

**EFFECTS OF GRAZING MANAGEMENT ON FORAGE PRODUCTION
AND RANGELAND CONDITION IN IL NGWESI GROUP RANCH OF LAIKIPIA
NORTH DISTRICT, KENYA.**



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A Thesis Submitted to the Graduate School in Partial Fulfilment of the
Requirements for the Master of Science Degree in Natural Resources Management of
Egerton University.

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DEDICATION

This work is dedicated to my dad Guyo Shibia, who passed away while I was collecting data. He is blessed with Hawo-Shobe, Shibia, Nuria, Abdala, Halima-Tanu, Habiba-Jamhuri, Mumina-Baby and Adan. I regard him a hero for his effort to champion dry land crop farming who won food security awards for his innovations. I consider him mentor, who until his death cared and was very industrious. His effort and sacrifice made my career dream a reality. Unfortunately he departed before testing the fruits of his labour. I loved dad but Allah loves him more. I pray that mum will live long to reap the fruits of dad's labour.

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ABSTRACT

Species contribution to forage production and rangeland condition in IL Ngwesi group ranch has not been investigated since the inception of grazing management. A study was carried out to assess effects of grazing management on these aspects of rangeland in three grazing sections namely core, buffer and settlement sections. A total of thirteen transects each measuring 500 m long were randomly located in Acacia, mixed Acacia and Commiphora woodlands. Sampling of vegetation was carried out in the month of February 2009 and repeated in April 2009 for herbaceous vegetation using nested quadrants that corresponded with peak herbaceous vegetation production and end of grazing periods, respectively. Herbage was clipped 2 cm above ground level and reference unit technique was used to estimate current season browse yield. Herbage and browse sample were oven dried at 80⁰ C for 48 h to constant weight for determination of dry matter. General Linear Model Univariate Procedure and correlation analysis were used to analyse data. Herbage on offer in core and buffer sections exceeded those in settlement section by 3950 kg ha^{-1} , 3762 kg ha^{-1} , respectively. Herbage on offer was highest in core section, which had least re-growth yield during peak production and at the end of grazing periods. Mean residual herbage in core and buffer sections exceeded those in settlement section by 2255 kg ha^{-1} and 1433 kg ha^{-1} , respectively. Core section had highest residual herbage attributed to least utilization factor of 0.49 while buffer and settlement sections had 0.61 and 0.59, respectively. Mean current season browse production in core and buffer sections exceeded that of settlement section by 1317 kg ha^{-1} , 1084 kg ha^{-1} , respectively. Mean weighted palatability condition (WPC) scores were similar during peak herbaceous production period. However, weighted palatability condition score was highest ($P<0.05$) in core section than that in buffer and settlement sections at the end of grazing period. There was improvement of ecological condition index with grazing intensity with highest score in core section and subsequently decreased in the buffer and settlement sections during peak herbaceous production period. Similarly, at the end of grazing period ecological condition index followed same pattern to peak herbaceous vegetation production period. Mean tree density in settlement section exceeded those in core and buffer sections by 605 TE ha^{-1} , 750 TE ha^{-1} , respectively. Settlement section was moderately encroached while core and buffer sections were rated low. Rangeland in core, buffer and settlement sections was classified into excellent, good and poor, respectively. Tree density and bare ground negatively correlated with ecological condition index; therefore, this study recommends management practices that reduce them.

TABLE OF CONTENTS

DECLARATION AND RECOMMENDATION	i
RECOMMENDATION.....	i
COPY RIGHT.....	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT.....	v
TABLE OF CONTENTS	vi
LIST OF TABLES.....	viii
LIST OF FIGURES.....	x
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background to the problem	1
1.2 Statement of the problem.....	2
1.3 Objectives of the study	3
1.4 Hypotheses.....	3
1.5 Significance of the study	3
1.6 Definition of operational terms:.....	3
CHAPTER TWO.....	5
LITERATURE REVIEW	5
2.1 Response of vegetation to grazing intensity	5
2.2 Conceptual framework.....	7
CHAPTER THREE.....	9
MATERIAL AND METHODS	9
3.1 Study area	9
3.1.1 Location and climate.....	9
3.1.2 Flora and fauna	11
3.2 Vegetation sampling	11
3.2.1 Procedures of sampling herbaceous vegetation.....	12
3.2.2 Procedures of sampling woody vegetation.....	13
3.3 Assessment of rangeland condition.....	14
3.4 Data analysis.....	15
CHAPTER FOUR	16

RESULTS AND DISCUSSION	16
4.1 Production of herbage.....	16
4.1.1 Response of herbaceous vegetation to grazing intensity	19
4.2 Yield of current season browse production	22
4.2.1 Response of woody vegetation to grazing intensity	22
4.3 Rangeland condition	25
4.3.1 Basal cover.....	25
4.3.2 Palatability composition of herbaceous vegetation	29
4.3.3 Ecological composition of herbaceous vegetation	31
4.3.4 Density and composition of woody vegetation	32
4.3.5 Rangeland condition and trend	36
4.3.6 Correlates of rangeland condition variables	38
CHAPTER FIVE	40
CONCLUSION AND RECOMMENDATIONS	40
5.1 Conclusion.....	40
5.2 Recommendations.....	41
REFERENCES	42
APPENDIX I: TRANSECT HITS SURVEY DATA SHEET	48
APPENDIX II: HERBACEOUS DATA SHEET	49
APPENDIX III: SHRUB SPECIES SURVEY DATA SHEET	50
APPENDIX IV: TREE SPECIES SURVEY DATA SHEET	51

LIST OF TABLES

Table 1: Comparison in the yield (kg ha^{-1}) of herbage in the core, buffer and settlement sections during November 2008 –January 2009.....	17
Table 2: Comparison in the yield (kg ha^{-1}) of moribund and regrowth in core, buffer and settlement sections at the end of grazing period.....	18
Table 3: Yield (kg ha^{-1}) by species in the herbage from previous season production in core, buffer and settlement sections during peak production period (November 2008 – January 2009).....	20
Table 4: Yield (kg ha^{-1}) by species for the current season herbage production in core, buffer and settlement sections during peak production period (November 2008 –January 2009).....	21
Table 5: Yield (kg ha^{-1}) by species for the current browse production in the core, buffer and settlement sections during November 2008-January 2009.....	23
Table 6: Yield (kg ha^{-1}) of current browse in core, buffer and settlement sections during November 2008-January 2009.....	24
Table 7: Comparison of basal cover in core, buffer and settlement sections during November 2008-January 2009.....	25
Table 8: Comparison of basal cover in core, buffer and settlement sections at the end of grazing period	26
Table 9: Frequency (hits) of herbaceous vegetation in core, buffer and settlement sections during November 2008-January 2009	27
Table 10: Frequency (hits) of herbaceous vegetation in core, buffer and settlement sections at the end of grazing period	28
Table 11: Comparison of palatability classes for herbaceous vegetation in core, buffer and settlement sections during November 2008- January 2009.....	29
Table 12: Comparison of palatability classes for herbaceous vegetation in core, buffer and settlement sections at the end of grazing period.....	30
Table 13: Comparison of ecological classes for herbaceous vegetation in core, buffer and settlement sections during peak production period (November 2008-January 2009).....	31
Table 144: Comparison of ecological classes for herbaceous vegetation in core, buffer and settlement sections at the end of grazing period.....	31
Table 15: Composition (TE ha^{-1}) of woody vegetation in core section during peak herbaceous vegetation production period (November 2008- January 2009).....	34

Table 16: Composition (TEha ⁻¹) of woody vegetation in buffer section during peak herbaceous vegetation production period (November 2008- January 2009).....	35
Table 17: Composition (TEha ⁻¹) of woody vegetation in settlement section during peak herbaceous vegetation production period (November 2008- January 2009).....	36
Table 18: Weighted palatability condition scores in core, buffer and settlement sections.....	36
Table 19: Ecological condition scores for the core, buffer and settlement sections.....	37
Table 20: Pearson coefficient of correlations (r) for rangeland condition variables in Il Ngwesi group ranch.....	39

LIST OF FIGURES

Figure 1: Path model showing interactions of variables that determines rangeland condition.....	8
Figure 2: Map of Il Ngwesi group ranch	10
Figure 3: Vegetation condition of IL Ngwesi group ranch January-December 2009	11
Figure 4: Mean yield of herbage on offer for the months of November 2008 –January 2009.....	16
Figure 5: Mean yield (kg ha^{-1}) of residual herbage following grazing by livestock and wild herbivores in core, buffer and settlement sections.	18
Figure 6: Current season browse yield (kg/ha) during November 2008-January 2009.....	22
Figure 7: Tree density (TEha^{-1}) in core, buffer and settlement sections.	32
Figure 8: Size distribution of woody vegetation in Il Ngwesi group ranch.....	33

CHAPTER ONE

INTRODUCTION

1.1 Background to the problem

Expansion of woody species reduced herbaceous vegetation cover in areas suitable for cattle production, caused inaccessibility to forage and decline in the number of medium sized wildlife (Georgiadis *et al.*, 2007; Augustine and McNaughton, 2004). This scenario also affected livelihood at wildlife and livestock interfaces (Harrison, 2001). Over the recent past, returns for livestock have been marginal relative to wildlife, which provides much needed additional revenues in form of tourism or game ranching. For this reason, isolation of cattle grazing was suggested in the favour of wildlife in Laikipia District (Odadi *et al.*, 2007).

Interactions of herbivore, fire and rainfall maintained herbaceous vegetation and woody species in the arid and semi-arid ecosystem (Angassa and Oba, 2010). The woody species increased in the absence of prescribed fire (Sankaran *et al.*, 2005), which was severe in areas with high intensity of cattle grazing. The rangeland was highly encroached under low rainfall patterns that supported regeneration and recruitment of tree species.

Vegetation composition is suited to browser species evidenced by herd diversification among cattle keepers to include camels (Jacobs and Coppock, 1999). Camels browse wide spectrum of browse avoided by grazers mainly cattle. Browse component provides palatable and nutritious forage, but more often woody species become undesirable from a livestock point of view because of excessive numbers. Tree density has consequences on herbaceous vegetation competition and cover, as well as for ease of predator detections and avoidance by medium body sized wild herbivores and intensifies competition for grazing resources.

Competition for grazing resources occurs when cattle and medium body sized wild herbivores utilized common rangeland (Truman *et al.*, 2005). Consequently, medium body sized wild herbivores track resource abundance in areas livestock had not grazed. These species declined in Laikipia District in areas they lack space for grazing and their niche overlaps that of cattle (Georgiadis *et al.*, 2007). The most affected medium body sized wild herbivores were zebras (*Equus burchelli* and *Equus grevyi*), buffalo (*Syncerus caffer*), eland (*Taurotragus oryx*), Beisa oryx (*Oryx gazella*), hartebeest (*Alcelaphus bucelaphus*) and Grant's gazelle (*Gazella granti*). Management of this complex herbivore assemblage poses challenges to land owners in Laikipia District because of dietary overlaps exhibited by these

species and cattle (*Bos indicus*) (Ego *et al.*, 2003). Isolation of livestock grazing was suggested as a means to increase forage on offer (Young *et al.*, 1998).

Response of herbaceous and woody vegetation to isolation of cattle grazing was not well documented. The existing studies examined interactions of cattle grazing and combinations of wild herbivores in a controlled experiment (Young *et al.*, 1998). While findings provided responses of vegetation to combinations of herbivore interactions, such combinations rarely exist in the natural environment. Understanding response of vegetation to herder practices was necessary to improve forage production and rangeland condition in areas both wild herbivores and livestock commonly utilized. Monitoring of vegetation determines potential productivity of available browse material and competitive influence on grass productivity (Roques *et al.*, 2001). Consequently, grazing management alter distribution of herbivores. Cattle exhibit a fairly uniform use of the range, whereas wild herbivores, with exception of elephants, exhibit strong preference for areas of low tree density (Young *et al.*, 1998). Timely grazing of rangeland was necessary for sustainable livestock systems.

This study evaluated response of vegetation to grazing intensity in core, buffer and settlement grazing sections in Il Ngwesi group ranch. A combination of cattle production and wildlife conservation has gained importance over the recent past and mixed strategy was economically optimal and helps maintain biodiversity. Only wild herbivores grazed while livestock was excluded in core section for 12 years. Wild herbivores were allowed in buffer section while livestock grazing was deferred over effective period of 60 days in the growing season from November 2008-February 2009. However, there was continuous livestock grazing in settlement section.

1.2 Statement of the problem

Long term herbivore grazing shift vegetation composition and affect vegetation productivity with some species exhibiting increase or suppression and production of some species may remain same depending on species response mechanism. Species contribution to forage production and rangeland condition in Il Ngwesi group ranch has not been investigated since the inception of grazing management. Inadequate information on species contribution to forage production will hamper future implementation of grazing guidelines.

1.3 Objectives of the study

The broad objective was to assess forage production and rangeland condition in the three grazing sections.

Specific objectives were;

- I. Determine effects of grazing management on the yield of herbage and browse production.
- II. Determine effects of grazing management on rangeland condition.

1.4 Hypotheses

- I. There was no difference in the yield of herbage and browse production.
- II. There was no difference in the rangeland condition.

1.5 Significance of the study

This study identifies important forage species in the core, buffer and settlement sections and provides recommendations to increase their production. This improves standing herbage that reduces high mortality of livestock that occurs during drought periods and increases diet choices for cattle and medium sized wild herbivore managed on the common range. The study provides the baseline information for future monitoring of the rangeland.

1.6 Definition of operational terms

Buffer section: Is an area where livestock grazing was deferred for period of 60 growing days. Livestock grazed the standing herbage to minimum stubble height of 2cm while wild herbivores were allowed both during this and deferment to the peak production period periods. The vegetation composition and structure was driven by moderate grazing intensity by wildlife and livestock.

Core section: Is a grazing area with livestock excluded while wild herbivores grazed throughout wet and dry seasons. Vegetation composition and structure was driven by species response to wild herbivores.

Decreaser: Highly palatable herbaceous vegetation that decline with high grazing intensity and may increase slightly or remain stable under moderate grazing condition to reach fair condition.

Encroachment: Increase in woody density at the expense of grass cover.

Forage production: Weight of forage produced within a designated period of time on a given area.

Forage: Browse and herbage which is available to animals or be harvested for feeding.

Grazing management: Involves manipulation of the grazing period and the number of the grazing and browsing animals to increase available herbage.

Increaser I: Herbaceous species present in the climax vegetation but those that are unpalatable may increase under grazing pressure or as site deterioration occurs.

Increaser IIa: Herbaceous species that invades rangeland in the state of deterioration but eventually can decrease if utilization occurs at later stages of deterioration.

Increaser IIb: Herbaceous species generally unpalatable and increase through final stages of deterioration.

Increaser II c: Herbaceous vegetation that invades and encroaches on to the sites from adjacent sites in a final stage of deterioration. These species were comprised of annuals and occurs in areas dominated by bare ground.

Moribund: Refers to herbage produced from previous season and excludes litter

Rangeland condition: Is an expression of the relative contribution to the proportion of vegetation that resembles climax for the site. Word 'condition' implies that desired vegetation cover in terms of quantity and quality exists for each range unit based on the objective of the management.

Rangeland trend: Describes change in the condition of rangeland, whether increasing, decreasing or stable to indicate success or failure of management practices.

Regrowth: Refers to the herbage production in the current season

Settlement section: Is an area continuous grazed both wet and dry seasons without resting and vegetation composition and structure were driven by grazing intensity.

CHAPTER TWO

LITERATURE REVIEW

2.1 Response of vegetation to grazing intensity

Herbivores can have a major impact on the vegetation of arid and semi-arid ecosystem. Several studies have shown that herbivore grazing has a significant effect on the relative abundance and composition of species in plant communities (Savadogo, 2007; Augustine and McNaughton, 2006; Augustine and McNaughton, 1998). Vertebrate herbivores are particularly influential on plant communities because of the amount they crop.

High grazing intensity by livestock especially cattle increases density of woody species (Tesfaye, 2008). Cattle exert selective influence on plant population greater than the amount of biomass they consume and suppresses further establishment of the grazed parts of the plant. In contrast, exclusion of livestock grazing for a long duration drives herbaceous vegetation composition to least palatable species (Oba *et al.*, 2001a). Because of the compensatory mechanisms, maximum production of herbaceous species is reached at intermediate level of grazing beyond there was decline in production (Oba and Stenseth, 2001; Keya, 1998a).

Indigofera spinosa displayed compensatory growth when moderately grazed (Oba and Post, 1999) and the same were established for perennial *Leptothrium senegalense* (Keya, 1997) and *Acacia tortilis* in northern Kenya (Oba, 1998). However, prescribed grazing minimizes negative impacts of cattle and maintains balance between woody and grass species (Angassa and Oba, 2010).

Inappropriate grazing management alter relative competitive abilities of palatable species evidenced by increased number of non-palatable species in rangeland, both woody and grass species (Briske *et al.*, 2008). Shift of vegetation composition to the dominance by none palatable species has challenged land owners and herders. The most affected are privately owned ranches dominated by cattle (Tainton *et al.*, 1999; Fynn, 2008) and sedentary settlements in the pastoral areas.

Long term consequences of continuous grazing are inversion of rangeland by least preferred herbaceous and woody species (Angassa and Oba, 2010). However, intensive short duration grazing was suggested to minimize these detrimental effects of continuous grazing and reduces course layer of herbaceous vegetation from previous seasons (Holechek *et al.*, 2000). Grazing pressure breaks layers of the least preferred species to give competitive

advantage to the highly palatable species (Savory and Butterfield, 1999). In this processes, degraded rangeland can be restored at a minimum cost. When herbaceous species were overgrazed they failed to recover from defoliation as long as grazing reoccurred before grazed species re-established (Keya, 1998; 1997). Increase in bare ground cover was also associated with continuous grazing (Rook *et al.*, 2004; Wallis de Vries *et al.*, 1998).

Browse make important component in the diet of herbivores in dry season. However, increase in number of trees affects accessibility to herbage by livestock and reduces predator visibility for the medium body size wild herbivores. Short duration grazing allows plant species maximize production relative to continuous grazing (Briske *et al.*, 2008; Milchunas and Lauenroth, 1993).

One most important was compensation mechanisms by species for the amount cropped depending on the development stage at the time of defoliation or for some species it induces production of chemical or physical defences that can change plant's quality and future allocation patterns.

The perennial herbaceous species tolerated grazing intensity when grazed during dormancy stage that persists over dry period and moderate grazing at the end of this period increased litter cover (Ekaya *et al.*, 2001). Residual herbage correlated strongly with herbage on offer in the following season for the production of perennial herbaceous vegetation (Keya, 1997). However, high rate of senescence occurred when livestock grazing was excluded for long period (Oba *et al.*, 2001) and this accumulation from previous season forms moribund cover that reduces establishment of herbaceous species.

Yield of herbaceous species strongly correlated with rainfall to reach maximum production at the peak production period (Augustine and McNaughton, 2006; Keya, 1998a). However, spatial distribution of perennial herbaceous vegetation was influenced by soil moisture content. Some species ceased to exist beyond a certain critical soil moisture level. *Panicum maximum* occurred under canopy of acacia species in overgrazed sites, displaced by *Eragrostis racemosa* in eroded areas deficient of soil moisture (Fynn and O'connor, 2000). Similarly, yields of herbaceous vegetation increased by three fold as the number of mature tree per unit area decreased (Synman, 1998). The existence of complex herbivore assemblage may regulate and suppress woody encroachment (Kraaij and Ward, 2006; Augustine and McNaughton, 2004). Low rainfall also contributes to the encroachment by woody species.

Deterioration of rangeland occurs when shift of vegetation reaches undesirable state depending on management objectives (Friedel *et al.*, 2000; Herlocker, 1999; Trollope *et al.*, 1990 and Vorster, 1982). Rangeland in the state of deterioration was dominated by least

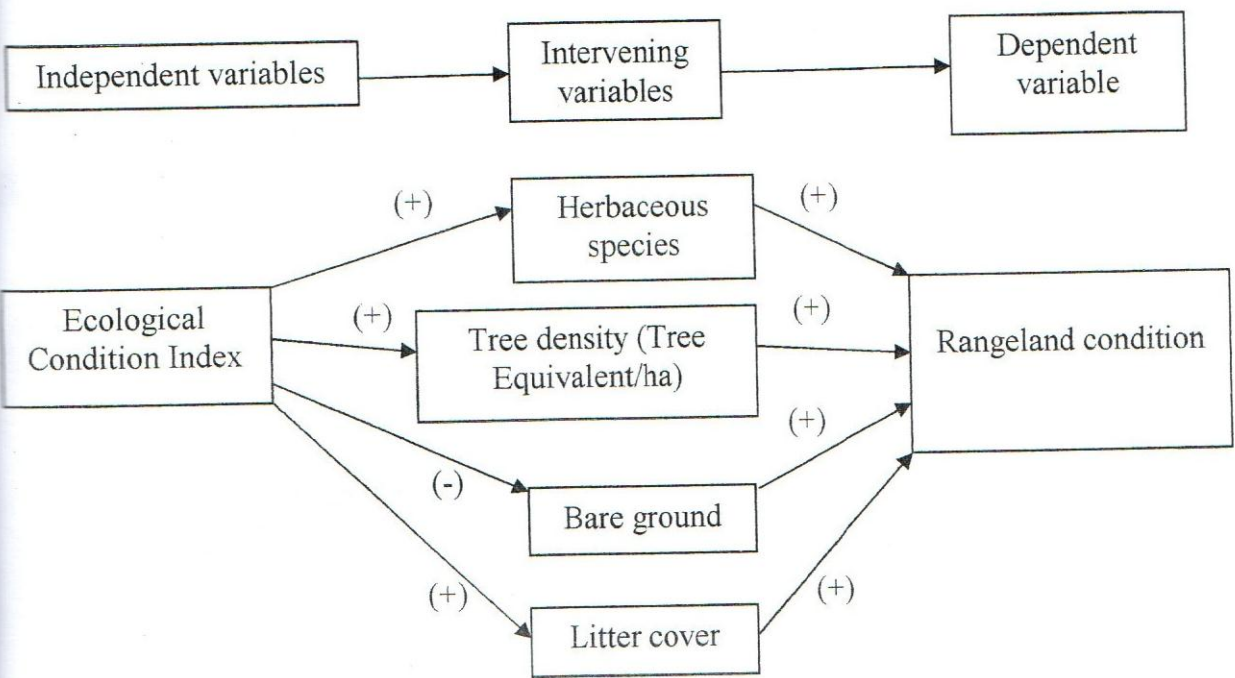
palatable *Pennisetum mezianum* and *P. stramenium*. These species tolerate high grazing intensity in settlement areas and around water points (Oba *et al.*, 2000a; Synman, 1998). The encroachments by woody species also affect rangeland condition, which was mainly associated with management practices in the absence of fire (Angass and Oba, 2010).

2.2 Conceptual framework

Changes in plant composition to herbivore grazing can be generally explained by four broad mechanisms; herbivore preference, plant tolerance to grazing and browsing animals, disturbance caused by herbivores in the environment and interactions of these mechanisms (Augustine and McNaughton, 1998). The relationship between plant tolerance to herbivores and persistence of species in ecosystem varied with level of grazing intensity. Generally, species preferred by herbivores had smaller biomass while none preferred species had greater biomass. Species tolerance to herbivores at individual level and their persistent in community is not well established under various grazing intensity.

This study assessed extent to which optimization hypothesis was evidenced in the arid ecosystem. The optimization hypothesis stated that maximum herbage production occurred at intermediate level of grazing intensity. The proponents (Hilbert *et al.*, 1981) provided evidence that herbaceous production increased with grazing intensity, reached a maximum at moderate and declined at high grazing intensity.

Species exhibit compensation mechanism to low, moderate and high intensity grazing in core, buffer and settlement sections, respectively. Responses depended on the tolerance of species to grazing intensity and alter competitive ability that compromises herbaceous production. Least biomass of species, basal cover and interactions of tree density determine condition of rangeland (Figure 1). Change in the environmental variables accelerates vegetation degradation and interactions with herbivores further speeds processes to irreversible state in arid areas. Consequently, light utilization of rangeland results to undesirable vegetation to suggest desirable condition of range exists at intermediate grazing intensity.



(Source: Author)

Key:

- Direction of flow
- (+) Improvement
- (-) Decline

Figure 1: Path model showing interactions of variables that determines rangeland condition

CHAPTER THREE

MATERIAL AND METHODS

3.1 Study area

3.1.1 Location and climate

Il Ngwesi group ranch is located in Laikipia County, which occupies 9,723 square kilometres and located between latitudes $0^{\circ} 17'$ south and $0^{\circ} 45'$ north and between longitudes $36^{\circ} 15'$ east and $37^{\circ} 20'$ east (Moorhead, 2010). The district is relatively dry due to the rain shadow effect of Mt. Kenya and annual rainfalls are typically between 450mm and 750 mm (Augustine and McNaughton, 2006). The group ranch comprises 24,700 ha located in Mukogodo Division (Figure 2). Core, buffer and settlement sections comprises 8700, 11000 and 5000 hectares, respectively. Group ranch receives bi-modal rainfall with long rains starting from April to May and short rains from October to December. Both onset and duration of rain seasons is unreliable with consistent dry season in the months of January, February, March, July, August and September (Georgiadis *et al.*, 2007).

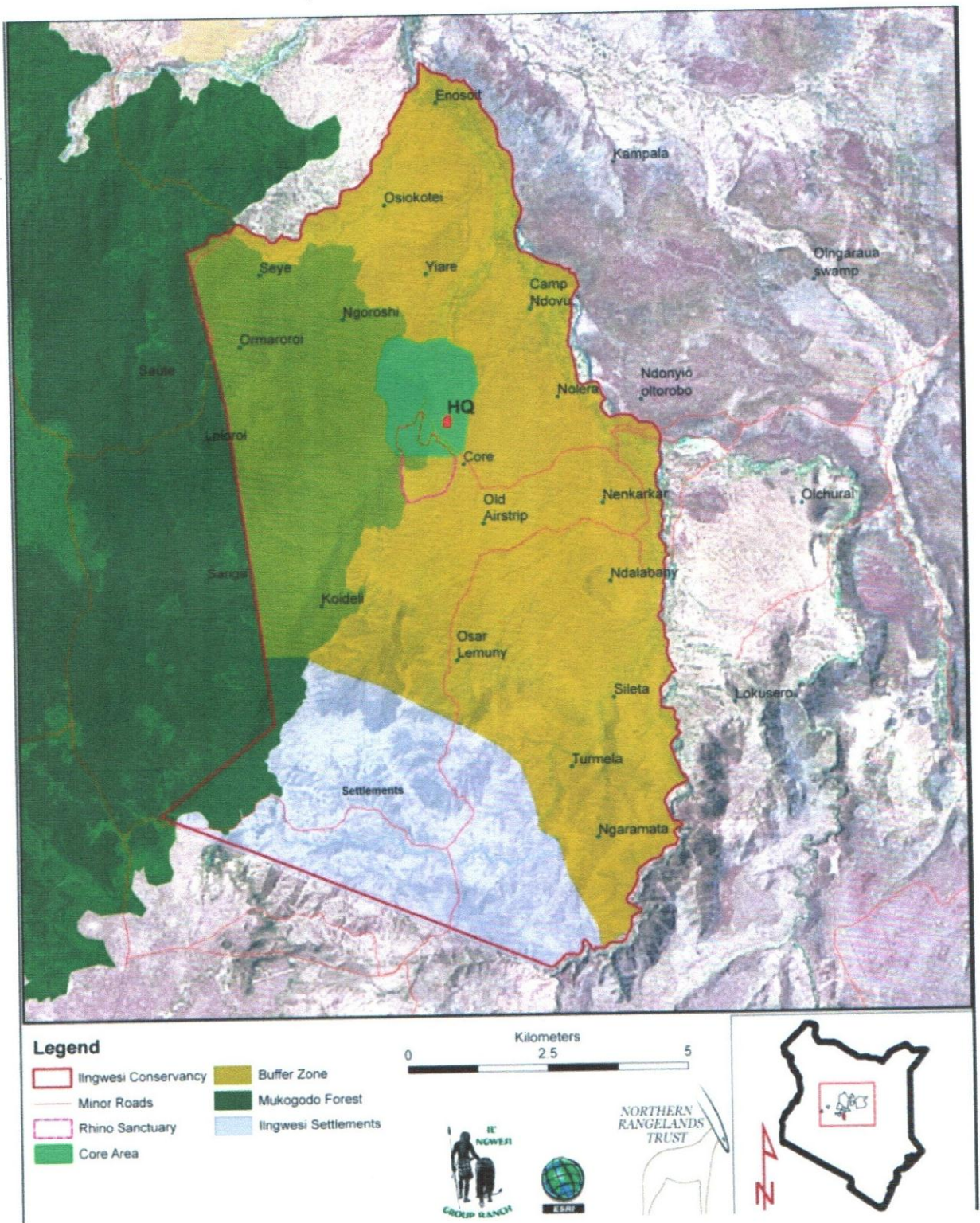


Figure 2: Map of Il Ngwesi group ranch

Rainfall distribution was erratic and ranch received average rainfall less than 400 mm during study period as indicated by vegetation condition, which was below long term average (Figure 3). Numbers of growing days consisted of 8 weeks, with subsidiary periods of growth

activity spread over parts of dry season. Herbage production followed rainfall pattern reaching peak later in the growing season (Augustine and McNaughton, 2006).

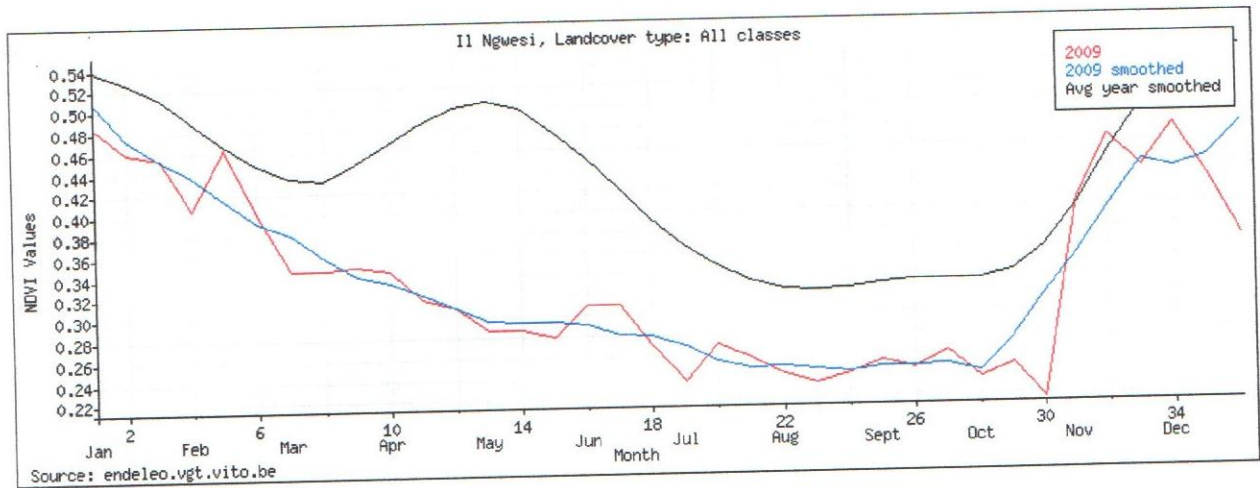


Figure 3: Vegetation condition of IL Ngwesi group ranch January-December 2009

3.1.2 Flora and fauna

Vegetation types were mainly comprised of Acacia-Commiphora woodland (Williams, 2004). Woody vegetation comprised of *Commiphora africana*, *Acacia tortilis*, *Acacia reficiens*, *Acacia brevispica*, *Acacia mellifera*, *Salvadora persica*, *Balanite aegyptiaca* and *Acacia etbaica*. Herbaceous vegetation was dominated by *Digitaria milanjiana*, *Pennisetum mezianum* and *Pennisetum stramineum*.

Most common native grazers and mixed feeders were impala (*Aepyceros melampus*), greater kudu (*Tragelaphus strepsiceros*), zebra (*Equus burchellii*), buffalo (*Syncerus caffer*), lesser kudu, Giraffe (*Giraffa camelopardalis*), eland (*Taurotragus oryx*) and elephants (*Loxodonta africana*). An increase in elephant population was estimated at an average rate of 4.6% per year (Wittemyer, 2005). Land use practices were compatible with the wildlife conservation. The group members raised livestock for both market and subsistence production. The herders depended on cattle for livelihood and they practiced sedentary lifestyle. These herders diversified livelihood that included an ecotourism lodge located in the core section.

3.2 Vegetation sampling

The study site has been established with specific grazing sections namely core, buffer and settlement. Vegetation in each section was classified into Commiphora, Acacia and Acacia-Commiphora woodlands. A total of thirteen line transects were randomly located and number

of transects was assigned based on the size of grazing section with 4, 6 and 3 transects in core, buffer and settlement, respectively. Each transect was 500 m in length and located 100 m from existing roads to minimize effects of surface runoff.

Sampling of herbaceous vegetation and woody species corresponded with peak herbaceous production period during February 2009 and was repeated in April 2009 for herbaceous vegetation at the end of grazing period. Repeated sampling of herbaceous vegetation provided estimate of residual herbage as suggested by Heywood and DeBacker (2007) and Mannetje (2000).

3.2.1 Procedures of sampling herbaceous vegetation

Basal cover was estimated from number of hits by each pin using 1 m 10-point pin frame that holds pins at a 45° angle and. Pin frame was systematically located at interval of 10 m along entire transects and total of 510 pins were counted for each transect. The sampling point corresponded with the herbaceous vegetation and tree sampling point every 100 m. A hit was recorded when point of a pin was in contact with herbaceous vegetation, litter or ground surface. Basal cover was expressed (equation 1) as a percentage of hits using formula by Bonham (1989):

$$\frac{\text{Number of hits}}{\text{Total number of pins}} \times 100 \dots\dots\dots (1)$$

Herbaceous was sampled in 1 m² quadrant every 100 m along entire transect. Species were identified and classified into respective ecological classes based on response to grazing intensity (Gezehegn, 2006). Herbaceous species were physically separated by hand into decreasers and categories of increaser species. Decreaser species are those highly palatable, which decreases with grazing pressure and increases or remains stable with moderate grazing. Increaser species are that increases with heavy grazing pressure and this class was further classified into increaser I, Increaser IIa, Increaser IIb and Increaser II c. Increaser I species occurs immediately range deterioration take place while increaser IIa, increaser IIb and increaser IIc subsequently invades rangeland in severe state of rangeland deterioration. Increaser IIc species had least ecological value and comprised of annuals that invades rangeland in a very poor condition.

Palatability and ecological classes was cross checked with literature for each species. Palatability was measured based on livestock and wildlife preference for the species when

forage contributed by all the species was abundant and herbivore had equal access to select forage component. Assistance was provided by experienced herders in the identifications of species and separation into respective ecological and palatability classes. Samples for herbaceous species not identified in the field were pressed for further identification at the Egerton University, Department of Natural Resources Management Laboratory.

Aboveground herbaceous biomass was clipped every 100 m along the entire transect during peak herbaceous production and repeated at the end of grazing period. Those areas previous clipped was avoided when the sampling was repeated. The difference between herbage produced during peak herbaceous production period and residual biomass provided herbage cropped and utilization factor for grazing section.

All herbage were clipped 2 cm above ground level using hand held shears in the four 1 m² quadrants randomly located at each sampling point. After each sampling date, the four 1 m² quadrants were randomly located to different sampling station but within the same zone and intervals. The height aboveground corresponded to the stubble height in the settlement section. A total of 24 plots clipped along each transect ensured 70 % of the herbaceous species were sampled (Tsutsumi *et al.*, 2007) and clipping procedure provided a reliable measure of the herbage produced by species.

Clipped herbaceous material was identified to species, sorted into forbs, herbs and grasses in the field. The herbage was separated by hand into those from the current and previous seasons. Litter comprised of standing dead and fallen weathered herbage produced in the previous seasons was isolated from the clipped material by hand. Litter production was highly dynamic and true measure was difficult to be captured (Ekaya *et al.*, 2001). Samples were sealed in carton bags with identification label and left to dry in the sun before taken to laboratory and oven dried at 80⁰C for 48 h to a constant weight following the procedure of Kohler *et al.* (2005).

3.2.2 Procedures of sampling woody vegetation

Woody vegetation were sampled along the entire transect using 25 m² and 30x20m quadrants for shrub and tree species, respectively. Each species were identified and their height and crown diameter recorded. Assistance was provided by experienced herder to sort them into respective desirability classes.

Tree species was classified into height classes less than 0.5 m, 0.5-1.5 m, and 1.5-5.0 m and above 5 m following the categories developed by Oba (1998). The height class less than 1.5 m represented regeneration class; recruitment class was represented in the height 1.5-5.0

m and replacement class in the height above 5 m. Woody species composition determines, to some extent, those browsers which utilize the vegetation because each species showed preference for certain kinds and parts of plants (Oba, 1998). Severity of encroachment by tree species was considered based on the criteria by Roques *et al.* (2001); very low (<600 TE ha⁻¹), low (>600-1200 TE ha⁻¹), moderate (>1200-1800 TE ha⁻¹), less severely (>1800-2400 TE ha⁻¹) and severe encroached (>2400 TE ha⁻¹).

Current season browse was estimated for shrub and tree species using the reference unit technique (Bonham, 1989). The current season production was clipped from a reference unit of the crown. This technique provided estimate of the browse available per unit area. The crown of each species was divided into equal reference units that comprised 20% of the foliage weight. The clipped browse was sealed in carton bag with identification label of the species and left to dry in the sun and later oven dried at 80^o C for 48 h. Total dry biomass of each species was estimated by multiplying dry weight of the clipped reference material by the number of reference units expressed to the nearest 0.10 g. The current season browse was estimated for all species in the quadrant.

3.3 Assessment of rangeland condition

Assessment of rangeland condition was based on occurrence of herbaceous vegetation, litter, bare ground and tree equivalent ha⁻¹ (Tesfaye, 2008; Tefera 2007a,b; Friedel, 2000; Van der Westhuizen *et al.*, 2001). Herbaceous vegetation was classified into respective ecological and palatability classes to derive Ecological Condition Index (ECI) and Weighted Palatability Condition (WPC) that was independently derived to confirm condition of grazing sections.

Ecological Condition Index was derived using relative index value assigned to each ecological class for the herbaceous vegetation according to Vorster (1982). The percentage composition for each ecological class was multiplied by the relative index value to derive ecological condition index. Sum ECI was classified into five categories that indicated status of rangeland condition: very poor (100-280); poor (>280-460); good (>460-820) and excellent (>820) according to Vorster (1982).

Herbaceous species was classified into palatability classes according to Barnes *et al.* (1984). Class I was highly palatable; class II-moderately palatable; class III-less palatable and class IV-poorly palatable and each class was assigned weightings of 4, 3, 2 and 1, respectively. The Palatability Composition (PC) was rated for each respective class derived as the sum of the products of relative abundance of each species and weighting expressed as

percentage of the maximum PC, with a scale that ranged from 25 to 100. The Palatability Composition values were then converted into WPC values (Equation 2). The Weighted Palatability Condition value was categorized into five categories: very poor (0-20); poor (>20-40); fair (>40-60); good (>60-80) and excellent (>80).

$$\text{WPC} = (\text{PC} - 25) \times 1.33 \dots\dots\dots (2)$$

3.4 Data analysis

Descriptive statistics was computed for means and percentages. Correlation analysis was done to establish strength of relationship for rangeland condition variables. The General Linear Model (GLM) Univariate procedures provided regression analysis and analysis of variance (ANOVA) for one dependent variable by one or more factors (equation 3). Using the GLM procedure, the null hypothesis was tested about the effects of factors on dependent variable. Means was considered significant at $P < 0.05$ and separated by multiple comparisons using LSD when means was significant (Steel and Torrie, 1980).

$$Y_{ij} = \mu + \tau_i + \beta_j + \varepsilon_{ij} \dots\dots\dots (3)$$

Where:

Y_{ij} -Effects of i^{th} grazing section in the j^{th} woodland type (block)

μ - Overall mean

τ_i -Effects due to i^{th} grazing section

β_j -Effects due to j^{th} block

ε_{ij} -Experimental error

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Production of herbage

Total biomass in core and buffer sections exceeded those in settlement section by 3950 kg ha^{-1} , 3762 kg ha^{-1} , respectively. There was no marked difference in the mean biomass between core and buffer sections (Figure 4). The highest herbage production in core and buffer sections was attributed to higher biomass fixation by herbaceous species. Yield reported in this study was higher than most of enclosures (Ahmad *et al.*, 2006; Keya, 1998a). Herbaceous vegetation was protected from intensive livestock grazing while ability of herbaceous vegetation to fix biomass had declined in settlement section.

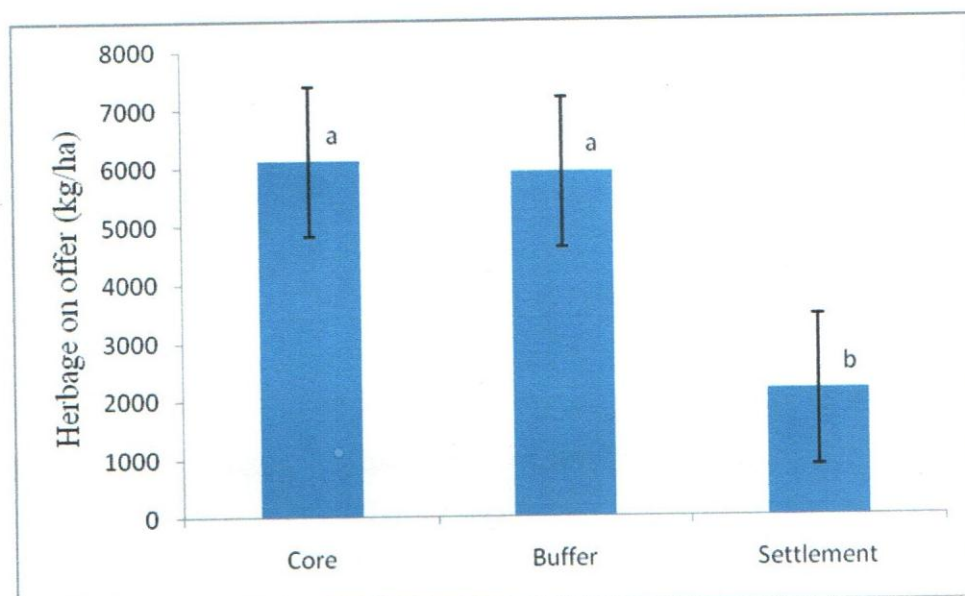


Figure 4: Mean yield of herbage on offer for the months of November 2008 –January 2009. a,b; bars are standard errors of the mean and those with different superscripts differ ($P < 0.05$).

Likewise, core section had highest ($P < 0.05$) yield of moribund, followed by buffer and least yield in settlement section (Table 1). Residual herbage accumulated in core section due to highly selective grazing behaviour of wild herbivores that favoured highly palatable parts of herbaceous vegetation. Residual herbage showed similar trend to that of herbage on offer in agreement with Abule *et al.* (2007) and Ekaya *et al.* (2001). Residual herbage supported production of herbage on offer; however, certain amount was necessary to support production in the following season. Spatial distribution of herbaceous vegetation would affect

distribution of the medium body sized wild herbivores especially known to track quality grazing resources (Odadi *et al.*, 2007 and Ego *et al.*, 2003) and these behavioural responses intensify competition for grazing resources in buffer and settlement sections.

In contrast, yield of re-growth for current season was highest ($P < 0.05$) in buffer, followed by settlement and least in core section (Table 1). Residual herbage in buffer section was critical for herbaceous vegetation to compensate for amount cropped whereas highest accumulation of herbage from previous season in core section suppressed establishment and regeneration of tillers. Generally, production of re-growth in settlement section was hampered by over grazing.

Table 1: Comparison in the yield (kg ha^{-1}) of herbage in the core, buffer and settlement sections during November 2008 –January 2009

Grazing sections	Herbage on offer (kg ha^{-1})	
	Moribund	Re-growth
Core	1850.14 \pm 6.57 ^a	412.54 \pm 3.39 ^c
Buffer	396.74 \pm 5.32 ^b	1586.96 \pm 5.26 ^a
Settlement	47.80 \pm 3.44 ^c	717.05 \pm 4.57 ^b

Means in the same column with different superscripts differ ($P < 0.05$)

Mean residual herbage in core and buffer sections exceeded those in settlement section by 2255 kg ha^{-1} and 1433 kg ha^{-1} , respectively. There was no marked difference in the mean residual herbage between core and buffer sections, however, means for these sections differed ($P < 0.05$) with that in settlement section (Figure 5). Residual herbage was least in settlement section. Core section had highest residual herbage attributed to least utilization factor of 0.49 by wild herbivores while buffer and settlement sections had 0.61 and 0.59, respectively. Highest utilization factor in buffer section depicts high efficiency for the utilization of herbaceous vegetation by livestock.

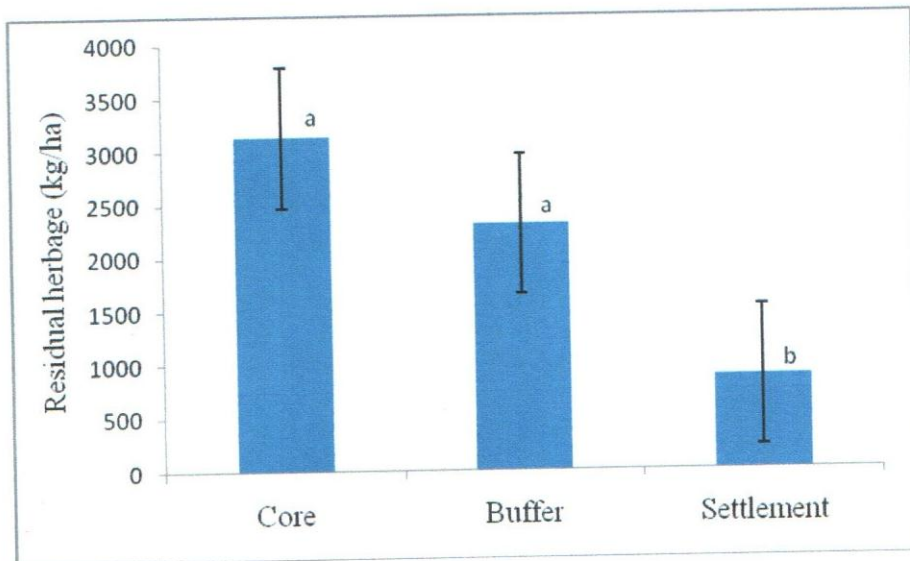


Figure 5: Mean yield (kg ha^{-1}) of residual herbage following grazing by livestock and wild herbivores in core, buffer and settlement sections. a,b; bars are standard errors of the mean and those with different superscripts differ ($P < 0.05$).

Core section had highest ($P < 0.05$) yield of herbage from previous season production than buffer and settlement sections (Table 2). Exclusion of livestock grazing was responsible for the accumulation of moribund layer in core section. Wild herbivores partially utilized standing herbage preferably part of current production and abandoned herbage from previous season. Settlement section had least ($P < 0.05$) production of previous season following continuous grazing. Buffer section had highest ($P < 0.05$) yield of re-growth than core and settlement sections. Yield of current season production in buffer section was attributed to species mechanism to compensate for amount cropped in agreement with finding by Keya (1998b) and Oba *et al.* (2000b). Core section had least ($P < 0.05$) yield of current season production at the end of grazing period.

Table 2: Comparison in the yield (kg ha^{-1}) of moribund and regrowth in core, buffer and settlement sections at the end of grazing period

Grazing sections	Residual herbage (kg ha^{-1})	
	Moribund	Re-growth
Core	840.34±9.69 ^a	210.08±7.92 ^c
Buffer	152.01±8.54 ^b	760.02±5.68 ^a
Settlement	40.59±5.00 ^c	291.64±6.75 ^b

Means in the same column with different superscripts differ ($P < 0.05$)

4.1.1 Response of herbaceous vegetation to grazing intensity

Yield of *Chloris woodii* and *Cenchrus ciliaris* accounted for most of herbage from previous season in core section during peak herbaceous vegetation production period. These species formed moribund layer that inhibited further regeneration of tillers and seedlings. However, yield of these species declined with grazing intensity in buffer and settlement sections (Table 3). These species were highly palatable and exclusion of livestock protected those in core section while least yield in settlement section indicated their sensitivity to heavy grazing intensity.

Yield of *P. stramenium* was highest ($P < 0.05$) in buffer compared to core and settlement sections. This species could fix biomass when moderately grazed in buffer section to compensate for amount cropped and production pattern of this species exhibited a hump back response largely positive except at high grazing intensity. Maximum production of *P. stramenium* was realized at intermediate level of grazing intensity in buffer section similar to previous study (Riginos and Grace, 2008).

Yield of *Andropogon macrostachys* was highest ($P < 0.05$) in core section and settlement sections while least yield occurred in buffer section. Response of this species indicates tolerance to light and heavy grazing intensity in core and settlement sections, respectively. They may increase slightly or remain stable under moderate grazing condition to reach fair condition due to low ability to fix biomass. Response further indicates suitability of this species for reseeding settlement section.

The highest ($P < 0.05$) yield of *Sanseveira robusta* occurred in settlement section and least at low and moderate grazing intensity in core and buffer sections, respectively. This species was least palatable to herbivores and invaded range unit in the state of deterioration. It formed dense stand, however, close association of this species and herbaceous vegetation was established for rangeland in state of transition (King and Franz, 2010).

Table 3: Yield (kg ha⁻¹) by species in the herbage from previous season production in core, buffer and settlement sections during peak production period (November 2008 –January 2009)

Species	Grazing sections		
	Core	Buffer	Settlement
<i>Chloris woodii</i>	27.63±2.23 ^a	7.44±2.80 ^b	4.83±0.20 ^b
<i>Penisetum stramenium</i>	13.42±4.18 ^b	35.07±2.02 ^a	9.54±0.01 ^b
<i>Cenchrus ciliaris</i>	12.41±0.87 ^a	2.50±0.01 ^b	1.62±0.20 ^b
<i>Andropogon macrostachys</i>	9.43±4.73 ^a	1.57±0.03 ^b	7.31±2.09 ^a
<i>Chloris roxyburghiana</i>	4.92±0.06	2.45±0.13	0.28±0.11
<i>Aristida mutabilis</i>	4.74±2.64	2.96±0.03	4.27±0.34
<i>Sanseveira robusta</i>	4.23±1.22 ^b	3.24±0.01 ^b	26.32±0.84 ^a
<i>Panicum maximum</i>	3.93±0.01	3.88±3.79	0.25±0.09
<i>Eragrostis superba</i>	1.29±0.01	3.43±0.90	3.62±0.18

All labelled row mean are statistically significant and those in the same row with different superscripts differ ($P<0.05$).

Mean current season yield of *C. woodii* was highest ($P<0.05$) in core section and there was no marked difference in the mean yield for buffer and settlement sections (Table 4). In contrast, mean yield of *D. velutina* was similar for core and settlement sections. *Chloris woodii* displayed L-shaped production trend as grazing intensity with increases to imply that species lack compensatory mechanism for amount cropped. *Digitaria velutina* had least yield in buffer section.

Mean current season yield of *A. macrostachys*, *B. leersioides*, *P. stramenium*, *Aristida adscensionis*, *Indigofera spinosa*, and *D. aegyptium* was highest ($P<0.05$) in buffer section compared to core and settlement sections. Current season yield of *P. stramenium* and *I. spinosa* indicated compensatory mechanisms when moderately grazed. Response mechanism by these species displayed hump back and compensated for the highest amount at moderate grazing intensity. Similarly, compensatory response mechanism was reported for *I. spinosa* in northern Kenya by Keya (1998b) and Oba *et al.* (2000b).

Mean current season yield was highest ($P<0.05$) for *Sanseveria robusta*, *Eragrostis cilianensis*, *Commelina bengalensis* and *Indigofera clifodiana* in settlement section. These had least yield in buffer and core sections and comprised annuals, which had least herbage

value. The finding concurred with previous studies (Keya, 1998a; Tefera *et al.*, 2007a and Abule *et al.*, 2007).

Table 4: Yield (kg ha^{-1}) by species for the current season herbage production in core, buffer and settlement sections during peak production period (November 2008 –January 2009)

Species	Grazing sections		
	Core	Buffer	Settlement
<i>Chloris woodii</i>	36.84±6.82 ^a	7.70±2.80 ^b	2.83±0.32 ^b
<i>Bracharia leersioides</i>	16.69±7.61 ^b	25.25±6.18 ^a	7.94±0.01 ^c
<i>Digitaria veluntina</i>	9.61±3.49 ^a	1.15±0.02 ^b	7.92±1.01 ^a
<i>Penisetum stramenium</i>	8.77±4.18 ^b	23.10±2.04 ^a	3.02±0.97 ^c
<i>Andropogon macrostachys</i>	5.43±4.73 ^b	17.57±0.02 ^a	5.21±1.79 ^b
<i>Aristida mutabilis</i>	4.74±2.64	0.26±0.02	2.42±0.68
<i>Penisetum mezianum</i>	4.65±1.80	3.20±0.19	4.72±0.04
<i>Sanseveria robusta</i>	4.23±1.22 ^b	3.24±0.04 ^b	15.41±2.50 ^a
<i>Aristida adscensionis</i>	3.90±0.70 ^b	6.39±0.30 ^a	1.67±0.55 ^b
<i>Hibiscus species</i>	3.43±0.41	2.11±0.53	1.52±0.03
<i>Erogrostis superba</i>	3.01±1.73	1.02±0.06	2.88±0.91
<i>Chloris roxyburghiana</i>	2.84±0.03	1.15±0.01	1.43±0.01
<i>Cenchrus ciliaris</i>	2.82±0.50	4.50±0.87	3.83±1.42
<i>Indigofera spinosa</i>	2.61±0.59 ^b	16.41±2.60 ^a	4.20±0.08 ^b
<i>Erogrostis cilianensis</i>	2.03±0.33 ^b	2.26±0.50 ^b	7.64±5.89 ^a
<i>Tribulus terrestris</i>	1.75±0.01	4.20±0.02	2.10±0.68
<i>P. cappacea</i>	1.52±0.51 ^b	0.18±0.01 ^b	10.08±1.92 ^a
<i>Solanum incanum</i>	1.13±0.73	2.01±0.62	4.93±0.02
<i>Chloris roxyburghiana</i>	1.04±0.37 ^b	11.96±2.31 ^a	1.58±0.01 ^b
<i>Panicum maximum</i>	0.93±0.01	0.39±0.30	1.59±0.02
<i>Dactyloctenium aegyptium</i>	0.78±0.05 ^b	21.76±3.79 ^a	2.18±0.11 ^b
<i>Commelina bengalensis</i>	0.61±0.05 ^b	1.74±1.08 ^b	8.06±4.56 ^a
<i>Sedge species</i>	0.46±0.04	0.57±0.01	4.35±2.43
<i>Indigofera cliffodiana</i>	0.11±0.01 ^b	1.70±0.02 ^b	5.87±0.73 ^a

All labelled row mean are statistically significant and those in the same row with different superscripts differ ($P<0.05$).

4.2 Yield of current season browse production

Mean current season browse yield in the core and buffer sections exceeded that of settlement section by 1317 kg/ha⁻¹, 1084 kg/ha⁻¹, respectively. Yield of current browse was highest in core section, followed by buffer and least in settlement section. There was marked difference in the means of current season browse production for core and settlement sections (Figure 6). Browse production was highly suppressed in settlement section while highest yield occurred in core section because browse components was inaccessible consistent with previous studies (Augustine and McNaughton, 2004, Roques *et al.*, 2001 and Styles, 1993).

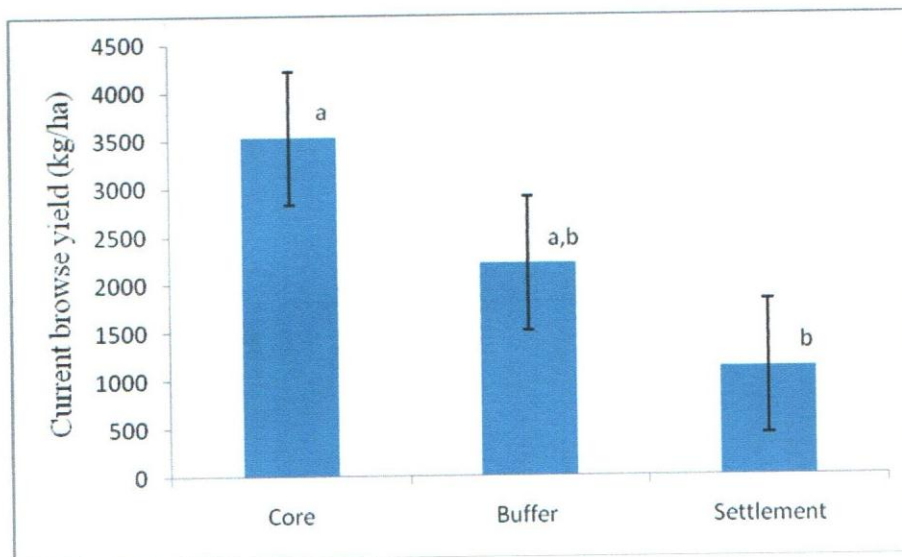


Figure 6: Current season browse yield (kg/ha) during November 2008-January 2009.

a,b; bars are standard errors of the mean and those with different superscripts differ ($P < 0.05$).

4.2.1 Response of woody vegetation to grazing intensity

Browse production of *Grewia tembensis*, *B. aegyptiaca*, *Embelia schimperi* and *Acacia melifera* was highest ($P < 0.05$) in core section compared to buffer and settlement sections (Table 5). Browse production by these species were suppressed in buffer and settlement sections. *Grewia tembensis* and *Acacia melifera* were very desirable to browsers but production was confined to medium body sized herbivores in buffer section. Browse production by *A. reficiens* and *Serichoia* species were highest ($P < 0.05$) in buffer section compared to core and settlement sections. Increased yield was associated with number of these species in buffer section. Yield of *Phyllanthus somalensis* and *A. brevispica* was highest ($P < 0.05$) in settlement section compared to buffer and core sections.

Most of shrubs and trees were deciduous and shed leaves after peak herbaceous production period except for *Acacia tortilis* with long browse production cycles and such can provide browse during critical periods. However, least desirable, serichoi species, *Balanites aegyptiaca* and *Salvadora persica* were also evergreen.

Table 5: Yield (kg ha⁻¹) by species for the current browse production in the core, buffer and settlement sections during November 2008-January 2009

Species	Grazing sections		
	Core	Buffer	Settlement
<i>Grewia tembensis</i>	74.58±5.60 ^a	4.62±2.57 ^b	10.66±4.20 ^b
<i>Acacia melifera</i>	68.55±4.78 ^a	33.24±0.60 ^a	2.76±0.21 ^b
<i>Embelia schimperi</i>	61.37±2.49 ^a	3.32±0.52 ^b	2.32±0.72 ^b
<i>Balanites aegyptiaca</i>	59.70±4.00 ^a	5.80±3.70 ^b	2.10±0.09 ^b
<i>Serichoi*species</i>	38.79±7.78 ^b	94.75±4.80 ^a	0.42±0.01 ^b
<i>Grewia villosa</i>	7.94±1.84	2.39±1.45	6.32±1.09
<i>Lippia grandifolia</i>	7.15±0.45	3.81±2.80	5.01±0.98
<i>Acacia reficiens</i>	6.83±1.20 ^b	74.02±2.60 ^a	10.50±1.09 ^b
<i>Cadaba farinosa</i>	6.21±4.70	26.51±3.28	4.50±1.65
<i>Salvadora persica</i>	5.60±0.60	1.12±0.75	0.60±0.01
<i>Acacia tortilis</i>	4.81±1.49	1.35±0.49	3.13±0.90
<i>Ipomoea hilderbrandtii</i>	2.74±0.23	4.87±1.07	7.10±2.01
<i>Boscia angustifolia</i>	2.67±0.98	3.80±1.23	5.08±0.65
<i>Phyllanthus somalensis</i>	2.60±1.78 ^b	4.62±1.50 ^b	94.36±2.13 ^a
<i>Acacia brevispica</i>	2.06±0.96 ^b	17.61±3.90 ^b	82.53±3.96 ^a
<i>Acacia senegal</i>	1.09±0.31	0.12±0.04	17.09±3.23

All labelled row means are statistically significant and those in the same row with different superscripts differ ($P<0.05$).

Core section had highest ($P<0.05$) yield of less desirable and highly desirable browse in the height classes 0.5-1.5 m and above 5 m, respectively (Table 6). Mega browsers can reach browse in the upper height class unlike medium sized wild herbivores.

Buffer section had highest ($P<0.05$) yield of less desirable and very desirable browse in the height class 1.5-5 m and above 5 m height, respectively. Browse production in buffer section closely resemble that in core section with highest yield of desirable browse occurred

in the upper height classes. The highest ($P<0.05$) yield of very desirable browse occurred in lower height categories in settlement section.

Table 6: Yield (kg ha^{-1}) of current browse in core, buffer and settlement sections during November 2008-January 2009

Grazing sections	Height classes (M)	Desirable classes		
		High	Medium	Low
Core	0-0.5	0.00	0.00	0.00
	0.5-1.5	5.37±0.10 ^b	42.94±9.48 ^a	8.91±1.34 ^b
	1.5-5	20.69±3.85	11.12±2.96	9.40±1.85
	Above 5.0	55.55±3.75 ^a	25.38±2.56 ^b	31.00±9.88 ^b
Buffer	0-0.5	3.24±0.01	16.74±4.65	4.31±2.35
	0.5-1.5	5.63±2.34	0.42±0.01	15.70±4.67
	1.5-5	11.19±3.89 ^c	84.38±4.76 ^a	45.07±7.88 ^b
	Above 5.0	70.27±5.76 ^a	14.35±2.95 ^c	22.97±4.97 ^b
Settlement	0-0.5	19.68±4.10 ^a	2.79±0.32 ^b	1.35±0.32 ^b
	0.5-1.5	16.31±1.72 ^a	2.21±1.25 ^b	1.75±0.05 ^b
	1.5-5	27.39±2.68 ^a	10.23±1.78 ^b	6.83±0.14 ^b
	Above 5.0	26.16±4.97 ^a	21.67±4.63 ^{a,b}	13.36±4.30 ^b

All labelled row means are statistically significant and those in the same row with different superscripts differ ($P<0.05$).

4.3 Rangeland condition

4.3.1 Basal cover

Mean herbaceous vegetation cover in buffer and core sections had marked difference ($P<0.05$) with that in settlement section during peak herbaceous vegetation production period (Table 7). The highest cover of herbaceous vegetation occurred in core and buffer sections. Mean litter cover showed marked difference ($P<0.05$) in buffer and core sections with that in settlement section. Continuous grazing section reduced litter cover in settlement section. Litter had accumulated in core section but decreased in settlement section due to continuous grazing by livestock in agreement with a previous study (Ekaya *et al.*, 2001).

Bare ground cover in settlement section showed marked difference ($P<0.05$) with that in the core and buffer sections. Continuous livestock grazing reduced herbaceous vegetation cover and subsequently increase bare ground cover in settlement section. The highest cover of bare ground indicated deterioration in rangeland condition in settlement section in agreement with study by Abule *et al.* (2007).

Table 7: Comparison of basal cover in core, buffer and settlement sections during November 2008-January 2009

Grazing sections	Herbaceous	Litter	Bare ground
Core	46.07±2.85 ^b	24.10±1.68 ^a	29.83±2.25 ^b
Buffer	50.7±3.71 ^b	24.53±1.39 ^a	24.77±3.35 ^b
Settlement	25.73±2.74 ^a	10.87±2.75 ^b	63.40±3.78 ^a

Means in the same column with different superscripts differ ($P<0.05$)

Cover of herbaceous vegetation varied ($P<0.05$) in core, buffer and settlement sections at the end of grazing period (Table 8). The highest herbaceous vegetation cover occurred in core section and least in settlement section because of continuous grazing that depleted herbaceous cover. These findings concurred with study by Riginos and Grace (2008).

Table 8: Comparison of basal cover in core, buffer and settlement sections at the end of grazing period

Grazing sections	Herbaceous	Litter	Bare ground
Core	39.60±3.26 ^a	32.53±3.57 ^b	27.87±2.39 ^b
Buffer	28.23±3.45 ^b	44.40±2.16 ^a	27.37±3.28 ^b
Settlement	15.27±1.80 ^c	29.67±3.02 ^b	55.07±4.57 ^a

Means in the same column with different superscripts differ ($P<0.05$)

Mean litter cover in buffer section differed ($P<0.05$) with that in core and settlement sections. Litter cover was attributed to moderate livestock grazing in buffer section especially parts of herbaceous vegetation had established tolerance when grazed. Subsequently, there was increased in litter for reduction of standing herbage.

Mean bare ground cover in settlement section differ ($P<0.05$) with that in core and buffer sections. Herbaceous vegetation cover was over utilized in settlement section, which reduced basal cover consistent with findings by Okoti *et al.* (2004) and Synman (2005).

The highest ($P<0.05$) cover of *P. stramenium*, *P. mezianum* and *Hibiscus species* occurred in core section than that in buffer and core sections (Table 9). Cover of *P. stramenium* and *P. mezianum* was highest following light grazing intensity in core section, hence, formed layer of hard tuft that inhibited further establishment of herbaceous vegetation. The highest cover of *Hibiscus species* indicated transition of core section to irreversible state encroached by woody vegetation.

Frequency of *D. veluntina*, *E. superba*, *A. macrostchys*, *C. woodii*, *C. roxyburghiana*, *I. spinosa*, *A. kenyensis*, *D. aegyptium*, *P. maximum*, *H. contortus* and *C. gyana* was highest ($P<0.05$) in buffer section, which had marked difference with that in core and settlement sections. Frequency of these species was ascribed to moderate grazing intensity in buffer section.

The highest ($P<0.05$) frequency of *E. cilianensis*, *C. bengalensis*, *Sedge species*, *Eclipta alba*, *A. mauritanum*, *Tribulus terrestris*, *B. argentia* and *S. incanum* occurred in settlement section and least in core and buffer sections. Increase in the number of annuals indicated deterioration of rangeland condition in settlement section. Generally, annuals increase under continuous grazing consistent with finding by Okoti *et al.* (2004).

Table 9: Frequency (hits) of herbaceous vegetation in core, buffer and settlement sections during November 2008-January 2009

Species	*Eco-class	Grazing sections		
		Core	Buffer	Settlement
<i>Pennisetum stramenium</i>	IIa	78.17±6.51 ^a	58.05±0.11 ^b	1.37±0.01 ^c
<i>Pennisetum mezianum</i>	IIa	58.17±2.51 ^a	38.05±0.31 ^b	2.97±0.01 ^c
<i>Erogrostis superba</i>	De	33.03±3.20 ^b	58.85±1.40 ^a	1.90±0.07 ^c
<i>Digitaria veluntina</i>	De	32.40±2.68 ^b	55.04±1.02 ^a	4.65±1.36 ^c
<i>Hibiscus species</i>	IIa	24.78±2.33 ^a	6.00±0.13 ^b	2.03±0.10 ^b
<i>Andropogon macrostchys</i>	I	20.11±0.23 ^b	43.29±2.30 ^a	0.98±0.11 ^b
<i>Erogrostis cilianensis</i>	IIc	15.76±2.89 ^c	28.07±2.94 ^b	52.12±1.18 ^a
<i>Chloris woodii</i>	De	12.39±5.64 ^b	32.41±0.10 ^a	0.05±0.01 ^c
<i>Indigofera spinosa</i>	De	8.34±0.52 ^b	57.45±2.33 ^a	2.22±0.11 ^b
<i>Aristida kenyesis</i>	IIc	11.53±1.21 ^b	38.02±2.27 ^a	7.46±0.46 ^b
<i>Chloris roxyburghiana</i>	I	11.39±0.89 ^b	52.44±0.01 ^a	1.11±0.50 ^c
<i>Dactyloctenium aegyptium</i>	De	6.85±1.64 ^b	68.61±3.05 ^a	4.78±1.28 ^b
<i>Panicum maximum</i>	I	5.29±3.00 ^b	43.88±0.01 ^a	1.23±0.11 ^b
<i>Commelina bengalensis</i>	IIc	4.06±1.50 ^b	0.81±0.10 ^b	25.23±1.62 ^a
<i>Sedge species</i>	IIc	4.04±1.50 ^b	3.85±1.25 ^b	38.33±1.17 ^a
<i>Hyperhania contortus</i>	I	2.04±1.52 ^b	31.01±0.01 ^a	1.41±0.10 ^b
<i>Chloris gyana</i>	De	1.84±0.94 ^b	22.42±1.21 ^a	7.10±0.89 ^b
<i>Eclipta alba</i>	IIc	0.83±0.04 ^b	2.04±0.13 ^b	41.81±0.01 ^a
<i>P. cappaeca</i>	IIc	0.00 ^b	18.03±0.01 ^a	26.15±1.10 ^a
<i>Brachiaria species</i>	IIc	0.00 ^b	36.10±0.06 ^a	43.19±2.37 ^a
<i>A. mauritianum</i>	IIc	0.00 ^b	0.73±0.01 ^b	67.93±2.49 ^a
<i>Tribulus terrestris</i>	IIc	0.00 ^b	3.71±0.92 ^b	35.91±2.33 ^a
<i>B. argentia</i>	IIc	0.00 ^b	0.00 ^b	28.14±3.87 ^a
<i>Solanum incanum</i>	IIc	0.00 ^b	1.07±0.02 ^b	16.38±2.24 ^a

*Eco-class; Ecological class- De-Decreasers; I-Increaser I; IIa-Increaser IIa; IIc-Increaser IIc
All labelled row mean are statistically significant and means in the same row with different superscripts differ ($P<0.05$).

Cover of *P. stramenium*, *P. mezianum*, *E. superba* and *Hibiscus species* was highest in core section that showed marked difference ($P<0.05$) with buffer and settlement sections at

the end of grazing period (Table 10). Exclusion of livestock grazing increased frequency of *P. stramenium*, *P. mezianum* and *E. superba*. These species were lightly grazed in core section and their cover followed that of peak production during November 2008- January 2009. In the absence of livestock grazing and fire, these species formed thick cover of litter and moribund that generally suppresses tiller formation and reductions of these layers were necessary.

Cover of *A. kenyensis*, *C. roxyburghiana*, *A. macrostachys*, *C. woodii*, *P. maximum*, *I. spinosa* and *D. veluntina* was highest in buffer section, which showed marked difference ($P < 0.05$) with that in core and settlement sections. These were perennial species with tufts that withstand moderate grazing intensity in buffer section.

Cover of *I. clifordiana*, *Sedge species*, *E. cilianensis*, *Leptothrium senegalense* and *B. argentia* was highest in settlement section, which showed marked difference ($P < 0.05$) with that in buffer and settlement sections. These annuals had least ecological value and accounted for most of herbaceous cover in settlement section that was continuously grazed consistent with Tefera *et al.* (2007c).

Table 10: Frequency (hits) of herbaceous vegetation in core, buffer and settlement sections at the end of grazing period

Species	Grazing sections		
	Core	Buffer	Settlement
<i>Pennisetum stramenium</i>	72.17±3.51 ^a	14.05±0.11 ^b	0.03±0.01 ^c
<i>Pennisetum mezianum</i>	56.11±2.51 ^a	11.05±0.31 ^b	1.37±0.01 ^c
<i>Erogrostis superba</i>	19.03±1.32 ^a	2.85±1.40 ^b	1.90±0.07 ^b
<i>Hibiscus species</i>	14.67±1.73 ^a	3.59±0.79 ^b	0.43±0.09 ^b
<i>Aristida kenyanensis</i>	10.06±0.61 ^b	19.33±3.02 ^a	2.85±0.31 ^c
<i>Chloris roxyburghiana</i>	10.46±0.38 ^b	30.20±0.30 ^a	0.58±0.06 ^b
<i>Andropogon macrostachys</i>	6.71±1.57 ^b	23.29±0.01 ^a	0.56±0.03 ^b
<i>Chloris woodii</i>	5.14±1.48 ^b	18.94±3.94 ^a	0.10±0.03 ^b
<i>Digitaria veluntina</i>	5.14±0.64 ^b	17.32±4.42 ^a	0.83±0.04 ^b
<i>Indigofera spinosa</i>	4.84±0.32 ^b	22.35±4.87 ^a	0.35±0.01 ^b
<i>Panicum maximum</i>	3.02±1.20 ^b	33.31±2.13 ^a	0.31±0.01 ^b
<i>Dactyloctenium aegyptium</i>	2.23±0.87 ^a	9.65±1.84 ^a	0.08±0.05 ^b
<i>Indigofera clifordiana</i>	0.86±0.03 ^b	3.09±0.90 ^b	14.48±0.03 ^a
<i>Sedge species</i>	0.79±0.03 ^b	3.10±1.00 ^b	19.14±0.29 ^a
<i>Erogrostis cilianensis</i>	0.37±0.06 ^b	1.47±1.30 ^b	23.26±0.88 ^a
<i>Commelina bengalensis</i>	0.13±0.01	0.01±1.42	4.60±0.80
<i>P. cappacea</i>	0.00 ^b	7.26±0.07 ^a	12.35±0.17 ^a
<i>Brachiaria species</i>	0.00 ^b	19.30±0.01 ^a	13.90±0.67 ^a
<i>Leptothrium senegalense</i>	0.00 ^b	3.23±0.07 ^b	65.43±0.01 ^a
<i>Tribulus terrestris</i>	0.00 ^b	0.00 ^b	9.11±0.09 ^a
<i>Barleria argentia</i>	0.00 ^b	0.00 ^b	12.82±1.50 ^a
<i>Solanum incanum</i>	0.00 ^b	2.50±0.34 ^b	18.83±0.40 ^a

All labelled row mean are statistically significant and means in the same row with different superscripts differ ($P<0.05$).

4.3.2 Palatability composition of herbaceous vegetation

The highest frequency of highly palatable herbaceous vegetation occurred in the core and settlement sections, which showed marked difference ($P<0.05$) with that in the buffer section during peak production period (Table 11). However, highest cover of moderately palatable herbaceous vegetation occurred in buffer section, which showed marked difference ($P<0.05$)

with that in core and settlement sections. The highest cover of poorly palatable herbaceous vegetation occurred in the core and settlement sections, which showed marked difference ($P<0.05$) with that in the buffer section. Frequency of poorly palatable species increased in the core section due to avoidance by the majority of the medium body size wild herbivores whereas highly palatable herbaceous vegetation was continuously grazed in the settlement section that offered competitive advantage for poorly palatable herbaceous vegetation.

Table 11: Comparison of palatability classes for herbaceous vegetation in core, buffer and settlement sections during November 2008- January 2009

Grazing sections	Palatability classes			
	High	Moderate	Poor	Very poor
Core	67.81±6.01 ^a	8.08±1.41 ^b	11.98±2.28	12.13±3.79 ^a
Buffer	57.60±4.12 ^b	21.37±2.67 ^a	16.68±3.69	6.34±2.10 ^b
Settlement	70.13±9.78 ^a	1.15±0.05 ^b	11.47±4.77	17.68±1.70 ^a

All labelled column mean are statistically significant and means in the same column with different superscripts differ ($P<0.05$).

The highest ($P<0.05$) frequency of highly palatable herbaceous vegetation occurred in the core and settlement sections than in the buffer section at the end of grazing period (Table 12). However, frequency of moderately palatable herbaceous vegetation was highest in the core and buffer sections than in settlement section. No differences were recorded for cover of poor and very poorly palatable herbaceous vegetation in core, buffer and settlement sections.

Table 12: Comparison of palatability classes for herbaceous vegetation in core, buffer and settlement sections at the end of grazing period

Grazing sections	Palatability classes			
	High	Moderate	Poor	Very poor
Core	67.02±4.12 ^a	11.94±0.61 ^a	15.20±3.17	5.69±1.45
Buffer	41.14±3.60 ^b	26.23±2.80 ^a	23.57±2.19	9.07±2.80
Settlement	60.74±3.23 ^a	0.86±0.01 ^b	24.40±3.34	13.90±0.84

All labelled column mean are statistically significant and means in the same column with different superscripts differ ($P<0.05$).

4.3.3 Ecological composition of herbaceous vegetation

Frequency of decreaser species was highest ($P<0.05$) in core section than buffer and settlement sections during peak herbaceous production period (Table 13). Exclusion of livestock grazing was attributed to highest frequency of decreaser species in core section. In contrast, frequency of increaser IIc was highest ($P<0.05$) in buffer and settlement sections than that in core section during peak production period. Increaser IIc species comprised of annuals and some of these species increased because of over grazing by livestock in settlement section. Similarly, Increase of these species was due to deferment of livestock grazing in buffer section. However, no differences were recorded on contribution of increaser I, increaser IIa and increaser IIb for core, buffer and settlement sections.

Table 13: Comparison of ecological classes for herbaceous vegetation in core, buffer and settlement sections during peak production period (November 2008-January 2009)

Grazing sections	Ecological classes				
	Decreasers	Increaser I	Increaser IIa	Increaser IIb	Increaser IIc
Core	22.67±2.05 ^a	1.47±0.07	1.47±0.73	1.05±0.10	9.97±1.87 ^b
Buffer	16.33±1.04 ^b	1.57±0.08	1.33±0.01	1.05±0.02	23.6±2.73 ^a
Settlement	8.33±0.98 ^c	0.89±0.03	1.04±0.07	0.15±0.08	17.93±3.45 ^a

All labelled column mean are statistically significant and means in the same column with different superscripts differ ($P<0.05$).

Frequency of herbaceous vegetation in respective ecological classes at the end of grazing period generally followed those during peak production period except decreaser species was highest ($P<0.05$) in core than in buffer and settlement sections (Table 14). These species were protected in core section from livestock grazing that fairly utilize herbaceous layer. Livestock highly utilized decreaser species in buffer and settlement sections at the end of grazing period.

In contrast, frequency of increaser IIc species was highest ($P<0.05$) in buffer section than that in core and settlement sections (Table 15). These species were over grazed in settlement section but frequency was highest in buffer section due to prescribed grazing of herbaceous vegetation to considerable stubble height.

Table 14: Comparison of ecological classes for herbaceous vegetation in core, buffer and settlement sections at the end of grazing period

Grazing sections	Ecological classes				
	Decreasers	Increaser I	Increaser IIa	Increaser IIb	Increaser II c
Core	22.93±2.37 ^a	2.3±0.25	1.0±0.53	5.02±0.09	5.57±0.39 ^b
Buffer	11.13±2.97 ^b	4.2±0.01	2.53±0.23	7.56±0.96	12.73±3.78 ^a
Settlement	4.8±0.90 ^b	1.47±0.41	3.04±0.43	9.12±0.07	1.20±1.67 ^b

All labelled column mean are statistically significant and means in the same column with different superscripts differ ($P<0.05$).

4.3.4 Density and composition of woody vegetation

Mean tree density in settlement section exceeded those in core and buffer sections by 605 TEha⁻¹, 750 TEha⁻¹, respectively. Tree density (TEha⁻¹) was highest ($P<0.05$) in settlement section than core and buffer sections (Figure 7). Livestock mainly cattle selected highly palatable herbaceous vegetation in settlement section that offered woody species competitive advantages. Settlement section was moderately encroached while core and buffer sections were rated low. Similarly, lower tree density was established in Maasai Mara reserve than in communal and privately managed areas outside the Reserve (Walpole *et al.*, 2004).

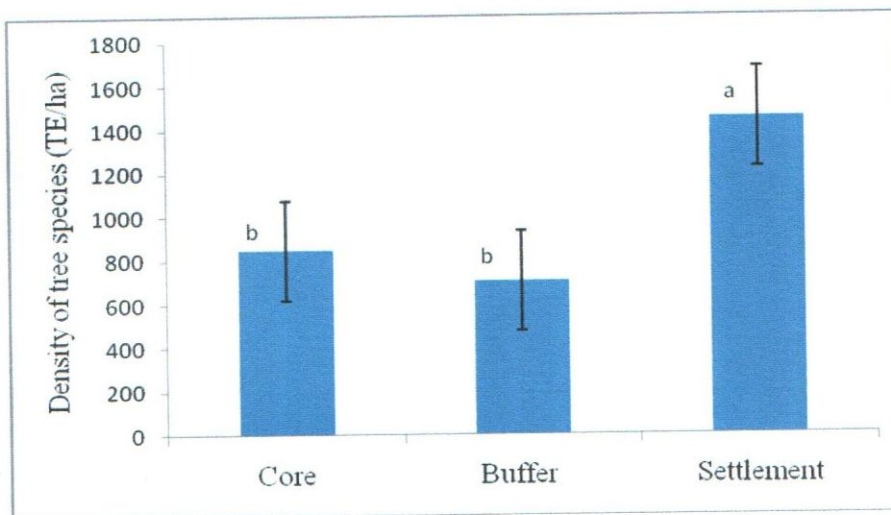


Figure 7: Tree density (TEha⁻¹) in core, buffer and settlement sections.

a,b; bars are standard errors of means and those with different superscripts differ ($P<0.05$).

Distribution of tree species in the core section displayed j-shape (Figure 8), with least tree density in the recruitment class. The highest tree density occurred in the upper height class indicating aging of the tree stand. Representation of tree density indicated succession pathway in the absence of fire. However, those species unpalatable to browsers may increase under light grazing pressure and as site deterioration occurs. Woody species would form inaccessible stand to the medium body size mixed feeders and affects distribution in the core section, a serious threats to the performance of this system.

Buffer and core sections displayed unimodal peaks at intermediate height classes although settlement section had higher density of trees in all height classes. Individuals were normally distributed with majority of tree species in the intermediate height classes. This finding indicated buffer section being the ideal grazing management option and implies livestock grazing is necessary to create gaps for recruitment of seedlings in the core section. Structural representation of size distribution of tree species in the core, buffer and settlement sections was influenced by complex browser assemblage, hence, differed from previous study by Young *et al.* (1998) that showed fewer trees in the upper height classes for *Acacia drepanolobium*.

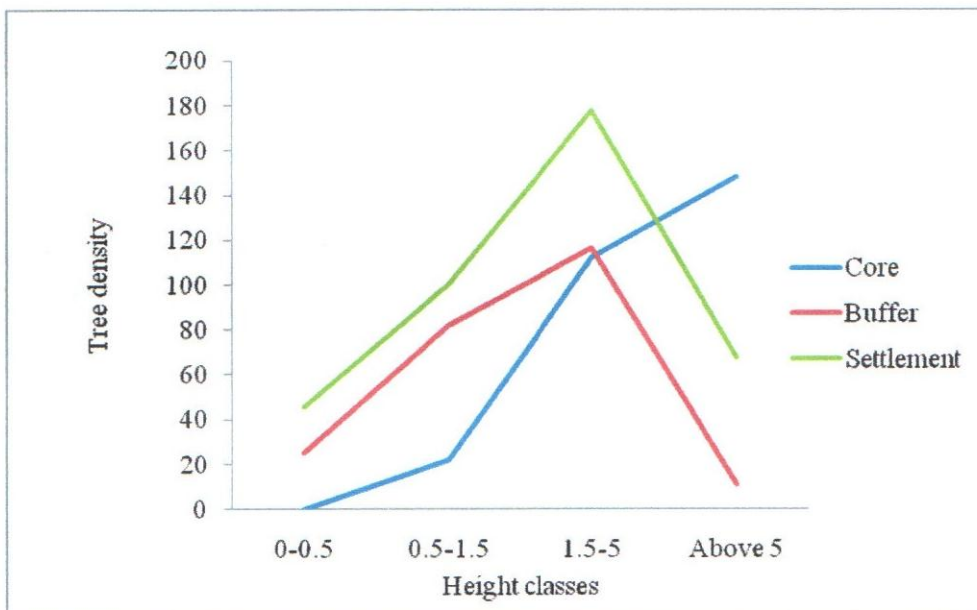


Figure 8: Size distribution of woody vegetation in Il Ngwesi group ranch

Density of *Grewia tembensis*, *Grewia villosa*, *Grewia bicola* and *Ipomea hilderandii* was highest ($P < 0.05$) in the height class 1.5-5 m while density of *E. schimpeis*, *B. aegyptiaca*, *A. melifera*, *A. reficiens*, *S. persica*, *A. tortilis* and *C. africana* was highest ($P < 0.05$) in the

height class above 5 m (Table 15). Tree density was suppressed by complex herbivore assemblage though most of these species were considered invaders in Southern Ethiopia (Tefera *et al.*, 2007d).

Table 15: Composition (TEha⁻¹) of woody vegetation in core section during peak herbaceous vegetation production period (November 2008- January 2009)

Species	Height classes (m)			
	0-0.5	0.5-1.5	1.5-5	Above 5.0
<i>Grewia tembensis</i>	0.00	1.39±0.03 ^b	5.13±1.61 ^a	0.56±0.05 ^b
<i>Grewia villosa</i>	0.00	1.11±0.09 ^b	2.37±0.47 ^a	1.45±0.96 ^b
<i>Enclea schimpeis</i>	0.00	0.00 ^c	2.20±0.65 ^b	3.90±1.06 ^a
<i>Balanite aegyptiaca</i>	0.00	0.00 ^c	3.32±0.51 ^b	5.74±0.04 ^a
<i>Cadaba farinosa</i>	0.00	0.00 ^b	1.84±0.75 ^a	1.63±0.03 ^a
<i>Grewia bicola</i>	0.00	0.83±0.03 ^b	6.73±0.70 ^a	1.81±0.31 ^b
<i>Acacia melifera</i>	0.00	0.28±0.11 ^c	3.03±0.44 ^b	18.61±0.51 ^a
<i>Acacia reficiens</i>	0.00	0.00 ^b	0.54±0.10 ^b	2.18±0.66 ^a
<i>Salvadora persica</i>	0.00	0.00 ^b	1.20±0.07 ^b	1.45±0.04 ^a
<i>Acacia tortilis</i>	0.00	0.00 ^b	0.36±0.01 ^b	4.35±0.51 ^a
<i>Ipomea hilderandii</i>	0.00	0.00 ^b	1.09±0.01 ^a	0.36±0.01 ^b
<i>Cadaba africana</i>	0.00	0.00 ^b	1.84±0.07 ^b	2.45±0.30 ^a
<i>Phyllanthus somalensis</i>	0.00	0.00	1.64±0.13	1.36±0.11

All labelled row mean are statistically significant and means in the same row with different superscripts differ ($P<0.05$).

Density of *G. tembensis*, *serichoi* species, *G. villosa* and *G. bicolar* was highest ($P<0.05$) in the height class 0.5-1.5 m while density of *D. kirk*, *A. melifera*, *A. tortilis*, *A. reficiens* and *C. africana* was highest ($P<0.05$) in height class 1.5-5 m (Table 16). Density of *Serichoi* species was highest in buffer section especially in recruitment class. Browse production by this species was least preferred by herbivores and might increase under current grazing management.

Table 16: Composition (TEha⁻¹) of woody vegetation in buffer section during peak herbaceous vegetation production period (November 2008- January 2009)

Species	Height class (M)			
	0-0.5	0.5-1.5	1.5-5	Above 5
<i>Serichoi species*</i>	6.08±1.11 ^b	14.76±0.12 ^a	13.81±0.40 ^a	0.47±0.05 ^c
<i>Acacia melifera</i>	0.49±0.03 ^b	0.54±0.02 ^b	5.85±1.89 ^a	0.65±0.03 ^b
<i>Acacia tortilis</i>	0.33±0.07 ^c	1.18±0.27 ^b	1.87±0.85 ^a	0.87±0.45 ^c
<i>Grewia villosa</i>	0.33±0.01 ^b	2.66±0.11 ^a	0.76±0.02 ^b	0.00 ^b
<i>Acacia reficiens</i>	0.16±0.01 ^b	0.33±0.09 ^b	2.88±0.47 ^a	0.33±0.07 ^b
<i>Bakanite aegyptiaca</i>	0.00 ^b	1.95±0.35 ^b	3.61±3.32 ^a	0.35±0.18 ^b
<i>Cadaba farinosa</i>	0.00 ^c	2.09±0.32 ^b	6.37±2.46 ^a	0.00 ^c
<i>Grewia tembensis</i>	0.00 ^c	1.96±0.02 ^a	0.61±0.01 ^b	0.00 ^c
<i>Salvadora persica</i>	0.00	0.00	0.33±0.04	0.32±0.10
<i>Grewia bicolar</i>	0.00 ^d	9.17±4.76 ^a	4.00±0.36 ^b	0.00 ^c
<i>Commiphora africana</i>	0.00 ^c	0.00 ^c	3.83±1.55 ^a	1.12±0.32 ^b
<i>Cadaba fascinosa</i>	0.00	0.00	0.33±0.10	0.00

*local name: All labelled row mean are statistically significant and means in the same row with different superscripts differ ($P<0.05$).

Density of *G. bicolar* and *G. tembensis* was highest ($P<0.05$) in height class 0.5-1.5 m (Table 17). Browse material by these species was desirable to supplement diet of mixed feeders during growing season and when production of standing herbage decline. Density of *A. tortilis*, *C. africana*, *A. brevispica*, and *C. fascinosa* was highest ($P<0.05$) in height class 1.5-5 m. *Acacia tortilis* were deep rooted and highly desirable and production of browse by this species can be guaranteed in dry season (Treydte *et al.*, 2009).

Table 17: Composition (TEha⁻¹) of woody vegetation in settlement section during peak herbaceous vegetation production period (November 2008- January 2009)

Species	Height classes (M)			
	0-0.5	0.5-1.5	1.5-5	Above 5
<i>Grewia bicolor</i>	1.63±0.02 ^b	8.42±0.52 ^a	9.09±1.25 ^a	0.59±0.02 ^c
<i>Acacia tortilis</i>	1.33±0.78 ^b	1.15±0.41 ^b	5.31±0.72 ^a	5.17±0.13 ^a
<i>Commiphora africana</i>	1.05±0.09 ^b	0.35±0.06 ^b	3.48±1.15 ^a	3.44±0.25 ^a
<i>Grewia tembensis</i>	0.47±0.06 ^b	1.28±0.38 ^a	1.40±0.04 ^a	0.00 ^b
<i>Acacia senegal</i>	0.35±0.03	0.00	0.12±0.01	0.00
<i>Commiphora species</i>	0.23±0.13 ^c	0.23±0.01 ^c	3.46±0.19 ^b	4.26±1.54 ^a
<i>Acacia melifera</i>	0.12±0.02	0.12±0.11	0.47±0.07	0.12±0.01
<i>Acacia brevispica</i>	0.12±0.06 ^d	1.05±0.02 ^c	8.49±1.02 ^a	7.18±4.31 ^b
<i>Sericho species*</i>	0.00 ^b	0.00 ^b	0.59±0.01 ^a	0.00 ^b
<i>Cadaba fasciosa</i>	0.00 ^b	0.00 ^b	0.70±0.04 ^a	0.00 ^b

All labelled row mean are statistically significant and means in the same row with different superscripts differ ($P<0.05$).

4.3.5 Rangeland condition and trend

Mean weighted palatability condition (WPC) scores were similar for core, buffer and settlement sections during peak herbaceous production period (Table 18). However, the WPC score was highest ($P<0.05$) in core section than that in buffer and settlement sections at the end of grazing period.

Table 18: Weighted palatability condition scores in core, buffer and settlement sections

Grazing sections	Peak production	End of grazing period
Core	77.19±4.03	80.5±3.40 ^a
Buffer	76.08±3.52	66.49±3.53 ^b
Settlement	76.53±1.10	69.48±2.67 ^b

All labelled mean are statistically significant and means in the same column with different superscripts differ ($P<0.05$).

Ecological condition score was highest ($P<0.05$) in core section and least in buffer and settlement sections during peak herbaceous production period (Table 19). Similarly, at the end of grazing period, ecological condition score followed same trend to that during peak herbaceous vegetation production period.

Table 19: Ecological condition scores for the core, buffer and settlement sections

Grazing sections	Peak production	End of grazing period
Core	964.80±2.33 ^a	978.61±2.10 ^a
Buffer	605.31±1.72 ^b	693.27±2.03 ^b
Settlement	539.62±4.10 ^b	488.43±1.09 ^b

Means in the same column with different superscripts differ ($P<0.05$)

Rangeland condition in core section was rated excellent having ecological condition scores above 80. Herbaceous vegetation in this section was highly dominated by *P. stramenium*, *P. mezanum*, *E. superba*, *D. veluntina*, *A. macrostchys*, *E. cilianensis*, *C. woodii*, *C. roxyburghiana*, *I. spinosa*, *D. aegyptium* and *P. maximum*.

Likewise rangeland condition in the buffer section was rated good having ecological condition scores that range from 460-820. Some of species encountered were common to that in core section but with slightly lower frequency in buffer section. There were *P. stramenium*, *P. mezanum*, *E. superba*, *D. veluntina*, *A. macrostchys*, *E. cilianensis*, *C. woodii*, *I. spinosa*, *A. kenyesis*, *C. roxyburghiana*, *D. aegyptium* and *P. maximum*. Those species with highest frequency but specific to buffer section were *H. contortus*, *Brachiaria species* and *C. gyana*. Overall, more herbaceous species had highest frequency in buffer section than core and settlement section.

In contrast, rangeland condition in settlement section was rated poor having ecological value ranging from 280-460. Herbaceous layer was highly dominated by *C. bengalensis*, *Sedge species*, *E. alba*, *P. cappacea*, *Brachiaria species*, *A. mauritianum*, *T. terrestris*, *B. argentia* and *S. incanum*. These were annuals and invade rangeland in a state of deterioration.

Weighted palatability condition composition scores for core were above 80 to indicate rangeland in excellent condition. However, buffer and settlement sections had score that range from 60-80, hence, classified as good condition. The finding contradicts rating by ecological condition index to suggest herbage value rarely provides measure of rangeland

condition. Annuals were highly palatable and their frequency was high in settlement sections to improve palatability score. These herbaceous species were *E. cilianensis*, *A. kenyesis*, *C. bengalensis*, *Sedge species*, *Brachiaria species* and *T. terrestris*.

4.3.6 Correlates of rangeland condition variables

Weighted Palatability Condition (WPC) score positively correlated with litter cover ($r=0.48$; $P<0.05$). The association of WPC and litter cover was modest but significant to indicate most of herbaceous species fed upon were highly palatable. Weighted Palatability Condition score positively correlated with cover of forb ($r=-0.49$; $P<0.01$) indicating forb species was highly palatable (Table 20). Finding concurred with previous study (Odadi *et al.*, 2007) and these authors established high preference of forb species by cattle.

Ecological condition scores negatively correlated with cover of bare ground ($r=-0.62$; $P<0.01$). Bare ground occurred when ecologically important herbaceous species were over grazed. Similarly, ecological condition scores negatively correlated with occurrence of tree density ($r=-0.67$; $P<0.01$). This finding suggests increased tree density reduces ecological condition score of rangeland and subsequently decline in herbaceous vegetation. Decreaser species improves ECI displayed by strong positive relationship ($r=0.92$; $P<0.01$). Strong positive correlates ($r=0.93$; $P<0.01$) exists between tree density and bare ground cover. There was negative relationship between bare ground cover and decreaser species ($r=-0.66$; $P<0.01$), increaser IIa species ($r=-0.48$; $P<0.01$) and herbs ($r=-0.61$; $P<0.01$).

Tree density negatively correlated with decreaser species ($r=-0.59$; $P<0.01$). Increase in tree density reduces decreaser species and above certain threshold production of decreaser species will decline. These findings concurred with previous studies (Riginos and Grace, 2008; Tefera *et al.*, 2007a). Increaser IIa species positively correlated with increaser IIc ($r=0.62$; $P<0.01$) indicating very close association of these species similar to finding by Young *et al.* (1998).

Table 20: Pearson coefficient of correlations (r) for rangeland condition variables in II Ngwesi group ranch

	Tree										
	WPC	ECI	Litter	Bare	density	Decr	Increal	Increalla	Incellb	Increalle	Forbs
WPC											
ECI	0.35										
Litter	0.48*	0.04									
Bare	-0.43	-0.62**	-0.47								
Tree density	0.01	-0.67**	0.001	0.93**							
Decr	0.43	0.92**	-0.07	-0.66**	-0.59**						
increal	0.10	0.41	-0.17	-0.08	0.37	0.36					
Increaser IIa	0.19	0.38	-0.18	-0.48**	0.34	0.47	0.19				
Increaser IIc	0.19	0.13	-0.43	-0.26	0.03	0.30	0.26	0.62**			
Forbs	-0.49*	-0.29	-0.46	0.38	0.09	-0.32	0.05	-0.08	0.18		
Herbs	-0.29	0.17	0.07	-0.61**	0.23	0.20	-0.27	0.20	-0.03	-0.01	-0.01

*Correlation was significant $P < 0.05$; **Correlation was significant $P < 0.01$

Wpc; Weighted palatability condition index; Eci-Ecological condition index; Decr-Decreaser species; Increal-Increaser I species; Increalla-Increaser IIa species; Increalle-Increaser IIc species

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Core section had highest herbage on offer, with significant proportion comprised of moribund layer during peak herbaceous vegetation production period. In contrast, buffer section produced highest amount of re-growth followed by settlement sections. Core section also supported production of corresponding amount of moribund component to residual herbage. The least amount of re-growth occurred in settlement section. Utilization of herbaceous vegetation was rated light, moderate and high in core, buffer and settlement sections, respectively.

Production of browse in buffer and settlement sections was highest in intermediate height class considered in the recruitment category indicating high suppression by browsers. As for core section, most of browse production occurred in the height above 5 m that would be inaccessible to medium body size browsers.

Buffer section had highest herbaceous cover during peak production and at the end of grazing periods. For these periods, cover of bare ground was highest in settlement section indicating effects of intensive grazing. While there was moderate tree encroachment in settlement section, low encroachment occurred in core and buffer sections.

Weighted palatability condition index was similar in core, buffer and settlement sections during peak herbaceous vegetation production period. However, weighted palatability condition index was highest in core section at the end of grazing period to indicate rangeland in good condition. Decreaser species accounted for the most of herbaceous vegetation in core section and least palatable increaser IIc herbaceous species was highest in settlement section.

Ecological condition index was highest in core section than in buffer and settlement sections during peak and at the end of grazing period. Condition of rangeland in core section was rated good based on weighted palatability condition and ecological condition indexes. The latter negatively correlated with bare ground cover and tree.

5.2 Recommendations

This study recommends introduction of livestock grazing in core section and grazing practices that reduces bare ground cover. Intensive short duration grazing by livestock is recommended when perennial species seeded. Herders should ensure minimum residual herbage remains for indicator species after grazing to boost re-growth in the following season.

Prescribed bush thinning to boost herbage production regrowth should be considered to improve herbage production and ecological condition index. Herders could be encouraged to use none palatable tree species to establish night corrals for cattle night enclosures as a tree thinning method to favour recruitment of desirable vegetation. Active management option such as rangeland reseeding is also recommended in settlement section to restock seed bank depleted after long history of over grazing.

The study also recommends long term monitoring of forage production and grazing trials under different scenarios of weather patterns and herbivore assemblage to establish stocking rates.

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APPENDIX III: SHRUB SPECIES SURVEY DATA SHEET

Transect number Bearing Coordinates; Start: X Y:
 Coordinates; Finishing: X Y Date
 Name vegetation type season Grazing management ...

Species	local	% Cover	Plant height	Palatability (1-4)	Livestock preference (VD, D, I,U)/season	
					Wet season	Dry season

Palatability: 1-unpalatable/never eaten, 2- occasionally eaten/only eaten by certain wildlife/livestock species, 3-eaten by most species, 4- highly palatable/ most preferred; VD: very desirable D: Desirable I: Intermediate UD: undesirable

APPENDIX IV: TREE SPECIES SURVEY DATA SHEET

Transect number Bearing GPS Coordinates; Start Point:

X Y: End point; X Y

Readers Vegetation type Grazing management

Species	Local name	Height (m)	Reference Unit (RU)	Number of RU	Crown Diameter (cm)		Desirable

Desirability classes: VD: very desirable D: Desirable I: Intermediate UD: undesirable