523$, $p<0.05$) however, it was not during the wet season ($F_{2, 357} = 2.97$, $p>0.05$) (Table 2). Sequential Tukey tests showed that the differences in standing crop of grass in both the mixed and the black cotton soils occurred between the bomas and the controlled grazing zones as well as between the bomas and the non-cattle grazing zones. Differences in standing crop of grass among the three grazing treatments during the dry season occurred between the between the bomas and the controlled grazing zones as well as between the bomas and the non-cattle grazing zones.

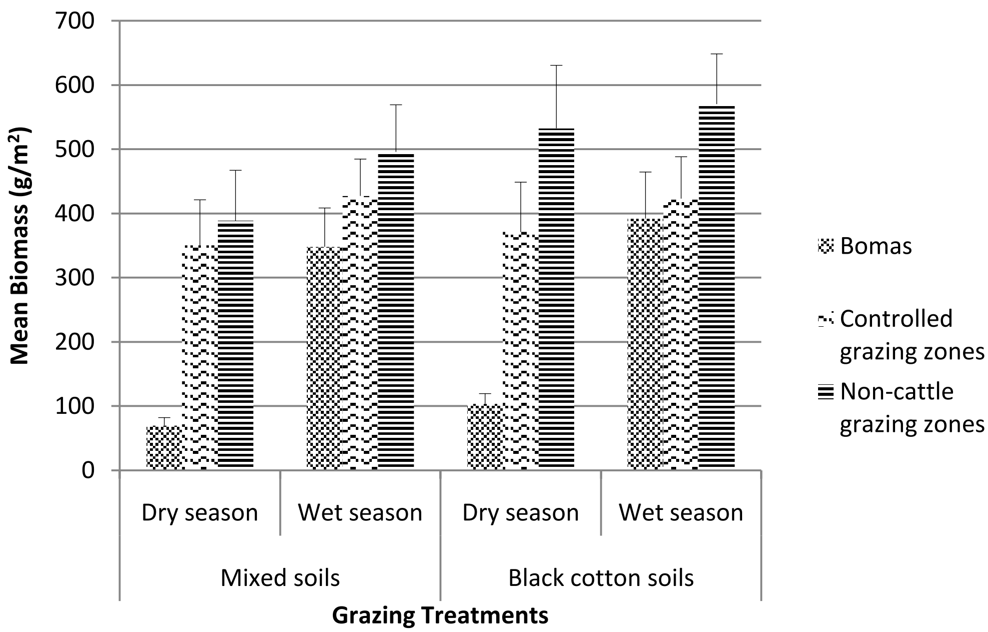


**Figure 4**: Mean standing crop of grass (g/m$^2$) ±SE in the bomas, controlled grazing zones and non-cattle grazing zones of the mixed soil and black cotton soil during the dry and wet seasons.

**Table 2:** Comparison of mean biomass (g/m$^2$) ± SE in bomas, controlled grazing zones and non-cattle grazing zones between the mixed soils and the black cotton soils and between the dry and the wet seasons (n = sample size, SE = standard error, NS = non-significant values, * = significant Values).

| | Grazing treatment | Mean biomass (g/m$^2$) ± SE | F- value | Significance level |
|---|---|---|---|---|
| Mixed soils | Bomas | 55.4 ± 9.0, n=110 | $F_{2, 327} = 6.720$ | * |
| | Controlled grazing zones | 98.1 ± 11.2, n=110 | | |
| | Non-cattle grazing zones | 111.8 ± 13.4, n=110 | | |
| Black cotton soils | Bomas | 65.3 ± 10.6, n=110 | $F_{2, 327} = 7.95$ | * |
| | Controlled grazing zones | 99.9 ± 12.5, n=110 | | |
| | Non-cattle grazing zones | 138.3 ± 15.4, n=110 | | |
| Dry season | Bomas | 21.7 ± 2.5, n=100 | $F_{2, 297} = 16.523$ | * |
| | Controlled grazing zones | 90.2 ± 13.1, n=100 | | |
| | Non-cattle grazing zones | 115.2 ± 15.7, n=100 | | |
| Wet season | Bomas | 92.5 ± 11.8, n=120 | $F_{2, 357} = 2.97$ | NS |
| | Controlled grazing zones | 106.3 ± 10.8, n=120 | | |
| | Non-cattle grazing zones | 133.3 ± 13.4, n=120 | | |

### 4.2.2 Percent Estimated Vegetation Ground Cover

Percent estimated vegetation ground cover was lower in the bomas (mean±SE, 46.6 ± 1.35 %) than in the controlled grazing zones (61.61 ± 1.13 %) or the non-cattle grazing zones (72.13 ± 1.46 %) in the mixed and the black cotton soils (Figure 5). There was a significant difference in mean percent estimated vegetation ground cover among the three grazing treatments, $F_{2, 1197} = 94.986$, $p<0.05$ and sequential Tukey test showed that significant differences in mean percent estimated vegetation ground cover ($p>0.05$) occurred in all the three grazing treatments as they were different from each other.

Percent estimated vegetation ground cover was not significantly higher ($t_{(2), 598} = -0.664$, $p>0.05$) in the black cotton soils (61.85 ± 0.943 %, n =600) compared to the mixed soils (58.37 ± 0.94 %, n = 600). The wet season at 76.53 ± 0.89 %, n = 600 had significantly higher mean percent estimated vegetation ground cover ($t_{(2), 1198}$= 24.639, $p< 0.05$) compared to the dry season at 43.69 ± 0.99 %, n = 600.

Percent estimated vegetation ground cover among the three grazing zones was significantly different in the mixed soils ($F_{2, 597}$ = 43.051, $p<0.05$) and in the black cotton soils ($F_{2, 597}$ = 56.119, $p<0.05$) as well as during the dry season ($F_{2, 597}$ = 228.17, $p<0.05$) and the wet season ($F_{2, 297}$ = 27.448, $p<0.05$) (Table 3). Sequential Tukey tests showed that the differences in percent estimated vegetation ground cover in the mixed soils occurred between the bomas and the controlled grazing zones as well as between the bomas and the non-cattle grazing zones while in the black cotton soils, the three grazing zones were different from each other in their estimated vegetation ground cover. During the dry and wet seasons percent estimated vegetation ground cover was different in each of the three grazing treatments.

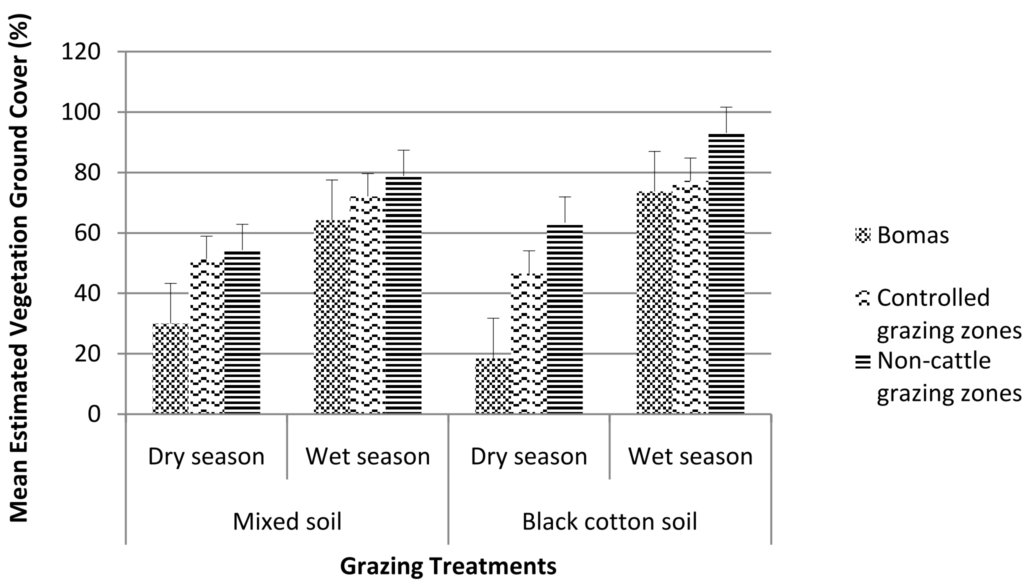


**Figure 5**: Mean percent estimated vegetation ground cover (%) ±SE in the bomas, controlled grazing zones and non-cattle grazing zones of the mixed soil and black cotton soil during the dry and wet seasons.

**Table 3:** Comparison of mean percent estimated vegetation ground cover (%) ±SE in bomas, controlled grazing zones and non-cattle grazing zones between the mixed soils and the black cotton soils and between the dry and the wet seasons (n = sample size, SE = standard error, NS = non-significant values, * = significant Values).

| | **Grazing treatment** | **Mean percent estimated vegetation ground cover(g/m²) ± SE** | **F- value** | **Significance level** |
|---|---|---|---|---|
| Mixed soils | Bomas | 47.1 ±1.7, n=200 | $F_{2, 597}$ = 43.051 | * |
| | Controlled grazing zones | 61.6 ± 1.3, n=200 | | |
| | Non-cattle grazing zones | 66.4 ± 1.6, n=200 | | |
| Black cotton soils | Bomas | 46.1 ± 2.4, n=200 | $F_{2, 597}$ = 56.119 | * |
| | Controlled grazing zones | 61.6 ± 1.8, n=200 | | |
| | Non-cattle grazing zones | 77.9 ± 2.1, n=200 | | |
| Dry season | Bomas | 24.2 ± 0.6, n=200 | $F_{2, 597}$ = 228.17 | * |
| | Controlledgrazing zones | 48.6 ± 1.3, n=200 | | |
| | Non-cattle grazing zones | 58.3 ± 1.4, n=200 | | |
| Wet season | Bomas | 69.0 ± 1.8, n=200 | $F_{2, 597}$ = 27.448 | * |
| | Controlled grazing zones | 74.6 ± 1.3, n=200 | | |
| | Non-cattle grazing zones | 85.9 ± 1.8, n=200 | | |

### 4.2.3 Proportion of Plant Parts Biomass

Leaves and stems available for consumption were highest in the non-cattle grazing zones and lowest in the bomas during both dry and wet seasons, however, the biomass of leaves in the black cotton soil bomas during the wet season was higher than the biomass of leaves in the black cotton controlled grazing zones for the wet season. Seed heads available for consumption were highest in the bomas and lowest in the controlled grazing zones (Figure 6 & 7).

Mean biomass of leaves, stems and seed heads differed significantly ($F_{4, 590} = 3.676$, $p<0.05$) among the three grazing treatments (Table 4) and a sequential Tukey test established that the mean available biomass differed between the seed heads and the leaves as well as between the seed heads and the stems. The leaves and the stems did not show any significant difference ($p<0.05$).

Biomass available for wildlife consumption during the dry season was highest in the stems (Figure 6) while in the wet season it was highest in the leaves (Figure 7). The wet season had more seed heads than the dry season. There was a significant difference in the mean biomass of leaves, stems and seed heads ($F_{2, 593} = 28.340$, $p<0.05$) during the dry and wet seasons (Table 4) and Tukey test showed that the differences in mean biomass occurred between the seed heads and the leaves as well as between the seed heads and the stems, however, there was no difference between the leaves and the stems in both seasons.

During the wet season, seed heads in the black cotton soil bomas were slightly more than seed heads in the mixed soil bomas (Figure 7). Available biomass of leaves, stems and seed heads was not significantly higher ($F_{2, 593} = 0.071$, $p>0.05$) in the black cotton soils compared to the mixed soils (Table 4).

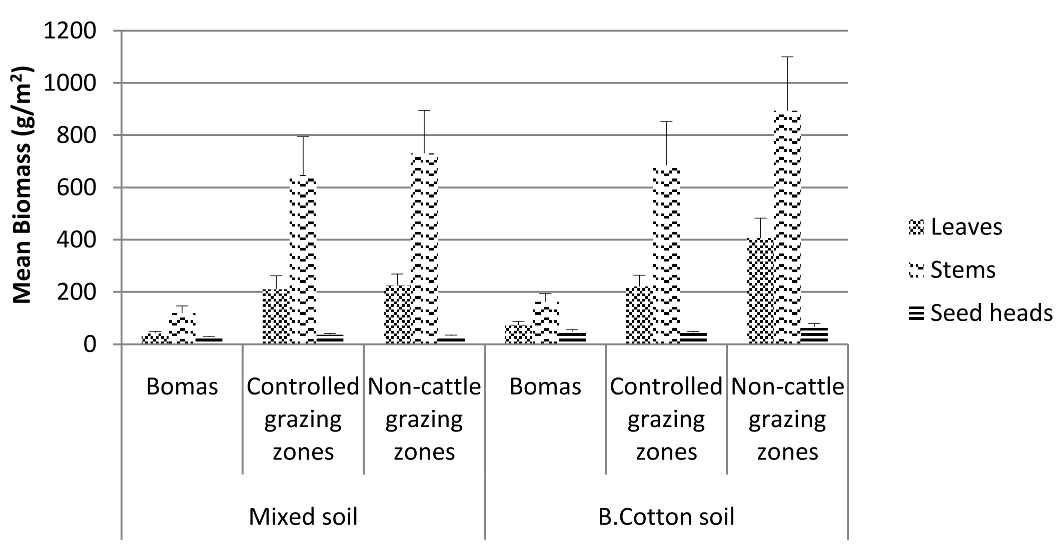


**Figure 6**: Dry season mean biomass (g/m²) ±SE of leaves, stems and seed heads in the bomas, controlled grazing zones and non-cattle grazing zones of the mixed soil and black cotton soil.

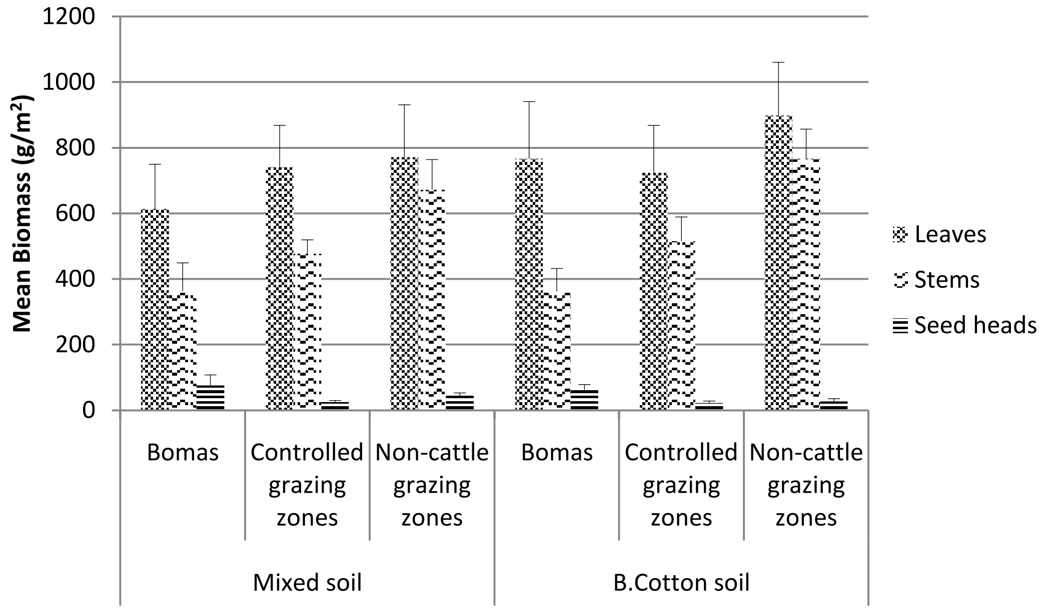


**Figure 7:** Wet season mean biomass (g/m$^2$) ±SE of leaves, stems and seed heads in the bomas, controlled grazing zones and non-cattle grazing zones of the mixed soil and black cotton soil.

**Table 4**: Two way ANOVA for comparing the mean biomass (g/m$^2$) of leaves, stems and seed heads between the three grazing treatments in the mixed and black cotton soils during both the dry and wet seasons.

| **Differences between mean plant part biomass among grazing treatments** | | | |
|---|---|---|---|
| **Factor** | **df** | **F-ratio** | **P value** |
| Mean biomass of different plant parts (g/m$^2$) | 2 | 8.429 | <0.001 |
| Grazing Treatment | 2 | 41.5 | <0.001 |
| Interaction (Biomass*Grazing Treatment) | 4 | 3.676 | 0.006 |
| Error | 590 | | |
| **Differences between mean plant part biomass between soil types** | | | |
| Mean biomass of different plant parts (g/m$^2$) | 2 | 38.945 | <0.001 |
| Soils | 1 | 0.241 | 0.624 |
| Interaction (Biomass*Soils) | 2 | 0.071 | 0.931 |
| Error | 593 | | |
| **Differences between mean plant part biomass between seasons** | | | |
| Mean biomass of different plant parts (g/m$^2$) | 2 | 47.883 | <0.001 |
| Seasons | 1 | 51.615 | <0.001 |
| Interaction (Biomass*Seasons) | 2 | 28.340 | <0.001 |
| Error | 593 | | |

### 4.3 Vegetation Quality

#### 4.3.1 Crude Protein and Crude Fibre Analysis

Crude proteins and crude fibres content analysis were done only for the dry season as the wet season samples got destroyed in the laboratory. There was no significant difference in crude proteins ($t_{(2),\ 10}$ = 0.764, p>0.05) and crude fibres ($t_{(2),\ 10}$ = 0.69, p>0.05) content between the mixed and the black cotton soils (Figure 8).

There were no significant differences in crude fibres content ($F_{2, 9}$ = 0.691, p>0.05) among the non-cattle grazing zones (mean±SE, 51.08 ± 1.32%), the controlled grazing zones (47.27 ± 1.91%) and the bomas (45.38 ± 1.75%). Similarly, there were no significant differences in crude proteins content ($F_{2, 9}$ = 0.691, p>0.05) among the non-cattle grazing zones (6.01 ± 2.07%), the bomas (5.97 ± 0.28%) and the controlled grazing zones (5.06 ± 0.32%) (Figure 8).

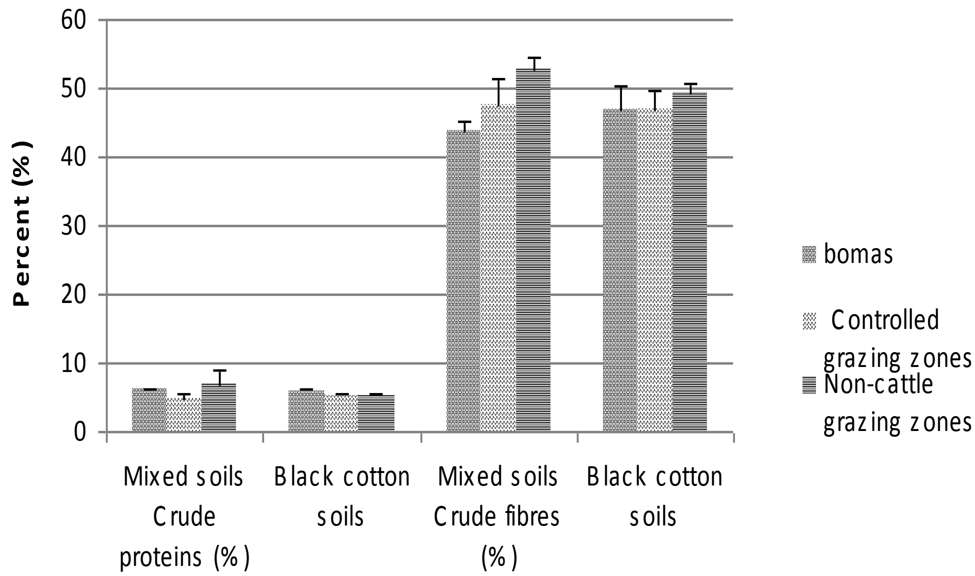


**Figure 8**: Dry season comparison of mean crude protein content (%) ±SE and mean crude fibre content (%) ±SE in forage between the mixed and black cotton soil.

#### 4.4 Species Diversity

There were significant differences in mean species diversity ($F_{2, 117}$ = 3.398, p<0.05) among the non-cattle grazing zones (0.5103 ± 0.069 H', n=40) the controlled grazing zones (0.4393 ± 0.068 H', n=40) and the bomas (0.2753 ± 0.059 H', n=40) (Figure 9). A sequential Tukey test showed that differences in the mean species diversity occurred between the bomas and the non-cattle grazing zones.

Mean species diversity in the mixed soils (0.526 ± 0.055 H', n= 60) was significantly higher ($t_{(2), 118}$ = 3.163, p<0.05) than in the black cotton soils (0.291 ± 0.05 H', n= 60) while species diversity in the wet season (0.60 ± 0.059 H', n= 60) was significantly higher ($t_{(2), 54}$ = -4.593, $p<0.05$) than in the dry season (0.216 ± 0.035 H', n = 60).

Plant species diversity among the three grazing treatments was significantly different in the mixed soils ($F_{2, 57}$ = 4.356, $p<0.05$) but it was not in the black cotton soils ($F_{2, 57}$ = 0.76, $p>0.05$). Plant species diversity among the grazing treatments was not significantly different in the dry ($F_{2, 57}$ = 1.917, $p>0.05$) or in the wet season ($F_{2, 57}$ = 2.635, $p>0.05$) (Table 5). Tukey test established that the differences in species diversity among the three grazing treatments in the mixed soils occurred between the bomas and the controlled grazing zones as well as between the bomas and the non-cattle grazing zones.

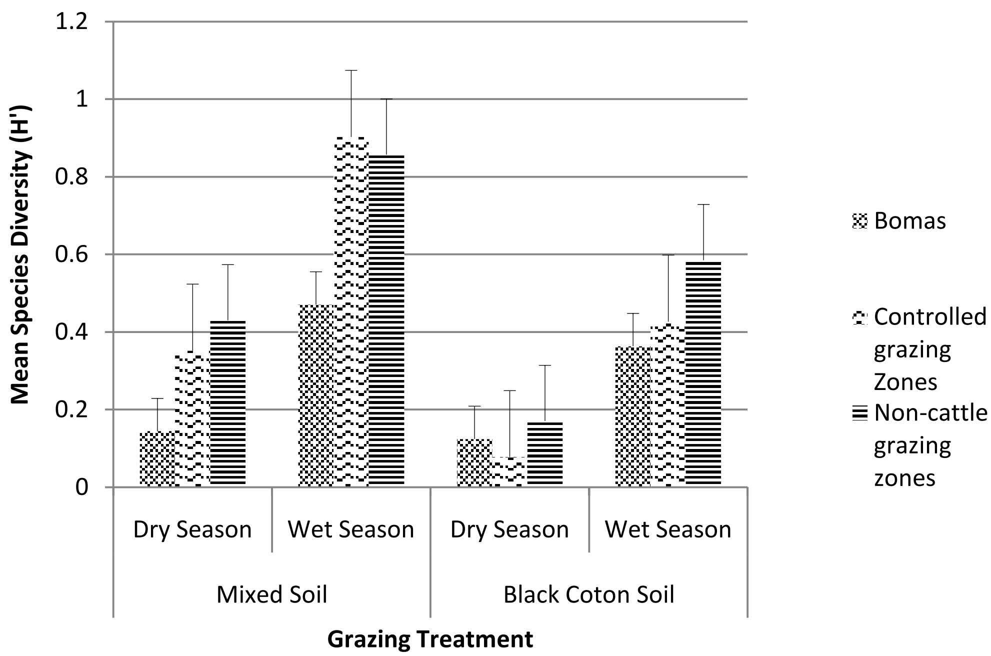


**Figure 9**: Mean species diversity (H') ±SE in the bomas, controlled grazing zones and non-cattle grazing zones of the mixed and black cotton soils during both the dry and wet seasons.

**Table 5:** Comparison of plant species diversity (H') ±SE in the bomas, controlled grazing zones and non-cattle grazing zones between the mixed soils and the black cotton soils and between the dry and the wet seasons (n = sample size, SE = standard error, NS = non-significant values, * = significant Values).

| | Grazing treatment | Mean plant species diversity (H') ±SE | F- value | Significance level |
|---|---|---|---|---|
| Mixed soils | Bomas | 0.307± 0.1, n=20 | $F_{2, 57} = 4.356$ | * |
| | Controlled grazing zones | 0.63 ± 0.1, n=20 | | |
| | Non-cattle grazing zones | 0.64 ± 0.08, n=20 | | |
| Black cotton soils | Bomas | 0.243 ± 0.08, n=20 | $F_{2, 57} = 0.76$ | NS |
| | Controlled grazing zones | 0.25 ± 0.07, n=20 | | |
| | Non-cattle grazing zones | 0.38 ± 0.1, n=20 | | |
| Dry season | Bomas | 0.134 ± 0.05, n=20 | $F_{2, 57} = 1.917$ | NS |
| | Controlled grazing zones | 0.214 ± 0.07, n=20 | | |
| | Non-cattle grazing zones | 0.3 ± 0.06, n=20 | | |
| Wet season | Bomas | 0.42 ± 0.1, n=20 | $F_{2, 57} = 2.635$ | NS |
| | Controlled grazing zones | 0.66 ± 0.1, n=20 | | |
| | Non-cattle grazing zones | 0.72 ± 0.1, n=20 | | |

### 4.5 Vegetation Productivity

The disc pasture meter height readings (cm) were converted to biomass (g/$m^2$) and used to estimate productivity. Mean vegetation productivity in the black cotton soils (294.48 ± 14.12 g/$m^2$/wk, n=70) was significantly greater ($t_{(2), 138} = -3.227$, $p<0.05$) than in the mixed soils (231.22 ± 12.77 g/$m^2$/wk, n=70) (Figure 10) while the wet season (309.34 ± 19.79 g/$m^2$/wk, n=40) had significantly greater ($t_{(2), 138} = -3.144$, $p<0.05$) vegetation productivity compared to the dry season (242.96 ± 10.76 g/$m^2$/wk, n=100).

A one way ANOVA which compared the means of the different groups whose biomass were taken after an interval of two weeks showed no significant differences ($F_{6, 133} = 1.726$, $p>0.05$) in mean biomass in the two weeks interval readings.

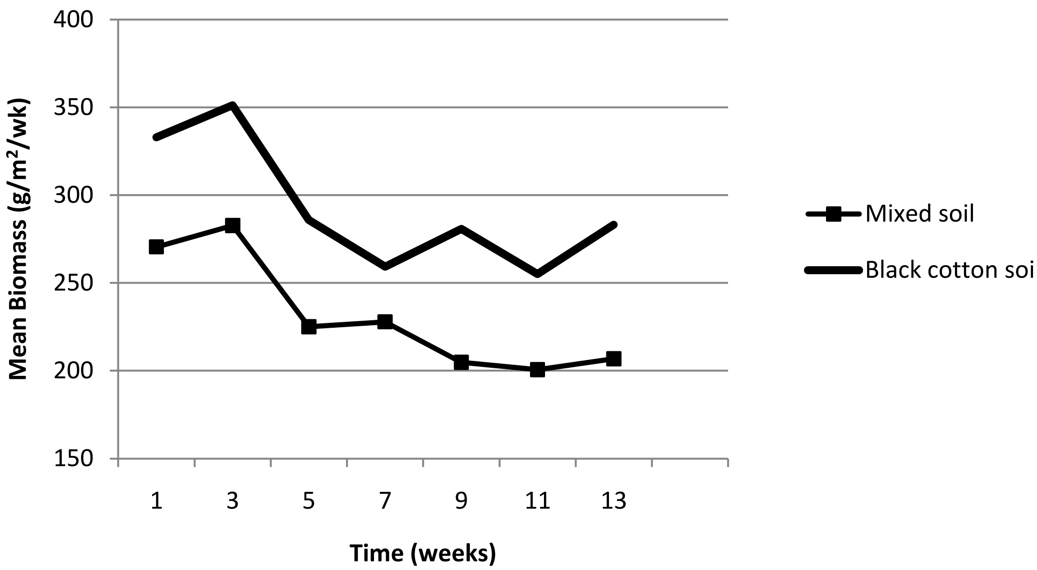


**Figure 10**: Comparison of vegetation productivity (biomass in $g/m^2/wk$) between the mixed and the black cotton soils.

#### 4.6 Off-takes by the Mammalian Herbivores.

Mean off-takes by mammalian herbivores were lowest in the non-cattle grazing zones ($5.5 \pm 5.65$ $g/m^2$, n=140) followed by the controlled grazing zones ($15.84 \pm 6.02$ $g/m^2$, n=140) and highest in the bomas ($37.82 \pm 3.43$ $g/m^2$, n=138). A significant difference in mean off-takes ($F_{2, 415} = 10.241$, $p<0.05$) was established among the three grazing treatments (Figure 11). Sequential Tukey test done to compare the three grazing treatments showed that differences in mean off-takes occurred between the bomas and the controlled grazing zones as well as between the bomas and the non-cattle grazing zones.

In total, 59 (1 x 1m) cages were placed at the different transects and out of the 59 cages, 11 cages were destroyed by the herbivores as they were trying to graze on the grass that was enclosed by the cage. Of the 11 destroyed cages, 8 were found in the bomas, 1 in the controlled grazing zone and 2 in the non-cattle grazing zones. Of the 8 cages destroyed in the bomas, 3 were located in the black cotton soils while 5 were located in the mixed soils.

Mean off-takes in the black cotton soils (33.91 ± 4.65, n = 210) were significantly higher ($t_{(2), 228} = -8.770$, $p<0.05$) than in the mixed soils (5.53 ± 3.66, n = 208) while off-takes during the wet season (16.77 ± 5.28, n =121) were not significantly higher ($t_{(2), 236} = -0.704$, $p>0.05$) than for the dry season (10.7 ± 6.86, n = 117).

Off-takes among the three grazing treatments was significantly different in the mixed soils ($F_{2, 182} = 3.537$, $p<0.05$) and in the black cotton soils ($F_{2, 181} = 12.371$, $p<0.05$) as well as during the dry ($F_{2, 249} = 9.263$, $p<0.05$) and the wet season ($F_{2, 114} = 3.748$, $p<0.05$) (Table 6). Sequential Tukey tests showed that the differences in off-takes in both the mixed and the black cotton soils occurred between the bomas and the controlled grazing zones as well as between the bomas and the non-cattle grazing zones. Differences in mean off-takes among the three grazing treatments during both the dry and wet seasons occurred between the bomas and the controlled grazing zones as well as between the bomas and the non-cattle grazing zones.

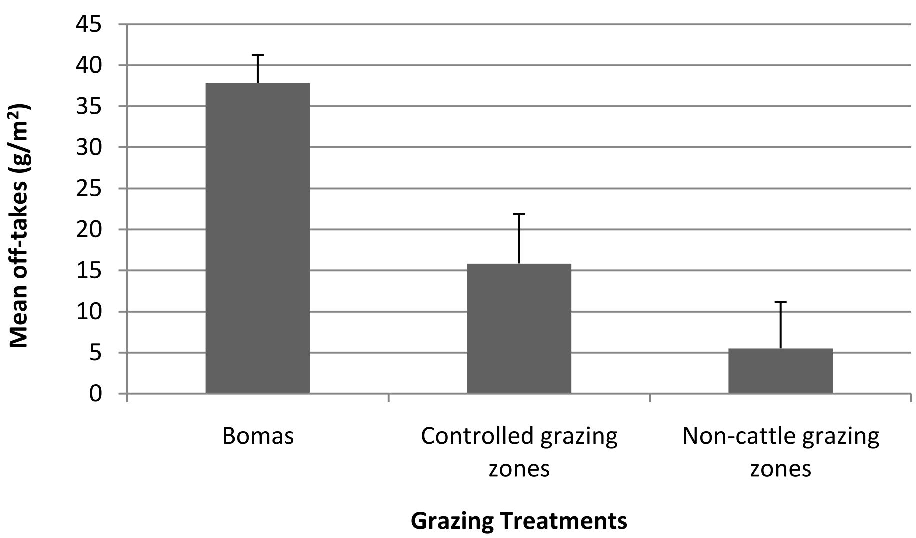


**Figure 11**: Comparison of mean off-takes (g/m$^2$) ±SE by mammalian herbivores in the bomas, controlled grazing zones and the non-cattle grazing zones in the mixed and black cotton soils.

**Table 6:** Comparison of off-takes by mammalian herbivores (g/m$^2$) ±SE in the bomas, controlled grazing zones and non-cattle grazing zones between the mixed soils and the black cotton soils and between the dry and the wet seasons (n = sample size, SE = standard error, * = significant Values).

| | **Grazing treatment** | **Mean off-takes by mammalian herbivores (g/m$^2$)** | **F- value** | **Significance level** |
|---|---|---|---|---|
| Mixed soils | Bomas | 0.3 ± 0.2, n=61 | $F_{2, 182} = 3.537$ | * |
| | Controlled grazing zones | -1.13 ± 0.5, n=66 | | |
| | Non-cattle grazing zones | -0.9 ± 0.5, n=58 | | |
| Black cotton soils | Bomas | 1.04 ± 0.3, n=59 | $F_{2,181} = 12.371$ | * |
| | Controlled grazing zones | -0.32 ± 0.5, n=70 | | |
| | Non-cattle grazing zones | -2.3 ± 0.6, n=55 | | |
| Dry season | Bomas | 1.0 ± 0.2, n=82 | $F_{2, 29} = 9.263$ | * |
| | Controlled grazing zones | -0.6 ± 0.4, n=96 | | |
| | Non-cattle grazing zones | -1.2 ± 0.4, n=74 | | |
| Wet season | Bomas | 0.08 ± 0.3, n=38 | $F_{2, 114} = 3.748$ | * |
| | Controlled grazing zones | -1.0 ± 0.7, n=40 | | |
| | Non-cattle grazing zones | -2.6 ± 0.7, n=39 | | |

### 4.7 Dung Density

There was a significant difference in mean dung piles/ha ($F_{2, 81} = 12.248$, $p<0.05$) among the bomas (4.59 ± 0.83 dung piles/ha) the controlled grazing zones (1.40 ± 0.27 dung piles/ha) and the non-cattle grazing zones (1.14 ± 0.29 dung piles/ha). Sequential Tukey test showed that the difference in mean dung density occurred between the bomas and the controlled grazing zones as well as between the bomas and the non-cattle grazing zones (Figure 12).

Mean dung density in the mixed soils (3.5 ± 0.64 dung piles/ha, n=42) was significantly higher ($t_{(2), 76} = 5.617$, $p<0.05$) than in the black cotton soils (1.5 ± 0.28 dung piles/ha, n=42) (Table 7).

Mixed feeders comprised of; Dikdiks, Elands, Elephants, Grant's gazelles, Impalas, Oryx and Monkeys while the grazers comprised of; Buffalos, Wart-hogs, Water bucks, Grevy's zebras, Plain zebras and the White rhinos. Mean dung density from the grazers (0.67 ± 0.08 dung piles/ha, n=121) was not significantly higher ($t_{(2),\ 324} = -0.444$, $p>0.05$) than that of the mixed feeders (0.61 ± 0.083 dung piles/ha, n=205) (Table 7).

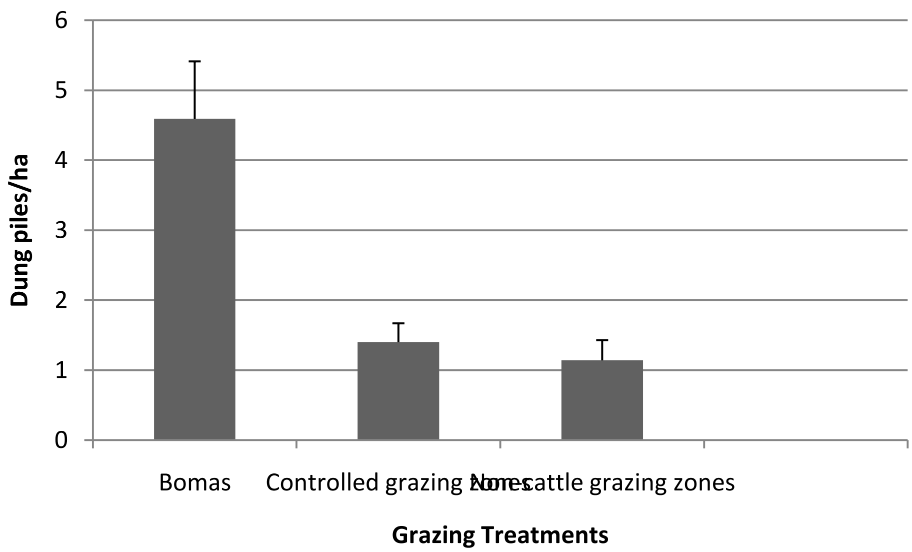


**Figure 12**: Comparison of mean dung density (dung piles/ha) ±SE for wild mammalian herbivores in the bomas, controlled grazing zones and the non-cattle grazing zones in the mixed and black cotton soils.

**Table 7**: Mean number of dung piles/ha and animal species richness (S) as estimated by dung density in the mixed and black cotton soils (n = sample size, SE = standard error).

| Soil Type | Grazing treatment | Type of feeder | Species richness | Mean number of dung piles/ha ± SE |
|---|---|---|---|---|
| Mixed soils | Boma | Mixed feeders | 7 | 1.41 ± 0.26, n = 56 |
| | | Grazers | 4 | 0.92 ± 0.24, n = 22 |
| | Grazing zones | Mixed feeders | 8 | 0.22 ± 0.04, n = 35 |
| | | Grazers | 5 | 0.56 ± 0.17, n = 26 |
| | Non-cattle grazing zones | Mixed feeders | 7 | 0.27 ± 0.06, n = 37 |
| | | Grazers | 4 | 0.427 ± 0.10, n = 31 |
| Black cotton soils | Boma | Mixed feeders | 5 | 0.58 ± 0.12, n = 30 |
| | | Grazers | 4 | 1.32 ± 0.4, n = 15 |
| | Grazing zones | Mixed feeders | 6 | 0.23 ± 0.04, n = 23 |
| | | Grazers | 5 | 0.47 ± 0.08, n = 27 |
| | Non-cattle grazing zones | Mixed feeders | 4 | 0.23 ± 0.08, n = 11 |
| | | Grazers | 3 | 0.26 ± 0.09, n = 13 |

### 4.8 Vegetation Survey in Abandoned Bomas

#### 4.8.1 Standing Crop of Grass

There was no significant difference in standing crop of grass ($F_{4,195} = 2.284$, $p>0.05$) among bomas aged one to five seasons old (Table 8). The mean standing crop of grass among bomas aged one to five seasons old was significantly different ($F_{4, 295} = 2.911$, $p<0.05$) in the mixed soils while it was not ($F_{2, 297} = 2.719$, $p>0.05$) in the black cotton soils. In the mixed soils, the mean standing crop of grass was highest in five seasons old bomas (479.9 ± 59.2 g/m$^2$) and lowest in one season old bomas (250.85 ± 60.9 g/m$^2$).

There were no significant differences in standing crop of grass among bomas aged one to five seasons old in the dry season ($F_{3, 296} = 0.193$, $p>0.05$) or in the wet season ($F_{3, 296} = 0.828$, $p>0.05$).

**Table 8**: Comparisons of mean standing crop of grass ($g/m^2$), percent estimated vegetation ground cover (%), species diversity (H'), off-takes by mammalian herbivores ($g/m^2$), and dung density (dung piles/ha) ±SE in different boma ages.(SE = standard error, NS = non- significant values, * = significant values).

| **Boma Age (Seasons)** | **Standing Crop of Grass ($g/m^2$)** | **Percent Estimated Vegetation Ground Cover (%)** | **Species Diversity (H')** | **Off-takes by Mammalian Herbivores ($g/m^2$)** | **Dung Density (Dung piles/ha)** |
|---|---|---|---|---|---|
| **1** | 85.34 ±17.08 | 24.12 ± 0.85 | 0.06 ± 0.06 | 42.83 ± 7.32 | |
| **2** | 294.09 ± 53.53 | 47.43 ± 2.613 | 0.14 ± 0.054 | 51.21 ± 6.058 | |
| **3** | 294.51 ± 69.74 | 55.0 ± 3.037 | 0.33 ± 0.142 | 24.58 ± 7.78 | 0.57 ± 0.10 |
| **4** | 351.76 ± 90.94 | 57.47 ± 3.67 | 0.79 ± 0.123 | 18.83 ± 3.43 | 1.65 ± 0.41 |
| **5** | 287.07 ± 115.23 | 55.53 ± 3.412 | 0.29 ± 0.29 | 33.06 ± 6.174 | 1.36 ± 0.35 |
| | $F_{4,195} = 2.284$ **NS** | $F_{4,395} = 9.788$* | $F_{4,35} = 6.076$* | $F_{4,135} = 0.698$* | $F_{3,111} = 2.356$ **NS** |

#### 4.8.2 Percent Estimated Vegetation Ground Cover

There was a significant difference in percent estimated vegetation ground cover ($F_{4, 395}$ = 19.788, $p<0.05$) among bomas aged one to five seasons. Sequential Tukey test showed that one season old bomas were different from the older bomas (Table 8).

Significant differences in percent estimated vegetation ground cover of different boma ages were established both in mixed ($F_{4, 595}$ = 45.370, $p<0.05$) and black cotton soils ($F_{2, 597}$ = 66.843, $p<0.05$). In the mixed soils, percent estimated vegetation ground cover was highest in five seasons old bomas (67.7 ± 1.9 %) and lowest in one season old bomas (43.6 ± 1.4 %) whereas in the black cotton soils, it was highest in five seasons old bomas (81.2 ± 2.1 %) and lowest in one season old bomas (42.4 ± 2.3 %).

During the dry season, there was no significant difference in percent estimated vegetation ground cover in different boma ages ($F_{3, 596}$ = 0.933, $p>0.05$) while there was during the wet season ($F_{3, 596}$ = 7.975, $p<0.05$). Wet season mean percent estimated vegetation ground cover was highest in four seasons old bomas (78.6 ± 2.0 %) and lowest in five seasons old bomas (64.5 ± 2.0 %) and a sequential Tukey test showed that percent estimated vegetation ground cover in five seasons old bomas was different from the younger bomas.

#### 4.8.3 Species Diversity

Significant differences in species diversity ($F_{4, 35}$ = 6.076, $p<0.05$) were found among bomas aged one to five seasons old with four seasons old bomas having the highest species diversity (0.79 ± 0.12 H') and one season old bomas having the least (0.064 ± 0.063 H') (Table 8).

Species diversity in different boma ages of the mixed soils was significantly different ($F_{4, 55}$ = 6.923, $p<0.05$) while it was not ($F_{2, 57}$ = 1.835, $p>0.05$) in the black cotton soils. Mixed soils species diversity was highest in five seasons old bomas (0.78 ± 0.18 H') and lowest in one season old bomas (0.21 ± 0.07 H').

Species diversity in different boma ages was significantly different ($F_{3, 56}$ = 7.222, $p<0.05$) in the dry season while it was not ($F_{3, 56}$ = 2.616, $p>0.05$) in the wet season. Mean species diversity in the dry season was greatest in four seasons old bomas (0.61 ± 0.11 H') and least in two seasons old bomas (0.10 ± 0.05 H').

#### 4.8.4 Off-takes by Mammalian Herbivores

Significant differences in off-takes ($F_{4, 135} = 3.698$, $p<0.05$) were found in different boma ages with mean off-takes being highest in two seasons old bomas (51.2 ± 6.1 $g/m^2$) and lowest in four seasons old bomas (18.8 ± 3.4 $g/m^2$) (Table 8).

Mean off-takes in different boma ages both in the mixed ($F_{4, 203} = 3.507$, $p<0.05$) and black cotton soils ($F_{2, 207} = 5.538$, $p<0.05$) was significantly different. Off-takes by mammalian herbivores in the mixed soils was highest in five seasons old bomas (23.4 ± 10.3 $g/m^2$) and lowest in one season old bomas (-13.9 ± 6.2 $g/m^2$ ) while in the black cotton soils it was highest in one season old bomas (48.0 ± 5.8 $g/m^2$) and lowest in three seasons old bomas (2.5 ± 14.7 $g/m^2$).

Off-takes in different boma ages was significantly different in the dry season ($F_{3, 294} = 8.164$, $p<0.05$) while it was not in the wet season ($F_{3, 116} = 0.385$, $p>0.05$). Off-takes during the dry season were highest in two seasons old bomas (46.5 ± 6.7 $g/m^2$) and lowest in four seasons old bomas (5.6 ± 6.1 $g/m^2$).

#### 4.8.5 Dung Density

There was no significant difference in dung piles ($F_{3, 111} = 2.356$, $p>0.05$) among bomas aged three to five seasons old (Table 8).

Dung density in different boma ages was not significantly different in the mixed soils ($F_{2, 196} = 1.049$, $p>0.05$) while it was in the black cotton soils ($t_{(2), 119} = 2.342$, $p<0.05$). Dung density in the black cotton soils was highest in three seasons old bomas (0.8 ± 0.2 dung piles/ha) and lowest in four seasons old bomas (0.4 ± 0.1 dung piles/ha).

# CHAPTER 5

## DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS.

### 5.1.1 Vegetation Quantity

Standing crop of grass was highest in the non-cattle grazing zones, followed by the controlled grazing zones and lowest in the bomas. This indicates that the intensity of cattle grazing and trampling was directly proportional to the standing crop of grass.

Biomass in the bomas and the non-cattle grazing zones of the black cotton soil was higher than that of the mixed soil indicating that the production potential of the herbaceous layer of the black cotton soils in Lewa Wildlife Conservancy could be higher than that of the mixed soils. This observation agrees with Botha (1999) that the grass cover and production potential of vertisols or black cotton soils are normally high but their recovery potential is slow in the event of overgrazing. There was a great increase in biomass from the bomas to the controlled grazing zones and to the non-cattle grazing zones in both the black cotton and the mixed soils during the wet season. This could mainly be attributable to rainfall.

Percent estimated vegetation ground cover was greater in the non-cattle grazing zones than in the controlled grazing zones or in the bomas. These results are consistent with the standing crop of grass in the three grazing treatments and are also directly proportional to the intensity of cattle grazing and trampling.

Leaves and stems available for consumption were highest in the non-cattle grazing zones and lowest in the bomas during both the dry and wet season. Two factors could be attributed to high proportion of leaves and stems biomass available for consumption in the non-cattle grazing zones. First, the high amounts of total herbaceous biomass available in the non-cattle grazing zones versus the small amounts of total herbaceous biomass available in the bomas. Secondly, off-take preference by the wild mammalian herbivores was highest in the bomas thus reducing the biomass available for wildlife consumption in the bomas. However, the biomass of leaves in the bomas located in the black cotton soil during the wet season was greater than the biomass of leaves in the black cotton controlled grazing zones for the wet season indicating the effect of rainfall and intensive cattle grazing on vegetation quantity.

Biomass tended to increase more in bomas than in the controlled grazing and non-cattle grazing zones after the rains. This suggests that intensive cattle grazing and trampling increase the vegetation quantity of the herbaceous layer by opening up the ground so that foreign seeds, dispersed by cattle through their metabolism, and existing seeds can sprout out with adequate light (Strang, 2008). The effect of rainfall on available biomass for consumption by wildlife is apparent because in the dry season, available biomass for wildlife consumption was greatest in the stems while it was greatest in the leaves during the wet season. In addition, the wet season had more seed heads compared to the dry season.

Seed heads available for consumption by animals were greatest in the bomas, suggesting that with time and depending on the amount of rainfall the bomas can turn out to be fertile clades compared to the surrounding areas due to the dunging and trampling effects of cattle (Morris *et al*., 2008).

### 5.1.2 Vegetation Quality

#### 5.1.2.1 Crude Proteins and Crude Fibres

Crude proteins in tropical pastures are generally low and they are considered to be a limiting nutrient for mammalian grazers (Sinclair, 1972; Fryxell, 1985; Githaiga, 1991). This explains the low amounts of crude proteins in the three grazing treatments - which did not have any significant differences - in both the mixed and the black cotton soils during the dry season. There was no significant difference in crude proteins between the mixed and the black cotton soils implying that there were no obvious discrepancies in herbaceous vegetation quality beween these soil types.

Crude proteins are strongly correlated with the concentration of other nutrients being high in leaves, growing parts and the storage organs of plants and they have an inverse relationship with crude fibres and thus they are positively related to digestibility (Van Soest, 1967; Githaiga, 1991). Crude fibre content was highest in the non-cattle grazing zones, moderate in the controlled grazing zones and lowest in the bomas. The high percentage of crude fibres at the non-cattle grazing zones may lower the quality of forage preferred by the animals. Cattle grazing and trampling could be suggested as effective tools in improving vegetation quality by reducing the amounts of crude fibres in the forage. This is supported by the small amounts of crude fibres found in the bomas and controlled grazing zones of the mixed and black cotton soils respectively. When cattle graze and trample in one area before transfering to another area where they can deposit their dung and trample on moribund vegetation, they could improve the herbaceous vegetation quality of the new area by depositing their dung and creating more space for new and existing seedlings to sprout through their trampling effects. These activities could result in an increase of plant species diversity and a reduction of moribund vegetation thus a decrease in crude fibres and consequently an increase in crude proteins.

### 5.1.3 Species Diversity

Species diversity was higher in the non-cattle grazing zones, than in the controlled grazing zones or the bomas suggesting that time is an important factor in the growth of new plants. All bomas considered for this project were abandoned between October 2007 and December 2008 indicating that the oldest boma considered for this study was at least twelve months old when observations began. Abandoned bomas had the greatest intensities of cattle grazing and trampling and by the time the cattle were moved to another area, vegetation in recently abandoned bomas was totally smothered. In the event of wet nights when the cattle were inside the bomas, the trampling effects of cattle left no observable standing crop only hoof prints of cattle. Growth and development of new plants either from existing seedlings buried in the soil or from dispersed seedlings by cattle would take more time in the bomas compared to the controlled grazing and non-cattle grazing zones where the intensities of cattle grazing and trampling were moderate and nil respectively.

During the wet season, the controlled grazing and the non-cattle grazing zones of both the mixed and the black cotton soils had greater species diversity compared to the bomas implying that rainfall did not have a great influence on increase in species diversity in bomas like time is assumed to have. The large dung deposits left in the corrals after they are abandoned could have an impact on plant succession for a long period of time. According to Muchiru (1992) and Morris *et al*., (2008) the nutrient enrichment effect of abandoned bomas creates fertile islands clearly visible in the savannas. Plant succession on these nutrient hotspots create a flush of grass that dominates the first twenty to sixty years post-abandonment, followed by a heavy cover of shrubs and trees. The effect of rainfall on species richness should, however, not be underestimated as rain enables new and existing seeds and grass butts to sprout and produce soft, green and abundant vegetation for plains game to feed on. Additionally, species diversity was observed to be greater during the wet season as opposed to the dry season.

Mixed soils had greater species diversity than the black cotton soils. Significant variations in species diversity in the black cotton soils and mixed soils could be as a result of different soil characteristics.

### 5.1.4 Vegetation Productivity

Variations in vegetation productivity among the grazing treatments was not considered due to limited funds for research. Vegetation productivity in the black cotton soils was greater than in the mixed soils. This observation corresponds to the bomas and the non-cattle grazing zones of the black cotton soils which had greater standing crop of grass than their counterparts in the mixed soils, further agreeing with Botha (1999) that the grass cover and production potential of black cotton soils are normally high.

Vegetation productivity during the wet season was greater than during the dry season implying that rainfall had an effect of increasing the production potential of the herbaceous cover of semi-arid moribund grasslands.

### 5.1.5 Off-takes by Mammalian Herbivores

Significant variations were observed in off-takes by mammalian herbivores among the three grazing treatments with most animals preferring to graze in the bomas, followed by the controlled grazing zones and lastly in the non-cattle grazing zones. Off-takes in the controlled grazing zones and the non-cattle grazing zones did not vary much as there was no significant difference between them though off-takes in the bomas were significantly different from these two treatments.

Most of the cages that were destroyed in the bomas were located in the mixed soil implying most animals utilize the mixed soils bomas compared to the black cotton soils bomas perhaps due to high plants species diversity, high crude protein content and low herbaceous biomass in the mixed soils.

### 5.1.6 Dung Density

Like off-takes by the mammalian herbivores, dung piles were greatest at the bomas. The controlled grazing zones followed and dung piles were least in the non-cattle grazing zones. This suggested that wildlife utilized the bomas more than they did in the controlled grazing and non-cattle grazing zones. Some of the reasons wild mammalian grazers would prefer to graze in the bomas compared to the other grazing treatments include: reduced biomass of grass in the bomas - which was soft and lush (Savory & Butterfield, 1999), high percentage of seed heads available for consumption, greater amounts of crude proteins than the controlled grazing zones and the low amounts of crude fibres compared to the controlled grazing and non-cattle grazing zones.

Dung density in the mixed soils was higher than in the black cotton soils suggesting that more animals utilized mixed soils and some of the reasons to explain this include: reduced biomass in mixed soils thus the degree of moribundness of the grass is reduced, greater species diversity and greater percent of crude proteins.

Both mixed feeders and grazers preferred to graze in the bomas, this is shown by the great numbers of dung densities in the bomas compared to the other treatments. They also preferred the mixed soil bomas to the black cotton soils bomas, maybe because of greater plants species diversity in the mixed soil bomas.

### 5.1.7 Vegetation Survey in Abandoned Bomas

Standing crop of grass was higher in older bomas compared to the younger bomas and this could be as a result of high biomass of grass in older bomas. One season old bomas in the black cotton soils had higher standing crop of grass compared to their counter-parts in the mixed soils implying that vegetation productivity in the black cotton soils was higher than in the mixed soils.

Percent estimated vegetation ground cover increased as the bomas became older implying that time had an effect on vegetation ground cover of semi-arid moribund grasslands practicing high levels of cattle grazing and trampling.

Species diversity was higher in older bomas compared to younger ones implying that time played an important role in increasing plants species diversity in semi–arid rangelands where intensive and controlled cattle grazing and trampling has been practiced. In the dry season, four seasons' old bomas had the highest levels of species diversity and were significantly different from the rest indicating further the effect of time on species diversity of abandoned bomas. Species diversity of different boma ages in the mixed soils was greater than in the black cotton soils indicating an ability of the mixed soils to improve species diversity faster than the black cotton soils. The difference in species diversity between the mixed and the black cotton soils could probably be as a result of different soil characteristics.

Younger bomas had higher levels of graze off-takes compared to older ones suggesting a preference of soft and green vegetation by wild grazers. Conversely mean off-takes in the wet season were higher in older bomas compared to younger ones perhaps due to high species diversity in older bomas during the wet season.

Older bomas had more dung piles compared to younger ones suggesting that most wild animals preferred to graze in older bomas perhaps due to their high levels of leaves, green plant parts and plants species diversity.

### 5.2 Conclusions and Conservation Management Recommendations

This study aimed to assess the effects of cattle grazing and animal impact as tools used in improving vegetation quality of moribund grasslands found in semi arid rangelands. These moribund grasslands had low species diversity, high and thick biomass and were not preferred by wild mammalian herbivores. This was confirmed by field methods during this project. Among other reasons why these grasslands had become moribund over the years was the under utilization of the vegetation by wildlife due to their availability in low densities. Improving their numbers and ranges was therefore of paramount importance and it was thought that the vegetation had something to do with their low densities. If vegetation could be improved, then the numbers of wild mammalian grazers could be improved due to improved fertility, increase of recruitment rates of juveniles into adults, increase of nutrients in the milk of lactating females among others (Lewa Wildlife Conservancy, 2007).

Cattle provide cheap and available tools for rangelands improvement; they are also readily available in large numbers in most semi-arid rangelands as these dry-lands are dominated by pastoral communities. Over the years these pastoral communities have overgrazed their livestock grazing areas and combined with changes to sedentary lifestyles, land for grazing livestock has greatly reduced. This however needs not to be the case. Cattle from the nomadic communities can be used to improve vegetation quality and in the long run both wildlife and livestock would greatly benefit from the improved health of the rangeland.

When one is planning for the number of cattle kept in a given area for a given duration of time, one should consider differing plant growth rates, maximization of rainfall, soil types, trampling levels, wildlife breeding, and water points among others. Recovery periods of vegetation rather than grazing periods should be considered (Grevy's Zebra Trust, 2009). Grazing periods should be derived from recovery periods. This would ensure proper management of grazing and trampling as tools used in improving the vegetation quality of rangelands.

The standing crop of grass was found to be related to the intensity of cattle grazing and trampling. This observation is important to rangeland managers as it would help them to understand how the stocking rate of grazers affect the vegetation quantity and therefore they would know how to regulate the stocking rate depending on their desired effect on vegetation quantity.

This study has unveiled the benefits of intensive but controlled cattle grazing and animal impact by trampling. Some of the benefits included reduction of moribund herbaceous biomass, greater number of seed heads which would translate to an increase in species diversity in future, high percentage of crude proteins in black cotton soils and reduced levels of crude fibres. Information from this study is therefore important for proper management of rangelands such that both livestock and wildlife can co-exist each occupying its own niche. As the cattle improve the vegetation quality, livestock owners can improve their financial status and wild mammalian herbivores can improve their numbers and range.

While the effects of intensive but controlled cattle grazing and trampling were unveiled from this study, further research would be required in the following areas:-

1. The effects of moderate intensities of livestock grazing and trampling on herbaceous vegetation quality, diversity and productivity of semi-arid moribund grasslands. Moderate intensities of animal grazing and impact reduced the vegetation quantity of moribund grasslands. However, no trends were established on vegetation quality, diversity and productivity of the controlled grazing zones.

2. The effects of time as a factor that affects vegetation quantity, quality and diversity on abandoned bomas need to be researched on. The oldest bomas considered for this study were six seasons old and though some trends were established, it would be important to monitor these bomas as time goes by so that long term changes in vegetation structure and composition of abandoned bomas can be known.

3. More research could also be done to establish other reasons beside soil characteristics as to why the black cotton soils have greater productivity and less species diversity.

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## 7.0 APPENDICES

### APPENDIX 1

A summary of regression equations used to calibrate the pin frame, the disc pasture meter and to estimate vegetative ground cover during the dry and wet season for both soil types (* = significant values at $p<0.05$).

| | | **BIOMASS ESTIMATED BY PIN HITS.**<br>Where:<br>Y=BIOMASS ($g/m^2$)<br>X=PIN HITS | **BIOMASS ESTIMATED FROM THE DISC PASTURE METER.**<br>Where:<br>Y=BIOMASS ($g/m^2$)<br>X = DISC HEIGHT READINGS (CM) | **PERCENT VEGETATION GROUND COVER ESTIMATED FROM PIN HITS.**<br>Where:<br>Y = % ESTIMATED GROUND COVER<br>X=PIN HITS |
|---|---|---|---|---|
| **MIXED SOILS** | **DRY SEASON** | Y=5.421+2.177x<br>$r^2=0.533$, $F_{1,40}=45.625$*, $p<0.001$ | Y=1.143+4.396x<br>$r^2=0.486$, $F_{1,19}=17.988$*, $p<0.001$ | Y=26.373+1.312x<br>$r^2=0.449$, $F_{1,19}=15.461$*, $p=0.001$ |
| | **WET SEASON** | Y=2.793+1.582x<br>$r^2=0.444$, $F_{1,124}=98.988$*, $p<0.001$ | Y=9.713+4.213x<br>$r^2=0.815$, $F_{1,18}=79.408$*, $p<0.001$ | Y=31.739+1.019x<br>$r^2=0.477$, $F_{1,19}=17.343$*, $p=0.001$ |
| **BLACK COTTON SOILS** | **DRY SEASON** | Y=8.792+2.239x<br>$r^2=0.515$, $F_{1,40}=42.511$*, $p<0.001$ | Y=12.557+4.116x<br>$r^2=0.575$, $F_{1,19}=25.708$*, $p<0.001$ | Y=11.354+1.849x<br>$r^2=0.476$, $F_{1,19}=17.226$*, $p=0.001$ |
| | **WET SEASON** | Y=1.690+1.712x<br>$r^2=0.342$, $F_{1,124}=64.353$*, $p<0.001$ | Y=5.408+5.298x<br>$r^2=0.838$, $F_{1,19}=98.031$*, $p<0.001$ | Y=31.386+1.243x<br>$r^2=0.577$,<br>$F_{1,19}=25.88$*, $p<0.001$ |

**APPENDIX 2**

Botanical names of grass species found in Lewa Wildlife Conservancy that contributed to the species diversity for this study.

| | **Names of grass species** |
|---|---|
| i) | *Aristida kenyensis* |
| ii) | *Brachiaria dictyoneum* |
| iii) | *Brachiaria eruciformis* |
| iv) | *Cenchrus ciliaris* |
| v) | *Cynodon dactylon* |
| vi) | *Digitaria abyssinica* |
| vii) | *Digitaria milanjiana* |
| viii) | *Digitaria velutina* |
| ix) | *Eragrostis cilianensis* |
| x) | *Eragrostis superba* |
| xi) | *Eriochloa nubica* |
| xii) | *Heteropogon contortus* |
| xiii) | *Lintonia nutans* |
| xiv) | *Microchloa kunthii* |
| xv) | *Panicum Poaeoides* |
| xvi) | *Pennisetum maasaicum* |
| xvii) | *Pennisetum mezianum* |
| xviii) | *Pennisetum stramenium* |
| xix) | Sedge- *Cyperus* |
| xx) | *Sehima nervosum* |
| xxi) | *Setaria acromelaena* |
| xxii) | *Setaria pumila* |
| xxiii) | *Sorghum Purpureo sericeum* |
| xxiv) | *Sporobolus pyramidalis* |
| xxv) | *Themeda triandra* |