ECOLOGICAL RESPONSE OF *CHLORIS ROXBURGHIANA* TO LIVESTOCK AND WILDLIFE GRAZING IN CHYULU HILLS NATIONAL PARK, KENYA

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Jesse Omondi Owino

Signature: _____

Date: 07/02/2013

APPROVAL

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

Dr. Elias K. Maranga (PhD)

Department of Natural Resources

Faculty of Environment and Resource Development

Egerton University

Signature: _____

Date: 7/2/2013

Dr. Fred Waweru (PhD)

Department of Tourism and Hospitality Management

Kimathi University College of Technology

Signature: _____

Date: 9/2/2013

2013/97326

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LIST OF ABBREVIATIONS AND ACRONYMS

ACC- African Conservation Centre

ADELE- Programme d'Appui au Development Local dans l'Est (Support program for local development in Eastern Africa)

ALRMP- Arid Lands Resources Management Project

ANPP- Above ground Net Primary Production

ASAL- Arid and Semi-Arid Lands

AU/IBAR- African Union Inter-African Bureau for Animal Resources

AWF- African Wildlife Foundation

BNPP- Below ground Net Primary Production

CAMPFIRE- Communal Area Management Programme

CBNRM Community Based Natural Resources Management

CHNP- Chyulu Hills National Park

DLWEIP- Dryland livestock wildlife environment interface

FGD- Focus Group Discussion

GEF- Global Environmental Facility

IUCN- International Union for Conservation of Nature

KWS- Kenya Wildlife Service

LGP- Length of Growing Period

MECV- Ministère de l'Environnement et du Cadre de Vie (Burkina Faso)

NEMA- National Environment Management Authority (Kenya)

NRM- Natural Resources Management

RCBD- Random Complete Block Design

RECOPA- Réseau de Communication sur le Pastoralisme (Burkina Faso)

TLU- Tropical livestock unit

TPN- Thematic Programme Network

UNCBD- United Nations Convention on Biological Diversity

UNCCD- United Nations Convention to Combat Desertification

UNEP- United Nations Environment Programme

UNFCCC- United Nations Framework Convention on Climate Change

ABSTRACT

The study aimed at evaluating the ecological response of *Chloris roxburghiana* which is a dominant graminoid species and provide bulk of forage to livestock and wildlife in Chyulu Hills National Park (CHNP) to grazing. The study was an attempt to evaluate the impacts of wildlife and livestock grazing within and outside the CHNP. The hypotheses tested by the study were based on the premise that livestock and wildlife grazing leads to negative consequences on biomass of forage resources. A Randomized Complete Block Design was used with 1 treatment and 12 replicates in each of the treatment blocks; livestock only, wildlife-livestock and wildlife only. The treatments were clipping at 1cm above the ground for the *Chloris roxburghiana* in 3 different sites in terms of type of grazing being impacted upon the site. Grazing simulation approaches were used to study the different grazing impacts in livestock only area, livestock wildlife area and wildlife only area. Frequency was once per each sampling area with replications within the block. Micro-histological analysis of faecal samples from both livestock and wildlife was done to determine dietary overlaps amongst livestock and wildlife. Analysis of Variance methods including the standard errors and standard deviations were used to determine the presence or absence of grazing impacts. The results of clipped weights *of Chloris roxburghiana* showed that livestock grazing alone had 8163.3kg/ha +/- 0.3, whereas wildlife grazing with livestock had 675510.2kg/ha +/- 0.7 and wildlife grazing alone had 614285.7kg/ha +/- 1.2. Abundance of *Chloris roxburghiana* in faecal composition was 91.14% in cattle, 90.74% in sheep, 94.54% in zebra and 95.75% in gazelle. These results indicate that livestock grazing had a greater effect on biomass of *Chloris roxburghiana* than wildlife livestock and wildlife only grazing in CHNP.

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TABLE OF CONTENTS

TITLE I

DECLARATION AND APPROVAL II

ACKNOWLEDGEMENT III

LIST OF ABBREVIATIONS AND ACRONYMS IV

ABSTRACT VI

TABLE OF CONTENTS VII

LIST OF FIGURES X

LIST OF PLATES XII

LIST OF TABLES XIII

CHAPTER ONE 1

INTRODUCTION 1

1.1 Statement of the problem 3

1.2 Broad objective 3

1.3 Specific objectives 3

1.4 Hypotheses 3

1.5 Justification 4

1.6 Scope of the study 4

CHAPTER TWO 6

LITERATURE REVIEW 6

2.1 Introduction 6

2.2 Land tenure systems of areas adjacent to protected areas. 6

2.3 Wildlife conservation in Kenya 7

2.4 Characteristics of grazed areas in Kenya 10
2.5 Wildlife and Environment Interface Management 11
2.6 Coexistence of livestock and wildlife 12
2.7 Trends in grazing rangelands 16
2.8 Livestock stocking rates 19
2.9 Trends in grazing land-use 20
2.10 Developmental morphology of grasses of Eastern Africa 21
2.10.1 Grass composition 21
2.10.2 Physiology 22
2.10.3 Defoliation 23
2.11 Conceptual Framework 26
CHAPTER THREE 30
RESEARCH METHODS 30
3.1 Study area 30
3.2 Geographical location 30
3.3 Climate 32
3.4 Drainage and Soil types 32
3.5 Vegetation type 32
3.6 Research design 34
3.7 Sampling 41
3.8 Sampling procedure 41
3.9 Sample size 42

3.10 Forage utilization and biomass measurements 45

3.11 Data analysis 49

CHAPTER FOUR 52

RESULTS AND DISCUSSION 52

4.1 Results 52

4.2 Discussion 63

4.2.1 Comparison of the study sites 67

4.2.2 Micro histological results 71

CHAPTER FIVE 73

CONCLUSIONS AND RECOMMENDATIONS 73

5.1 Conclusions 73

5.2 Recommendations 74

REFERENCES 75

APPENDICES 87

LIST OF FIGURES

Figure 1: Components of Sward Structure (Montague *et al*,1986)..... 27

Figure 2: The relationships of precipitation, grazing with biomass of *C.roxburghiana*..... 29

Figure 3: Map showing the study sites in CHNP. Source this study 2010 31

Figure 4: Satellite Map of CHNP showing vegetation distribution. Source Google Maps 2010 34

Figure 5: Map showing the transects in CHNP. Source this study 2010 38

Figure 6: Mean numbers of *C.roxburghiana* tuft height categories in livestock only area. 52

Figure 7: Mean numbers of *C.roxburghiana* tuft heights in wildlife only area..... 53

Figure 8: Mean numbers of *C.roxburghiana* tuft height categories in wildlife and livestock mixed area 53

Figure 9: Comparison of mean numbers of *C.roxburghiana* tuft heights in the study sites..... 54

Figure 10: Distribution comparisons of *C.roxburghiana* tuft heights categories in different sites. 54

Figure 11: Comparisons of culms of *C.roxburghiana* categories in study sites..... 55

Figure 12: distribution of comparisons of culms of *C.roxburghiana* categories in the study sites . 55

Figure 13: Distribution trends showing weights of clipped *C.roxburghiana* in comparison by sites 56

Figure 14: Mean weights of clipped *C.roxburghiana* across sampling sites..... 56

Figure 15: Means in weight of clipped *C.roxburghiana* comparison by sites..... 57

Figure 16: Frequency of *Chloris roxburghiana* culm categories comparison by sites..... 57

Figure 17: Percentage abundance of *Chloris roxburghiana* comparison by sites. 58

Figure 18: Abundance of *C.roxburghiana* in livestock. 61

Figure 19: Abundance of *C.roxburghiana* in wildlife 61

LIST OF PLATES

Plate 1: Livestock holding area within the wildlife-livestock area. 36

Plate 2: Faecal matter used to also corroborate the area being livestock- wildlife because of presence of both wildlife faeces as well livestock faeces in the same site. 41

Plate 3: Quadrat size used in the clipping treatments in a livestock only area. 42

Plate 4: Sample quadrat in a wildlife only area highlighting the dominant graminoid species *(C.roxburghiana)*. 43

Plate 5: Scale bars = 15 mm. Abaxial foliar epidermal tissues with stomatal complexes *C. roxburghiana*..... 44

Plate 6: Wildlife-livestock area only area without grass cover with a zebra in the mid-ground. 47

Plate 7: Livestock crowded in a wildlife-livestock area inside the park..... 4

Plate 8: Sampling area in a livestock only area after livestock has been moved showing no g cover.....

Plate 9: Wildlife and livestock grazing in the same site. .....

LIST OF TABLES

Table 1; Total fields of occurrence of *C. roxburghiana* in the livestock faecal samples which were compared with the reference slides..... 59

Table 2; Total fields of occurrence of C. roxburghiana in the wildlife faecal samples which were compared with the reference slides 60

Table 3; ANOVA results from clipping means 62

CHAPTER ONE

INTRODUCTION

Pastoralists and wildlife have co-existed in African rangelands for many hundreds of years (IUCN, 1997; Enors *et al.* 2007), though with few of the tensions evident today. In the past, human and livestock populations were relatively small and widely dispersed. However, competition for scarce grazing and water resources is increasing, and the potential for conflicts between wildlife managers and livestock owners is growing as pastoralists and agro-pastoralists move into new areas and/or live in the vicinity of protected areas. The main factors driving this transformation are increasing demographic pressure, the expansion of cultivation, and the reduction in rangeland resources, through privatization for commercial agriculture and ranching, and nationalization for conservation (IUCN, 1997; Oguge *et al.* 2006; Enors *et al.* 2007).

Large pastoral herds have generally been excluded in the participation of decisions regarding utilization of park resources. This transition has been accompanied by an overall reduction in tsetse infestation, either by direct control measures, or as an indirect consequence of the general decline in wildlife, habitat conversion and land use change associated with agricultural expansion. It has also been facilitated by increased access to veterinary drugs allowing herds into previously disease-prone areas (IUCN, 1997; Oguge *et al.* 2006; Enors *et al.*2007). The pastoralist communities living adjacent to CNHP have recently been violating park boundaries and grazing their animals in these areas. Livestock numbers are also increasing, presenting a challenge to the park authorities. The park authorities need information on the status of the resources accessible to both livestock and wildlife in the park. There is also concern on how livestock enters the parks and the consequences on the vegetation at their entry points (Mishra *et al.* 2004; Begzsuren *et al.* 2004).

Chyulu Hills National Park (CHNP) was gazetted in 1984 and further extended in 1996. It is under the KWS management. The park is located in a semi-arid ecosystem that falls within ecological zone IV (RoK, 2002). CHNP is a protected area that was established in total disregard to the communities which were living in the areas adjacent and some within the protected areas themselves (Mosse, 2003). It covers a total area of 74,518 ha; the park has continued to provide a life support system for a myriad of herbivores, spermatophytes (flowering plants) and fauna. In 1999, Kajiado District had a population of 406,054 people with Mashuru and Loitokitok Divisions

having 35,666 and 95,430 people respectively (RoK, 2002). In 1999 Makueni District had a population of 771,545 people with Mtito Andei, Makindu and Kibwezi Divisions having population of 66,663, 50,299 and 80, 236 people respectively (RoK 2000; RoK 2002). These show the increasing trends in human settlements around the park and the pressures being faced on CHNP.

Attempts by the KWS to evict human populations of pastoralists who had been residing in the areas North West of CHNP and who had been associated with the park from the time of inception have not yielded the desired results (KWS, 1996; Mosse, 2003). Communities adjacent to protected areas have been going on with their socio-economic activities such as in Kamnaret National Reserve where residents are found inside the reserve to date (KWS, 2008). *Chloris roxburghiana* is a dominant species in dryland areas of Kenya, and is usually found growing in association with *Chrysopogon aucheri* (Rattray, 1960). Despite its wide distribution, Herlocker (1999) treats this vegetation type as a subtype of the *Chrysopogon* mid-grass region. *Chloris roxburghiana* is widespread throughout the entire region of CHNP and is an important species for livestock and wildlife, in the areas from mid to north western of CHNP it occurs in pure stands.

The issue of competition between livestock and wild herbivores has remained contentious (IUCN 1997; Mishra *et al.* 2004; Western *et al.* 2007). Many have compared forage availability and population structures between rangelands differing in livestock density. The studies have found that livestock grazing causes a significant reduction in the standing crop of forage. Graminoid availability per unit livestock biomass was three times greater in a moderately grazed rangeland compared with an intensively grazed one (IUCN, 1997; Mishra *et al.* 2004; Western *et al.* 2007). There has been considerable diet overlap among the herbivore species. High diet overlap between livestock and wildlife, together with density-dependent forage limitation, results in resource competition and a decline in wildlife density (IUCN, 1997; Western *et al.* 2007). The various impacts of livestock and pastoralists in the protected areas have yet to be fully documented. The present study was thus conceived to evaluate the ecological response of *Chloris roxburghiana* to livestock and wildlife grazing.

1.1 Statement of the problem

The CHNP is exposed to a myriad of challenges especially from community activities such as grazing, charcoal burning, bee keeping and extraction of plant products for reasons such as herbal medicine. Like many other parks trespass by livestock from adjacent communnal grazing land is a major source of concern to park authorities. Also recent expansion of CHNP has been central to forced evictions of communities in the area, changing demographic patterns, invasion by non-pastoralist communities and causing increased agricultural practices hence causing an escalation in human-wildlife conflicts. The issue of grazing has been the bone of contention between the park authorities and the communities living adjacent to the park. The study evaluated the impact of human activities within and outside the park in terms of effects of livestock and wildlife grazing on the biomass of *Choris roxburghiana*.

1.2 Broad objective

The broad objective of this study was to evaluate the ecological response of *Chloris roxburghiana* to livestock and wildlife grazing in CHNP.

1.3 Specific objectives

1. To assess the effects ecological response of *Chloris roxburghiana* height in the areas grazed by livestock only, wildlife-livestock and wildlife only within and outside of CHNP.
2. To evaluate effects of livestock and wildlife grazing on biomass of *Chloris roxburghiana* in the areas dominantly used by livestock only, wildlife-livestock and wildlife only within and outside of CHNP.
3. To evaluate the extent of overlap of *Chloris roxburghiana* in diets of livestock and wildlife in CHNP.

1.4 Hypotheses

- There are no significant differences in height of *Chloris roxburghiana* in the areas dominantly used by livestock only, wildlife-livestock and wildlife only.

- There are no significant differences in biomass in the sites grazed by wildlife only, wildlife-livestock and livestock only.
- There is no significant difference in the diet composition of livestock and wildlife grazers.

1.5 Justification

The study was carried out in CHNP because of the special role CHNP plays as a water catchment area for the Mzima springs in Tsavo area. The area thus has unspecified economic value, for it would be very costly if the integrity of the water catchment role is compromised. Socially the area adjacent to CHNP has both the Maasai and Kamba community thus it provides a tourist base to sample two very distinct cultural communities. Despite these special and unique roles CHNP ecosystem is being degraded by human activities, particularly overgrazing leading to the punitive measures that involve use of helicopters to drive out large herds of livestock from the park thereby causing deaths in hundreds of livestock which is employed by the park management on the adjacent human communities. Wildlife parks undergo many impacts of human activities and more so incursion from livestock is usually perceived by park authorities to outcompete wildlife on grazing resources. The various impacts on national parks have been documented but whereas the issue of livestock grazing in national parks the rule has been not to allow any consumptive use with evidence of incursions by wildlife still present.

Motivation for the study is raised with the need to carry out research solutions to develop strategic interventions to enhance human and livestock-wildlife coexistence, also due the interest to find out if the management of parks should allow for grazing by the livestock of the communities adjacent to the parks in the buffer areas of park boundaries. The impacts of livestock-wildlife grazing on *Chloris roxburghiana* occasioned by trespass grazing often exceeding the carrying capacity have not been determined and documented.

1.6 Scope of the study

. The study was restricted to the north western side of the park boundaries as this is where trespass grazing mostly occurred. This study was limited to the park area that is being infiltrated by livestock, the area under both livestock and wildlife and a sample of the area grazed by wildlife only. The study embraced one season for rain and grazing simulation based on the limitations to

season as the grass production is by rain season to allow for study beginning of rainy season and follow through to the end of rain season. Also the grass species under study was the dominant grass *Chloris roxburghiana.*

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The wellbeing of societies and communities is dependent on resources. Resources are defined as those economically and ecologically useful goods and services that have an economic value and can be utilized to satisfy human needs. Natural resources such as land, water, vegetation and wildlife have a direct effect on the welfare of the society (Berkes, 1989, Oguge *et al.* 2006). Agriculture, tourism and other economic activities depend upon a number of natural resources and ecological systems which include soils, water, forests, wildlife and fisheries (Mugabe *et al.* 1996). Land is a vital environmental resource not only for agriculture, but also for all the other sectors of development, such as industry, commerce, conservation and sustainability of biodiversity and tourism. Land is generally taken to mean the soil and the natural resources which exist above and below that soil, such as water, plants and wild animals (Juma, 1996; Belnap, 2001).

The management and effective utilization of natural resources is determined by the prevailing land use systems. The rules governing access to land resources and the manner of their current use affect the welfare needs of current and future generations as well as ecological status of the natural systems of which land is part. Resource use conflicts in Kenya are a function of an attempt to play a delicate balance between, on the one hand government policies, the agro-ecological factors and the socio-economic factors and on the other hand the need for individuals and communities to utilize and manage natural resources on a short or long term basis (Mishra *et al.* 2004; Pekka, 2005; Reid *et al.* 2005).

2.2 Land tenure systems of areas adjacent to protected areas.

Due to the rapid demographic changes there has been effort by governments to control the livestock populations of the communities living adjacent to protected areas. (Collett, 1987; King'oriah, 1995; Mosse 2003) documented that the colonialists yearned to destock the Maasai because; the strategy of overstocking did not contribute to the development and progress of the colony, overstocking would threaten the wildlife and jeopardize revenue raising potential of the game reserve and overstocking and overgrazing of pastoral rangelands was contributing to increased environmental degradation.

The formulation of the group ranch concept in the Maasai rangelands, was necessitated by what was perceived to be a problem of human and livestock population growth, combined with limited range resources leading to overgrazing and environmental deterioration. The implementation of the group ranch concept encountered many problems. The growing acceptance of sedentary life as a result of the group ranches led to range deterioration around settlement sites, land adjudication into group ranches created problems of squatters and illegal grazers particularly during dry seasons (King'oriah, 1995; Mosse, 2003).

2.2.1 Establishment of protected areas

Kenya recognizes the importance of tourism as an important foreign exchange earner and has therefore expended a lot of effort in wildlife conservation through the establishment of various categories of protected areas on which tourism thrives. Despite the government's goal to increase agricultural production for food self-sufficiency, it is a paradox that over the last three decades, a considerable growth in the number of protected areas has been observed in Kenya eating into available land for agriculture. At independence there were only four national parks and five reserves in Kenya, but at present the numbers stand at 22 national parks and 24 national reserves (Juma, 1996; KWS, 2008; Reid *et al.*2005).

2.3 Wildlife conservation in Kenya

2.3.1 Wildlife conservation

The origins of conservation can be traced to religious and philosophical beliefs concerning the relationship between society and the natural world. Since ancient times human beings have unconsciously practiced conservation (Mugabe, 1993; Mosse, 2003). Stone-age hunters and gatherers hunted only a limited numbers of wild animals for their daily subsistence. They killed only mature and healthy animals but left the young ones and potential mothers unharmed (Western *et al.* 2007).

2.3.2 The development of wildlife conservation in Kenya

Traditional African societies were conservationist in their philosophies and economies. Wild animals and plants were not overexploited and humans lived a life that was culturally and ecologically interwoven with that around them (Lelo, 1994; IUCN, 1997; Western *et al.* 2007).

The communal land ownership system was also designed to enhance living in balance with nature. Some communities in Kenya developed specific intrinsic knowledge systems for managing both animal and plant wildlife (Mugabe, 1993; Lelo, 1994; Western *et al.* 2007).

In Tsavo West a community conservation project aimed at establishing dialogue between park authorities and pastoral communities living around the park with programmes on how the communities living next to the park could benefit from wildlife was implemented (Lusigi, 1990). The project addressed the problem of illegal grazing of livestock in the park by the Maasai pastoralists from Kuku and Rombo group ranches, which are two community managed areas of rangeland bordering the park. Portions of this land were leased to outsiders for cultivation, and this loss of grazing combined with an increase in livestock numbers was accommodated by the Maasai moving into the national park to graze their livestock, resulting in serious overgrazing within the park and competition for available grazing between wildlife and livestock resulting in environmental degradation (Lusigi, 1990). Between 1990-1992 community conservation dialogue involved many different stakeholders both individuals and in groups. The meetings were used to agree to a 5 km wide buffer zone along a 60 km edge of the park which could only be used for dry season grazing. Community conservation can achieve results without revenue sharing, but such gains can be fragile, being affected by external factors such as climate, politics and changing land use (COBRA, 1994).

2.3.3 Issues of change to the human balance with nature

The existence of wildlife in many parts of east Africa can be attributed to the coexistence between livestock herds, people and wildlife for thousands of years (Lindsay, 1987; Western *et al.* 2007). This coexistence without destruction was only possible because; the population was considerably small in relation to the available natural resources. Today wild animals have mainly survived in areas where external forces have not turned on the principle of competitive exclusion.

The agrarian laws created by the colonial government to pave way for white settlement areas, establishment of areas under exclusive public tenure for purposes of wildlife conservation resulted in the indigenous people losing grazing, hunting and cultivation land. Rural populations, particularly those at the interface between settlement and conservation areas bear the costs in terms of alienated farming and grazing land for exclusive use of wildlife and tourists, restrictions on resource use and damage to life and property (Collett, 1987; Mombeshora 1989; Muruthi 2005).

The overall authority in ensuring rational conservation, management and utilization of wildlife resources in national parks and national reserves and non gazetted areas is entrusted to the Kenya Wildlife Service under the Wildlife and Conservation Act of 1976 (amended 1989). KWS is charged with ensuring that no settlement or consumptive uses occur in the parks and reserves (KWS, 2008).

Generally all wildlife in national parks and the space in the national parks are legally protected from human use. However, use of some resources in national reserves may be allowed. Ayieko 1977, Mombeshora 1989 and Muruthi 2005 contend that the wildlife conservation areas have a tendency of standing out as protected islands within the ecosystem. An increase in human population is putting pressure on other rangelands. Some national parks are already being threatened by the surrounding human populations. For example increased population pressures with growth of subsistence agriculture and land clearing for charcoal burning have already inhibited the free normal movement of wildlife in Chyulu Hills and onto the rangelands north west of Chyulu range (Lusigi, 1990; Mosse 2003).

From the foregoing it is evident that conflicts in resource use are inevitable. The authorities concerned have in the past made no serious assessment of how the alienation of land for wildlife conservation could impact on communities. Where compensation has been offered it has not been equivalent to the resources that the communities have forfeited. Although the gazettement of Chyulu Hills into a national park was primarily meant to protect park resources from human destruction (bush burning, charcoal burning, poaching, livestock grazing), no study was carried out to establish if this goal had been achieved or if it was necessary to effect the gazettement. There was also need to establish the effect of excluding the human factor from the Chyulu Hills. That was the case before the park extension (Lusigi, 1990; KWS, 1994; Muruthi 2005).

The present classification of the country as either part of a protected area or outside protected area is simplistic. Past wildlife planning efforts that were confined only to protected areas are grossly flawed. The KWS Five Person Review Group (1994) acknowledges that the space outside protected areas is not homogeneous. There was therefore need for land use mapping for areas outside the protected areas as a starting point to understanding and resolving human-wildlife conflicts.

2.4 Characteristics of grazed areas in Kenya

The african grazing lands are famous for their vast numbers of ungulates, whereas the grazing systems in africa are old, with vegetation in a greater part of East Afrrica being profoundly influenced by anthropogenic fire (Prins, 1987). Thus it is possible to find vast areas of single stand grazing resources. Introduction of livestock modified the vegetation to a large extent since 1000 BC in southern Kenya (Prins, 1987).

The best protection against erosion lies in establishing and maintaining good vegetation cover. Perennial vegetation cover is central to protecting landscapes against runoff and erosion. The litter layer that accumulates beneath perennial vegetation prevents soil crusting (Belnap, 2001), increase soil organic matter (Hibbard et al., 2001) and promote infiltration and moisture retention (Dunkerely, 2002a; 2002b). Perennial grass tufts improve water infiltration much more effectively than annual grasses by channeling rainwater via the root base into their own rhizospheres (Rietkerk et al., 2000), stimulating biological activity and decreasing bulk density, thereby increasing retention and availability of soil water. Bulk density beneath perennial grass is also lower than on bare ground (Rietkerk et al., 2000). It has been established that perennial grass pastures extract more soil water than annual grass pastures. Also, perennial pastures have less surface runoff, subsurface flow and deep drainage. Thus, perennial grass pasture can play a critical role in enhancing rainwater use efficiency. However, the infiltration enhancing processes of perennial vegetation become less efficient when disturbed (Fierer and Gabet, 2002), especially by the hoof action that removes biotic crusts (Nyangito *et al.*2009) and compacts the soil (Taddese et al., 2002). Also, not all vegetation types have threshold vegetation cover below which runoff increases sharply (Nyangito et al. 2009).

The vegetation managed in livestock and wildlife production systems is produced by a series of developmental and physiological processes within individual plants. The series of structural changes displayed by organisms from inception to maturity, including cellular division, differentiation and growth, are collectively referenced as developmental morphology. The developmental morphology of plants defines their architectural organization, influences their palatability and accessibility to herbivores, and affects their ability to grow following defoliation.

Physiological processes establish the capacity for solar energy capture and product synthesis necessary to sustain structural development (Gryseels 1988; Briske, 1991).

The predominant impact of grazing on plant growth is a reduction in photosynthetic capacity associated with a decrease in leaf area. Species cope with grazing by minimizing the probability of being grazed and/or rapidly replacing leaf area removed by herbivores. Morphological attributes and biochemical compounds influence the probability and severity of grazing by affecting tissue accessibility and palatability. The capacity for rapid leaf replacement is conferred by physiological processes and meristem availability (Briske, 1991).

The inherent morphological and physiological attributes of individual species influence the structure and function of populations and communities by determining the extent of competitive interactions among plant species. Grazing alters competitive interactions among species by removing various amounts of leaf area and establishing the potential for differential growth rates following similar defoliation severities. Species composition is altered when a particular intensity, frequency and/or seasonality of grazing shifts the competitive advantage from one group of species to another. Species composition changes subsequently influence livestock production and managerial strategies by affecting the quantity, quality and seasonality of plant production. Consequently, the design and evaluation of grazing management strategies must be based in part on the developmental morphology and physiological function of the dominant plant species to conserve rangeland resources and maintain production stability (Briske, 1991).

2.5 Wildlife and Environment Interface Management

It is estimated that 43 % of land area in Africa falls within the Savanna drylands, and that an estimated 45 % of the population or approximately 325 million people in Africa live in these areas. Among the major challenges facing communities in Sub Sahara Africa drylands are recurrent droughts leading to conditions of food insecurity. People living here are also faced with socio-economic, political and ecological factors that affect their livelihood diversification potential/interventions. Climate change is expected to increase the frequency of droughts in many parts of the world, especially Sub-Saharan Africa (McNeely 1996; Mosse 2003). It is also known that pastoralists and wildlife have harmoniously co-existed in African rangelands for many years. However, competition for scarce grazing and water resources is increasing and the potential for

conflicts between wildlife managers and livestock owners is growing as pastoralists and agro-pastoralists move into new areas and/or live in the vicinity of protected areas. Conflicts between people and wildlife are therefore a daily occurrence as wildlife migrates from parks to surrounding areas, where animals, people, and livestock compete for resources. The Kenya sites represent the wildlife rich savannah ecosystems in East Africa. Drylands constitute about 80 % of land in Kenya. In Kenya, arid and semi-arid lands support nearly half the livestock population of the country and over 30 % of the total human population, and are home to most wildlife species (McNeely 1996; Mosse, 2003).

Sustainable management of livestock and wildlife at the interface is seriously threatened by modification of agro-ecosystems in Kenya. The livestock marketing routes have similarly been taken over by sedentary populations. The co-existence of livestock and wildlife in the savanna landscape is threatened by over-exploitation of natural resources due to increasing human populations and weakening of traditional institutions that control and regulate access to grazing resources and protection of wildlife. Loss of biological diversity in agro-ecosystem is also resulting in the loss of the cultural diversity of traditional communities and increased vulnerability to poverty and natural resource based conflicts. Dryland livestock wildlife environment interface (DLWEIP) was addressing a complex problem of sustaining mixed production systems in Sub Sahara Savannah agro-ecosystems that are undergoing rapid changes due to modernization of agriculture and other emerging land use practices such as new approaches to natural resources conservation under community management (conservancies in Kenya) (Njoka 2008; Mathu, 2009).

2.6 Coexistence of livestock and wildlife

Human population growth, agricultural expansion, deforestation, hunting and the ramifications of economic development have had profound, cumulative impacts on the environment, natural habitats and wildlife populations all over the world. East Africa is no exception. The number of people in Kenya, Tanzania and Uganda has doubled over the past 20 years, and is set to double again in the next 30-40 years (ILCA 1987; Charlotte *et al.*1999; Bourn and Blench 1999). Settlement and cultivation are concentrated in areas of higher rainfall and greater agricultural potential, around Lake Victoria, in the highlands, and along the coast. Mean population density is highest in Uganda and lowest in Tanzania. Agricultural land scarcity, however, is greatest in Kenya because of generally lower rainfall. Nevertheless, the general trend

in all three countries is for agricultural expansion and the transformation of natural habitats to farmland. Extensive habitat conversion and unauthorized hunting, exacerbated by a proliferation of high-powered automatic weaponry in recent years, has hastened the long-term decline and disappearance of wildlife from many areas (Bourn and Blench 1999; Hodge 2011). Population estimates for the Kenya rangelands indicate that the overall number of wildlife has fallen by a third over the past two decades. Wildlife has been eliminated from much of Uganda, including many protected areas. In Tanzania, wildlife has also declined, but because of the country's size and relatively low human density, substantial wildlife populations survive in the extensive wild lands that still remain.

Livestock trends are less clear. Monitoring surveys indicate that cattle and small ruminant populations in the Kenya rangelands have fluctuated widely over time, but no significant long-term trends are evident (Charlotte *et al.*1999; Bourn and Blench 1999; GOK 2007a, 2007b, 2007c). Low level aerial surveys suggest that livestock out-number wildlife by a factor of 10:1. Limited data from the Ngorongoro Conservation Area in Tanzania indicate that cattle numbers have decreased over the past 40 years, whilst there has been a substantial increase in small ruminants. National livestock population estimates for Tanzania indicate increases of between 150-250 % from 1971 to 1994. The best prospects in East Africa for demonstrating the sustainable co-existence of livestock and wildlife are: in zones adjoining protected areas; in regions with relatively low rainfall and there is limited potential for arable farming; where human population density is relatively low; and where livestock owners predominate, or are a major component of local communities. Potential zones of interest include: Maasai Mara, Meru, Tsavo and Samburu in Kenya; Mikumi, Mkomasi, Ngorongoro, Tarangire, Ruaha, Serengeti and Udzungwa in Tanzania; and Kidepo Valley and Lake Mburo in Uganda (Bourn and Blench 1999; GOK 2007a,2007b, 2007c) this is also confirmed by the increase in livestock numbers within protected areas.

A comparable inverse relationship between deer and cattle use was observed on the Apache-Sitegreaves National Forest. Livestock grazing is essential for the management of many of England's most important wildlife habitats. Grassland, heathland, wood pasture, floodplain and coastal marshes all require some grazing to maintain the structure and composition upon which a variety of plants and animals depend for their survival. Livestock grazing plays a key role in maintaining species-rich habitats by controlling more aggressive species which would otherwise

dominate these areas and by preventing scrub encroachment (English 2004, 2010; Western *et al.* 2007).

Cattle use their tongues to pull tufts of vegetation into the mouth (Njoka 2008; Western *et al.* 2007). This means that they do not graze vegetation too close to the ground and often leave tussocks of grass which are used by insects and small mammals, because of their wide mouths cattle do not graze selectively and as a result do not target flower heads and herbage which is important for botanically diverse habitats. Cattle are able to create their own access into rough areas and the trampling of these areas can be an important way of controlling scrub (Western *et al.* 2007).

The information thus is available to different sectors of stakeholders thus due to such there is misunderstanding with an immediate consequence that is conflict among pastoralists, government and conservation lobbies. Uncertainties about pastoral tenure have made it difficult for pastoralists to lodge effective land claims, and very often potential grazing land is simply appropriated. Pastoralists then enter conservation areas which they consider traditional grazing areas and encounter game or forest guards, with predictable results. In marked contrast to the high values placed on wildlife and wilderness in the affluent North, rural communities in rangeland areas have a long-standing and deep-rooted antipathy towards potentially dangerous and destructive wild animals (Abel 1992; KWS, 1996; Western *et al.* 2007).

It is correct to assign a high priority to wildlife, because of the income from tourism and the global importance of the conservation of biodiversity; or pastoralists have rights that should be protected. A widespread position is that pressure for establishing reserved areas is strong and well-funded, and it would be better to make agreements with both pastoralists and villagers to compensate them for their loss of access to resources, through revenue sharing (KWS, 1996; Western *et al.* 2007). Such agreements with villagers have been extensively tested in Zimbabwe through the CAMPFIRE programme, but developing similar programmes with occupationally specialized pastoralists is altogether more difficult and, although this is in development in East Africa, there are no clear examples of success. Establishing pastoral access rights in a fluid land use situation is problematic and a source of disputes. Similarly, the lack of central organization makes effective revenue sharing more complex and open to manipulation (KWS, 1996; Western *et al.* 2007; Njoka 2008).

The livelihoods of pastoralists and agro pastoralists in the semi-arid rangelands of sub-Saharan Africa are vulnerable to drought, epidemics and loss of access to key natural resources. New perceptions of rangeland dynamics and the emergence of more community-oriented conservation philosophies have focused attention on the potential benefits of livestock and wildlife coexistence. Integrated management is an approach that can reduce vulnerability, enhance food security and mitigate the negative impacts of wildlife on the livelihoods of pastoralists and agro pastoralists (KWS, 1996; Western *et al.*2007).

Interactions between pastoralists and wildlife occur on many levels. The nature and intensity of these interactions evolve in response to changes in land use and availability. The general trend in higher-rainfall areas is the intensification of livestock production, with smaller herds on smaller tracts of land leading a movement away from "pure" pastoralism towards agro pastoralism (Fratkin 1997; Barrow, 2009; GOK, 2007a, 2007b, 2007c). This is as much the result of political intervention as of pastoralists' attempts to avert risk within a diminishing resource base in a non-equilibrium environment by diversifying income sources. Pastoralists may thus be more willing to incorporate opportunities from wildlife into their livelihood strategies, especially through community-based natural resource management initiatives in areas that possess sufficient wildlife for sustainable use through consumptive and non-consumptive means.

Predation of livestock and humans is often cited as the major risk by pastoralists (and indeed non-pastoralists), particularly women, who live near wildlife – although it is argued that such perceptions are exaggerated (Oguge *et al.* 2006; Mathu, 2009). Damage to crops and infrastructure by wildlife is another key issue. Simple protective fencing is easily destroyed by such wildlife as elephants, buffaloes and zebra. In theory, both predation and infrastructural damage can be limited through improved physical protection. However, this is usually costly at the individual level, even though it may result in overall better health and performance of livestock. In practice, wildlife's potential to contribute to the sustainable rural livelihood strategies of pastoralists is constrained by many factors. Perceptions of the costs and benefits of wildlife, and the ability to limit or exploit them, vary according to such factors as national and international wildlife legislation, natural resource tenure, the type of pastoralists involved, the degree of

community homogeneity, the quality of institutional management, and gender (Oguge *et al.* 2006; GOK 2007a,2007b, 2007c; Mathu, 2009).

2.7 Trends in grazing rangelands

For most of this century, there has been concern about the sustainability of communally grazed rangelands in Africa and other parts of the world. Pastoral systems are commonly viewed as overstocked, overgrazed, degraded and unproductive (Abel, 1993; ILRI 2009) and this has resulted in widespread interventions to reduce stock numbers in an attempt to halt degradation. Overgrazing is commonly thought to be inevitable in communal pastoral systems because people keep more livestock than they need for a variety of reasons (ILRI, 2009) and because of the problems inherent in communal ownership of the resource, where individual benefit is maximized at the expense of the communal resource (Oguge *et al.* 2006; Mathu, 2009). Increasing human population pressure, encroachment of rangelands by other land use, control of livestock diseases and the breakdown of traditional resource management structures are thought to contribute to the degradation problem. This way of viewing and managing communal grazing systems has come under considerable criticism regarding its underlying ecological and economic assumptions, and the idea that communal rangelands are necessarily mismanaged is now widely challenged (Pekka, 2005; Barrow, 2009).

From a broader debate about interpretations of desertification, and the identification of pastoralists as its major causative agent, a debate around the ecological dynamics and appropriate management of semi-arid rangelands has developed. This debate arose in the 1980s in response to a growing concern that interventions aimed at stabilizing spatially and temporally variable rangelands were inappropriate and damaging to pastoral livelihoods (Pekka, 2005; Barrow, 2009). This coincided with an increasing recognition that equilibrium dynamics were difficult or impossible to demonstrate conclusively in many ecological systems (Enors *et al.* 2007), and it was suggested that a different paradigm was necessary to describe non-equilibrium systems. Enors *et al.* 2007 applied non-equilibrium concepts to rangelands and pointed out that a fundamental misunderstanding of their ecological dynamics was leading to inappropriate and failed interventions. The debate gained momentum in the early 1990s after two international workshops around emergent new paradigms in rangeland ecology and socio-economics (Fratkin 1997, Barrow, 2009).

The ''new rangeland ecology'' posits that traditional, equilibrium-based rangeland models have not taken into account the considerable spatial heterogeneity and climatic variability of semi-arid rangelands, and that mobility, variable stocking rates and adaptive management are essential for effectively and sustainably utilizing semi-arid and arid rangelands. In a grazing system with relatively predictable rainfall and hence forage production, livestock populations are regulated in a density-dependent manner via competition for food resources. As population size nears carrying capacity, increased competition for resources leads to reduced herd productivity. A sign of density dependence is that population growth rates decrease with increasing population size because of the effects of competition on reproductive and mortality rates. This is exemplified by the (GOK 2007b) model of the effect of stocking rate on cattle weight gain. Rainfall in different years affects grass production and composition (Vetter, 2005) and hence the effective carrying capacity at different times. If livestock populations are near carrying capacity, and hence already competing for resources, they are likely to experience population crashes in drought years when resources become scarce (Vetter, 2005). If livestock populations are well below the ecological carrying capacity, drought mortality is reduced because livestock are buffered against such stress events by greater forage and body fat reserves. Thus the recommended management practice is the maintenance of conservative stocking rates which can be maintained in drier years.

In grazing systems with very high climatic variability, forage availability varies to such a great degree with rainfall that herbivore population dynamics are driven by rainfall via its direct effect on forage availability in any given year. In such none equilibrium systems, density-dependent interactions such as competition for resources play a minor role in regulating (Bartels *et al.* 1993; Joris, 2006). Mortality is high and density-independent during severe droughts, particularly droughts lasting longer than 1 year (Bartels *et al.* 1993; Joris, 2006). Livestock numbers build up during series of wet years. Population size thus fluctuates dramatically, and cannot track rainfall closely because of the time it takes populations to recover from crashes. The dichotomy between density-dependent and abiotically driven population dynamics is an oversimplification of the range of situations found in reality. The strength of density-dependent interactions varies over time and in space. For example, density-dependent dynamics in non-drought years can alternate with density-independent mortality during droughts and subsequent recovery (Scoones 1993, 1994) in southern Zimbabwe.

In a grazing experiment examining the relative importance of rainfall and stocking rate on plant composition and primary and secondary production, Vetter, 2005 found that density-dependent consumer–resource coupling was largely limited to drought periods and was greater at high stocking rates. This example illustrates that a measure of grazing pressure (the number of livestock per unit of available forage) is more informative if harder to quantify than stocking rate (the number of animals per area) in systems where livestock numbers and rainfall vary over time. It is exceedingly difficult to infer density dependent mechanisms or their absence from livestock population census data. Part of this problem lies in the extreme difficulty and cost involved in obtaining detailed enough data on population size, mortality, fecundity and migration over a long enough time series. Simulation models are a useful tool for exploring the mechanisms which regulate livestock.

The basic systems of ownership possible within East African grazing lands are: private land, where an individual or group is responsible for limiting utilization under the assumption that self-interest will lead it to optimize the output of the asset controlled, and public land -- as through a parastatal ranch, where public officials must act essentially as private owners, or community makes group decisions in regards to the use of the said land (Jarvis, 1991).

Public control and operation of rangelands in Africa has been very unsuccessful in nearly all cases (Sandford, 1981, 1983; Jarvis 1991). Both equity and efficiency grounds argue strongly against this solution to the overgrazing problem.

Private control has a better record, and offers the only long run solution in many areas. The primary issue in considering changes toward individuated tenure is equity, not efficiency: how should "land" be divided among pastoralists (groups of pastoralists), or between pastoralists and non-pastoralists. These are extremely knotty issues (Sandford, 1983; Jarvis, 1991). The principal need -- from the pastoralists' perspective -- is to ensure that lands traditionally considered his grazing territory are reserved. But this involves myriad claims and counter claims -- by different pastoralist and agriculturist groups -- which can be adjudicated only by those who know the specific situation. There is a growing literature on experiments with group and individual ranches in Africa which indicate that such ranches have been less successful than expected in achieving output increases and in achieving clear rules of tenure. They often have benefited some at the

expense of others. However, there is little long run alternative and continuing, if cautious, efforts to promote this sort of change appears to offer the greatest hope for pastoralists welfare.

2.8 Livestock stocking rates

In East Africa, pastoral ethnic groups exercise strong sovereignty over the rangeland domains they occupy. These groups, including Boran, Gabbra, Turkana, Samburu and Masai, are widely spread from Ethiopia and Somalia in the north to the United Republic of Tanzania in the south (Valk, 1985; Fratkin, 1997; Begzsuren *et al.* 2004). As a result of the close linkage between grazing domains and ethnic groups, conflicts are common. Other characteristics of East Africa are the greater heterogeneity of the landscape, which is dotted with resource-rich mountain islands, and the bimodal rainfall, which promotes perennial grasses and high-quality dwarf shrubs but discourages rain-fed cropping since the seasonal rainfall and length of growing period (LGPs) are highly erratic. Therefore, whereas in West Africa, because of unimodal rainfall, rain-fed cropping extends northwards up to isohyets of 300 to 400 mm - coinciding with the 75-day LGP limits mixed-cropping systems in East Africa are rarely found where annual rainfall is less than 500 to 600 mm.

Both the arid and semi-arid zones in East Africa are more heavily stocked than in West Africa. Also, because of lower population density, livestock wealth per capita is higher. These aggregated data, however, mask the increasing livestock density along the arid to semi-arid gradient. Whereas in arid Kenya densities average 9 TLU per km2, farther south grazing pressure increases rapidly with rainfall. In Kajiado district, which straddles the arid and semi-arid zones and harbours mainly Maasai pastoralists, the average stocking rate during the period from 1983 to 1988 was 26 TLU per km2, ranging from 32 TLU per km2 in the semi-arid zone to 18 TLU per km2 in the arid zone. During drier years, however, stocking rates were as low as 21 TLU per km2 in the rainy season and 9 TLU per km2 in the dry season since many Maasai herds moved to wetter areas (Leeuw 1989, 1990, 1991, 1992, 1993; Solomon-Bekure *et al.* 1991).

While the semi-arid zone in the United Republic of Tanzania was stocked at 15 TLU per km2, Mwalyosi, 1992 recorded livestock densities ranging from 30 to 80 TLU per km2 in predominantly Maasai grazing areas in the northeast. Despite this high pressure, the author concluded that "grazing affected plant composition and contributed to localize severe soil erosion

but did not affect primary production; even at 80 TLU per km2, primary production appeared high enough to support the high livestock biomass". Equally high stocking rates were found in mixed smallholder farms in semi-arid Kenya, where most land is held in freehold and little free grazing is available. While livestock wealth increased with farm size, grazing pressure showed the opposite trend. The larger landowners (> 8 ha) on average kept 1 TLU per hectare of land, whereas on small farms (1 to 3 ha), stock:land ratios of up to 4 TLU per hectare were recorded; perhaps renting of grazing land or entrusting stock to relatives and friends made up for recurrent feed shortages (Jaetzold and Schmidt, 1983; Leeuw *et al.* 1990).

2.9 Trends in grazing land use

Other studies show the highest livestock densities were mostly found in heavily populated areas in the highlands and in the semiarid zone, particularly in Nigeria. Except where oxen traction remains important, small ruminants increased as a proportion of total mass as farm size declined and only the larger households continued to keep cattle. In the closely settled area around Kano in Nigeria, overall stocking rates are about 100 TLU per km2, half of which are small ruminants. Soil fertility is maintained by heavy manuring combined with applications of inorganic fertilizers, while crop residues are stored and fed along with purchased feed-stuffs mainly destined for dry-season feeding of draught oxen and fattening of sheep (Sperling 1990; Mortimore, 1991; Agyemang *et al.* 1993). It was demonstrated that similar stocking densities prevailed in other farming systems with high population densities, particularly in the Ethiopian and Kenyan highlands.

In several areas in the West African semi-arid and sub humid zones, livestock densities appear to stabilize in farming systems in which the human support capacity is enhanced, as a result of advanced crop/livestock interactions fuelled by cash-crop cultivation. In semiarid Nigeria, Cameroon and the Gambia, Jahnke (1982) recorded stocking rates of 20 to 25 TLU per km2, with corresponding densities of 30 to 50 rural people per km2. It seems that, more than a decade later, these levels had not been substantially exceeded (Leeuw, 1993). In Nigeria, with the exception of the closely settled areas in the semi-arid zone, aggregate densities in the northern states varied from 18 to 30 TLU per km2 (averaging 20 TLU/km2). These densities are similar to those found in the more developed cotton-growing areas in Mali and northern Côte d'Ivoire (Lhoste, 1990; Leeuw *et al.* 1993).

It is postulated that, at these population and livestock densities, most of the better arable land is under crops or short-term fallows, producing more dry-season feed per hectare than the natural pastures on the poorer soils (Leeuw *et al.*1993; FAO 2011), and that crop residues are more optimally utilized when animal-drawn transport is available to allow on-farm storage. In addition, because of better manure management and inorganic fertilizer inputs, combined with further mechanization - for ex ample, the use of seeders and weeding equipment yields of cereal crops and cash crops (cotton, groundnuts) increase, thereby enhancing feed output from residues (Adesina, 1992; Sumberg, 1992; Sumberg and Gilbert, 1992).

2.10 Developmental morphology of grasses of Eastern Africa

Management practices can directly influence the physiological and morphological characteristics of a grass. Grasses belong to the subclass monocotyledon which are characterized by monocot seeds. Grasses account for much of the pasture, turf, and hay fields that are used in production situations (Miller, 1984). Grasses can be differentiated by their adaptation to different climates. Warm-season grasses require higher and warmer temperatures like those in the tropics, whereas cool-season grasses prefer temperatures that are similar to the cooler, temperate climates. Grasses are also divided by seasonal growth habit, namely annual, winter annual, and perennial grasses. These seasonal differences can be further divided into the two growth types of sod forming and bunch type grasses. Sod forming grasses have a prostrate growth habit and have tillers that may grow horizontally through the leaf sheath to insure spreading. In contrast, bunch type grass growth is primarily between the leaf sheath and the culm to provide upright erect growth (Miller, 1984; Williams, 2012).

2.10.1 Grass composition

The smallest unit of a grass is the phytomer. that consists of a blade, internode, node, axiliary bud , and root initials. Each young phytomer is organized into a tiller. The tiller is the basis from which most morphological classification occurs. These classifications are divided into vegetative, reproductive, and seed ripening growth stages. The seedling is composed of a primary tiller. The expansion of the young seedling is dependent on the original tiller producing buds from which replacement tillers are produced, i.e. secondary tillers, tertiary tillers, etc.. The dormant or inactive buds can produce new shoots with their own growing point. These buds are the origin of

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new growing points when the old tiller dies. This process explains why a perennial plant can live for many years. As long as the tiller stays in the vegetative stage the potential for leaf production is increased (Valentine, 1990, Williams 2012).

2.10.2 Physiology

According to Williams (2012), photosynthesis occurs in all green tissues, especially in most crop leaves, that have the following: a large, flat external surface, upper and lower protective surfaces, many stomata per unit area, extensive internal surface and interconnecting air spaces, an abundance of chloroplast in each cell and a close relationship between the vascular and photosynthetic cells. The leaves in grasses serve as the large, flat surface that intercepts light to maximize the solar energy being received. The epidermis or protective layer limits the gas exchange due to the cuticle, a waxy substance creating a thin surface layer that lies between the plant and the atmosphere. The cuticle also prevents water loss by the plant. The guard cells, located within the stomata, serve as the transport mechanism for CO2 exchange when the stomata is open. Stomatal closure is important in prevention of water loss when water is a limiting factor.

Within the leaf, anatomical differences in the structure of the mesophyll cells, bundle sheath cells, and the intercellular spaces affect the efficiency of the plant. The arrangement of mesophyll cells allows for an increase in the internal surface area, and therefore aids in the diffusion of CO2 from the stomata to the cell surface. These mesophyll cells contain large numbers of chloroplasts and are located where the actual light reaction for photosynthesis takes place.

Highly productive forage grasses elevate their tissue deposition rate at some time during the growth period. This places their upper leaves in a higher position in the canopy. The result is more direct sunlight and thus maximum food production (Williams, 2012). Reserves are located in the roots and rhizomes of perennial grasses and in the seeds and roots of many annual grasses. These reserves help provide energy when the plant is in need, such as a growing period. In perennial species, this may occur after the grass has been grazed or cut. The grass is in a vulnerable position, and the recovery is dependent on how close the cutting occurred. The new growth has to occur from a dormant bud situated close to the crown.

2.10.3 Defoliation

Defoliation refers to a grass being clipped or grazed and has many effects on a stand of grass. If the carbohydrates in the roots and rhizomes of perennial grasses have been left depleted from the previous year the current stand will have a low survivability rate. Williams, 2012 believed carbohydrate reserves play a significant role in the phenology, vigor, development and productivity of plants. Exhaustion of reserves as a result of excessive defoliation has generally been associated with reduction in vigor and ultimately, range deterioration.

The effect of defoliation of a grass tiller in a vegetative stage will depend on the portion of the shoot taken (Walton, 1983; Valentine, 1990). The time of year and frequency of defoliation can make a difference. The single cuttings should be taken earlier in the spring and the two cuttings are best if they come from June and August. Very heavy stocking rates could be detrimental to the carbohydrate reserves, but moderate to heavy stocking rates have a positive significant effect on carbohydrate concentration and TNC (total non-structural carbohydrate) concentrations for both the crowns and roots.

Management seems to be the largest factor for avoiding depletion of a stand. Some key points made by Waller et al. (1985) are to delay initial grazing period, permit ample photosynthetic area to remain at the conclusion of grazing period, allow adequate rest intervals following grazing periods, and allow plenty of time for carbohydrate reserves and bud development to replenish. Some of the morphological characteristics that can be taken advantage of are a lower growing point, vegetative shoot production over reproductive shoot formation, and a deep and expansive root system (Valentine, 1990).

Plant cell walls contain non-carbohydrate substances that are resistant to digestion, particularly lignin (Williams, 2012). Lignins are strengthening components that occur within the cellulose and other polysaccharides of certain cell walls (Williams, 2012). Growth can be described as cell enlargement, cell division and cell differentiation. All of these processes are irreversible and involve many types of substances and syntheses. During the plant cell development, the primary cell wall is a thin wall and composed of cellulose microfibrils. The cellulose microfibrils are embedded in a matrix which includes compounds like hemicellulose and pectic substances. The secondary cell wall is much thicker than the primary wall. These walls consist of cellulose, hemicellulose, and lignins. The lignin makes the structure resistant to changes

in form and compression. The secondary wall is much more rigid compared to the primary wall and has an elastic composition similar to a balloon (Salisbury and Cleon, 1992).

Lignin is the chemical constituent that is associated with nutrient indigestibility and facilitated with the determination of fiber digestibility. Lignin concentrations on a cell wall basis doubled with maturity in grass stems, but when the stems are immature, they are almost twice as digestible as mature stages on a cell wall-lignin basis. These digestibility concentrations could be related to the various monomers within the lignin. Protein is a large component in the consideration of a diet. Many producers are concerned with the crude protein and also the amino acid composition of their forage.

Plant proteins can be broken into two different categories, proteins of the leaf and stem, and storage protein of the seed (William, 2012). Leaf and stem protein represents the actively metabolizing matter of living plants and leaves contain a high level of proteins. Although the leaves contain a larger amount of protein, some proteins are present as insoluble heat-denatured cytoplasmic and chloroplastic proteins. Solubility has received attention due to its effect on digestion efficiency. Soluble compounds are degraded faster and at different rates than insoluble proteins due to microbial activity within the digestion system. Protein reaching the lower digestive tract without significant degradation is called escape protein. An important implication in ruminal protein disappearance is the difference in species. Due to these differences, generalizations regarding protein degradability should not be made. Other factors such as, plant maturity, degradation rate, animal type, and other plant characteristics, should be considered when evaluating and developing strategies for protein supplementation.

The grasslands of Eastern Africa have a wide range of dominant species dependent on management or grazing system. When classification of the vegetation into types that cover large areas of the region. Rattray (1960) identified 12 types of grassland in eastern Africa, based on the genera of the dominant grass in the grassland. These include *Aristida, Chloris, Cenchrus, Chrysopogon, Exotheca, Hyparrhenia, Heteropogon, Loudetia, Pennisetum, Panicum, Setaria* and *Themeda triandra*. There are an estimated 1 000 species of grass indigenous to the region, with more than 600 species found in Kenya alone (Boonman, 1993). The wide distribution and adaptability of many of these species across a range of environments and management systems indicates the presence of considerable genetic diversity within the region. The arid area such as the

areas around Tsavo, Chyulu have presence of *Commiphora, Acacia, Cenchrus ciliaris* and *Chloris roxburghiana*. Plant biomass, quality and species numbers decline in the absence of grazing, are at a peak under moderate to high grazing (McNaughton, 1984) and can decline under very high grazing. In the CHNP region in Kenya, to the north west, which is a grassland ecosystem, *Chloris* makes up about 95 % of the grass cover in lightly to moderately grazed sites, dropping to 1-5 percent cover near settlements where Maasai corral their livestock each night (Ngene *et al.* 2011). Rattray (1960) recognized the *Chloris* areas as a vegetation type in its own right this is due to the colonization potential being high with *Chloris Sp.*

The production of pastoral systems in East Africa has usually been measured in terms of biomass, completely ignoring the food used for human subsistence. The animal protein (AP) and gross energy (GE) produced annually from each hectare are more appropriate comparative indices of production (Cossins, 1984). This has led to interests in quantifying the amounts of biomass available in these rangelands so as to offer a guide on estimating the effects of animals grazing on these grasslands.

Pastoralists have been known to utilize highly heterogeneous landscapes, in terms of pasture and forage types and species of forage quality, availability (quantity) and terrain. Lateral movement is a key strategy utilized by pastoralists to optimize production from the heterogeneous landscapes. It is common practice among pastoralists, to designate forage sources as primary grazing sites (those routinely used as communal grazing land during favourable periods and usually located close to the household) or emergency grazing sites including private grazing sites (those specifically reserved as individual enclosures for use during stress periods) (Flintan *et al.* 2011). During drought, some pastoralists would divide herds into core and satellite groups. The core herd includes the breeding stock (pregnant and lactating females) and young, old and vulnerable animals. The satellite herd includes the hardy males, non-lactating females, and larger and hardier livestock. The satellite herds were usually trekked to the emergency grazing sites located further from the households than the primary sites (Flintan *et al.* 2011). Thus the type of livestock arriving at a particular grazing site was the fittest and would have walked long distances to reach such sites. It leads to emergency sites being utilised in a manner that has to guarantee survival of the stock.

The data available on overgrazing, range degradation, and the effect of herd controls are limited (Javis, 1991).

2.11 Conceptual Framework

The area studied was subjected to various impacts and thus the study sought to evaluate the impacts of livestock and wildlife grazing on the *Chloris roxburghiana* within sites both within the CHNP and outside the park boundaries.

The area is exposed and affected by the hydrological conditions of the environment where rains have been scarce, this is an exogenous factor.

There are trampling impacts by the large numbers of livestock that is kept by the communities on the *Chloris roxburghiana* production, also its physical appearance would depend on the grazing regimes also thus impacting on the soil moisture and hence the micro climate. On the *Chloris roxburghiana* the analysis is on its production, where the various intensity of grazing was assessed to determine the level, its abundance and production.

Figure 1 demonstrates a useful concept that is the feeding station, which is defined as the area within which an animal can feed without moving its feet (Montague *et al.* 1986; Ecologigal Sampling Methods, 2009). The station is composed of potential bites which are the volume encompassed by an area the size of a sweep of the tongue and a maximum height. The potential bite is a product of this volume and the bulk density of the forage

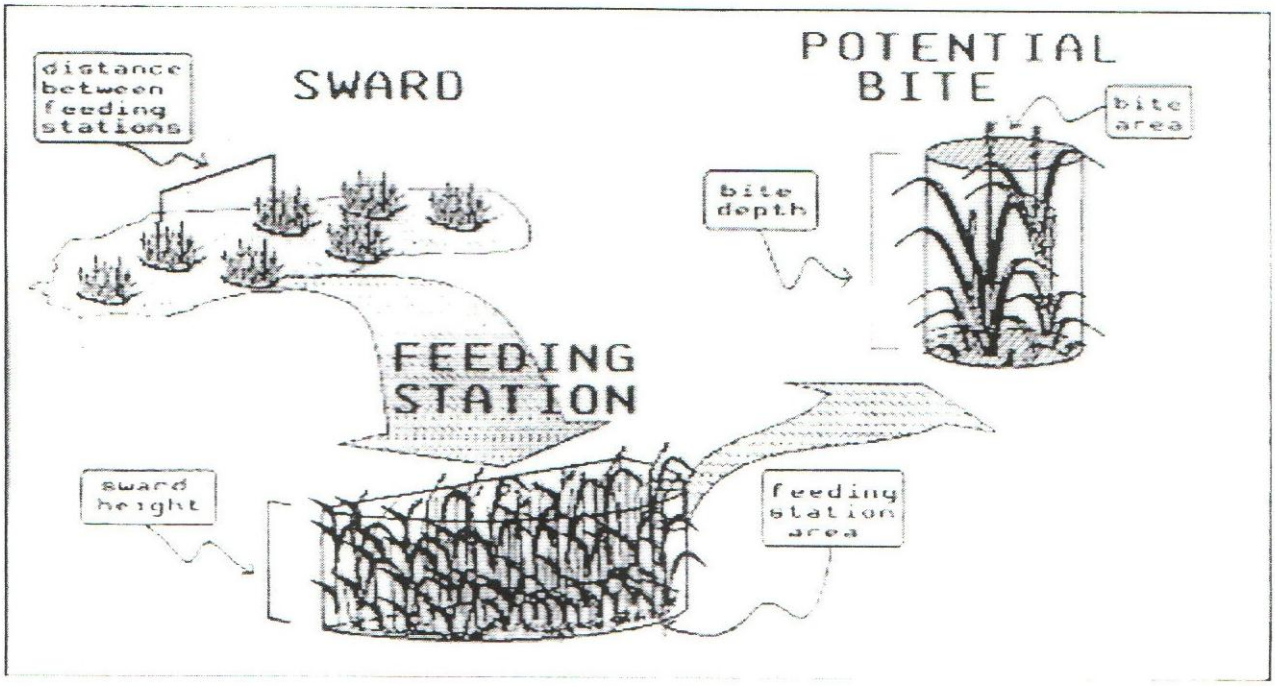


Figure 1: Components of Sward Structure (Montague *et al*, 1986)

The conceptual framework illustrated in Figure 2 of this research depicts the three key contemporary determinants (Climate; Physiography; Grazing type of land use, of *Chloris roxburghiana* structure and function (center circle) and their interactions. The interplay of biotic and abiotic factors ultimately determines the ecological trajectory at a given location, resulting in a range of possible ecosystem states or types that co-occur at landscape and regional scales. The spatial arrangement of these different ecosystem types can affect the states of adjacent types, or organisms that operate over large spatial scales. Hence, understanding the interaction depicted in the center circle at multiple points across the landscape and in response to changes in the three determinants is critical. Figure 2 shows that as a social-ecological system, changes in land-use, policy and management decisions, or economic factors on the *Chloris roxburghiana* can rapidly change the mosaic of ecosystem types over the landscape. This study combined experimental and comparative approaches with season-term monitoring, cross-site studies and modeling to understand the interactions among these components and forecast responses of *Chloris roxburghiana* structure and function to regional and global change. The solid arrows in Figure 2 show direct linkages while the checked arrow demonstrates indirect linkage.

The functional dynamics of the trophic web suggest that the acceleration of energy and nutrient flow rates due to intense herbivory has resulted in the development of an entire consumer food web due to additive fluxes rather than mere quasi-parasitic fluxes from plants to animals (McNaughton 1985)

Climate controls the attributes of precipitation trends which are key in growth of vegetation. Insolation trends are also key factors in temperature and thus these are key in the vegetation characteristics and in determining type and extent of land cover on any particular site. Thus climate change heavily impacts the hydrological cycle that determines growth of plants (Sullivan, 2002).

Physiography of the particular site causes impacts on grazing due to its effects on soil type and the antecedent processes of the site. Figure 2 shows that *Chloris roxburghiana* would be affected heavily by climatic factors as well as grazing impacts and the physical chemical processes within the soil. Grazing biogeochemical transformations within the sites is thus affected by both climate and physiography of the sites as well as grazing also contributes to the change (Sullivan 2002).

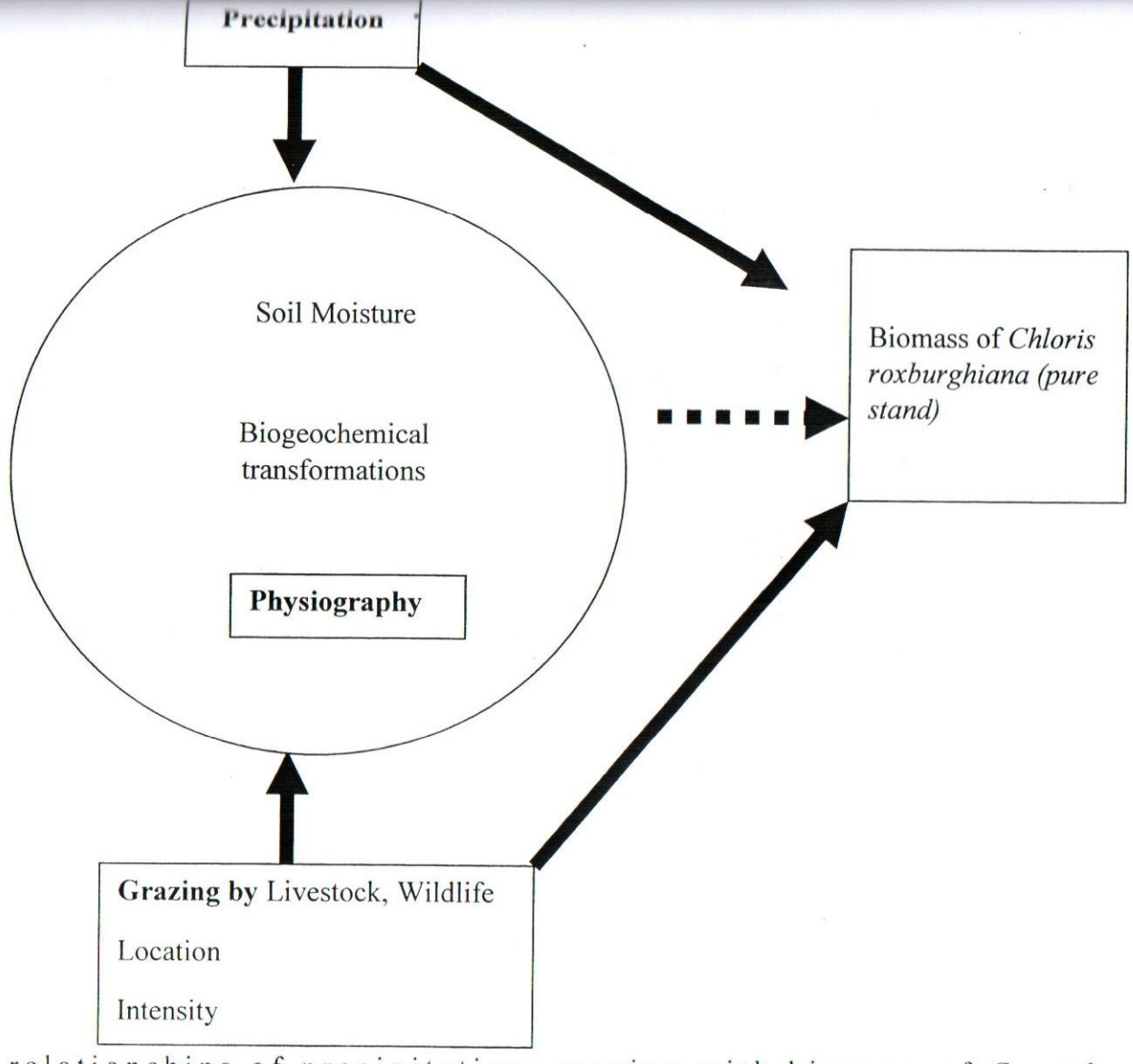


Figure 2: The relationships of precipitation, grazing with biomass of *C.roxburghiana*

CHAPTER THREE
RESEARCH METHODS

3.1 Study area

Chyulu Hills National Park is situated 250 kilometers southeast of Nairobi along the Nairobi- Mombasa highway in Kibwezi District. The park headquarters can be accessed through a murram road, a short distance from Kibwezi town as one drives towards Mombasa. It lies between latitudes 2021S and 2050S, and longitudes 37045'E and 3802'E. Mashuru and Loitokitok Divisions and West Chyulu Conservation Area of Kajiado District border the park to the west. The Kiboko River marks the park's boundary to the northwest, while Tsavo West National Park is on the southeast of the park.

3.2 Geographical location

The target area was the areas North West towards west of the park in the areas of Donyo Engeloreti, Ol Doinyo Sambu; these locations provided areas with cattle grazing in the park. Due to the distance and staffing levels it made establishing controls in this area difficult. The area of Ukatu to the North East provided an area with no cattle grazing with its electric fence and militarized KWS personnel. This is because the areas south west towards south had a conservancy and the remaining areas were inaccessible by humans and cattle. The park headquarters and Mkururo station are militarized zones thereby enforcing controls within these areas (FAO, 1978, 2011; Republic of Kenya, 1997b and c, 2002; GOK 2007a, 2007b, 2007c).

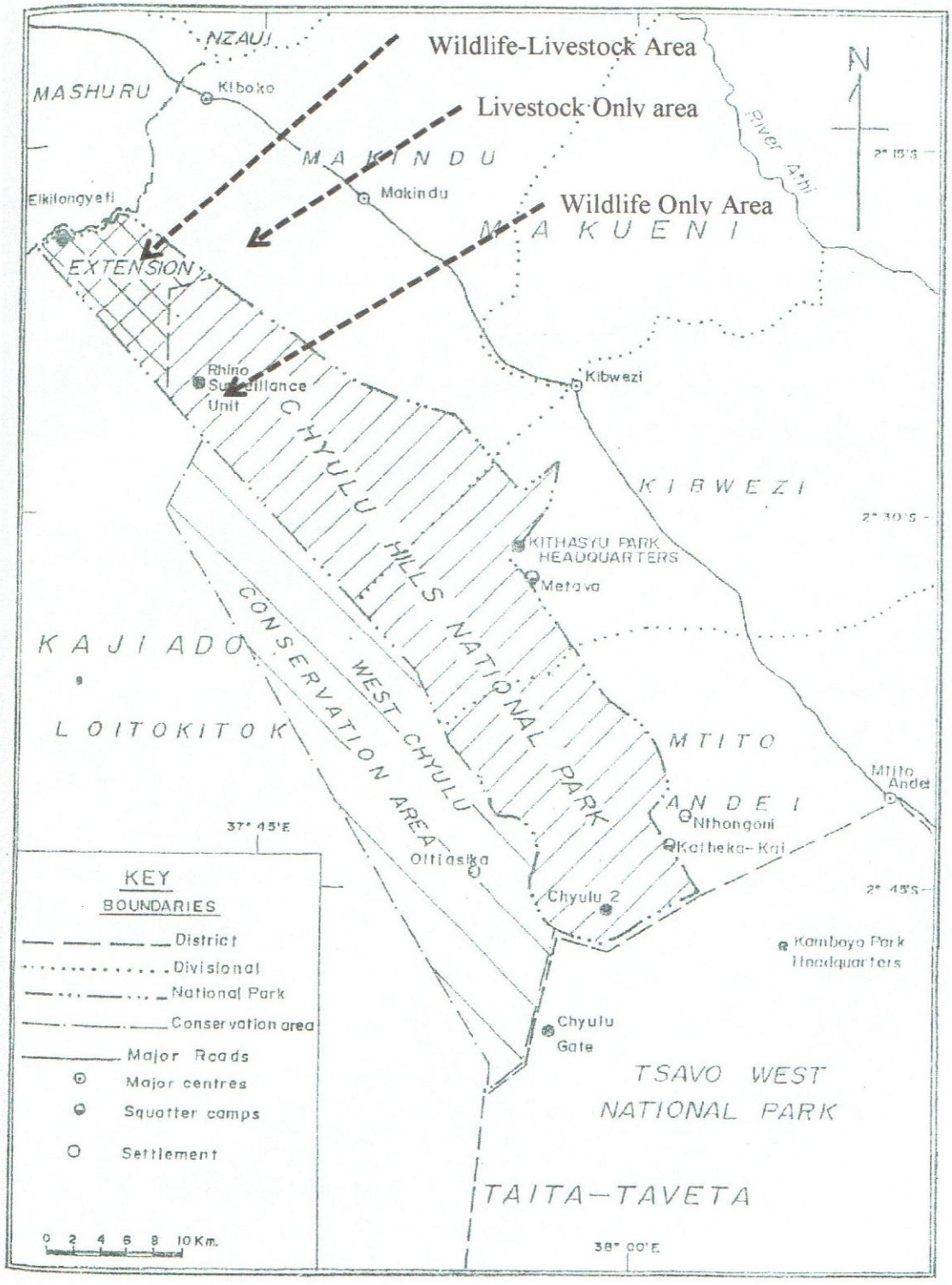


Figure 3: Map showing the study sites in CHNP. Source this study 2010

3.3 Climate

The region (Makueni and Kajiado Districts) has a bimodal rainfall pattern. The short rains fall between October and December, while the long rains fall between March and May (RoK, 1997b). The altitude of Chyulu Hills at 7,177 metres above sea level influences the climate in the surrounding areas. The low lying areas are hot and dry and receive as little as 200mm of rainfall per year. The flanks of Chyulu Hills receive rainfall ranging between 400mm in the lower plains to over 1000mm on the crest of the hills. Rainfall is fairly reliable, especially on the peaks of Chyulu Hills (RoK, 1997b). During the dry season between May and October, the low-lying areas around Chyulu Hills experience extreme heat, while high altitude areas experience cool temperatures.

3.4 Drainage and Soil types

The study area has few perennial rivers such as Thange, Kiboko and Kiumbi (Makindu) which drain into River Athi. The Chyulu range consists of recent strings of volcanic ashes and cinders. It is surrounded by plains of ash blankets and lava flows (RoK, 1983; King'oriah, 1995; (Mosse, 2003). The Chyulu range and its surrounding ash covered plains have porous, deep, fine gravelly clay loam soils. Lava flows in this region feature as mere rock outcrops. Black cotton soils are found in the southern divisions of Kibwezi, Makindu and Mtito Andei. Piedmont plains dominate on the western side towards Amboseli (RoK 1983; Mosse, 2003). Moderately fertile soils occur in the Chyulu Hills due to the widely distributed presence of volcanic ashes.

3.5 Vegetation type

The study area is composed of wooded grassland with the dominant graminoid species being *Chloris roxburghiana* in open savanna areas and the woody species include: *Abutilon mauritanium, Acacia mellifera, Acacia tortilis, Albizia anthelmintica, Astripomea hyoscyamoides, Astripomea lachnosperma, Barleria taitensis, Bauhinia taitensis, Cleomea hirta, Capparis tomentosa, Euphobia spp* among others (RoK 2002; Mosse, 2003). The vegetation consists of remnants of formerly extensive *Commiphora-Acacia* woodlands that have been

destroyed or at least thinned out by elephants (Cobb, 1976; Ngene *et al.* 2011). Densities of trees and shrubs are generally lowest near rivers, except for local patches of riverine forest or fringes of trees along water courses. Large portions of the originally dense woodlands, dominated by *Commiphora* and *Acacia* spp., CHNP was transformed into more open vegetation types primarily by elephants through destruction of trees and excessive utilization of woody regeneration, added to that anthropogenic fires led to formation of vast grass stands of *Chloris roxburghiana* (Ngene *et al.* 2011). The dominant vegetation is dominated by a mixture of the perennial grasses *Digitaria macroblephara*, *Chloris roxburghiana*, and *Bothriochloa radicans* and the annual legumes *Tephrosia subtriflora* and *Tephrosia villosa* (Belsky *et al.* 1987). The tree component includes *Acacia tortilis*, *Adansonia digitata*, *Delonix elata* and *Melia volkensii* surrounded with distinct patches of under storey species. The grasslands are dominated by the perennial grasses *Cenchris ciliaris* to the south western, *C. roxburghiana* to the north, *Digitaria macroblephara* and *Eragrostis caespitosa* occurring in the higher altitude areas in the middle of CHNP. These occur in stands where also herbaceous-layer vegetation under tree canopies is dominated by the stoloniferous perennial grass *Cynoden nlemfuen* and *Panicum maximum*. These under storey species, along with *Aneilema johnstonii*, *Coccinia microphylla*, and *Commelina benghalensis*, are replaced at or near the edge of the canopy zone by a more species-rich mixture dominated by *Bothriochloa radicans*, *Chloris roxburghiana*, *Digitaria macroblephara*, and *Eragrostis caespitosa*, among other species. The under storey species also occur away from the trees in association with small shrubs but at lower cover values. Other frequent species (> 5% cover) in the open grasslands include the dicots, *Cassia mimosoides*, *Commelina africana*, *Portulaca oleraceae*, *Solanum incanum*, *Momordica boivinii*, *Heliotropium steudneri*, *Ipomoea obscura* and *Hibiscus micranthus*, and the grasses *Cenchris ciliaris*, *Microchloa kunthii*, *Sporobolus pellucidus*, *Aristida adscensionis*, and *Sporobolus fimbriat* (Belsky *et al.*, 1989; Ngene *et al.* 2011).

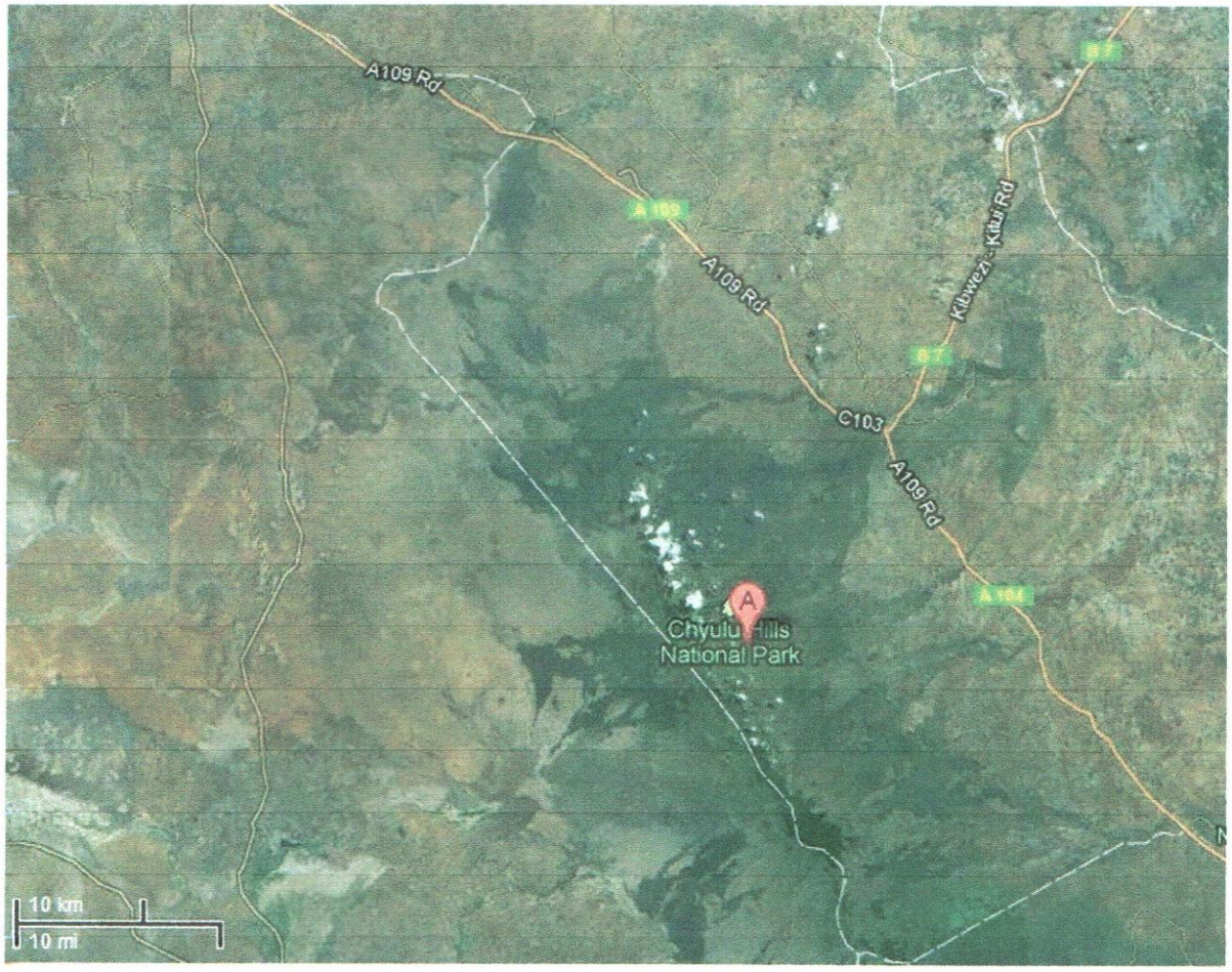


Figure 4: Satellite Map of CHNP showing vegetation distribution. Source Google Maps 2010

3.6 Research design

The field research employed Randomized Complete Block Design with three blocks; outside CHNP, non militarized zone inside CHNP and militarized zone inside CHNP . Where treatment combinations were based on the type of animals occurring on the site impacting grazing on the *Chloris roxburghiana* hence Livestock only area, wildlife-livestock area and wildlife only area. The main advantage of experimental approach is it eliminates bias and due to repetition/replication it improves accuracy (Joris and Han, 2006).

The antecedent conditions were such that there were already areas that were of similar ecological status but undergoing different grazing impacts. *Chloris roxburghiana* was selected as

in the stands where it was the majority were the blocks with distinct grazing system from the various animals whether livestock or wildlife. These sites identified for the study were based on location of livestock and wildlife grazers. The Livestock only area selected had carrying capacity being exceeded whilst the wildlife-livestock area did not exceed the carrying capacity as well as the control site which was wildlife only.

Difference in animals grazing on the areas varied from livestock comprising of cattle, sheep and wildlife comprising of zebra and grants gazelle. The sites had in common *Choris roxburghiana* which was being grazed at different intensities outside the park and inside the park. The intensities would vary from heavy intensity of animal stock unit more than the carrying capacity of the particular location and also frequency of the grazing regime impacted on the *Chloris roxburghiana.* Thus the blocked areas were due to the site conditions where livestock only area was a site outside the park with no wildlife species measuring approximately 5028.57 ha, the livestock wildlife area was a site within the park with no fence measuring approximately 5028.57 ha and had little control from KWS due to the distance from park headquarters, and a militarized zone within the park where the controls were in place and the area was wildlife only also measuring approximately 5028.57 ha.

The three sites provided the blocks understudy with the wildlife only area providing the control to be used in the study due to the perception from null hypothesis showing evidence in the livestock only area and the wildlife-livestock area being in contention as where the effects of livestock grazing were to be estimated. The militarized zones had the electric fence that ensured that the micro environment was least impacted by the activities of livestock. Grazing intensity and grazing frequency treatments were the grazing impacts by livestock and wildlife on the *Chloris roxburghiana.* Clipping of the grass at selected random sampling sites within the blocks were carried out to simulate grazing and the grass weighed (Joris and Han, 2006; Ecological Samplling Methods, 2009). This was done by use of transect lines measuring 20km cutting across the blocks and six 100m by 100m being selected on either side of the transect.

Initial cover conditions for the livestock only area was degraded area with little graminoid presence, while the wildlife livestock area had abundance of cover as well as the control wildlife only area. This provided for a base where to measure the effects of grazing on the amounts due to a perceived notion as in the null hypothesis (Joris and Han, 2006).

The three sites provided 12 areas used as sampling frames within which clipping of the *Chloris roxburghiana* would be performed in smaller quadrats to avoid negative effects to the environment. The 12 sampling frames thus offered sufficient replications for the study to be statistically valid (Valerio *et al.* 2004; Joris and Han, 2006; Ecological Sampling Methods 2009).

In order to simulate the natural conditions to an accuracy of 95%, the blocks set were not to be enclosed (Valerio *et al.* 2004; Joris and Han, 2006; Ecological Sampling Methods 2009). The variables to be controlled were the type of animals grazing on a particular site. This resulted due to the antecedent conditions where livestock only area was distinctly clear with pastoralism as the key economic activity with no evidence of another type of land use. The wildlife-livestock area was selected with evidence of livestock encroachment within the known CHNP boundary just as shown in Plate 1. The wildlife only area was selected as an area with guaranteed no livestock presence hence a militarized zone with a fence that only had wildlife was selected.



PLATE 1: Livestock holding area within the wildlife-livestock area.

The sample quadrats measuring 1m by 1m were used for determining frequency of *Chloris roxburghiana*. In this study the different blocks were Wildlife only, wildlife-livestock and Livestock only. The sites were controlled by there being a fence to delineate park boundary thus providing livestock only area, an area not fenced with evidence of both wildlife and livestock and a militarized zone within the park where no pastoralist would go beyond providing the control for wildlife only area (Ross 1997; Valerio *et al.* 2004; Joris and Han, 2006; Ecological Sampling Methods 2009).

A line plot transect, 20 km in length was laid out covering each of the sites. The 20km allowed for wide monitoring of encroachment path of livestock into CHNP, it also allowed for collection of fresh dung and also made the assessment of the effects thorough as it offered monitoring of the impacts while still fresh (Ecological Sampling Methods 2009) (within the protected area and outside) and stations chosen through random stratified sampling strategy to provide for clipping areas (Valerio *et al.* 2004; Joris and Han, 2006; Ecological Sampling Methods 2009). The strategy was used to minimize variability and cover the entire sampling frame. The biomass was measured by clipping plots in a manner that simulated grazing frequency and intensity. This was done by clipping 1cm above the ground. There were 30 quadrats of 1m by 1m within the 12 selected areas of 1km by 1km within each of the blocks. After which the measurements in the quadrats were weighed and means in each of the 12 selected sampling frames on the study sites calculated. Use of transects allows for logical flow of data collection points (Ecological Sampling Methods 2009).

Clipping was done on once per site during the end of the short rain season in the month of June 2009 and at the end of the long rainy season in the month of May 2010 to determine whether any growth was realized. These sites for clipping were determined 30m from the line plot transect and moved in a perpendicular line to the direction of the transect line.

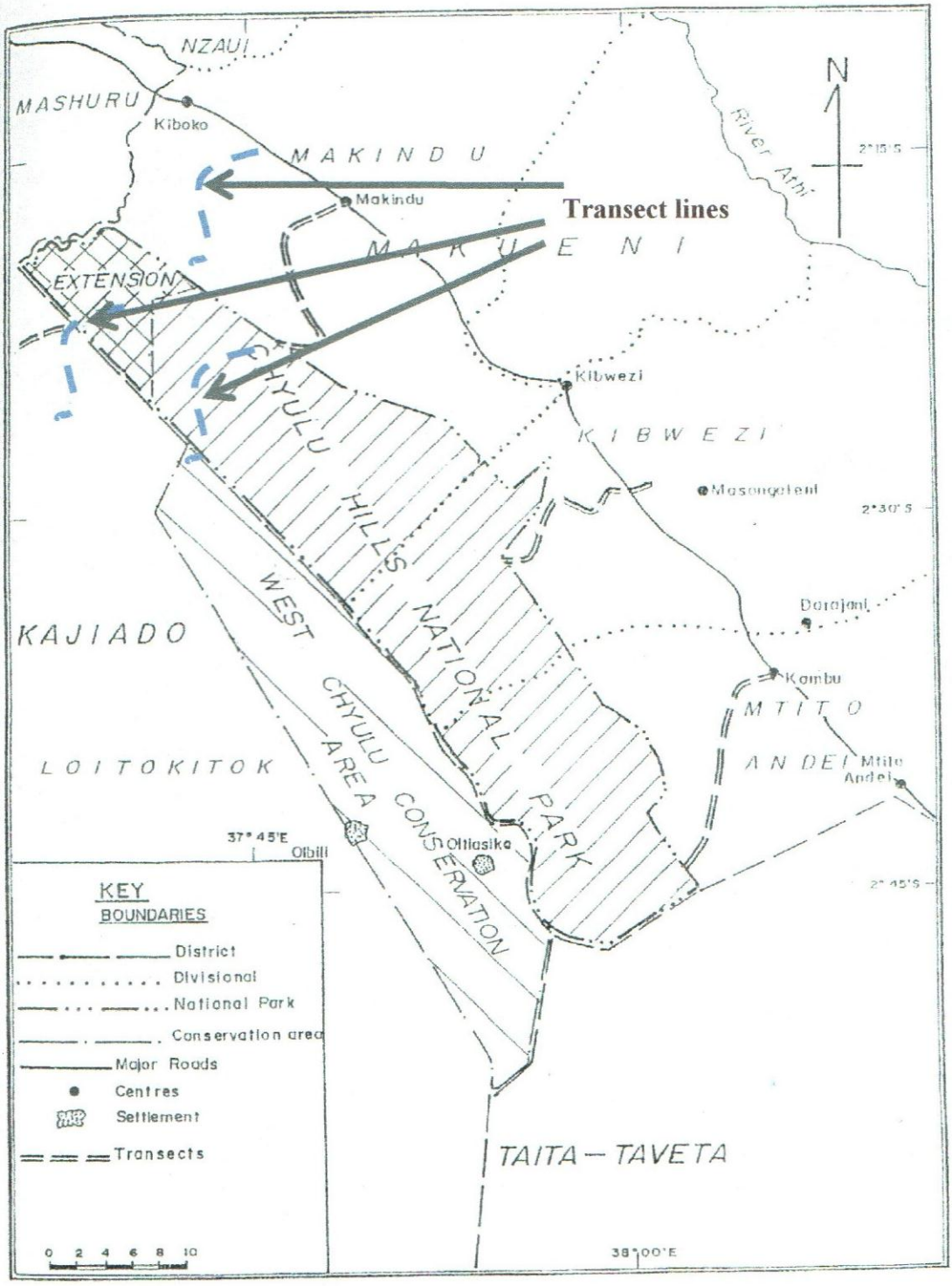


Figure 5: Map showing the transects in CHNP. Source this study 2010

A micro histological comparison of faecal matter was done to provide insight on the presence or absence of *Chloris roxburghiana* on the diet of livestock and wildlife. Micro histological analysis involves identifying and quantifying epidermal and/or cuticle fragments of ingested plants. This is possible as the plant cuticle, an indigestible layer covering the epidermis, bears a specific pattern of underlying epidermal cells and hairs along with structures of its own. This pattern is best developed in mature leaves and can be identified down to species level, even after passage through the herbivore gut. For this method to be successful, a reference slide 'library' of the possible food items must be established. Plate 2 shows how the dung was free occurring within the sites under study. This procedure involved Specimen accessioning where all the collected dung was put in sample bags and numbered. This was done to clearly identify the source as well as the site the dung was retrieved. Gross examination of the dung collected was done with description in further details to include the quadrat of sourcing and type of animal whether cattle, sheep, zebra or gazelle. Tissue fixation this was preservation of cells an tissue constituents through use of airtight sample bags. This coagulates tissue proteins and constituents to prevent their loss during processing.

Tissue processing of the dung samples was done with an objective to embed the tissue in a solid medium firm enough to support the tissue with sufficient rigidity to enable thin sections to be cut. Proceeding after the collection is sun drying the matter for 48hours to lose as much moisture as possible, then oven drying at 70^0C for 24 hours. Once the faecal matter is dry it is ground to fragments and sieved using a 200um sieve where small scoops of dried material was put in 50 vials for which processing ensued.

Dehydration is done on the samples to remove as much water and fixative as possible through use of the sun and then ethanol to remove all the water. Clearing a procedure where use of paraffin wax which is miscible with both the dehydrating fluid ethanol and an embedding medium is applied. Impregnation where embedding medium epoxy resin is utilized is performed on the dung samples.

Tissue embedding a process where tissues are orientated in the desired direction and surrounded by wax medium which when it solidified provided sufficient external support during sectioning. In sectioning the hardened tissue samples are cut into very this sections 3-5 mucrons through use of a microtone. Herbaceous material was boiled in hydrochloric acid (HCL) and

water for 2 hours to simulate digestion. One drop of pellet solution or a small portion of the herb rrdxture was placed on a glass slide. Treatments consisted of adding Hertwig's solution and boiling the mixture, adding a dye and boiling, adding Hertwig's and dye and boiling, and adding Melzer's reagent in combination with the other dyes. Dyes used were cotton blue, safranin, Gram's iodine, phloxine B, trypan blue, and Melzers' reagent. Control slides 6 in number had no Hertwig's solution or dyes and were not heated. Two drops of polyvinyl alcohol (PVA, a mounting medium, Johnson and others 1983) were added to the mixture, which was then covered with a 22- by 40-millimeter cover slip. Fifty slides were made for each study site. We then subjectively compared the degree of specific staining of fungal and plant material, the effects of clearing on identifying fungi and plant structures, and the effects of clearing on staining (Ecological Sampling Methods, 2009).

Making micro-histological slides for comparison with known graminoid slides called reference slides that have been made and stored at various research centers' herbariums to identify the common graminoid species between wildlife and livestock through identification of botanical fragments (Valerio *et al.* 2004; Joris and Han, 2006; Ecological Sampling Methods, 2009). Determination of the diet through analysis of faecal material collected from the field as used by Storr (1961), Voth and Black (1973), Martin (1982), Waweru (1985), and Barker (1986) was adopted in this study.

Thus the reference slides made were 6 for each species of grass found as they provided control to compare with the ones at the established herbarium at the Kenya National Museums Herbarium.

Unlike other food habits techniques the micro histological faecal analysis techniques provided an objective way of validating the records reported by an observer. The basis of this technique is the ability to identify fragments of plants in herbivore faecal material mounted on the microscopic slides .The sampling involves gathering of the faecal material which is relatively simple (Peden *et al.* 1973; FAO 2010).



PLATE 2: Faecal matter used to also corroborate the area being livestock-wildlife because of presence of both wildlife faeces as well livestock faeces in the same site.

3.7 Sampling

Three sites were selected for the study, Livestock only area found at Mashuru where KWS erected a fence to prevent humans from accessing the park also wildlife from leaving the park area, Wildlife only area found inside the park at Mkururo due to the electric fence providing an enclosure with wildlife only which is also reinforced by a KWS militarized camp which prevents pastoralists from approaching the sites and Livestock-Wildlife area this is in the Makindu area as there is no fence hence humans could easily drive their livestock into the park.

3.8 Sampling procedure

The areas under study were stratified based on the three units as described above, where transects were drawn along grazing areas in the middle of each block and 12 quadrats randomly selected from either side of the line plot transect. Each side of a line plot transect was labeled as the left-site A and right Site B, providing data for tabulation possible for ease of statistical analysis (Valerio *et al.* 2004; Joris and Han, 2006; Ecological Sampling Methods 2009).

3.9 Sample size

Each side of the line plot transect provided for 6 study sites on each side 1km by 1km making 12 sampling sites in each block for biomass and height measurements. In each of the study sites 30 quadrats each measuring 1m by 1m were used for clipping. The quadrats were randomized using simple random sampling. This was done by picking the sites from the boundary or fence and on both sides of the transect 3km apart along the 20km transect line set out in each site, where quadrats of 1m x 1m were used for clipping treatments of the *Chloris roxburghiana*. A sample size of 6 (in each of the sites A and B) quadrats per side of each transect with there being 12 quadrats per site was arrived at due to the modest budget under which the researcher was going to operate, the size of the sites under study and the accuracy desired (Valerio *et al.* 2004; Joris and Han, 2006; Ecological Sampling Methods, 2009). Plate 3 shows the quadrat within a larger sampling site where clipping was done. The quadrat shown had been placed in a livestock only area.

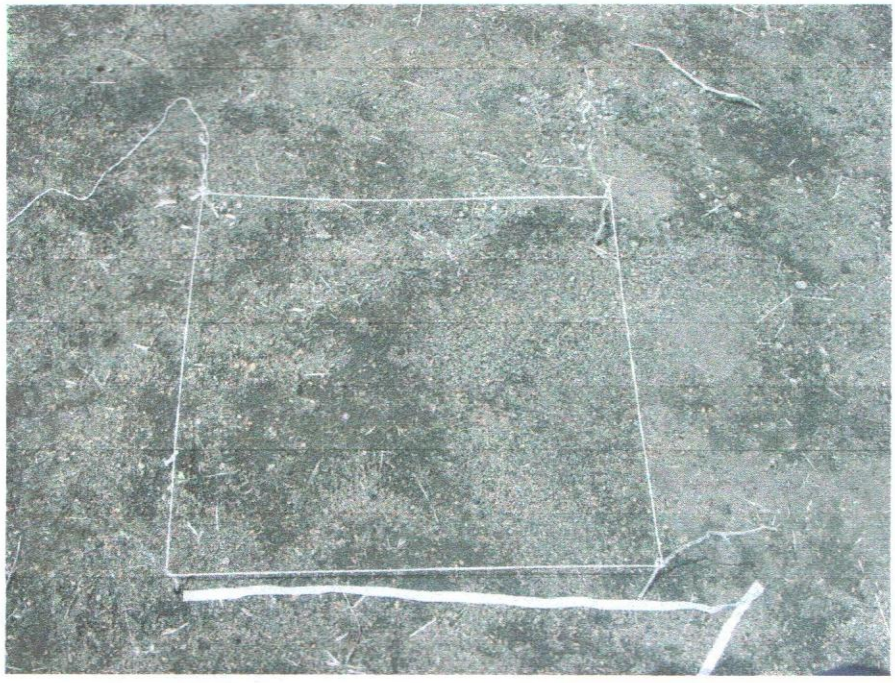


PLATE 3: Quadrat size used in the clipping treatments in a livestock only area.



PLATE 4: Sample quadrat in a wildlife only area highlighting the dominant graminoid species *(C.roxburghiana)*.

A representative sample for micro histological analysis of what was eaten by the herbivore population was obtained through subsampling from 15 defecations per species per study area (Chetri, 2003; Ecological Sampling Methods 2009). This gave a total of 12 defecations from livestock and 12 defecations form wildlife. The basic problem is that plant pigments make identification of epidermal material difficult (Chetri, 2003). However, sample preparation techniques to reduce this problem have been developed and discussed by (Chetri, 2003; Ecological Sampling Methods 2009). The Hertwigs' clearing solution has been used to remove the plant pigment. In this study Sodium hypochlorite was used for bleaching of samples before making slides to overcome this problem. Sample of faecal material were collected from fresh dung. The dung was obtained anywhere along the transect line and put in a polythene sealed bag. From each dung pile several Subsamples are taken, whenever possible, the subsample were collected from different dung balls where scraping had not fully broken them down. Amount taken from each sample was about 2gms. To enhance fragmentation identification the samples were preserved to stop microbial activity by adding common salt and thoroughly mixing it with the sample. The fecal material was then washed through a series of sieves, 500um, 250um, 200um, (Chetri, 2003). The material that remained in the 200um sieve

was further washed by running water and the filtrate collected in a container placed at the bottom. All the faecal filtrates were oven dried and subjected to the same grinding procedure. The resulting ground samples were then put in self-sealing polythene bags and stored for slide preparation.

The ground reference samples and prepared faecal samples were placed in test tubes into which sodium hypochlorite solution was added and heated for a minute. The tube was then left to stand until most of the pigment had disappeared then the bleach was then washed off using warm water.

Using a binocular compound microscope equipped with phase contrast, the reference slides were studied and for each plant species the identifiable unique characteristics were noted and digital photos taken as shown in Plate 5 where epidermal tissues with stomatal complexes are used to identify samples.. On each slides 25 then 50 microscopic fields were studied and in every field identifiable fragments were recorded using present or absent technique. A minimum of 3 characteristics were used for species identification.

Faecal matter was collected from each site and prepared for micro histological comparison. With the area being sampled being mono stand in terms of grass species occurring on the site reference slides made were from the species with the rest developed after analysis of the dung samples.

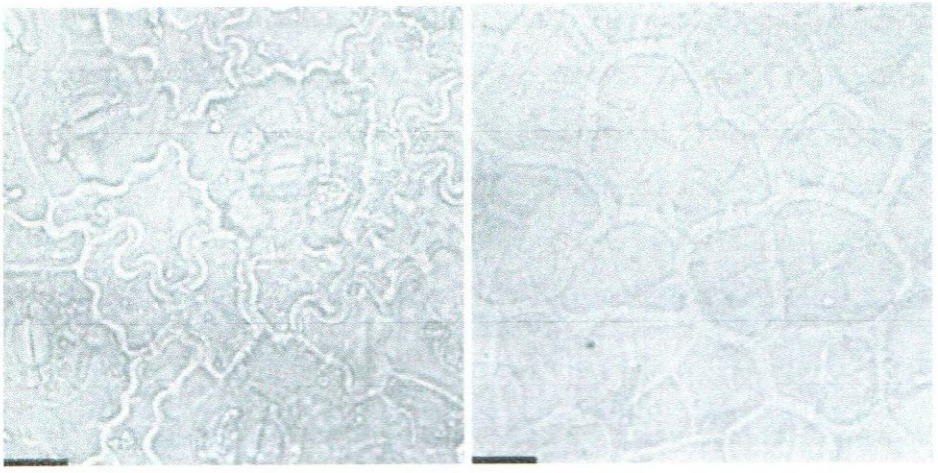


PLATE 5: Scale bars = 15 mm. Abaxial foliar epidermal tissues with stomatal complexes *C. roxburghiana*

3.10 Forage utilization and biomass measurements

An initial visit in all the sites that had been identified and a herbarium of grass species found on the study sites compiled. On each day of observation, information on the grass species available and grazed upon was collected by backtracking along the foraging path of the herd, identified through the presence of fresh dung, tracks and recent grazing (Valerio *et al.* 2004; Kiruki, 2006; Joris and Han, 2006; Ecological Sampling Methods 2009)).

12 Foraging sites (1km by 1km) were located off the transect line in the direction of foraging movement per sampling day. At each site on either side of the transect, 30 1m × 1 m quadrats were placed 200 m apart in two parallel lines along the foraging direction. In the event that the tracks were not followed, the nearest grazed site along the general direction of movement was sampled. The grass species choices that were made at feeding stations spaced 5Km apart was assumed to be independent, although the grass species available may have remained similar. The experimental units were 12 in each of the areas livestock only, wildlife-livestock and wildlife only which was the control area (Valerio *et al.* 2004; Kiruki, 2006).

The landscape position of each foraging site was also recorded as livestock only, livestock-wildlife and wildlife only area. Within each quadrat, grazed and ungrazed grass tufts were identified from signs of fresh cropping. The total number of tufts and the number of freshly grazed tufts were counted for each grass species occurring within each quadrat. Differences in tuft size were ignored. Grass height was recorded by measuring the height of the tallest basal leaf above ground level for each grass tuft and then grouped into five tuft height classes: 1–10, 11–30, 31–50, 51–70, >70 cm. The number of emergent culms in each grass tuft was counted and classified into four stem classes: Non Emergent (NE), 1–2, 3–4, 5+ stems (Bonham 1989; Valerio *et al.* 2004; Kiruki, 2006).

Sample sites were randomly selected using simple stratified sampling procedure and quadrats were used to provide areas for clipping. The same quadrats provided a scientific space within which frequency of species were carried out to determine amounts. This method was used to estimate the frequency of measurements where a physical count of *Chloris roxburghiana* was made and average percentage of occurrence per site. The weights of clipped grass were used in

the comparison analysis of means to estimate biomass per study site (Canfield, 1941; Bonham, 1989; Kiruki, 2006). A simulation of the livestock grazing was done to estimate the number of livestock that it would take for the herbaceous material to be utilized fully at the time of the study. This was done by clipping to simulate both frequency and intensity of grazing in each of the 12 (1km by 1km) sampling frames within the 30(1m by 1m) quadrats per frame. This was by clipping an area twice in the end of each rainy season and also clipping at 1cm from the ground to simulate heavy grazing intensity (Paine; 2004; Ecological Sampling Methods, 2009).

Sample weights of herbaceous material were taken in areas without livestock grazing, in areas with both wildlife and livestock grazing and in areas with exclusive wildlife grazing. This was done so as to compare by weight livestock consumption and utilization in order to obtain situational analysis data. Assessment of herbaceous material preferred by livestock when entering the park was made and recorded using tabular methods, also distance covered by livestock at each transect line was measured.

Micro-histological samples were to confirm if there was overlap between wildlife and livestock and also give the abundance in their diet. Standard fecal collection protocols and analytical procedures as defined by National Museums of Kenya fecal analysis lab were followed. Collection sites were selected along the transect lines. Multiple pellets were collected from individual locations and were pooled as samples to reduce variability and increase local representation. Fresh, recently deposited fecal material, was collected in order to closely establish the time of forage consumption. Individual samples were prepared for microscope analysis. A percent composition of plant epidermal fragment present in each sample was determined and plant species were identified down to genus and sometimes species.

Above ground biomass was measured for the grass species in the sites selected through clipping and weighing and mass recorded (g). Forage biomass was used as the dependent variable in the analysis. Production can be estimated using variables that correlated with it, such as amount of emerging tufts based on grazed and ungrazed tuft (Sala *et al.*2000; Valerio *et al.* 2004). The simple quadrat method (Canfield, 1941; Valerio *et al.* 2004; Joris and Han, 2006; Ecological Sampling Methods 2009), which is a 1m by 1m square that provides an area for clipping, has been widely used in grasslands. There was a template used to fill information from

the measurements in the field. Laboratory analysis was required for the micro histological slides identification through comparison with established reference slides.

Photographs were utilized in documenting various results and procedures for comparison of various sites and impacts. Such as shown by Plate 6 showing how in a wildlife livestock area the characteristics and general abundance of *Chloris roxburghiana.* Plate 7 shows livestock crowded within the park and the photograph was taken 18km within the park boundary. Plate 8 showing the characteristics observed in the livestock only area at the end of rainy season showing no grass cover. Plate 9 showing cattle and wildlife grazing together in the beginning of a rainy season in the wildlife-livestock area.



PLATE 6: Wildlife-livestock area only area without grass cover with a zebra in the mid-ground.



PLATE 7: Livestock crowded in a wildlife-livestock area inside the park.



PLATE 8: Sampling area in a livestock only area after livestock has been moved showing no grass cover.



PLATE 9: Wildlife and livestock grazing in the same site.

Duration of experiment was designed for 1 year the appropriate period for studying a perennial graminoid species (Ecological Sampling methods, 2009). The study started in June 2009 which was the marked month for the beginning of the short rains (RoK, 1997b) and first clippings were done in the month of August to allow for rain to cause any growth, the second and final clipping was done in May of 2010 with the end of the long rains period (RoK, 1997b). this periods provided seasonality regimes desired to measure growth and biomass.

3.11 Data analysis

In order to carry out statistical analysis standard errors were employed thus there were blocks in random where the sample quadrats were laid in with replications totaling 30 per sample frame. Each objective would be tested using these techniques. Means per sites where quadrats were measured were used as independent units for the calculation of standard errors. For analysis and determination of utilized in diet by both livestock and wildlife grazers' faecal samples of wildlife and livestock grazers were analyzed using micro histological analysis.

From faecal samples, the proportion contributed by the grass species was estimated by counting the number of identified slides of that grass species identified and dividing this by the 50 slides used for observation.

Proportion of *C. roxburghiana*= (No of slides of grass identified/50 slides)*100%

Standard errors were calculated assuming independence among the samples. The availability of the grass species in each site was estimated by its frequency of occurrence, calculated by dividing the number of quadrats where the species were present by the quadrats sampled.

$$\text{Frequency of occurrence} = \frac{\text{No of quadrats where species were present}}{\text{Total No of quadrats sampled in the area}}$$

The frequency of acceptance was calculated by dividing the number of quadrats where the species was eaten by the total number of quadrats in which the species were present.

$$\textit{Frequency of acceptance (overlap)} = \frac{\text{No of quadrats where species was eaten}}{\text{Total No of quadrats in which present}}$$

The dietary contribution of the grass species was estimated from plant-based observations by counting the number of tufts of the species that were grazed and dividing this by the total number of grazed tufts of all species for each day.

Plant frequency data was collected through recording of the numbers of *Chloris roxburghiana* culms in each sampled site and tabulated as per the sampling sites where percentages were calculated and provided comparison of the sites. Biomass per block was estimated using variables that correlated with it, such as amount of emerging tufts based on grazed and ungrazed tuft (Sala and Austin, 2000; Valerio *et al.*2004). Also the total clipped weight of the block divided by the total number of quadrats in the block. This could be then presented on kg/ha. This was also in tabulated format thereby allowing for standard errors to be calculated and means established.

$$\textit{Mean biomass} = \frac{\text{Total clipped weight}}{\text{total number of quadrats}}$$

Botanical identification of the select species was done by physical observation of the graminoid species and also collection of samples for comparison at reference herbarium at the National Museums of Kenya. This provided a base to get reference slides for micro-histological evaluation for diet overlap. Fecal data were entered into a spreadsheet to create a matrix depicting samples and vegetation species identified in the fecal material. This allowed for the calculation of similarity indices inherent in the use of plant community analytical techniques, such as ordination (Hosten *et al.* 2007; Ecological Sampling Methods, 2009). Analysis was conducted at different levels of biological organization - individual grass species and vegetation life-forms. While individual sample values were used in the analysis by ordination, averaging by sampling frame was completed for the subset of samples that included species/life-from of interest. Sorting was used to identify individual plant species utilized by cattle, sheep, gazelle and zebra. Sorting was based on the average percent composition of samples and relative percent occupancy within the total number of fecal samples collected over the study area.

The analysis was performed at 95% significance level ($P < 0.05$) using MS EXCEL.

The dietary contribution of each grass species in terms of proportion of grazed tufts and proportion of fragments in the dung was compared between landscapes using Standard Errors.?? The dietary analysis was used to name the species of grass selected.

ANOVA was done at 95% significance level ($P < 0.05$) to analyze the differences in the sites: wildlife only, wildlife-livestock and livestock only area. The proportions of foraging sites in different landscape positions was derived by dividing the number of foraging sites within each landscape position by the total number of foraging sites sampled for each sampling period.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Results

In the livestock grazed area, the category of 1-10cm *Chloris roxburghiana* tuft height was the only category present. This meant that the area had no *Chloris roxburghiana* growing for a while and the *Chloris roxburghiana* tufts available had been grazed hence their low height (Figure 6).



Figure 6: Mean numbers of *C.roxburghiana* tuft height categories in livestock only area.

The comparison of the three sites in terms of the grass tuft height demonstrated that the livestock only area recorded the least *C. roxburghiana* tuft heights in the 1-10cm category, whereas the wildlife only area recorded the highest numbers and the wildlife only to have recordings in the above 70cm height category (Figure 9).

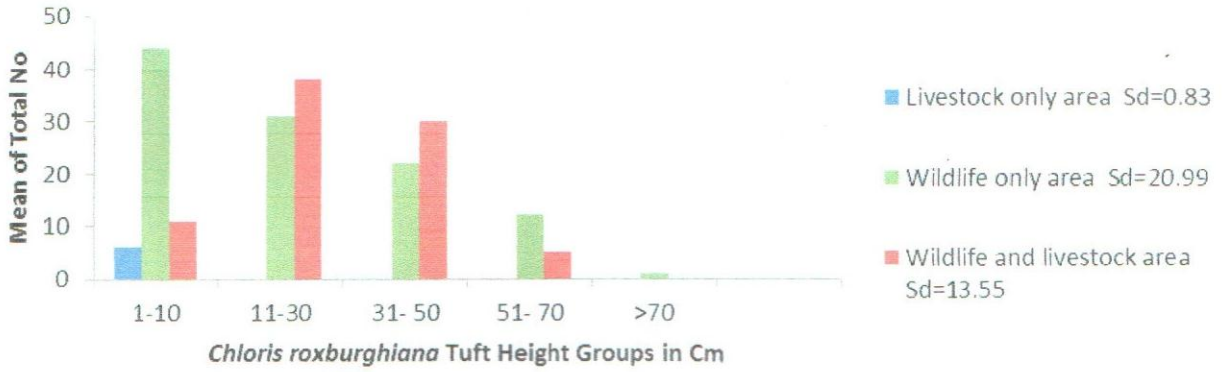


Figure 9: Comparison of mean numbers of *C. roxburghiana* tuft heights in the study sites

The comparison of the three sites showing the Trends in the grass height distribution among the three sites revealed high values in the wildlife - livestock and the wildlife areas with low values in the livestock area (Figure 10). The sites showed a general reduction in grass height numbers. In other words the sites exhibited the greater numbers of *C. roxburghiana* culms in the shorter categories suggesting higher grazing pressure.

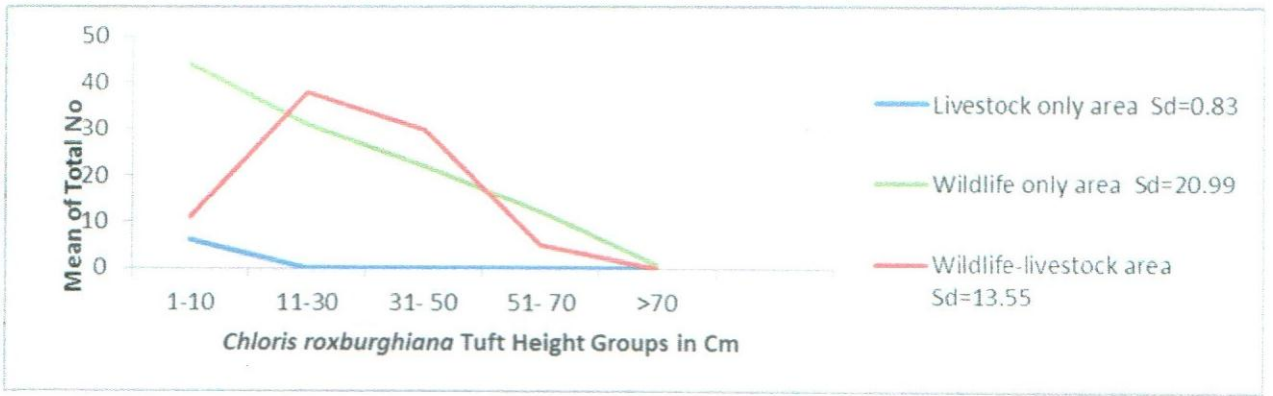


Figure 10: Distribution comparisons of *C. roxburghiana* tuft heights categories in different sites.

The histogram showing comparison among the different sites for the numbers of emerging grass culms with the highest peak being observed in the wildlife only area as well as the lowest number observed in the category of zero growth being from livestock only area. The highest peak in the category above 5 culms was observed in wildlife-livestock area (Figure 14).

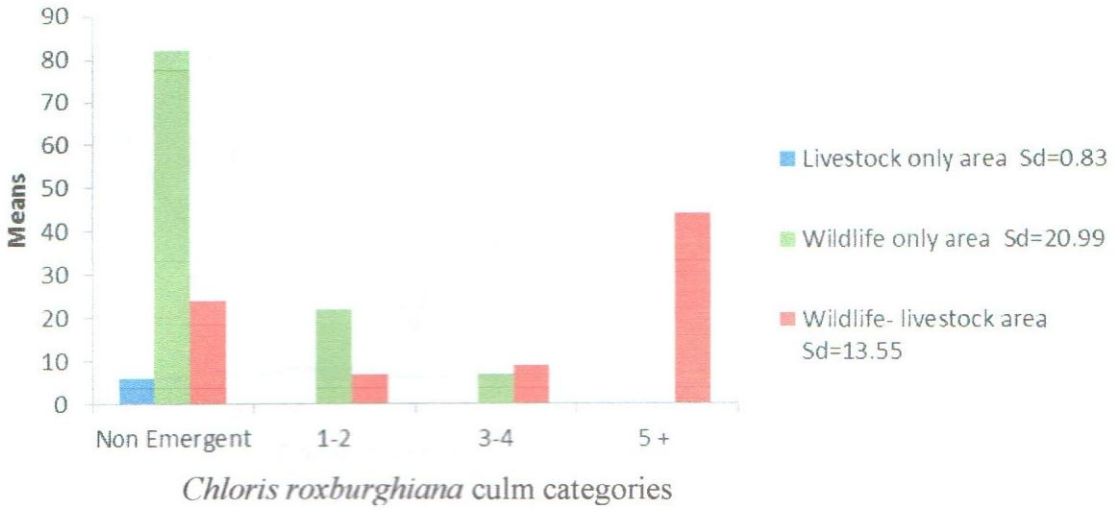


Figure 11: Comparisons of culms of *C.roxburghiana* categories in study sites

The distribution trends comparing all the sites show emerging culms of all categories from wildlife and livestock area and from wildlife area being high in all categories as compared to the livestock area (Figure 15).

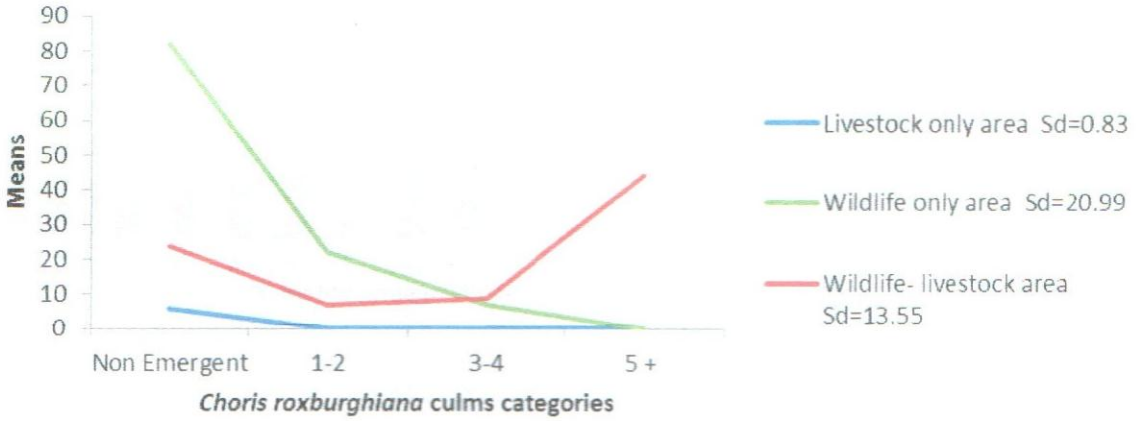


Figure 12: Distribution of comparisons of culms of *C.roxburghiana* categories in the study sites

The comparison of different quadrats in different sites showing higher mass observed in the samples from wildlife only area and wildlife and livestock area with very low mass of samples in the livestock only areas (Figure 16).

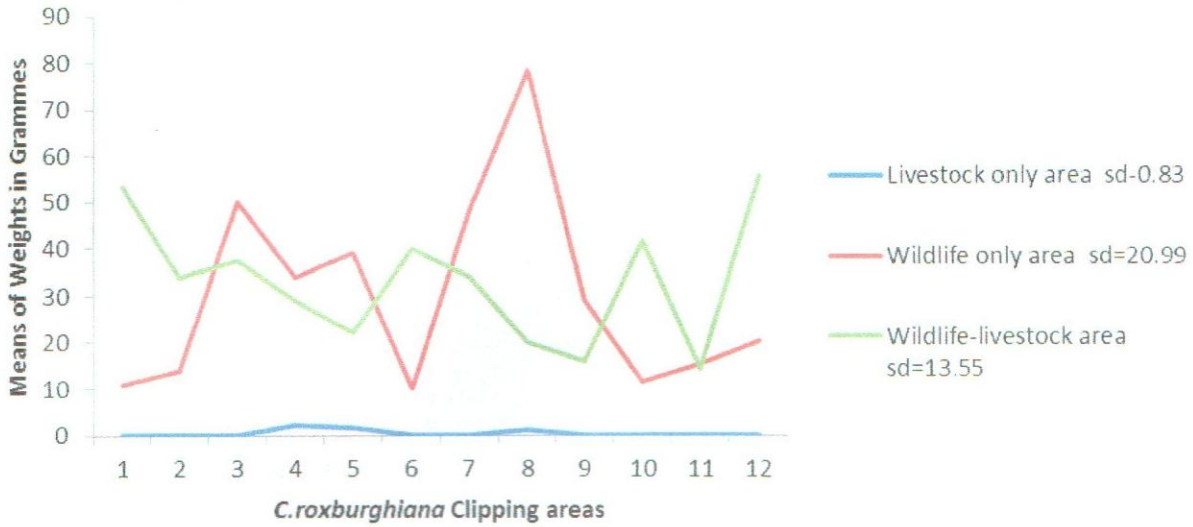


Figure 13: Distribution trends showing weights of clipped *C.roxburghiana* in comparison by sites

Comparison of the mass of samples from sites showing livestock area with almost zero mass recording and highest peak in the wildlife only area (Figure 17).

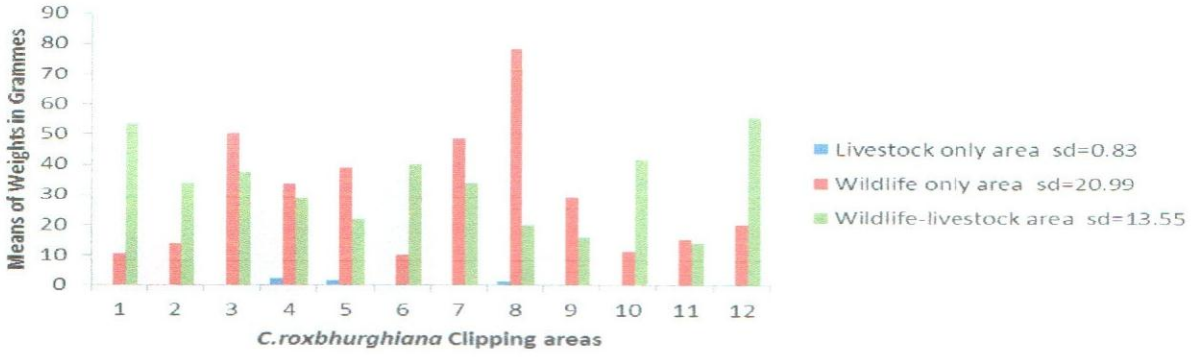


Figure 14: Mean weights of clipped *C.roxburghiana* across sampling sites

Comparison of mean weights among sites showed the livestock area being the lowest while the wildlife - livestock area gave the highest weight (Figure 18).

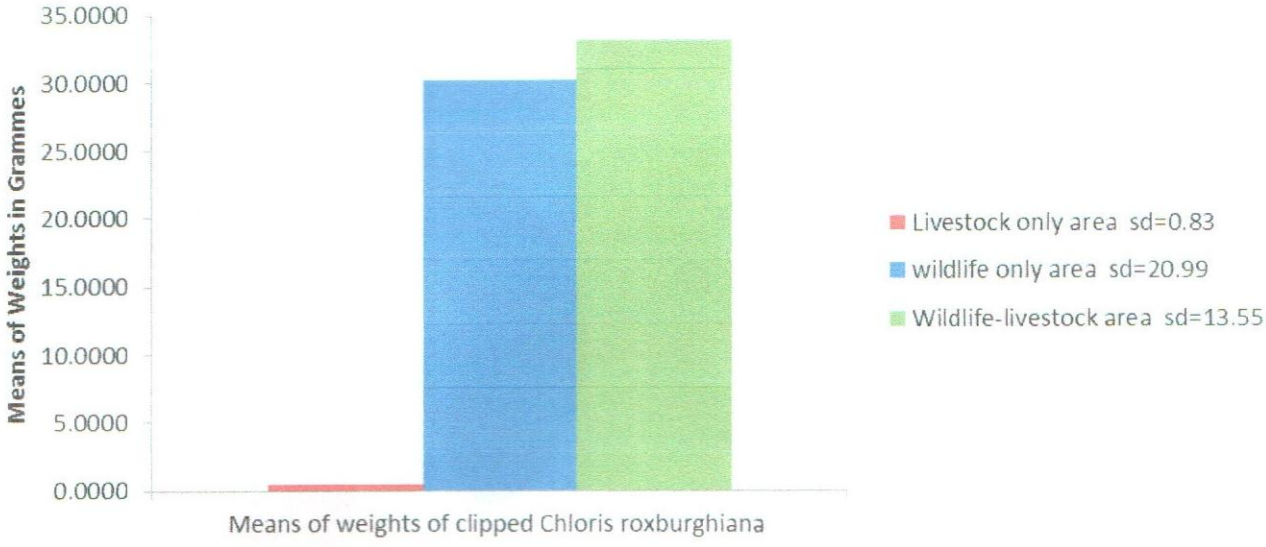


Figure 15: Means in weight of clipped *C.roxburghiana* comparison by sites

Frequency of *C.roxburghiana* culms categories was tabulated and compared per sites. This showed high values on the wildlife-livestock area and in the wildlife only area with low values in the livestock only area (Figure 19).

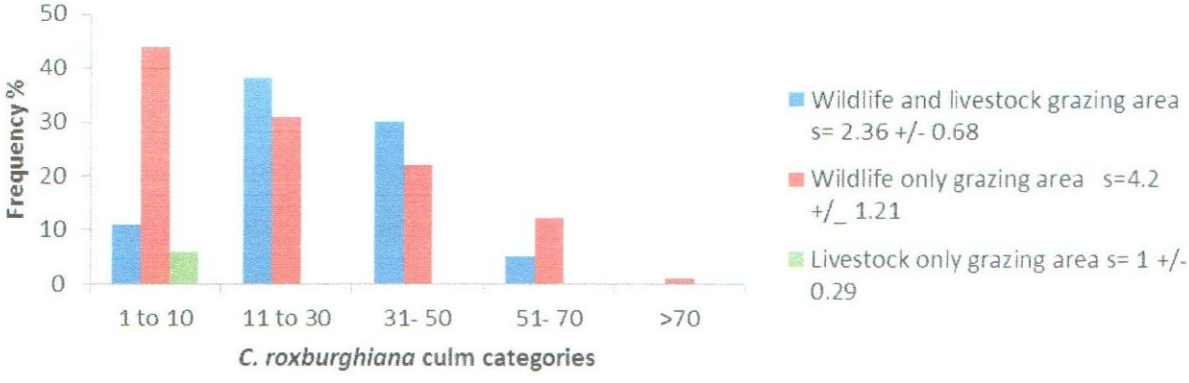


Figure 16: Frequency of *Chloris roxburghiana* culm categories comparison by sites

The total counts of *C.roxburghiana* were taken per sampled sites and means derived to show comparison of abundance per study area. Highest counts were recorded in the wildlife only area (Figure 17)

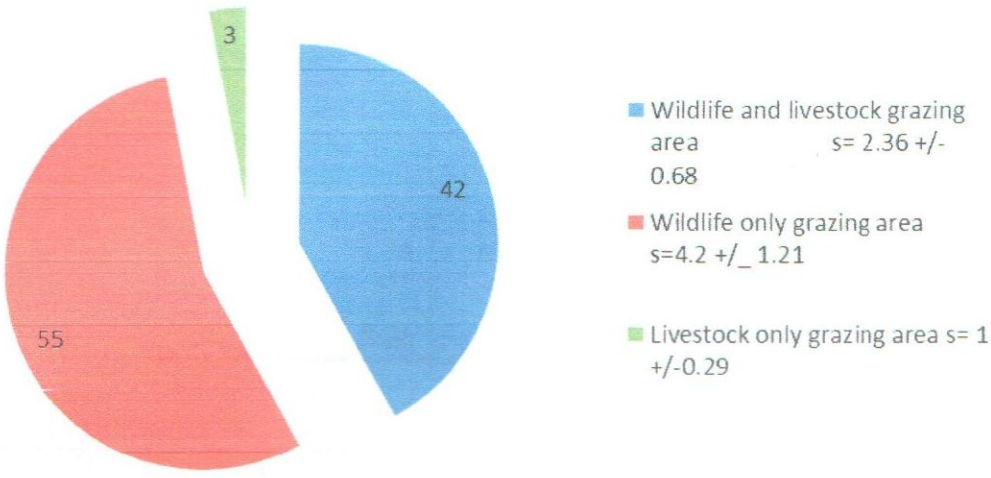


Figure 17: Percentage abundance of *Chloris roxburghiana* comparison by sites.

Micro histology results

From the fields per slide observations, *C.roxburghiana* was the dominant food type across animal species (Tables 1 and 2). Most common components exhibited minimal variation in relative frequency per slide. As the number of fields per slide increased from 25 to 50, little difference in relative frequency was observed. Differences in coefficient of variation (CV) values for some items probably were due to intersample variations in occurrence.

Table 1; Total fields of occurrence of *C. roxburghiana* in the livestock faecal samples which were compared with the reference slides.

attle	25 fields per slide (n = 15 slides)			50 fields per slide (n = 40 slides)			All slides (n = 55 slides)		
iet mponent	Total Fields	Mean RF	CV	Total Fields	Mean RF	CV	Total Fields	Mean RF	CV
			%			%			%
oxburghiana	329	21.93	91.14	1106	27.65	84.43	1435	26.09	85.88
ther	32	2.13	8.86	204	5.1	15.57	236	4.29	14.12
heep	25 fields per slide (n = 15 slides)			50 fields per slide (n = 40 slides)			All slides (n = 55 slides)		
iet mponent	Total Fields	Mean RF	CV	Total Fields	Mean RF	CV	Total Fields	Mean RF	CV
			%			%			%
oxburghiana	402	26.80	90.74	1283	32.075	86.46	1596	29.02	88.23
ther	41	2.73	9.26	201	5.025	13.54	213	3.87	11.77

NB: Other species composed of *Digitaria macroblephara*, *Bothriochloa radicans* ,*Tephrosia subtriflora* and *Tephrosia villosa,* and *Cenchris ciliaris* all of which were not significant in the analysis,

Table 2; Total fields of occurrence of C. roxburghiana in the wildlife faecal samples which were compared with the reference slides

Zebra	25 fields per slide (n = 15 slides)			50 fields per slide (n = 40 slides)			All slides (n = 55 slides)		
Diet component	Total Fields	Mean RF	CV	Total Fields	Mean RF	CV	Total Fields	Mean RF	CV
			%			%			%
C. roxburghiana	502	33.47	94.54	1297	32.425	88.71	1511	27.47	88.83
Other	29	1.93	5.46	165	4.125	11.29	190	3.45	11.17
Gazelle	25 fields per slide (n = 15 slides)			50 fields per slide (n = 40 slides)			All slides (n = 55 slides)		
Diet component	Total Fields	Mean RF	CV	Total Fields	Mean RF	CV	Total Fields	Mean RF	CV
			%			%			%
C. roxburghiana	496	33.07	95.75	1086	27.15	94.52	1388	25.24	94.10
Other	22	1.47	4.25	63	1.575	5.48	87	1.58	5.90

From the micro-histological analyses of both livestock and wildlife for increase of credibility first occurrence per sample was conducted for the samples from which slides were derived. In comparison of the abundance of *Chloris roxburghiana* of both livestock species and wildlife species there was relative similarity in abundance as shown by the histograms in Figure 18 and Figure 19.

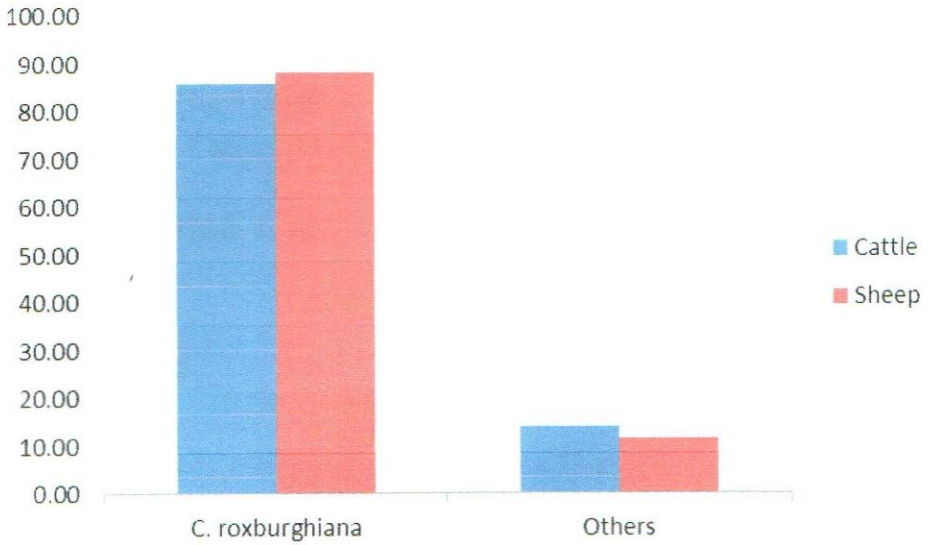


Figure 18: Abundance of *C.roxburghiana* in livestock.

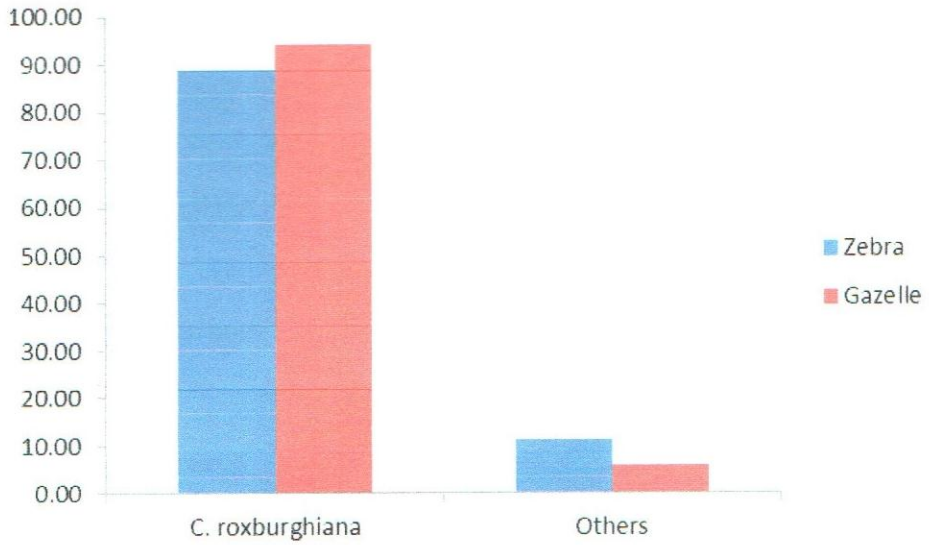


Figure 19: Abundance of *C.roxburghiana* in wildlife

Analysis of the results for the various sites showing the comparison of mean weight of *Chloris roxburghiana* among wildlife only areas, wildlife – livestock area and livestock only areas through statistical analysis to give comparison among wildlife only area, livestock only area and wildlife - livestock area.

Table 3; ANOVA results from clipping means

	1st clipping Mean	Standard Deviation	2nd clipping Mean	Standard Deviation
Wildlife	26.38	16.96	33.8	25.47
Livestock	0.68	1.07	0.20	0.50
Wildlife-Livestock	36.03	10.68	30.22	16.42

	F Calc	**F Tab**
F-test for wildlife against livestock	0.08	0.8600
F-test for livestock against both	0.10	0.8600
F-test for wildlife against both	0.85	0.8600

4.2 Discussion

In order to assess the effects of livestock and wildlife grazing on the amount and abundance of *Chloris roxburghiana* in CHNP and its environs being affected by grazing, the various measurements were performed for amounts and biomass to simulate grazing and dietary composition were recorded with observations of evidence to show areas where significant growth was observed. Anderson D. E (1974) highlighted that the species originated in Kenya and its characteristics have been explained by other authors doing studies where the graminoid species *Chloris roxburghiana* occurs.

Observations in regard to the biomass of *Chloris roxburghiana* indicated scanty vegetation in grasses season long in the livestock only areas, this was also accompanied by a two year long drought. Various researchers have noted similar patterns in areas grazed where there are pure stands. Williams (2012) documented continuous defoliation depleted the whole stand of the grass species being studied with the grazing was intense. This was evidenced through high intensity high frequency grazing treatment on the *Chloris roxburghiana* in the livestock only area. Thus due to the prolonged drought the grass never recovered as to cause regrowth. In the measurement of emerging culms the livestock grazed area realized very low numbers from all the areas sampled under livestock only. The results as confirmed by Plate 8 that shows no *Chloris roxburghiana* species being observed and Figure 6 confirm the observation. The results of the ANOVA in Table 3 where the study fails to reject null hypothesis that states that there is significant difference in areas grazed by wildlife and areas grazed by livestock, as Ecologigal Sampling methods (2009) state that reject Ho if F-calculated is greater than F-tabulated which was the case. The results also show the biomass of *Chloris roxburghiana* was 8163.3kg/Ha implying that grazing pressure impacted on the *Chloris roxburghiana* affected the regrowth capacity of the grass thereby causing loss of vegetation materials. As a response mechanism to high intensity grazing *Chloris roxburghiana* is inhibited in terms of its growth vigour in the livestock only grazing than in wildlife livestock area and wildlife only area.

Chloris roxburghiana is a dominant species in dryland areas of Kenya, and is usually found growing in association with *Chrysopogon aucheri* (Rattray, 1960). Despite its wide distribution, Herlocker (1999) treats this vegetation type as a subtype of the *Chrysopogon* mid-grass region. *Chloris roxburghiana* is widespread throughout the entire region of CHNP and is

an important species for livestock and wildlife, in the areas from mid to north western of CHNP it occurs in pure stands. This species contributes up to 90 percent of the diet of wild herbivores in eastern Kenya (IBPGR, 1984) but is in danger of disappearing due to overgrazing and land degradation. *Chloris roxburghiana* was found within the livestock grazed areas it was the most abundant graminoid species obtained both from the faecal matter of livestock confirmed through micro-histological analysis. This scenario further confirms that livestock in communal lands overutilise the available pasture due to high grazing intensity and also trampling impacts (Flintan *et al,* 2011). In this ecological area of CHNP *Chloris roxburghiana* was the dominant graminoid species and also in terms of frequency many of the sampled areas registered zero for any other graminoid species and only *Chloris roxburghiana* was observed.

Table 3 which is the ANOVA confirmed that grazing by livestock on the livestock only area had reduced significantly the potential for the livestock only area to allow for regrowth of *Chloris roxburghiana.* Results showed there is significant difference in areas grazed by wildlife-livestock and areas grazed by livestock only and rejected the hypothesis that there is significant difference in areas grazed by wildlife only and wildlife-livestock. Cattle use wooded and open habitats more opportunistically (Hartnett *et al.*1997). As Williams (2012) in his studies of depletion of graminoid species due to grazing, confirmed that in pure stands especially the preferred vegetation type chances of depletion is high due to livestock numbers being high as most of those areas are common property and also livestock tends to overstay in those areas during months of drought. Flintan *et al,* (2011) in is studies of land fragmentation observed how community land has shrunk thereby grazing impacts are severe on such land. The livestock only areas are undergoing through many changes in the Soil-Plant-Animal- continuum (SPAC) which is highlighted in Flintan *et al*, (2011) showing how trampling impacts due to large numbers of livestock grazing in one area would cause a loss of production in terms of reduced frequency and growth of food resources such as the impact on *Chloris roxburghiana* as shown in Figure 17. The data shows Livestock only area with the smallest portion in the pie charts authenticates overutilization of grazing resources by livestock. In other studies the rangeland and the pastoral society have seen significant change including almost total resource privatization of grazing areas and water. In the majority of areas there has been a carving up of the rangeland into individual household plots for grazing and some crop production. This has completely restricted the movement of livestock along traditional migration routes and across grazing areas. Plate 4

shows the *Chloris roxburghiana* availability in the wildlife only area and abundance in the faecal matter of the grazing livestock is shown in Table 1, thus there was authentication from Table 1 in terms of percentage with other genera thereby the recording highlights the site under livestock only had *Chloris roxburghiana* as the dominant grazing resource available. This is further explained by studies on examination of ruminants grazing habits in Flintan *et al*, (2011)

Wildlife-Livestock area had abundance of *Chloris roxburghiana* recorded both from the clipping weights as shown in Figure 8. This area despite being frequented by both wildlife and livestock exhibited high numbers of biomass available for grazing. In terms of graminoid species availability and abundance *Chloris roxburghiana* occurred in pure stands in these areas this was due to anthropogenic fires in CHNP (Ngene *et al,* 2011) and also was very abundant as all sampling areas within wildlife-livestock areas registered pure stands of *Chloris roxburghiana* as shown by Plates 4 and 7. Plate 7 authenticated the distribution of tuft height groups in Figure 8. Studies show that North American prairies developed under the influence of fire and bison (Coppedge and Shaw 1998). These are huge areas with pure stand grass that benefits from regeneration. The study indicates that the combination of fire and bison grazing created the prairie ecosystem; not just fire or bison acting alone. Fire may be an important determinant of the pattern of large herbivore grazing activity, which is often spatially and temporally heterogeneous. In rangelands where pastoral people graze their livestock, wildlife avoid areas that livestock graze heavily (around water points and villages), which cover about 10 % of the land area. In the remaining and extensive lands with fewer people and livestock, wildlife and livestock graze together (Reid, 2011). This explaines that in areas within the wildlife-livestock grazing area experienced a higher intensity in those sites. This is explained by the high numbers of livestock but due to the forage availability the animals were grazing in larger areas than when the observation was made in the livestock only area. Reid (2011) also recorded in his study that pastoral people may only enrich savannas when they use them at low to moderate levels because higher use will extinguish biodiversity. This is what was shown in the livestock only area where there were areas without grass growing after the rain season.

The total emergent culms of *Chloris roxburghiana* recorded were more than the non-emergent culms Figure 11. This suggests the presence of growth in wildlife-livestock and wildlife only areas. However, wildlife-livestock area did not record *Chloris roxburghiana* grass category at tuft height above 70cm, the same area also recorded the area to have majority of the

tufts category of 11-30cm which showed that the *Chloris roxburghiana* grass tufts were fairly even in this study site as the next major category was 31-50cm height. This confirmed the low grazing pressure experienced in the wildlife- livestock grazed area also that the feeding habits utilized the tall *Chloris roxburghiana* species allowing for the growing culms to grow. Bourne and Blench (1999) have suggested that in rangeland dynamics and resilience livestock management is less ecologically damaging if pastoralists have access to more diverse sources of grazing and water..

Microhistological data suggested coexistence between wildlife and livestock in the wildlife-livestock area with evidence of feeding on the same sites after analysis of faecal samples. This is an attribute in ecological segregation where the animals utilize different parts of the same vegetative material. English Nature (2003) highlights the advantages of livestock grazing on areas with wildlife by controlling encroachment of more aggressive species and also preventing scrub encroachment. This ensures that pure stands are maintained and therefore grazing resources are made available to both wildlife and livestock. Figure 7 offers a description of the area under wildlife only showing that majority of the tuft height recorded for *Chloris roxburghiana* was in the 1-10cm category which when compared to Figure 11 showing that the majority numbers of emergent *Chloris roxburghiana* counted were not emergent thus it showed that the *Chloris roxburghiana* that was in this area was not productive and also was of majority low height in the 1-10cm as shown in Figure 7. Figure 7 highlights the responses of *Chloris roxburghiana* due to grazing pressure that is moderate and shows that it grows and has all categories of grass tufts which was the case in the wildlife only area unlike in Figure 6 where the high grazing pressure realized absence of all but one category that was the case in livestock only area.

Wildlife grazed area was cordoned off livestock hence the reduced production which was at 26.13 % meaning the growth of *Chloris roxburghiana* is limited by its own abundance when it is exposed to low grazing intensity and pressure. Thus the grass would remain at a low height and delay maturity (Anderson, 1974; IBPGR, 1984). The abundance of *Chloris roxburghiana* in wildlife grazed area was also high as all the quadrats sampled registered only this graminoid species. Thus showing that *Chloris roxburghiana* as a graminoid species has colonized the ecological area. This has also been shown by Ngene *et al,* (2011) where in similar studies

realised abundance of feed resources inhibits growth. In Anderson, (1974) the genus is known to have inhibited growth when left unutilized

4.2.1 Comparison of the study sites

Site comparisons as shown in Figure 9 show that the wildlife only area had the highest tuft height categories. The comparison of the three sites in terms of the grass tuft height shows the livestock only area registering an observation only in the 1-10cm and the wildlife only area showing observations in the above 70cm height categories to mean that the wildlife only area had an abundance of *Chloris roxburghiana* growing hence the environment had very little interruption in terms of growth and impacts of grazing by wildlife on the grass species. The intensity of grazing was low in the wildlife only area and in the same Figure 9 there was a general decline in counts of tuft height as the height categories increased to mean the *Chloris roxburghiana* had not grown to full height and there was general stagnation. The observations here disagree with Vavra (2005) who assuaged that the ecological costs of livestock grazing is the loss of biodiversity this was evidenced only in the livestock only area while proof of coexistence was realised in the wildlife-livestock area. As there is evidence of loss of biodiversity even in low utilization.

The observations in Plate 4 and Figure 9 of the wildlife only area confirmed that the area was undergoing least grazing intensity hence the biomass of the *C. roxburghiana* was higher than in the two sites of wildlife livestock and livestock only, with wildlife-livestock still having a higher biomass of *C. roxburghiana* than the livestock only area. McNoughton (1998) present information that the effects livestock and wildlife have on plant communities depend on the balance between feeding selectivity of herbivores and the ability of plant species to recover from tissue loss. English Nature (2003) also explains the different grazing ways with sheep having thin mobile lips hence move slowly over the sward, and target flowering plants which have negative impact on species diversity, they can push themselves through scrub and browse samplings preventing new growth. This was evidenced in the livestock only area where there was no new growth of *Chloris roxburghiana*. English Nature (2003) also found evidence that sheep find it harder to grazer longer vegetation which is trampled instead. It also describes how cattle use their tongues to pull tufts of vegetation into the mouth. This means that they do not graze vegetation too close to the ground and often leave tussocks of grass which are used by

insects and small mammals. Because of their wide mouths cattle do not graze selectively and as a result do not target flower heads and herbage which is important for botanically diverse habitats. Cattle are able to create their own access into rough areas and the trampling of these areas can be an important way of controlling scrub. This is the scenario in the wildlife livestock areas where there was grazing without much biomass loss.

Figure 10 shows the decreasing trend of the *C. roxburghiana* across the tuft height categories in the sites under study. This showed that the sites exhibited abundance of the *C. roxburghiana* in the 1-10cm category to mean there was grazing occurring in all the sites and the lower values toward the 70cm and above categories means the areas with such responses had lower grazing intensity had the rest as the *Chloris roxburghiana* was being let to reach maximum height of growth. The categories 11-70cm showed that the grazing pressure allowed for production that even as grazing was going on the intensity would still allow for growth of the *C. roxburghiana*. Vavra (2005) highlighted the competition theory that suggests in a landscape inhabited by herbivores that prefer one type of forage such as the site with *Chloris roxburghiana*, that preferred forage will through defoliation be less competitive than other species. Figure 11 showed the comparison of *C. roxburghiana* emerging culms. This highlighted that the wildlife-livestock area had the highest number of emergent culms of a tuft with over 5 emergent culms per site sampled. This showed that the grazing pressure being impacted on the site by both wildlife and livestock is beneficial to the *C. roxburghiana* growth hence the production. Thus this confirms that the interaction was allowing for the dying grass matter to be utilized as forage to allow for regrowth.

The wildlife only area is observed in Figure 11 to have the highest number of non-emergent *C. roxburghiana* culms thereby being caused by the low grazing pressure which means the sampled culms were not allowing growth as the grazing intensity was very low in this area hence when compared with livestock only area. The area recorded highest height of the *C. roxburghiana* tufts. The same Figure 11 highlights that only the wildlife-livestock area and wildlife only area did record any emergent culms. This is due to the lower grazing intensity as compared to the livestock only area which had highest grazing intensity thereby causing the area to have zero observable emergent culms.

Comparison by trend of the sites as shown in Figure 12 highlighting the wildlife livestock area realizing recordings in all the emergent culm categories thus showed that the interaction of livestock and wildlife in the same grazing area causes a balance as the area would still realize increased biomass of the *Chloris roxburghiana* than in the wildlife only area where the low grazing intensity caused the area to have highest numbers of non-emergent culms and also increased biomass than in the livestock only area where the grazing intensity was highest thus causing zero biomass available. This has been confirmed in the studies by English Nature (2005) and Vavra (2005). Figure 13 was made from means of clipped *Chloris roxburghiana* by the sampling quadrats in the season and there were very many recordings of zero weights in the livestock grazed area. Also the trend in both the wildlife only area and wildlife-livestock area was recordings in all the quadrats with varying peaks. Thus the means recorded and the standard errors realized were well within the confidence limits of 95% and the difference among the sites was very clear when the two sites; wildlife-livestock area and wildlife only area was compared to the livestock only area which showed the difference in grazing intensity on the livestock only area than the other two sites. When compared in Figure 14 the highest weight from clipped *C. roxburghiana* was in the wildlife only area and since this was the area with the highest tuft height also confirms that the forage availability in this site was the highest followed by the wildlife-livestock area.

Figure 16 compares the mean of the clipped *Chloris roxburghiana* by the sites and also confirms the difference by site between livestock only area and the two sites wildlife-livestock and wildlife only areas. This when analysed by ANOVA realized that there were no significant differences in the means of the wildlife livestock and the wildlife only area. The ANOVA also realized that there were significant differences in the livestock only area and the other two sites. This is to show when extrapolated in Kg/Ha the abundance of *Chloris roxburghiana* in the wildlife only areas and wildlife-livestock area confirm the availability of grazing resource whilst the livestock only area has very little available grazing resource. This shows the over extraction of grazing resource in areas of little control.

Chloris roxburghiana was the selected graminoid species the frequency was calculated by comparison with the percentage cover on each sampled quadrats by the culms counted. Thus the higher frequency values were realized in the wildlife only area and wildlife-livestock area to also confirm the clipping weights as there is similarity within the two sites. Figure 17 is a pie

chart showing which area had more *Chloris roxburghiana* than the other and it is evident the wildlife only area had most followed by the wildlife –livestock and in distant third was the livestock only area.

There was different utilization behavior in the wildlife grazed area Figure 7 and in the livestock grazed area with higher grazing pressure being realized from the areas of livestock grazing as shown in Figure 6. This confirms that livestock only grazed areas at high intensity than wildlife only grazed areas.

Livestock only area's F-calculated (0.10) is less than F- tabulated (0.8600) the hypothesis that there is no significant difference in biomass in the areas dominantly used by livestock is rejected as there is proof that there is significant difference in the areas used by livestock only having little or no *Chloris roxburghiana* with α=0.05. this has been highlighted in other studies such as Ngene *et al,* (2011) and English Nature (2005) also describes the detriment livestock in previous areas have had on the grazing resource with depletion of grazing resources being documented in common property areas. Also Williams (2012) in his studies of depletion of graminoid species due to grazing, confirmed that in pure stands especially the preferred vegetation type chances of depletion is high due to livestock numbers being high as most of those areas are common property and also livestock tends to overstay in those areas during months of drought.

Since wildlife only area's F-calculated (0.08) is less than F-tabulated (0.8600) we fail to reject the hypothesis that there is no significant difference of biomass in the areas dominantly used by wildlife and wildlife-livestock with α=0.05. Belesky *et al,* (2002)that certain species of grasses have been known to predominate huge area and that as even evidenced in English Nature (2005) where cattle has been shown not to be detrimental to sites provided they do not overstay in an area confirm the case in both wildlife livestock and wildlife only area.

With the livestock only area's F-calculated being greater than F-tabulated and with both wildlife only areas and wildlife-livestock areas having lower F-calculated than F-tabulated we reject the hypothesis that variations in frequency and intensity of utilization of *Chloris roxburghiana* species do not produce significant differences in botanical composition with α=0.05..

Since wildlife only area F-calculated is less than F-tabulated the same with wildlife-livestock area the hypothesis there is no significant difference between the dietary composition of livestock and wildlife grazers is rejected with α =0.05. Figure 18 and Figure 19 showed

similarity in abundance of *Chloris roxburghiana* in the faecal content thus confirming the dietary overlap of the livestock and wildlife. The selected graminoid species was determined to be *Chloris roxburghiana* with 95% confidence (Anderson, 1974; FAO, 2010) after comparison of faecal matter of both selected livestock and selected wildlife herbivores through micro histological analysis. The area under livestock had over utilized the *Chloris roxburghiana* until the land was left bare.

4.2.2 Micro histological results

These results of Tables 1 and 2 confirmed that the majority of the vegetative cover in the faecal matter of both livestock and wildlife was *Chloris roxburghiana* thus the grass was common in diet of both the wildlife and livestock. This was shown in Figure 18 and Figure 19 where the relatively high abundance was shown with others species not raising even 10%.

At the grazing patch scale, cattle are more selective foragers (Peden et al. 1973; Plumb and Dodd 1993). This explained the findings in the micro histological study such that cattle preferred the *Chloris roxburghiana* hence the higher percentages in its diet. Patch diversity can also be affected by dung and urine composition and trampling (Knapp et al. 1999), but this is likely to occur with cattle. Thus the pure stand is maintained due to such preference as the *Chloris roxburghiana* grows faster. Forage intake rate and grazing density may be much greater for cattle (Towne et al. 2005).

In the livestock only area the faecal matter was drier than in the other areas thus confirming the observation that the wildlife-livestock and wildlife only area had more animals grazing regularly in those sites and that the ones which used to graze in the livestock only area had moved. Hosten *et al.* 2007 reported diet overlap in grazing species of wildlife and livestock. Studies that have evaluated livestock forage utilization on open ranges show that cattle favor green grass over forbs and shrubs (Miller and Krueger 1976,; Mohammad *et al.* 1996, Hosten *et al.* 2007). Diets comprised a higher percent grass composition (Hosten *et al.* 2007). Browsing of shrubs by cattle, particularly upland shrubs, usually occurs when more palatable food is depleted from the available range (Mohammad et al. 1996). This explains the presence of the other species in the gut of the animals as it confirms that even with the areas for grazing having near

pure stand of *Chloris roxburghiana* the animals have to also complement their diet with other species. The same behavior is found on wildlife too (Hosten *et al.* 2007).

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- There are significant differences in the heights of *Chloris roxburghiana* in the areas dominantly used by livestock only, wildlife-livestock and wildlife only.
- High utilization of *C. roxburghiana* impacts on the growth and thus the biomass , also low utilization in areas of wildlife only has impacts on biomass.
- *Chloris roxburghiana* was consumed significantly by livestock and wildlife and therefore there is no significant difference in the diet composition of livestock and wildlife grazers in the areas around and inside CHNP.

5.2 Recommendations

From the study, data collected and the analysis it is true that the livestock did overutilise the areas allocated for their grazing in the livestock only area, the areas under wildlife-livestock and wildlife. It is beneficial to allow the livestock to graze in areas within the park with control of numbers of livestock..

Since *Chloris roxburghiana* is common as a diet for livestock and wildlife, the park management and the pastoralists should be sensitized on sustainable use of grazing resource.

This study has shown that both *Chloris roxburghiana* availability in terms of abundance and production declines highest in livestock only area than the decline in wildlife-livestock and wildlife only area through the duration of the grazing period. Thus the study recommends training of communities adjacent to national parks to take measures in regards to their grazing areas and stocking rates this will cause reduced grazing intensity on the forage resources thus minimizing the park incursions.

Further research should be done on utilization of other grass species and browse in national parks with different climatic conditions to show the effect of the intensity of browsing by wildlife of forage resources..

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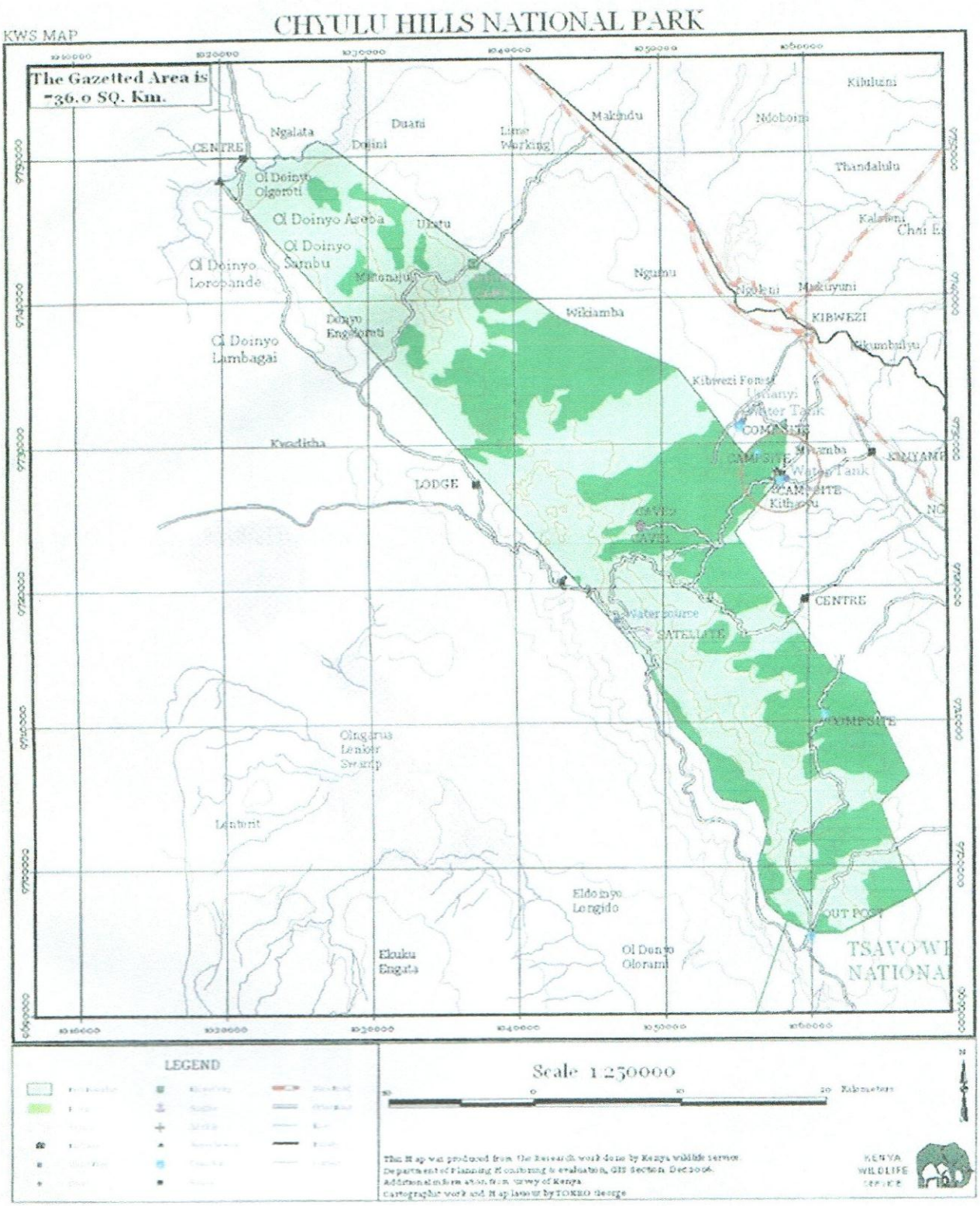
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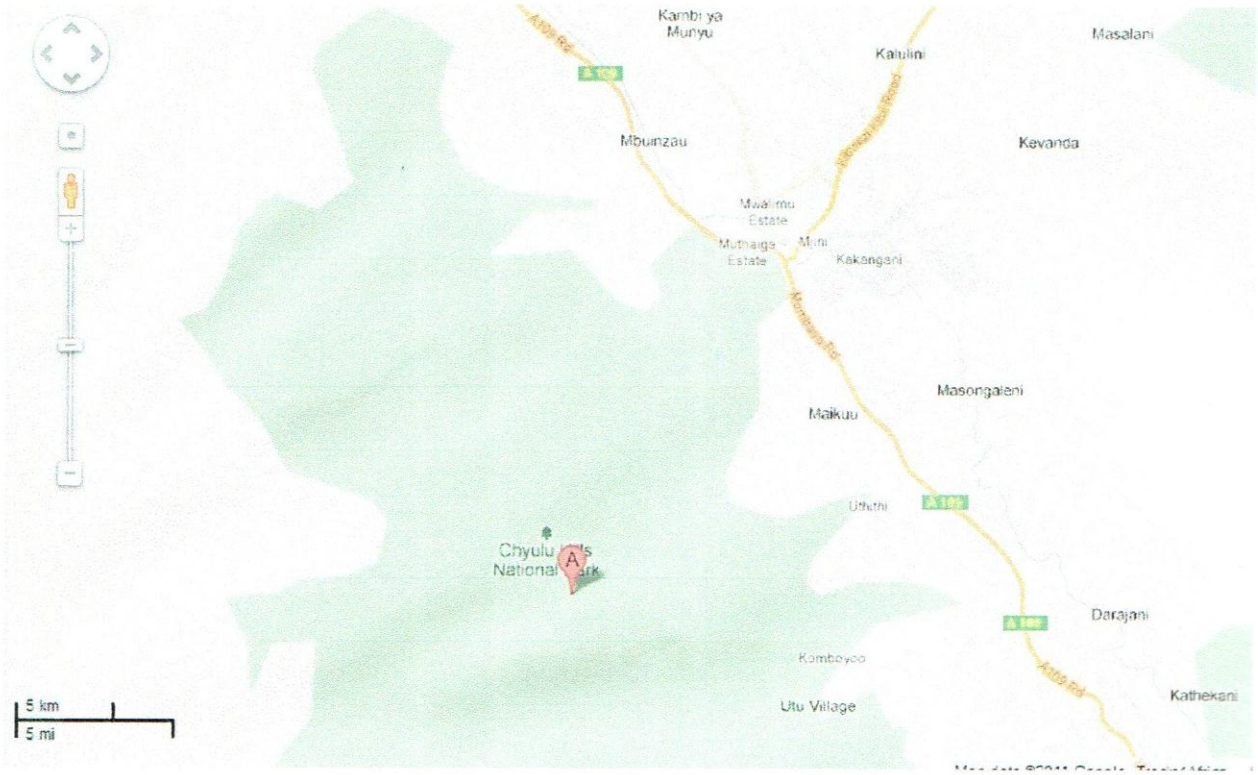
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APPENDICES

Map of Chyulu Hills National Park





Map of study area-Chyulu Hills National Park Source Google Maps 2010

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