INFLUENCE OF HOLISTIC GRAZING MANAGEMENT ON HERBACEOUS SPECIES DIVERSITY, RANGE USE PATTERN AND LIVESTOCK PRODUCTIVITY IN LAIKIPIA COUNTY, KENYA

BY

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A thesis submitted to the Board of Postgraduate Studies in partial fulfillment of the requirements for the degree of Master of Science in Range Management (Ecology option) in the Department of Land Resource Management and Agricultural Technology, Faculty of Agriculture, University of Nairobi.

DECLARATION

THIS THESIS IS MY ORIGINAL WORK AND HAS NOT BEEN PRESENTED FOR AWARD OF A DEGREE IN ANY OTHER UNIVERSITY.

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To My late brother Ben Silas and late Fr. Aldo Vettory; for their ceaseless support towards my education, may God rest their souls in eternal peace.

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LIST OF ABBREVIATIONS

HGA	Holistic Grazing Areas
TGA	Traditional Grazing Areas
HGM	Holistic Grazing Management
SOC	Soil Organic Matter
DM	Dry Matter
GPS	Global Positioning System,
ADG	Average Daily Gain
FAO	Food and Agriculture Organization
GOK	Government of Kenya
WRI	World Research Institute
KARI	Kenya Agricultural Research Institute
AEZ	Agro-Ecological Zone

ABSTRACT

Rangelands are essential for maintaining biodiversity and are sources of livelihood for many rural communities. However, in the recent past they have been threatened by unsustainable use of their resources resulting in degradation. Whereas overgrazing is considered one of the causes of degradation in the rangelands, where it occurs it reflects the breakdown of the local natural resource governance institutions, land use and tenure changes that work in concert to undermine the otherwise flexible and sustainable pastoral grazing management systems. The result is decline in range and animal productivity that translates to reduced food and returns from livestock production. Pastoralists have evolved strategies to sustainably manage their grazing resources, notably by manipulating the grazing animals to ensure that the available forage resources are utilized efficiently throughout the year. Holistic grazing management (HGM) is designed to mimic the traditional pastoral grazing system and the wild herbivore grazing behavior that involves congregation of the grazing animals in an area for a short period of time on a rotational basis. This system is akin to high intensity, short duration grazing that ensures that the grazed areas get enough rest time to recover before the next use. Although HGM is currently being promoted in the pastoral areas of northern Kenya, there is little empirical evidence to guide its up-scaling under pastoral systems. This study was therefore carried out to assess influence of holistic grazing management practices on herbaceous species diversity, range use pattern and animal performance in Laikipia County of northern Kenya. Eight study plots were set in Holistic Grazing Areas (HGA) where rotational high intensity-short duration grazing has been practiced for the last two years, and Traditional Grazing Areas (TGA) which were grazed on continuous basis. Camera traps were placed in the plots to determine animal visits to the two grazing areas. Step point sampling procedure was used to determine vegetation cover and species diversity in the plots. Four experimental goats and sheep of same age and sex were chosen from pre-selected six herds to determine the effects of HGM on average daily animal weight gains and milk yield. Herbaceous cover was found to be significantly ($P<0.05$) higher in HGA (34.1±9.5%) than in the TGA (20±9.5%). The number of livestock grazing in the in HGA (74±12%) was found to be significantly ($P<0.05$) higher than in the TGA (57±12%). Wildlife visits were significantly ($p<0.05$) higher in HGA (307±60) than in TGA (162±60) but this was low during wet season. Animals that grazed in HGA had significantly higher ($p<0.05$, 106±20.1) milk yield than those that grazed in TGA (101±20). Weight gain of animals in HGA was significantly ($p<0.05$, 13±1%) higher as compared to those in TGA (5±1%).) Results indicate that holistic grazing enhances herbaceous cover and species diversity, an indicator of better range productivity. It also improves milk yield and weight gains in range animals and this is expected to translate to better returns in rangeland livestock production. However, longer studies would be necessary to further confirm the reported results.

Key words: Holistic grazing areas, Traditional grazing areas, milk yield, wildlife visits, weight gain, plant species abundance &frequency

CHAPTER ONE

1.0 INTRODUCTION

1.1 THESIS ORGANIZATION

The schematic organization of this thesis is shown in Figure 1.1. This thesis is organized into six Chapters. The first Chapter provides background information to the study regarding the extent of rangelands and their importance. This Chapter also presents the problem statement, justification and objectives of the study. The second Chapter presents literature review; an overview of rangelands ecosystems; and the effects of grazing on vegetation and range use by wildlife and livestock. Chapter Three comprises of the study area and research design. Chapters four and five are presented as scientific papers that comprise abstracts, introductions, data collection and analyses, results and discussions, and conclusions for the four objectives under study. Chapter Seven summarizes the findings of the study and gives recommendations. References are presented at the end of the thesis.

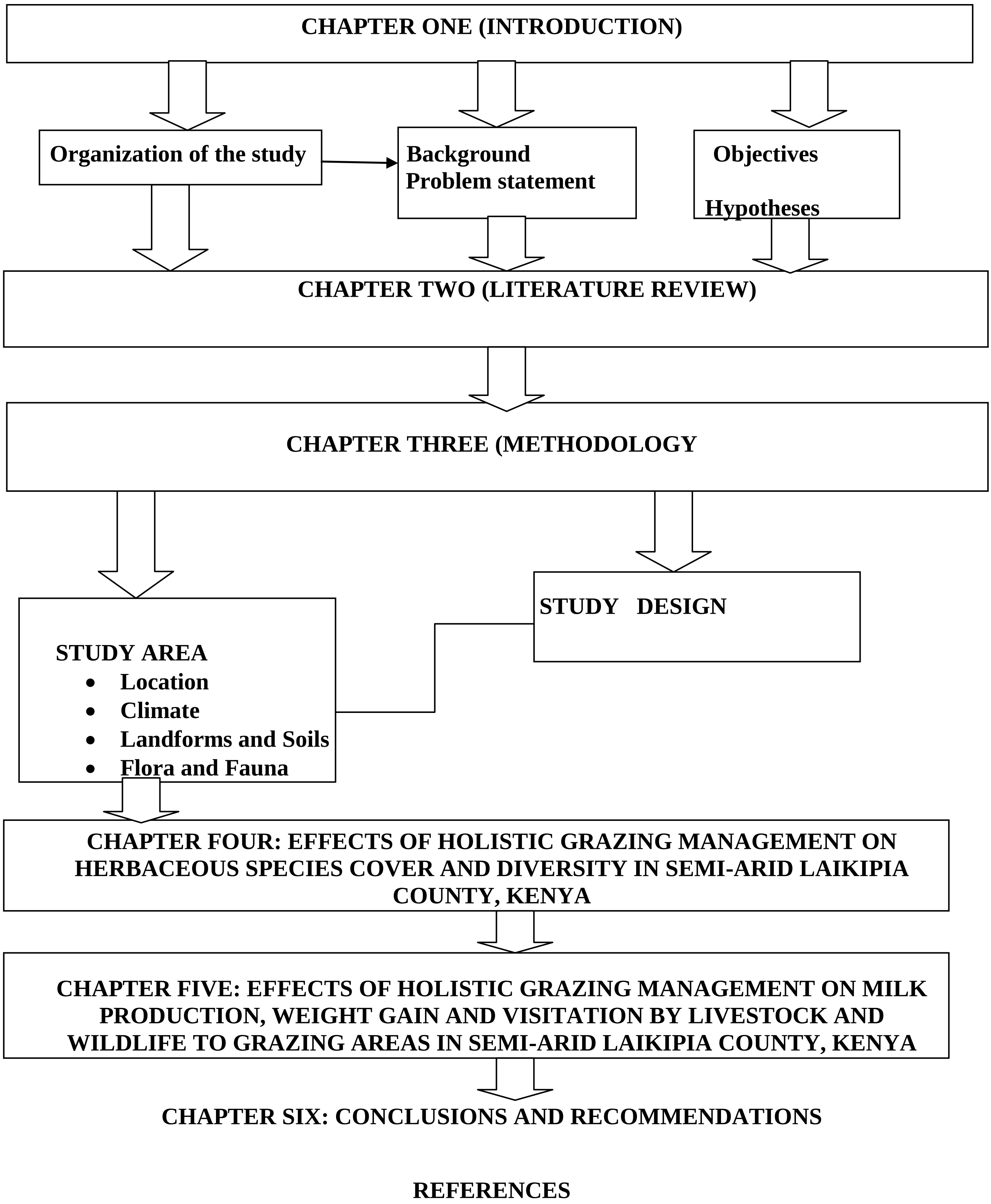


Figure1. 1: Thesis plan

1.2 BACKGROUND INFORMATION

Rangelands are estimated to cover half of terrestrial Earth's surface, making them the largest ecosystems globally (Wolf 2011; Kgosikoma, 2012; Asner *et al.,* 2004). They are important for maintaining biodiversity and are a resource base for diverse livelihoods, especially for rural communities (Eriksen and Watson, 2009; Muhumuza and Byarugaba, 2009), which inhabit the dry lands. In Kenya, rangelands cover over 80% of land surface, which has traditionally been utilized for pastoralism and wildlife conservation (Kgosikoma 2012; Rohde *et al.,* 2006; Masike and Urich, 2008). Over 50% of Kenyans livestock population and about 80% of large wildlife species and wildlife protected areas are found in the rangeland ecosystems (Ottichilo *et al.,* 2000; Odadi *et al.*, 2011*).* Rangelands face many challenges including low and erratic rainfall and high temperature, degradation and improper resource management systems. Range degradation is perceived to be caused by overgrazing, deforestation and conversion of grasslands to croplands areas. Degradation results in reduced access to grazing areas and water hence reducing the ability of pastoral communities to cope with the challenges of a complex and dynamic system.

Despite the aforementioned challenges, rangelands provide an array of goods and services to the inhabitants (Mortmore *et al.,* 2009), as well as contribute to national, regional and international economies. They support livelihoods of over 40% of the world's population (De Jode, 2009). In China, rangelands form the largest terrestrial ecosystem and one of the three most important food producers (Bekele and Kebede, 2014; Li, 1997). In sub-Saharan Africa alone, 25 million pastoralists depend on rangelands for livestock production (FAO, 2009). In the Horn of Africa, pastoralists depend on livestock as a source of livelihoods and also use it for the purpose of wealth accumulation, for marriage gifts and debt payment (Amaha, 2006). Rangelands in Kenya support over 50% of livestock population and about 80% of large wildlife species (Ottichilo *et al.,* 2000; Odadi *et al.,* 2011*).* Rangeland also provide habitat for wildlife, act as water catchment areas (Lund, 2007) and play an important role in sequestering atmospheric carbon especially through their large size (Allen-Diaz, 1996).For many centuries, African rangelands have been used for grazing by both livestock and wildlife, (Kgosikoma, 2012; Rohde *et al.,* 2006: Masike and Urich, 2008), pastoralism being the most dominant land use in these areas. Pastoralism is considered as the most viable production system in arid and semi-arid rangelands (Schareika, 2010; Galvin, 2009) due to its strategic utilization of the resources that are unevenly distributed in space and time through herd mobility. For pastoralists to take advantage of available forage and water at different time, they have to move oftenly to different areas. However their mobility has been restricted by loss of grazing land to agriculture, encroachment of urban areas and settlements, conflicts and insecurity, and socio-economic changes (Lutta, 2015: De Jode, 2009). Restricted livestock mobility and poor grazing management practices have been reported to cause deterioration of rangelands condition (WISP, 2008 and Li *et al.,* 2011).

Land degradation is defined by UNCCD (2012) as “reduction or loss, in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands. This is caused by land uses or process or combination of processes, including processes arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical, and biological or economic properties of soil; and (iii) long-term loss of natural vegetation. It has detrimental effects on livestock production and wildlife conservation because it reduces the capacity of the ecosystem to support forage production and wildlife habitat. Consequently, land degradation leads to loss of a number of range ecosystem services, as well as livelihoods of pastoral communities who depend on the natural resource base, thereby compromising their ability to cope with the challenges of a complex and dynamic system.

Africa's pastoral rangelands are some of the most degraded rangelands in the world (Ritchie *et al.,* 2012, Kioko, 2012, Kamau, 2004). This has been attributed to human activities, including timber harvesting, infrastructure construction, grazing, mining, and water diversion, (Dahmed, and Yazman, 1994) and fragmentation of communal grazing land (Olson, 2006), which reduce land available for grazing. Grazing pressure from livestock as a result of rangeland conversion to croplands, protected areas and settlements are believed to be the principal drivers of rangeland degradation in many countries (Barrow 1991) as they lead to restricted pastoral livestock mobility. When land is continuously grazed without sufficient rest periods plants are overgrazed and this leads to land degradation through increased soil erosion and spread of invasive plant species. Changes in plant community affect the productivity of these ecosystems resulting in low livestock production. Unsustainable grazing leads to reduction of palatable plant species and increase of the undesirable ones (Smet and Ward, 2005). It also affects the soil quality (Snyman and Preez, 2005; Elmore and Asner, 2006), herbaceous plant species composition (Tefera *et al.,* 2007) and woody vegetation cover.

Degradation of African pastoral lands has been largely associated with unsustainable grazing practices (Lutta, 2015; Maraseni *et al.,* 2008). In order to restore them and improve their productivity, it is important to device grazing management strategies that enable sustenance of ecosystem services and enhancement of the livelihoods of pastoral communities. Holistic grazing management is one such system already in use by conservationists and livestock ranchers to restore degraded rangelands. The system involves congregation of the grazing animals in an area for a short period of time on a rotational basis. This system is akin to high intensity, short duration grazing that ensures that the grazed areas get enough rest time to recover before next use. Despite its adoption in some of the rangelands in Texas (Warren *et a1.,* 1986), Nebraska, (Redden, 2014), Iran (Amiri *et al.,* 2008; Tamartash, 2007), Scotland

(Savory, 1999) and Zimbabwe (Kgosikoma, 2011), there is no sufficient information on its effects on forage and animal productivity in pastoral ecosystems in Africa.

1.3 PROBLEM STATEMENT

Increased human influence on rangeland ecosystems has resulted in decreased productivity and heightened potential for and severity of competition between livestock and wild herbivores (Odadi, 2010). Traditionally, pastoralists grazed their animals and exercised mobility to utilize transient resources without any restrictions. This is no longer the case as grazing areas have reduced in size and pastoralists are confined to smaller areas thereby compromising the otherwise strategic use of the range resources. Most of the observed degradation in the rangelands ecosystems is mainly due to a combination of factors such as changing land tenure and land use, sedentarization of pastoral households, as well as conflicts that restrict herd mobility thereby leading to high grazing pressure on the range. This trend has adverse implications for rangeland productivity and pastoral livelihoods. There is therefore need to device strategies of restoring rangeland health to ensure their sustainable productivity and improvement of pastoral livelihoods. Holistic grazing management is one such strategies being implemented in northern rangelands though on trials basis. It involves bunching grazing animals to exert maximum pressure on land for a short period of time alternated with rest periods, and strategic placement of livestock *bomas* (night enclosures) to restore degraded areas. However, most of the studies on the impacts of holistic grazing management have not investigated the impacts of HGM on forage diversity, range use pattern and livestock productivity. In addition, these studies have focused on private commercial ranches, and therefore little is known about the impact of HGM under pastoral production systems in the drylands of Africa.

1.4. JUSTIFICATION

Understanding the effects of grazing management on rangelands productivity is critical in designing sustainable grazing management plans. Holistic grazing management has been reported to increase vegetation production and improve plant diversity as a result of improved soil function and fertility arising from even distribution of grazing pressure (Gompert, 2010). A study by Savory (2013) in a rangeland in Scotland reported that trampled vegetation under holistic grazing covers and protects soil from erosion thereby increasing soil hydrologic function, seedbed preparation and germination rates of grassland plants. Peterson (2014) reported that high stocking densities used in holistic grazing systems result in even distribution of grazing, hoof action, and excreta across the pasture which enhances water infiltration and plant growth. However no studies have been done to determine the effect of HGM on livestock productivity and range use pattern in pastoral production systems. This study was therefore conducted to generate information on the effects of HGM on herbaceous species diversity, range use pattern and livestock productivity in the pastoral ecosystems in northern Kenya. The results of this study are expected to contribute to existing pool of knowledge on grazing management in the rangeland ecosystems. Specifically, the findings will inform up-scaling of HGM, decisions on grazing management plans by wildlife conservationists, commercial ranchers and group ranches, as wells as guide formulation of policies on natural resource use at County level to ensure sustainable range management.

1.5 OBJECTIVES

1.5. 1 BROAD OBJECTIVE

The overall objective of this study was to assess the influence of holistic grazing management on range productivity and livestock performance to contribute to informed decision making on the appropriate and sustainable grazing management strategies suitable for the pastoral ecosystems.

1.5.2 SPECIFIC OBJECTIVES

The specific objectives of this study were to:

1. Determine the effect of holistic grazing management on plant herbaceous cover, composition and diversity.
2. Assess the effect holistic grazing management on milk yield and weight gains of sheep and goats.
3. Determine the frequency of visitation to grazing areas by livestock and wildlife.

1.5.3 HYPOTHESES

1. There is no difference in plant herbaceous cover, composition and species diversity between holistic grazing areas and traditional grazing areas.

2. Milk yield and weight gain of goat and sheep grazed on holistic grazing areas are not different from those grazed on traditional grazing areas.

3. There is no difference in frequency of wildlife and livestock visits to grazing areas between holistic grazing areas and traditional grazing areas.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 An overview of rangeland ecosystems

Approximately half of the world's terrestrial surface is covered by rangelands, with grazing lands constituting around 3.5 billion hectares (Follett and Reed, 2010; Wolf, 2011). Rangelands cover about 40% of the global land surface and are approximately 69% of the world's agricultural land (FAO, 2009). Rangelands occur extensively in Africa, making up 43% of the total land surface area (Lutta, 2015). They support 40% of world's population (De Jode, 2009) and due to their contribution, there is growing recognition of their importance in meeting the global food security as well as other needs of the inhabitants (Mort more *et al.,* 2009). Rangelands are also important as carbon sinks, storing up to 30% of world's soil carbon (Lutta, 2015; FAO, 2009).

Rangelands have been mainly used for wildlife conservation and livestock production through the traditional nomadic pastoralism for many years. In sub-Saharan Africa alone, 25 million pastoralists and 240 million agro-pastoralists depend on livestock for their primary income (FAO, 2009). Pastoralist livelihoods depend on utilization of natural resources, and sustainable use of these resources has traditionally been ensured through customary rangeland resource management practices by pastoralist societies (Barrow and Mlenge, 2003). However, introduction of intensive livestock production, cultivation and settlements has led to breakdown of customary pastoral resource management practices. This in turn has exerted immense pressure on the rangelands resulting in decline in wildlife populations and livestock production (Heath, 2000; Ottichilo *et al.*, 2000; Prins, 2000; Odadi *et al.*, 2011). For many years, livestock herd movement has been a central component of land management (Lutta, 2015; Galvin, 2009). Mobility has been important part of pastoral life and through it pastoralist were able to sustainably utilize the available forage resources in space and time.

Loss of grazing land to agriculture, poor watering point management, conflicts and insecurity, shifting boundaries (county, national and regional) have restricted mobility (De Jode, 2009, Gao *et al.,* 2009) hence pastoralist have been confined to smaller areas. Restricted access to grazing areas has resulted to overuse of resources causing rangeland degradation. When rangelands are degraded, the ability of dry land communities to cope with challenges of a complex and dynamic system is undermined (Lutta, 2015).

Rangeland degradation is occurring at various scales in the world rangeland ecosystems and this is undermining their ability to support livestock production. Pastoral systems have become less resilient since coping mechanisms undertaken are failing due o environmental degradation (Kassahun *et al.,* 2008). One of known causes of degradation in rangelands is overgrazing by livestock coupled with land use change to cultivated farmland (Bekele and Kebede, 2014; Barrow 1991). Rangeland degradation has serious consequences which negatively affect pastoral livestock production, wildlife conservation and pastoral livelihoods. It undermines pastoral mobility hence making the pastoral communities vulnerable to drought and other challenges facing rangelands.

Grazing is one of the key determinants of the dynamics of the arid and semi-arid rangelands. If well-managed, grazing is known to have beneficial effects on both soil and range vegetation such as stimulation of aboveground growth, root growth, and tillering (Derner *et al.,*1997; Wolf, 2011), and enhancement of nutrient cycling rate, aboveground plant decomposition and annual shoot turnover (Schuman *et al.,*1999; Reeder and Schuman, 2002). However, unsustainable grazing practices may result in degradation of rangelands (Savory and Butterfield, 1999; Huang *et al.,* 2007; Wolf, 2011).

2.2 Effects of grazing on range vegetation

Herbivores influence vegetation in different ways depending mainly on the grazing duration, frequency, timing and intensity, among other factors. Grazing modifies pasture production by affecting photosynthesis process through its effects on leaf area and light interception (Briske & Heitschmidt, 1991; Lemaire &Chapman, 1996: Baron *et al.*, 2002). Livestock grazing may affect the properties of pastureland by altering plant cover, by the mechanical effects of the hooves on soil (Mwendera and Saleem, 1997) and deposition of feces and urine. Livestock also reduces grass biomass and often creates patchy vegetation alternated by bare soil making the areas susceptible to soil erosion. Trampling by livestock results in compaction of the soil surface (Faizul *et al.,* 1995) and this affects seed emergence, soil organic matter and water infiltration. Urine and dung from grazing animals adds nutrients to the soil and this enhances plant growth in rangelands.

Whereas high stocking densities of cattle can severely reduce grass cover, moderate densities are known to stimulate grass productivity (Pe´rez *et al.*, 2012). Imbalance between range capacity and the number of livestock therefore results in many changes in vegetation cover and various soil properties. High grazing intensity affects the botanical composition and species diversity of the grazed pasture by depressing the vigor of dominant species. This results in colonization by highly competitive and grazing tolerant plant species (Kgosikoma *et al.,* 2013; Sternberg *et al*., 2000). Previous studies have reported increased biomass production in response to frequent grazing in the rangeland (Klein *et al.*, 2007; Hiernaux & Turner, 1996) and most conservation practitioners now recognize that grazing may be used as an important land management tool (Collins *et al*, 1998; Pillsbury *et al*., 2011).

Holistic grazing management (HGM) involves congregating grazing animals together to achieve high intensity grazing for a short duration alternated with rest periods. This grazing regime has been recognized as one approach that not only seeks to enhance rangeland productivity but also take cognizance of the economic benefits of sustainable grazing management. The proponents of holistic grazing management argue that when animals are concentrated in small areas for short periods of time, they break the ground, allowing for water and nutrient flow, whilst incorporating grass seeds into the soil and adding fertilizer through dung and urine (Strauch, 2009; Savory, 1983). As an emerging approach of restoring degraded rangelands, HGM has gained popularity among private commercial ranches in Zimbabwe (Abel, 1989), in USA (Strauch, 2009), and South Africa, Botswana and Namibia (Oba, 2000). Its beneficial effect has been linked to the action of the hooves of the animals that break down the hard crusts in the compacted soil, thereby improving the soil structure and subsequent increase in vegetation production (Dore, 2001). Coupled with rest period in between grazing seasons, it ensures that plants regenerate; this makes the rangeland healthier and more productive (Lutta, 2015; Abel, 1989; Savory, 1978).

Northern rangeland Trust has been promoting adoption of HGM in the semi-arid pastoral ecosystems of Laikipia County in northern Kenya (Ritchie *et al.*, 2012). Several communal group ranches have already implementating this grazing system. This has however been going on in the absence of adequate empirical evidence to guide its adoption and out-scaling. Specifically, information on effects of HGM on vegetation cover under pastoral ecosystem, as well the influence on animals' productivity and range patch utilization patterns unavailable. This makes it necessary to explore the aforementioned vegetation dynamics and animal behavior and performance in relation to holistic grazing management regime.

2.3 Grazing and livestock nutrition in rangelands

In Kenya's Arid and semi-arid lands (ASALs), the livestock sub-sector contributes 40% of Kenya's Agricultural Gross Domestic Product and 10% of the country's total Gross Domestic Product (KARI, 2004). It employs 90% of the population and contributes 95% of the family income in the arid and semi-arid lands (GoK, 2003). The potential of arid lands and the livestock sub-sector are recognized by the government under Vision 2030 as important drivers for economic growth (GoK, 2008).

The main livestock species kept in Kenya's rangelands are cows, goats, sheep, camels and donkey. Feeding is one of the most important determinants of livestock milk production and it determines the productivity of an animal. Most pastoral range livestock depend entirely on natural pastures without any supplemental feeding and therefore the condition and quality of pasture are key to determining livestock productivity. Therefore efforts aimed at enhancing range productivity and sustaining livestock production and pastoral livelihoods should pay attention to sustainable utilization of the natural resource base to ensure continuous supply of both quantity and quality forage for the livestock.

Weight gain is an important indicator of animal performance because it results from a balance of several factors that influence intake, assimilation and conversion of nutrient to animal tissue (Anderson, 1981; Poppi *et al.*, 1987). Main regulating factors of forage intake are grouped into two categories, non-nutritional and nutritional factors. The non-nutritional also referred as behavioral factors determine the influence of forage characteristics on feeding behavior (Hodgson, 1990). Nutritional factors are related to crude protein and neutral detergent fiber content and dry matter (DM) digestibility of forage. Diet quality is one of the factors that influence forage intake since it affects digestion. It can influence animal's performance by affecting food conversion to animal tissue (Zimmermann, 1980; Odadi 2010). Mertens (1994) reported that changes in feed intake account for 60 to 90% of variations in animal performance. Increase in forage quality may lead to increase of animal performance while decline in forage quality may lead to low weight gain or even weight loss (Stobbs, 1975).

Animal performance is greatly influenced by grazing system because it affects forage production, harvest efficiency and utilization. Proper grazing management minimizes livestock cost and increase forage production while poor grazing management result in rangeland degradation (Garay *et al.,* 2004; Franzluebbers *et al.,* 2000; Newman and Sollenberger, 2005; Wright *et al.,* 2004). Grazing animals affect species composition, biomass yield and distribution of biodiversity (Oba *et al.,* 2001, Zerihun & Saleem, 2000). Continous grazing without rest period reduces the amount of regeneration and pushes vegetation farther away from climax (Blench & Florian, 1999). Continous grazing also enhances selective grazing which results in overuse of palatable species and growth of unpalatable ones (Adler *et al*., 2001; Fuhlendorf and Engle, 2001). This in turn forces the livestock to graze on the unpalatable species, which are less nutritious leading to poor animal performance. Applying appropriate grazing management ensures that range is utilized sustainably and that it economically provides quality forage to meet the animal's nutritional requirements, while maintaining forage in a healthy vegetative state (Oba *et al.,* 2001).

To obtain optimum animal performance in the rangelands, it is crucial to implement grazing regimes that allow adequate recovery of pastures after defoliation and reduce the incidences of undesirable forage species at the expense of palatable species.

2.4 Range use pattern by pastoral herds and wildlife

Human population in rangelands has increased over the years and this comes with higher demand for land for the purposes of settlement, agriculture, waste disposal and other activities that alter natural surroundings such as mining and associated industries. As a result, there has been shrinkage of areas set aside for grazing as compared to during the pre-industrial era, when both human and livestock populations were relatively low and widely dispersed (Boyd *et al.*, 1999: Maleko *et al.,* 2012). Traditionally, there was limited restriction on livestock mobility in Africa's rangelands, leading to nomadic livestock production system being dominant in these areas (Rasmussen, 1999; Maleko *et al.,* 2012). This was favorable for both livestock and wildlife as any communal land used by cattle can be utilized by wildlife as well (Rasmussen, 1999; Maleko *et al.*, 2012).

Livestock and wildlife have co-existed in Africa's rangelands for many hundreds of years, with few of the tensions evident today. This is due to the fact that human and livestock populations were relatively small and widely dispersed, and domestic animals were managed to minimize the risks of predation and disease transmission. In addition, wildlife habitats were intact and therefore their movement outside their areas into human occupied areas was minimal. In the present day, grazing and water resources have reduced due to degradation and habitat fragmentation. Livestock and wildlife 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 (Charlotte *et al.*, 1999).

Pastoral people and livestock in rangelands tend to concentrate around water points due to the fact that most livestock species require drinking water either everyday or every other day (Stoddart *et al.*, 1975; De Leeuw *et al.*, 2001). As a result a radial gradient in overgrazing may develop around a water point (Andrew, 1988; Pickup, 1989; Pickup and Chewings, 1994; Pickup *et al*.,1998; De Leeuw *et al*.,2001) or around other key resources that congregate people and livestock. In conservation areas too, most wildlife species concentrate around water points (De Leeuw *et al.,* 2001; Western, 1975) with artificial water points often built to attract more wildlife. Due to water points being shared, areas for both livestock and wildlife, there may arise a competition for water and forage resources with herders' intentionally or unintentionally scaring away wildlife.

Livestock- wildlife interaction may have both positive and negative effects. Competition for pasture between livestock and wildlife can lead to livestock depopulation especially during dry season when there is inadequacy (Prins, 1992; Heath, 2000: Prins and Grootenhuis, 2000; Odadi, 2010). De Leeuw *et al*., (2001) reported that wildlife avoided areas near water points where livestock herds frequented and this may have a negative effect on wildlife population in such areas. Disease transmission between livestock and wildlife and human-wildlife conflicts are also some of the challenges in livestock–wildlife interaction. However, growing evidence suggests otherwise in some situations. Livestock and wildlife are compatible and can even have complementary interactions. For instance, when there is proper grazing management, livestock can alter vegetation composition, increase productivity of certain plant species, increase nutritive quality of forage and increase diversity of habitat by altering its structure (Severson & Urness, 1994) and this favours wildlife habitation. Livestock and wildlife frequency of visits to various grazing patches will depend on effects of their interaction and how forage and water resources are shared.

It is therefore important for livestock managers and wildlife conservationists to work together to come up with strategies that will enable wildlife and livestock to coexist successfully to enable improved livestock production for pastoral communities and wildlife protection.

Studies on effects of this interaction under holistic grazing management are rare. Specifically, impacts of holistic grazing on wildlife and livestock frequency of visits to holistically grazed areas are yet to be conducted.

CHAPTER THREE

METHODOLOGY

3.1 STUDY AREA

3.1.1 Location

The study was conducted in Ilmotiok and Koija group ranches in Laikipia County of Kenya, which is situated between longitudes 36°5´ and 37°55´ East and latitudes 1°10´ and 3°10´ South. The two sites are under Naibung'a conservancy which is made up of nine group ranches namely: Tietmut, Kijabe, and Koija, Ilmotiok, Musul, Ilkilorit, Moropusi, ll-polei and Munishoi (Fig,3.1). Laikipia County is situated on the equator on the leeward side of Mt Kenya and covers $9,666km^2$.

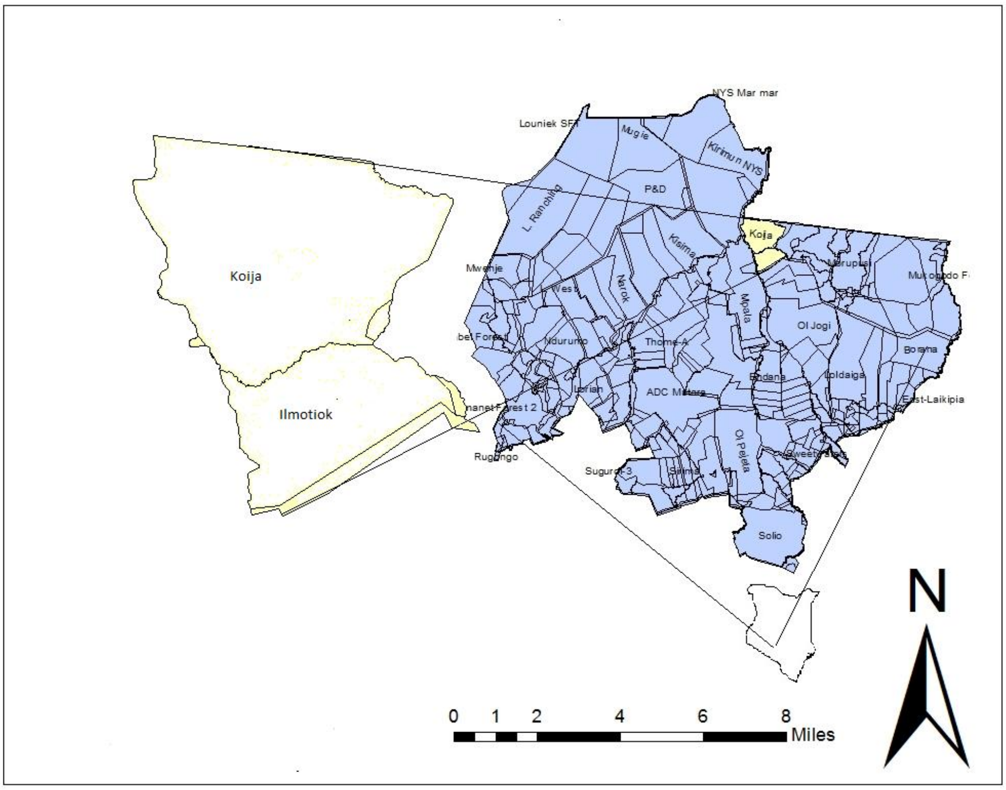


Figure3.1: Study area (Koija and Ilmotiok group ranches)

3.1.2 Climate

The Rainfall in Laikipia County is highly variable both in space and time with an annual range of 400-800mm. The long rains occur between March and May, while short rains fall in October to November (Odadi, 2010). Mean monthly maximum temperature range from 25^0C to 30^0C, while minimum temperature ranges from 12^0C to 17^0C with July and August being the coldest and windiest months (Odadi, 2010).

3.1.3 Landforms and soils

Laikipia County consists mainly of plateau bounded by the great rift-valley to the west and the Aberdare ranges and Mt. Kenya ridges to the south. The plateau descends towards the floor of rift valley in North West, while in the north and east it falls into areas that extend over hundreds of kilometers towards the north. There are two main soil types in Laikipia County; red soils (oxisols) and black cotton soils (vertisols). On the eastern part of the County, there are mainly sandy and well drained red soils on steep slopes and areas of high elevation. The Black cotton soils characterized by impeded drainage, high clay content and high levels of calcium carbonate are mainly found in the Laikipia plateau on western part of County. Ilmotiok and Koija group ranches are dominated by red soils with black cotton soils found in some areas

3.1.4 Flora and fauna

Vegetation in the study area is largely classified as wooded grasslands comprising of *Themenda–pennisetum* grassland, *Acacia* bushland. *Acacia brevispica* dominates the open thickets, while *Acacia mellifera* and *Acacia nilotica* mainly occur in arid zones. Acacia bushlands are commonly found on the well-drained red soils in the Agro Ecological Zone (AEZ) VI (Odadi, 2010).

Laikipia County hosts one of the largest wildlife populations in Kenya (Heath, 2000). The current aerial count estimates in the area put biomass density of large wild herbivores excluding elephants at 0.83tonnes km^{-2} (Georgiadis *et al.*, 2007). Cattle are the dominant livestock comprising 85% of total livestock biomass density in the County (Georgiadis *et al.*, 2007). Other livestock species in the study site include sheep, goats, camels and donkeys.

3.2. STUDY DESIGN

Study sites in Ilmotiok and Koija group ranches were selected to represent the holistic grazing management and traditional grazing regime, respectively. Unlike Ilmotiok group ranch where holistic grazing management was being implemented, study sites in Koija had been under continuously grazing throughout the year.

The study sites were selected on the basis of grazing history. Holistic grazing areas (HGA) represented areas in which high intensity grazing, short duration grazing alternated with rest period had been practiced for two years prior to time of the study, while the traditional grazing areas (TGA), which were used as controls were sites where continuously grazing had been practiced throughout the year. Completely randomized design considering the two existing soil types was used to choose and establish eight experimental plots measuring 25m by 25m in the study area, four in each of the two sites namely the holistic grazing (HGA) and traditional grazing areas (TGA) as shown in Figure 3.2. Sampling for herbaceous species cover and diversity, range use pattern and animal productivity attributes were conducted in these plots. Details of method used are presented in chapter four and five.

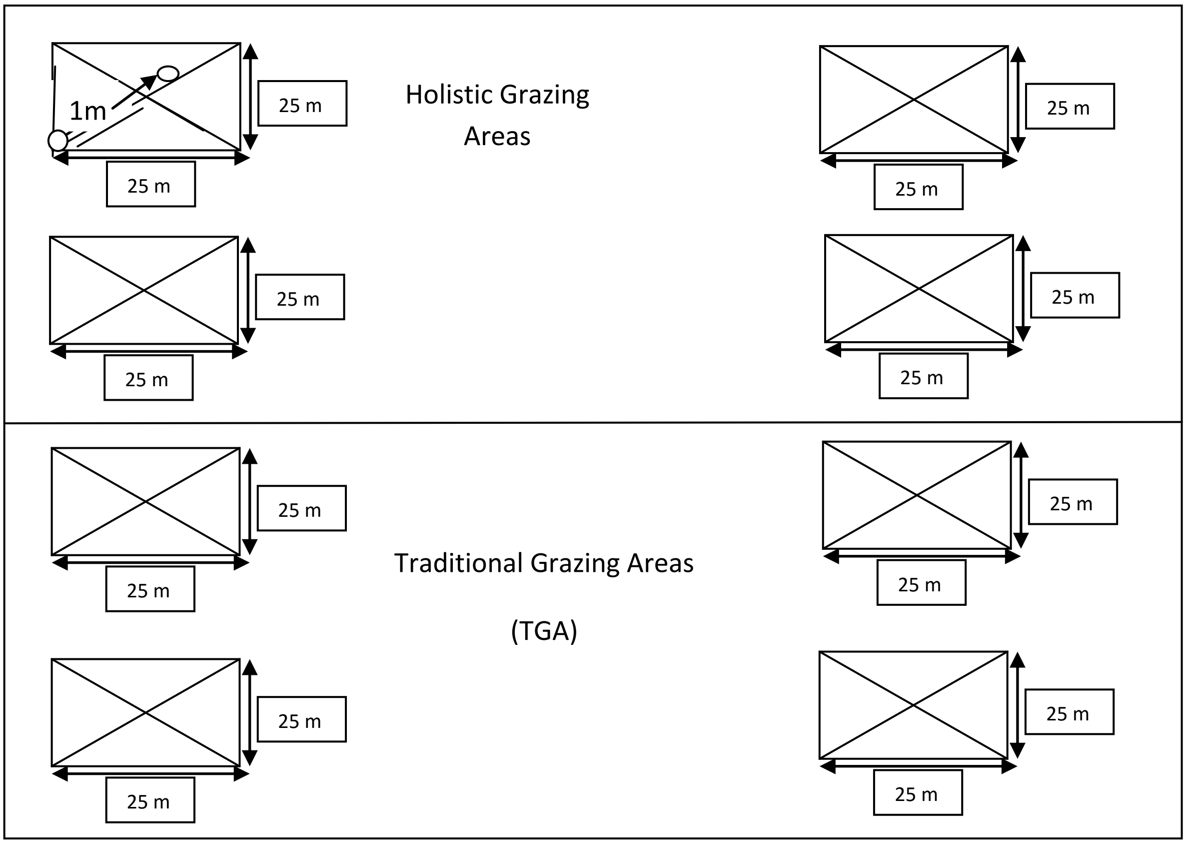


Figure 3.2: Experimental layout of the study

CHAPTER FOUR

EFFECTS OF HOLISTIC GRAZING MANAGEMENT ON HERBACEOUS SPECIES COVER AND DIVERSITY IN SEMI-ARID LAIKIPIA COUNTY, KENYA

ABSTRACT

Rangelands ecosystems provide important habitats for world biodiversity and support many rural communities especially the pastoralists who dependent on extensive livestock production as their main source of livelihood. Grazing is an important determinant of condition of the vast tropical rangelands. It is therefore critical to understand the effects of grazing management on rangelands productivity to guide sustainable planning and use of the resource base. This study assessed the effects of holistic grazing management on herbaceous species cover and diversity in Laikipia County of Kenya. Comparisons of herbaceous cover and species diversity were made between the Holistic Grazing Areas (HGA) in which high intensity grazing combined with rest rotation had been practiced for the last two years from 2012 to 2014, and Traditional Grazing Areas (TGA) where animals were allowed to graze continuously throughout the year. Herbaceous cover was found to be significantly higher in HGA ($p<0.05$, 34.1 ± 9.5) than in the TGA ($p<0.05$, 20.1 ± 9.5). The results indicate that holistic grazing enhances species cover and diversity, an indicator of better range productivity which is expected to translate to better livestock production in the rangelands.

KEY WORD: Traditional grazing areas, species abundance& frequency, Annual & perennial species

4.1 INTRODUCTION

Africa's rangelands cover about 20 percent of the earth's land surface area (Bond & Midgley, 2000; Sankaran *et al.,* 2005). In Kenya, rangelands cover over 80% of land surface and are mainly used for livestock production and wildlife conservation (Kgosikoma 2012; Rohde *et al.,* 2006; Masike & Urich, 2008) and support a large human population dependent on grazing livestock.

Rangelands are very important to the society because of goods and ecological services they provide. However, competing land uses such as cultivation, and human settlements, among others, have increasingly put rangeland ecosystems under pressure (Heath 2000; Odadi *et al.,* 2011) thereby causing degradation and reducing their capacity to support livestock production. Rangeland degradation includes a change to a simple floral/ fauna composition or a transition from one organic form to a lower organic form, loss of topsoil and continuous reduction of productivity/biomass of the ecosystem (Bekele & Kebede, 2014). Rangelands are considered degraded when pastures are getting unattractive to livestock and support only low stocking rates (Rischkowsky *et al.,* 2003). Degradation in general therefore manifests in decline in productivity and affects the capacity of land to sustain grazing animals. Rangeland degradation is caused by many factors including climate change effects, soil erosion and overgrazing. Overgrazing occurs when stocking rate is set at higher stock densities causing decline in the most palatable perennial species and an increase in less favourable species (Oba & Kotile, 2001). According to World Resource Institute (WRI, 1992), overgrazing is the most pervasive cause of soil degradation. It reduces the amount of regeneration and pushes the vegetation further away from climax while reduced grazing allows the system to move back along the succession pathway (Blench & Florian, 1999). Grazing fields heavily (particularly at flowering and seed set times) therefore results in production of fewer seeds, decreasing recruitment of new individuals into the plant population. Changes in plant community associated with overgrazing affect the productivity of rangeland ecosystems resulting in low livestock production. Therefore there is need for proper grazing management for sustainable ecosystem services and pastoral livelihoods.

There has been a growing interest in holistic grazing management as a means of restoring rangeland health and productivity in Africa, USA and Australia. This grazing regime is known to reduce stress on vegetation by controlling the amount of time the animals are on and off the land, and has been reported to increase forage production and enhance grassland health, through rapid top soil development and carbon storage (Gompert 2010). Increased nutrient cycling is another benefit of holistic planned grazing and this result in nutrient rich ecosystem in which plants grow rapidly, produce litter that decomposes to a greater extent and maintains health of grazing animals (Brown, 2014; Hobbie, 1992). Reports from holistic grazing practitioners suggest that it can enhance pasture density, improve plant diversity, and increase herbage production (Johnson, 2012). As indicated by Gompert (2009), the increased herbage production under holistic grazing enables high stocking rates and greater profitability for livestock producers.

Holistic grazing management is being piloted in parts of northern Kenya rangelands as a strategy to rehabilitate degraded range (Ritchie *et al.,* 2012). This system has been practiced in Texas (Warren *et a1.,* 1986), Nebraska, (Redden, 2014, Iran (Amiri *et al.,* 2008; Tamartash, 2007) and Scotland (Savory, 1999) and Zimbabwe (Kgosikoma, 2011) under ranching systems. However, there is paucity of empirical evidence of its performance under the arid and semi-arid pastoral production systems in East Africa. Traditional grazing entails grazing animals continuously on the land without controlling the numbers or time of grazing. In this type of grazing, forage is utilized unevenly and selective grazing is enhanced where some preferred species are heavily grazed on leaving behind unpalatable species hence resulting to overgrazing. This study was therefore conducted to assess the effects of holistic grazing management on herbaceous species cover and diversity in selected group ranches Laikipia County of Kenya.

4.2 DATA COLLECTION AND ANALYSIS

Vegetation sampling for determination of herbaceous species cover and diversity was conducted along each transects (see Figure 3.2 in Chapter 3 and Plate 4.1) using step point sampling method. The sampling involved making steps along the transect and dropping a pin perpendicular to the ground at an interval of 1meter. Hits on plant species were recorded.

Plate 4.1: Vegetation sampling using step point method

Vegetation sampling was done every week during the wet and dry seasons over a period of four months. Vegetation cover, species diversity and evenness, as well as the frequency of individual species were calculated using the following formulae:

Herbaceous cover (%) $= \frac{Number\ of\ hits\ on\ species}{Total\ Number\ of\ hits} \times 100$

Shannon weiner diversity index,= $\sum \left(p_{i \times lnp_i}{}^{2}\right)$

Evenness $= \left(\frac{H}{H_{max}}\right)$ Where H=Shannon Weiner index, and H_{max}=Maximum possible diversity

Species frequency= $\frac{Total\ number\ of\ a\ species}{Total\ number\ of\ observations}$

Species abundance= $\frac{Total\ number\ of\ a\ species}{Total\ area}$

Relative frequency = $\left(\frac{Frequency\ of\ a\ species}{Total\ frequency\ of\ all\ species}\right) \times 100$

Relative abundance =$\left(\frac{abundance\ of\ a\ species}{Total\ abudance\ of\ all\ species}\right) \times 100$

The collected data was analyzed using GenSTAT statistical software. The data was subjected T-test to determine if there is significant difference in herbaceous cover, species composition and diversity between the dry and wet seasons in HGA and TGA. Fisher's protected LSD test was used to separate the treatment means.

4.3 RESULTS

4.3.1 Herbaceous species cover, diversity, evenness and density

Table 4.1 presents species cover diversity, composition and evenness in the areas under holistic grazing and traditional grazing regimes (control plots). There was significantly ($p<0.05$) more herbaceous cover in HGA than in the TGA. Species cover was also significantly ($p=<0.05$) higher during wet than dry season in HGA. However, there was no seasonal variation in cover in the TGA.

Species diversity and evenness was significantly higher ($p<0.05$) in the HGA than in TGA (Table 4. 1). Significantly higher species diversity and evenness was also recorded during the dry season than in wet season (Table 4.1).

Table 4.1: Herbaceous species cover and diversity in the holistic and traditional grazing areas

Grazing treatment	Species cover (%)		Species richness		Shannon Wiener index		Species evenness	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Holistic Grazing Areas	34.1±4.5[a]	50.3±4.5[b]	4.69±0.48[a]	5.75±0.48[a]	1.7[a]	1.6[a]	0.9[a]	0.8[a]
Traditional Grazing Areas	20.1±4.5[b]	29.3±4.5[b]	3.97±0.48[b]	4.53±0.48[b]	1.4[b]	0.7[b]	0.7[b]	0.8[a]
LSD	9.5		1.006			0.2		0.1

Values with same superscripts in the columns are not different at p <0.05

Density of annual plant species, mostly forbs, were significantly higher (68 plants/ha, $p<0.05$) in TGA than in HGA (44plants/ha, $p<0.05$) during dry season (Figure 4.1). On the contrary, density of perennial species was higher (1500 plants/ha, $p<0.05$) in the HGA than in TGA (1340 plants/ha, $p<0.05$) both in the dry (Figure 4.1). During wet season HGA had significantly higher (940planta/ha, $p<0.05$) perennial species than TGA (636plants/ha, $p<0.05$) with annual species being higher in TGA than HGA.

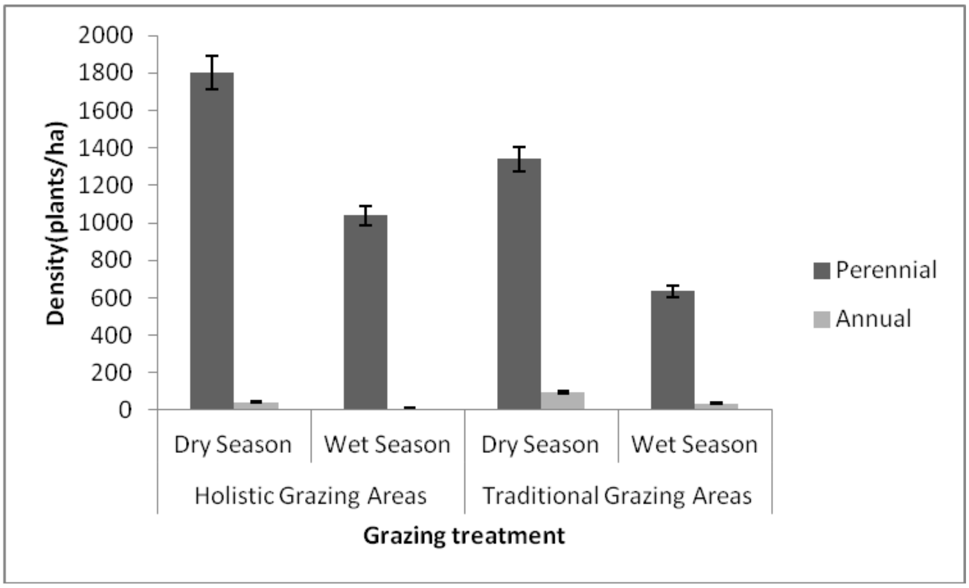


Figure 4.1: Density of annual and perennial plant species during dry and wet season

The most common species in both HGA and TGA were *Cenchrus ciliaris, Cynodon nlemfuensi*s, *Pennisetum mezianum, Cynodon americanus, Cynodon dactylon, Pennisetum stramineum, Themeda triandra, Solanum incanum, Hibiscus sp and Tribulus sp* (Figure 4.2). *Balaria sp* and *Tragus sp* were only found in HGA, while *Justicia sp* was recorded in TGA (Figure 4.2). *Cynodon dactylon*, *Pennisetum stramineum* and *Pennisetum mezianum were* dominant in the HGA, while *Cynodon dactylon and Cynodon americanus* dominated the *TGA* .

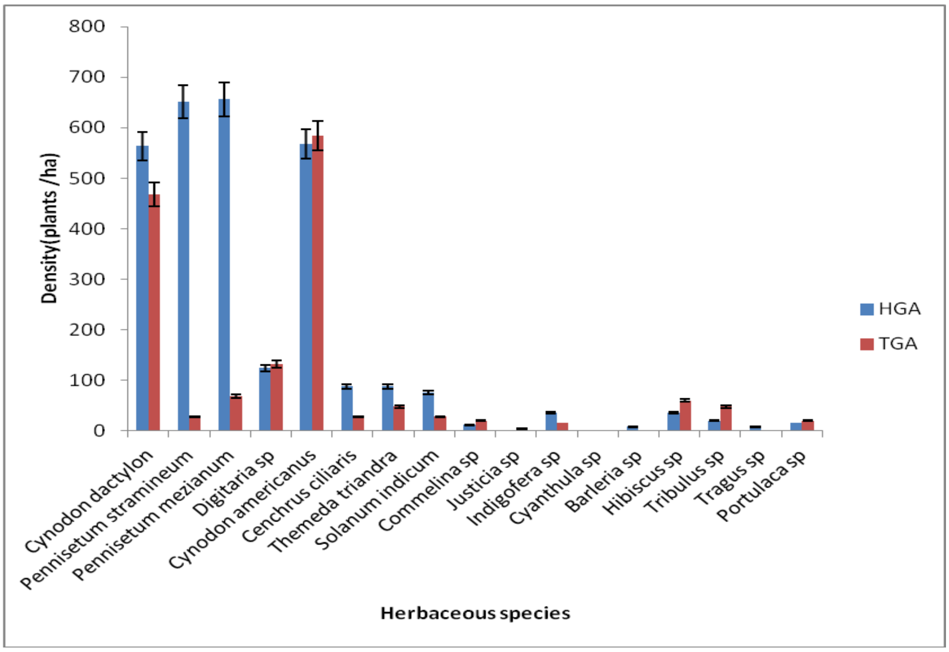


Figure 4.2: Density of plant species in holistic and traditional grazing areas

Figures 4.3 and 4.4 present species relative frequency and abundance, respectively in the areas under holistic grazing and the traditional grazing. *Pennisetum mezianum, Pennisetum stramineum, Cenchrus ciliaris and Solanum incanum* had higher relative abundance and frequencies in HGA than in TGA. *Pennisetum mezianum, Pennisetum stramineum and Cenchrus ciliaris* dominated in HGA, while *Cynodon nlemfuensi*s and *Cynodon americanus* dominated the TGA.

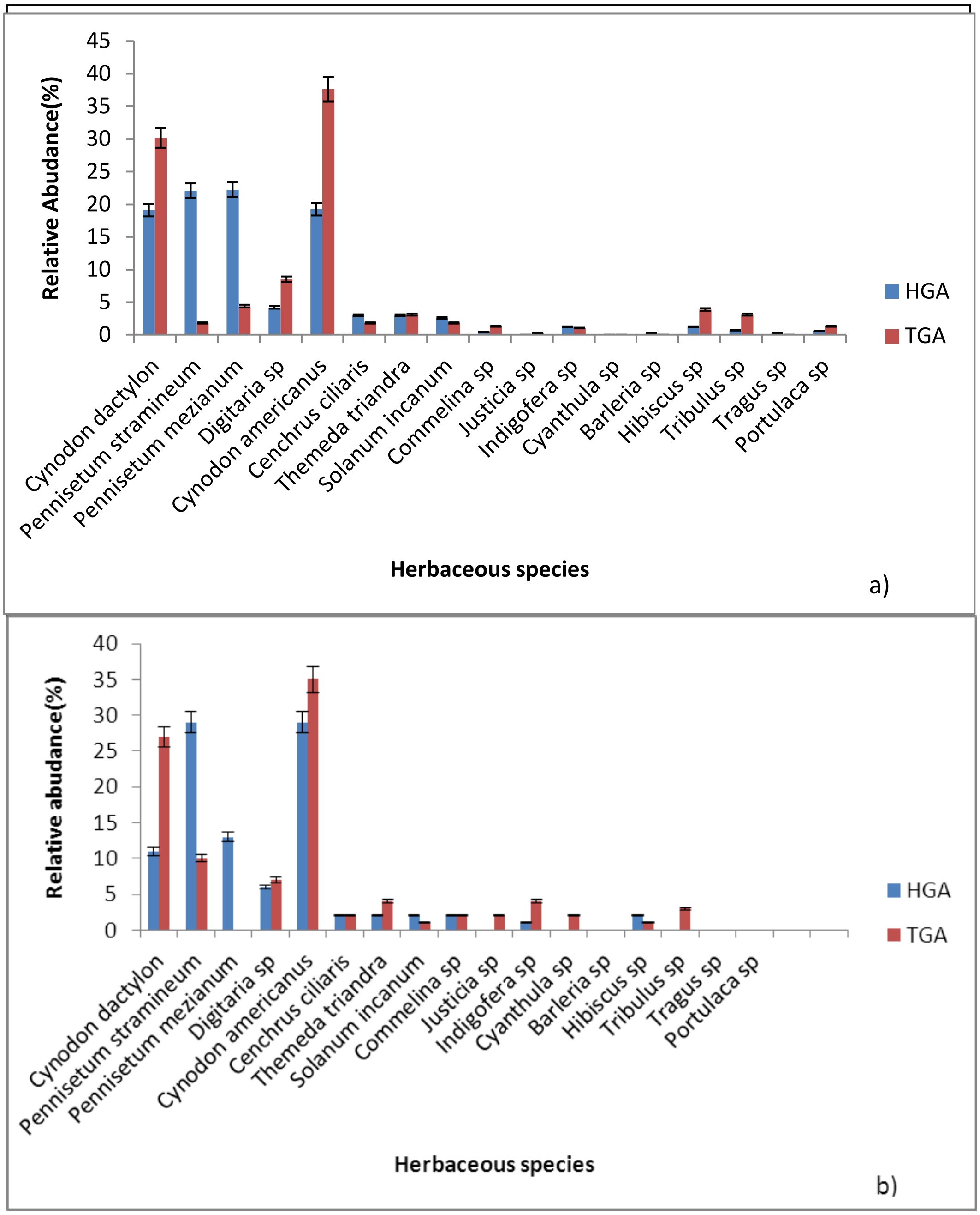


Figure 4.3.Relative abundance of plant species under the two grazing regimes during dry (a) and wet (b) seasons

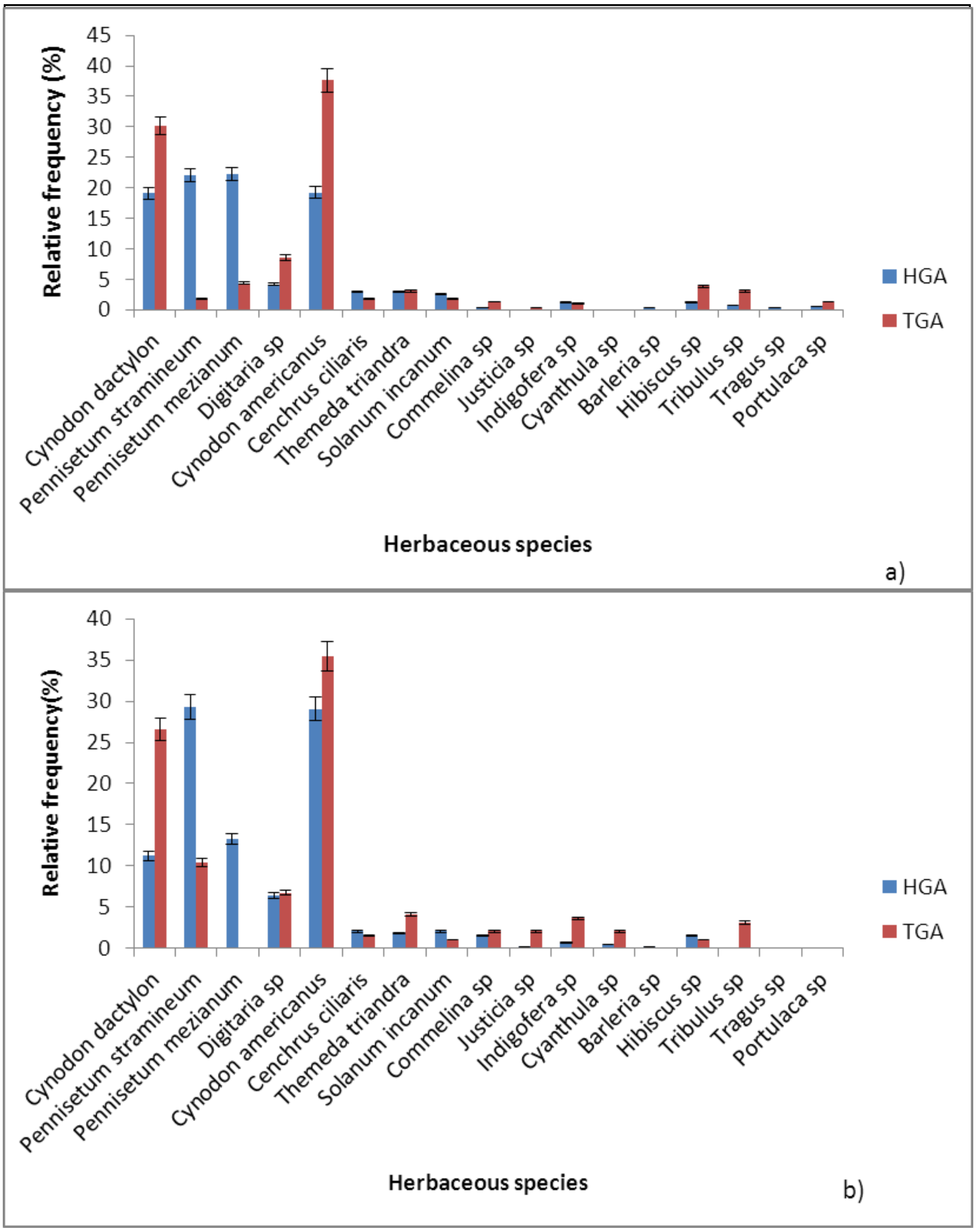


Figure 4.4.Relative frequency of plant species under the two grazing regimes during dry (a) and wet (b) seasons

4.4 DISCUSSIONS

4.4.1 Herbaceous species cover

The herbaceous species cover was lower in areas where traditional grazing was practiced than under holistic grazing management. High herbaceous cover in HGA than TGA can be attributed to adequate rest periods that allowed plant to recover from grazing as compared to continuous grazing in TGA system. In addition, the manuring caused by dung and urine deposited incorporated into the soil by intense hoof action may have improved the soil nitrogen levels, which in turn enhanced growth of plants under holistic grazing regime. Whereas these beneficial effects of grazing are also expected in the TGA, the high intensity of grazing under holistic grazing is expected to have higher impact with respect to improvement of both soil physical and chemical properties Traditional grazing areas have continuous year-round stocking which exerts pressure on plants leading to decrease in their abundance and vigour. This occurs due to livestock's spatial patterns of repetitive use that lead to heavy use of preferred plant species and patches, while avoiding or lightly using others (Willms *et al*., 1988; O'Connor, 1992; Ash and Stafford-Smith, 1996; Bailey *et al*., 1996; Gerrish, 2004; Witten *et al*., 2005; Teague *et al*., 2011). It is known that condition of grasslands can deteriorate even under light stocking rates when they are continuously grazed due to constant high grazing pressure on preferred areas and plant species (Thurow *et al.,* 1988; Norton, 1998; Tainton *et al*., 1999; Teague et al., 2011). The observations from this study disagree with those of Tamartash *et al.,* (2007) who reported less cover under high intensity grazing in Konjour rangelands in Iran. This can be explained by the fact that their study had no rest periods in the heavily grazing areas. The higher herbaceous cover during wet than in dry season could be attributed to increased plants growth due to enhanced soil moisture regime following the rains. In the study conducted in Iran, Chaichi *et al*., (2005) and Amiri *et al.,* (2008) found that forb cover decreased under continuous grazing, which is reported to also cause decline in proportion of grass species (Amiri *et al.*, 2008; Dormaar *et al.,* 1989). This concurs with the findings of Chaichi *et al.,* 2005) in Lar rangelands in Iran that grass-green cover declined from 38 to 9.5% at the end of grazing period due to continuous grazing, which also resulted in cessation of growth of certain herbaceous species. This also corroborates the results of Teague *et al*. (2011) who reported a higher proportion herbaceous cover high intensity grazing with rest periods than in lightly stocked continuous grazing in North Central Texas. A negative relationship is reported to exist between herbaceous cover and intensity of grazing in rangelands (Amiri *et al.*, 2008; Page *et al.*, 1999). Several studies conducted by (Akbarzadeh *et a*l., 2007; Bowns and Bagley, 1986; Willms *et al.*, 1990; Qelichnia, 1996; Qaredaghi and Jalili, 1999; Savadongo *et al.*, 2007; Tamartash *et al.*, 2007) reported that where grazing intensity is high with limited or no rest periods, herbaceous cover is known to reduce significantly giving way to shrubs dominate these areas (Hosseinzadeh, 2006). The higher herbaceous cover during the wet than dry season can be explained by enhanced soil moisture content that favours more growth, especially of the annuals during the rains which enhances plant growth and establishment hence high grass and forb cover during wet season than dry season.

4.4.2 Species diversity, relative frequency, abundance and evenness

Congregation of animals in holistic grazing management minimizes selective grazing and therefore ensures uniform use of forage resources. HGA had more perennial species with *Pennisetum mezianum*, *Pennisetum stramineum, Themeda triandra and Cenchrus ciliaris* dominating. These species are palatable and preferred by animals and therefore their dominance indicates good range condition. On the other hand, TGA had more annual than perennial species with less preferred species such as *Cynodon nlemfuensi*s, *Cynodon americanus, Tribulus sp, Commelina sp and Digitaria sp* being the dominant species. The higher dominance of palatable species in HGA can be attributed to rest periods that enabled plants to recover from grazing and also reduced selective grazing thereby minimizing overuse of palatable species. In the absence of holistic grazing, animals graze selectively therefore putting more pressure on the palatable species, which gives room for less palatable species to dominate (Chaichi *et al.*, 2005). Selective grazing leads to higher grazing pressure on preferred patches and plants which is not sustainable for the area as a whole. This results in progressive resource deterioration in preferred areas of the landscape even at low stocking rates. The process is characterized by replacement of taller perennial grasses by shorter perennial grasses, then annual grasses and forbs, and finally bare ground (Thurow, 1991; Fuls, 1992; O'Connor, 1992; Ash and Stafford-Smith, 1996; Teague *et al*., 2004; Teague *et al.*, 2011). The lower species diversity, evenness and relative abundance in the TGA than HGA can be attributed to overgrazing that occurs under continuous grazing in the TGA, leading to decline and replacement of preferred forage species by less palatable ones that are capable of tolerating high grazing pressure. On the contrary, the rest periods in holistic grazing ensures more even use of forage resources thereby allowing growth of more diverse species and increase in their numbers. In a study conducted in the regions of North Central Texas, Teague *et al.*, (2011) reported that more palatable species dominated in heavily grazed area with rest periods, while unpalatable species dominated areas with continuous grazing. As indicated by Vinton and Hartnett (1992), Vinton *et al.,* (1993) and Teague. (2011), the preferred forage species decrease and disappear under heavy continuous grazing or if plants are not allowed to adequately recover after defoliation and this is concurs with the result obtained from this study. Palatability of range species decreases with increased continuous grazing because palatable species are overgrazed leaving behind less palatable species. Hosseinzadeh (2006) studied effects of grazing on soil characteristics and vegetation cover in rangelands of Mazandaran province in Iran and found out that less palatable species were more abundant where there was high grazing intensity with no rest periods than areas with continous grazing. Result from this study corroborates Kakinuma and Takatsuki (2008) observation in Northern Mongolia that species diversity and biomass decrease with continuous grazing. Under continuous grazing, the preferred plants are not allowed to recover hence overgrazing occurs. There was lower relative abundance and frequency of species during dry season than in wet season in TGA than HGA. These results could be attributed to the fact that there are more annuals than perennial species under continuous grazing regime. This is because most perennial forage species are replaced by annuals as soil moisture content declines due to a combination of high grazing pressure and prolonged dry spells. This is evident in the higher number of annual species observed in the TGA as compared to HGA in this study. However, the annuals germinate and complete their life cycle during the rains, resulting in lower frequency and abundance of the species during the dry season. The effects of continuous grazing, leading to increased defoliation are exacerbate by frequent droughts (McIvor, 2007), which may lead to significant loss of cover as a result of poor pasture regeneration

As indicated by Teague *et al*. (2011), Dyksterhuis (1946) and Dyksterhuis (1948), under continuous grazing, excessive grazing pressure is exerted on plants for an extended period of time thereby changing vegetation to primarily annual forbs, and mid- and short grasses. This was the case in traditional grazing areas as opposed to holistic grazing areas where grazing intensity was high but plants were allowed to recover before subsequent grazing.

4.5 CONCLUSION

Although the reported findings arise from a short duration study, they demonstrate that holistic grazing management has the potential to enhance rangeland health through improved herbaceous cover and species composition and diversity. Long term studies replicated in different environments are however necessary to further confirm these results.

CHAPTER FIVE

EFFECTS OF HOLISTIC GRAZING MANAGEMENT ON MILK PRODUCTION, WEIGHT GAIN AND VISITATION TO GRAZING AREAS BY LIVESTOCK AND WILDLIFE IN LAIKIPIA COUNTY, KENYA

ABSTRACT

Grazing is an important management tool for maintaining healthy ecosystems and improving rangelands productivity. However, its effectiveness for this purpose is dependent on timing and frequency of grazing, as well as the type of animal. Understanding the effects of grazing management on rangeland ecosystems is critical in ensuring sustainable use of grazing resources and enhanced livestock production. This study assessed the effects of holistic grazing on animal productivity and range use pattern in Laikipia County of Kenya. The results revealed that the average milk yields (106±20.1) of animals in the HGA were significantly ($p<0.05$) higher than in the TGA (101±20.1).Weight gain of animals in HGA was significantly (13±1%) higher as compared to those in TGA (7±1%). The number of livestock grazing was significantly ($p<0.05$) higher in HGA (74±10, than those in TGA (57±10, 32±18). In addition, the number of wildlife grazing was significantly ($p<0.05$) higher in HGA (74±18) than in TGA (32±18). The results indicate that holistic grazing management has the potential to improve animal performance, as well as condition of range areas as evident in the preference shown by frequent visits to HGA by both livestock and wildlife.

KEY WORDS: Camera traps, Continuous grazing, Animal performance, Rest periods**,** Wildlife visits

5.1 INTRODUCTION

In Kenya, rangelands cover over 80% of the land surface. They are mainly utilized for livestock production and wildlife conservation (Ottichilo *et al.,* 2000; Odadi *et al.,* 2011*),* and support livelihoods of many rural communities (Eriksen and Watson, 2009). However, their productivity and sustainability is threatened by unsustainable land-use systems that perpetuate among them causes of rangeland degradation. Overgrazing, mainly attributed to restricted herd mobility due to conversion of rangelands to other land uses, leads to reduction of palatable herbaceous plant species and increase of the unpalatable ones (Smet and Ward, 2005) that constitutes a form of range degradation. It also affects the soil quality (Snyman and Preez, 2005; Elmore and Asner, 2006), herbaceous plant species composition (Tefera *et al.,* 2007) and woody vegetation cover. Palatable species decline as grazing pressure increases and are replaced by shrubs or other vegetation which are less preferred by livestock and more resistant to grazing (Thurow *et al.,* 1986; Dyksterhuis 1949). Pastoralism offers a viable production system that enables rangelands to be used productively (Scharwenka, 2010; Galvin, 2009) because it allows mobility which enhances pastoralist adaptation to spatial and temporal variations in rainfall and grazing resources. In drought years, many communities make use of fall-back grazing areas unused in 'normal' dry seasons because of distance, land tenure constraints, animal disease problems or conflict (Blench & Florian, 1999). It's therefore imperative to maintain and improve sustainable production of pastoral communities (Brooks *et al.*, 2009) by identifying and implementing suitable grazing management strategies that enhance rangeland productivity. Holistic grazing management is one of the grazing management regimes that have been adopted in some of the rangeland ecosystems. In Kenya, the system has been introduced in some group ranches in Laikipia County of Northern Kenya as way of rehabilitating degraded rangelands. It is still being implemented on trial basis and is yet to undergo rigorous scientific assessment to reveal its performance with respect to pasture and animal performance. This practice involves short periods of high grazing impact alternated with rest periods. It is known to reduce stress on vegetation by controlling the amount of time the animals are on and off the land. The optimal number, size of paddocks, stocking density, and length of grazing and recovery periods vary widely with site, time, and management objectives (Barnes *et al.*, 2008). Holistic grazing is modeled from the grazing patterns of wild herbivores such as wildebeest and zebras, which graze various patches in large herd on rotational basis. Such herds spend a short time in a small area before moving on, leaving behind manure and considerable plant residues, above and below ground, both of which contribute to soil organic matter (SOM) and to soil nutrients (Savory and Butterfield, 1999). Holistic grazing regime is known to increase forage production and enhance grassland health through rapid top soil development and carbon storage (Gompert 2010). Increased nutrient cycling is another benefit and these results in nutrient rich ecosystem in which plants grow rapidly, produce litter that decomposes to a greater extent and maintains health of pastures (Brown, 2014; Hobbie, 1992). The system has been practiced in Nebraska, Iran and Scotland and Zimbabwe under ranching system (Redden, 2014; Amiri *et al*,. 2008; Tamartash, 2007; Savory 1999; Warren *et a1.*, 986). However, there is inadequate empirical evidence of its performance under the arid and semi-arid pastoral areas in Africa. Specifically, information on its effects on livestock productivity under pastoral systems in Kenya is lacking. The objective of this study was therefore to assess its effects on goat and sheep weight gain, goat milk production and range use pattern by both livestock and wildlife.

5.2. DATA COLLECTION AND ANALYSIS

5.2.1 Measurements of goat and sheep weight gain and goat milk yield

Six herds were chosen from the households in the study area, three each in HGA and TGA. In each herd, four one-year old small East African goats weighing 22-23kg and red Maasai sheep of male sex with comparable weighing 28-29 kg were chosen for the experiments. Two of the selected animals were fitted with collar GPS devices (Plate 5.1) to track their movements, determine distances travelled and proportion of time spent in the HGA and TGA. The GPS data was downloaded and used to determine distance covered when grazing, proportion of time spent grazing and to generate animal movement tracks.

Plate 5.1: Livestock being fitted with GPS devices

In addition, two small east African goats in the mid lactation stage were selected in each herd for milk yield measurements. Each of the selected goats had given birth three times and had aged between 3 years.

Body weight measurements of the experimental animals were done before the experiment and thereafter at a week interval for a period of four months using an electronic portable weighing scale. The measurements were done during both the wet and dry seasons. Weight measurements were routinely carried out at 7am and 8am after overnight starvation to ensure that undigested materials do not introduce biases in the estimates. Average daily weight gain for individual animals was calculated using the following formulae:

Average daily weight Gain = $\left(\frac{\boldsymbol{Weight\ gain\ in\ kg}}{\boldsymbol{number\ of\ days}}\right)$

Distance travelled = $\frac{\boldsymbol{Total\ distance\ travelled\ in\ Km}}{\boldsymbol{Number\ of\ days}}$

Proportion of time spent (%) =$\left(\frac{\boldsymbol{number\ of\ hours\ spent\ in\ a\ grazing\ area}}{\boldsymbol{Total\ time\ spent\ outside\ the\ homestead\ in\ hours}}\right) \times \mathbf{100}$

Milk yield measurements from goats were taken every day in the morning for a period of four months during dry and wet season. Average daily milk yield were computed using the following formula;

Average milk production= $\frac{Total\ amount\ of\ milk\ in\ ml}{Number\ of\ days}$

5.2.2 Estimation of frequency of animal visits to holistic and traditional grazing areas

Eight Cameras traps (Plate 5.2) were placed in all the plots as described in Chapter 3, and set to take three pictures every nine second for 24 hours a day. The cameras were placed strategically on the corner of each plot on pole or tree at the height of about 3m above the ground to enable it take pictures of the whole plot.

Plate 5.2: Infrared digital scouting camera used to capture animal visitation to grazing areas

The number of animals visiting HGA and TGA was estimated from counts of the photos taken by the installed cameras. From the pictures it was possible to determine whether the animals were grazing or just walking through the plots. The Number of animals grazing and walking in both the HGA and TGA during wet and dry seasons was computed using the following formulae:

Percent animals grazing= $(\frac{number\ of\ animals\ grazing}{Total\ number\ of\ animals}) \times 100$

Percent animals walking= $(\frac{Number\ of\ animals\ walking}{Total\ number\ of\ animals}) \times 100$

The collected data was analyzed using GenSTAT statistical software. T-test was used to determine if there was significant difference in livestock milk yield, weight gain, and frequency of visits by wildlife and livestock between HGA and TGA. Fisher's protected LSD test was used to separate the treatment means.

5.3 RESULTS

5.3. 1 Milk yield of goats and sheep and goat weight gain

Average daily milk yield from goats that accessed the HGA was significantly ($p<0.05$) higher than those in TGA (Figure 5.1). Seasonal variation in milk yield was not significant.

Goats and sheep in HGA had significantly ($p<0.05$) higher average daily weight gain than those that accessed TGA (Figure 5.1). Significant ($p<0.05$) increase in average daily weight gain was observed during the wet season than in dry season in both HGA and TGA. The observed increase was however higher in HGA than TGA (Figure 5.1).

Average daily weight gain was significantly ($p<0.05$) higher in sheep grazed in HGA as compared to those in TGA (Figure 5.1). Significant ($p<0.05$) seasonal variations was observed with weight gain in the dry season being higher than in wet season in HGA.

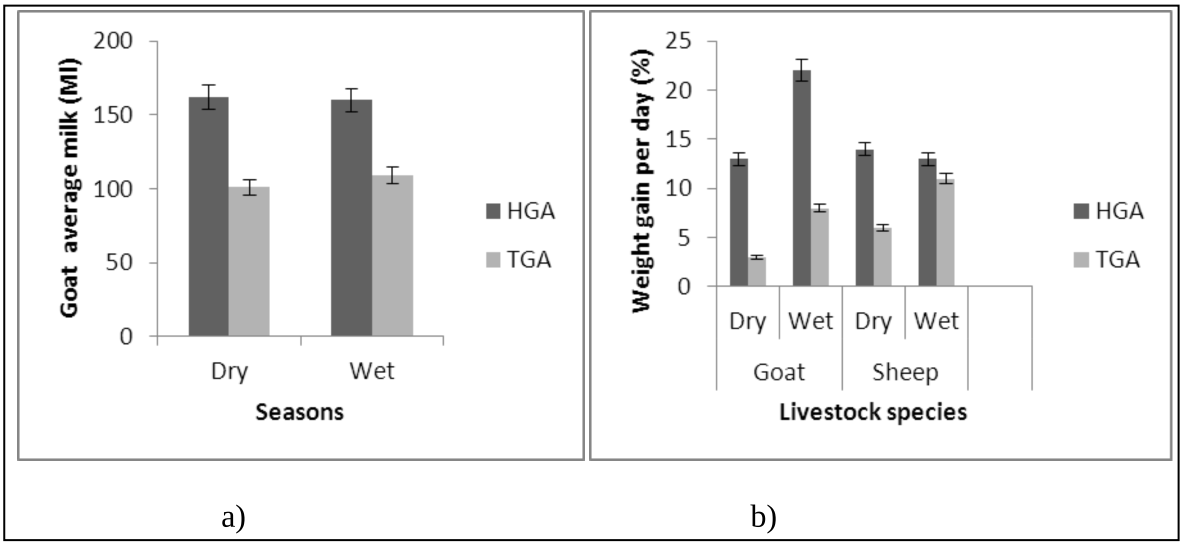


Figure 5. 1: Goat milk yield (a) and weight gain of sheep and goats (b) during wet and dry season

5.3.2 Time spent and distance travelled by goats and sheep in holistic and traditional grazing areas

Distance travelled, time spent, livestock tracks in holistic and traditional grazing areas are presented in Figure 5.2, 5.3,5.4 and 5.5 respectively.

Animals were found to spend significantly ($p<0.05$) more time in HGA than in TGA. Seasonal variations were observed with animals spending significantly ($p<0.05$) more time in holistic grazing areas during wet season than in dry season. Time spent in TGA was also found to high during wet season.

Goats and sheep travelled significantly ($p<0.05$) shorter distance in HGA than in TGA. In addition, distance travelled by both goats and sheep was significantly ($p<0.05$) shorter in the wet than in dry season.

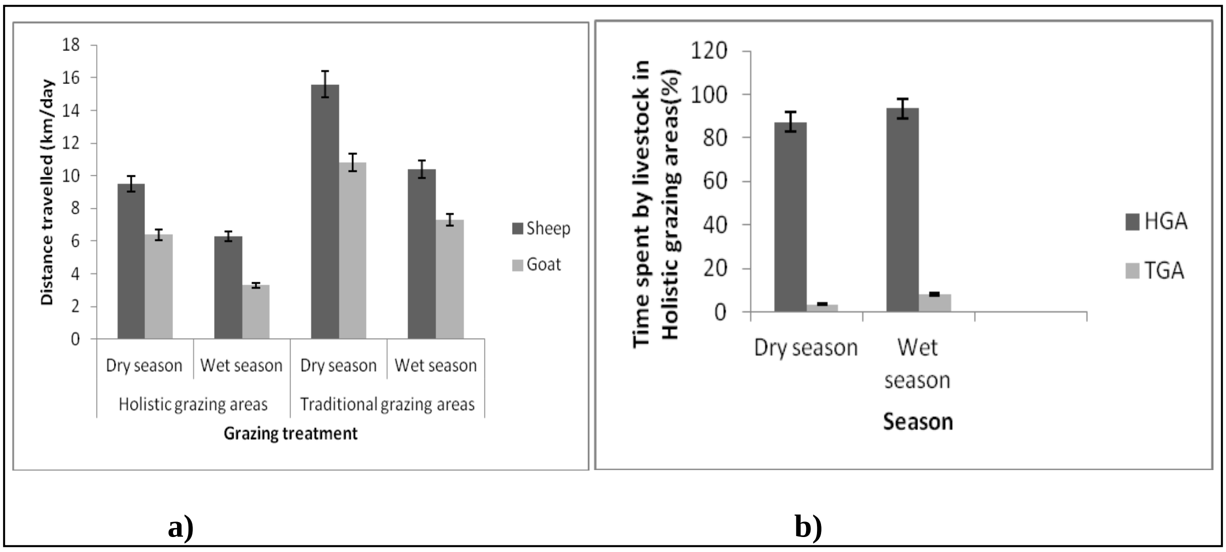


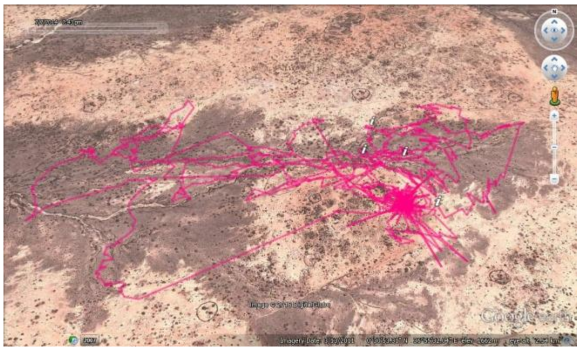
Figure 5.2: Distance travelled (a) and time spent (b) by sheep and goats in holistic and traditional grazing areas

Grazing movement patterns of goats were scattered (Plate 5.3 a), while movement of sheep were concentrated (Plate 5.3 c). Sheep and goats movement in HGA were cyclic and concentrated, while in TGA movements were scattered (Plate 5.3 b and d). Sheep tracks were more concentrated as compared to goat's movements which were scattered.

During the dry season, the tracks in HGA were cyclic and linear as livestock went to water points (Plate 5.4 a). In TGA, the tracks were linear and show livestock travelling longer distance as they go to water points (Plate 5.4 b). On the other hand in TGA, the tracks were cyclic too but seem to spread outside the concentrated areas which are the bomas (Fig5. 4b).

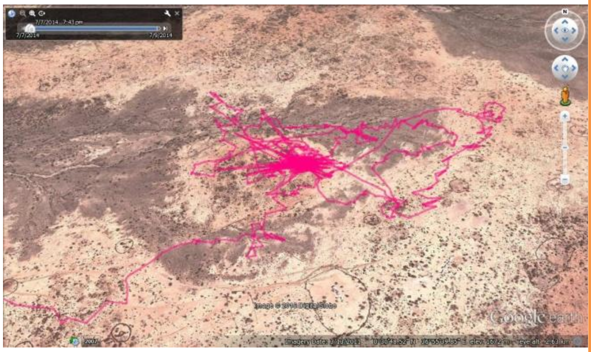
During wet season movement patterns in HGA were concentrated (Plate5.5a) while in TGA they were spread out though not like in dry season (Plate 5.5b)

a) Goats in HGA



b) Sheep in HGA

c) Goats in TGA



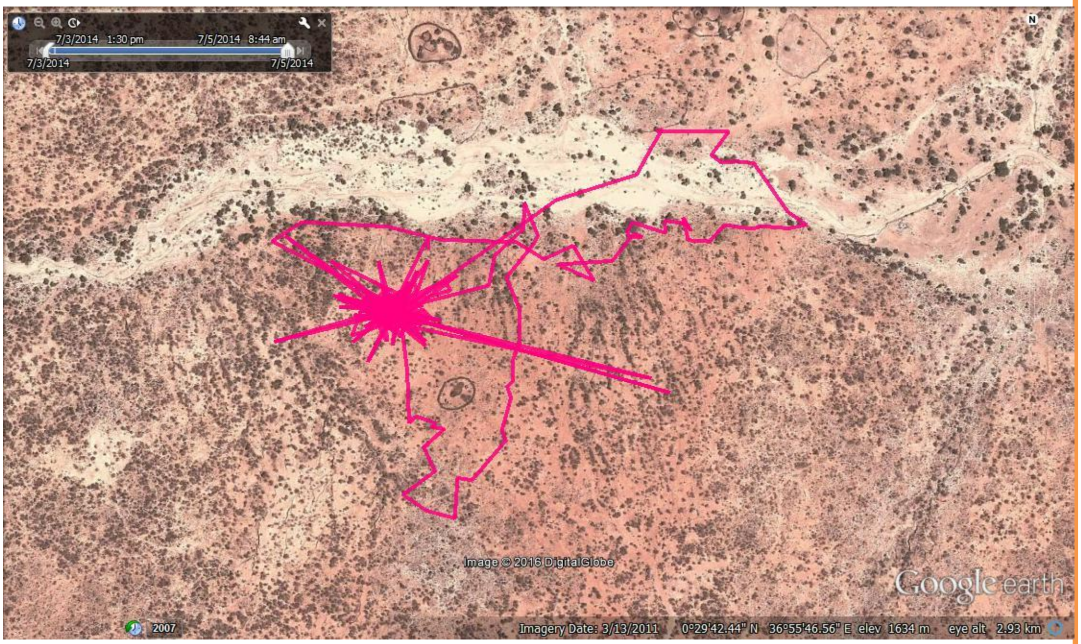
d) Sheep in TGA

Plate 5.3: Goats and sheep grazing movements in holistic and traditional grazing areas

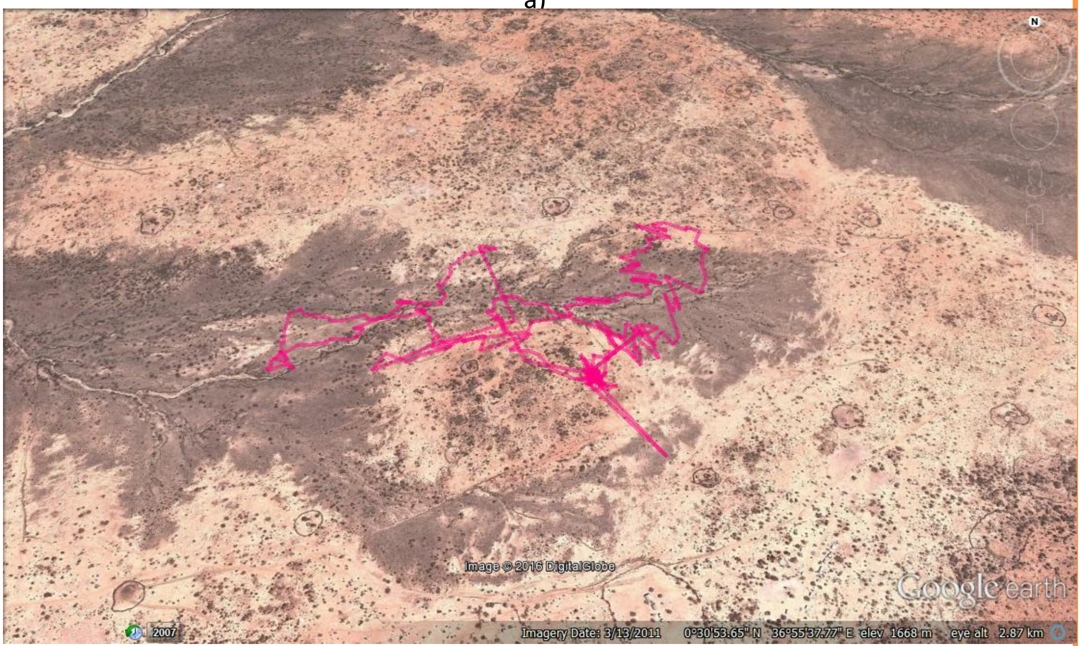
a)

b)

Plate 5. 4: Livestock grazing movement tracks in HGA (a) and TGA b) during dry season



a)



b)

Plate 5.5: Livestock grazing movement patterns in HGA (a) and TGA (b) during wet season

5.3.3 Frequency of livestock and wildlife visits to grazing patches

Table5.1 and 5.2 present frequency of livestock and wildlife visits, respectively in holistic and traditional grazing areas. The total number of livestock visits was significantly ($p<0.05$) higher in HGA than in TGA and lower in wet season both in HGA and TGA. Significant ($p<0.05$) number of livestock was found grazing in HGA as compared to TGA. The number of livestock walking in TGA was significantly ($p<0.05$) higher than in HGA, and lower during the wet season both in HGA and TGA. Holistic grazing areas had significantly ($p<0.05$) higher frequency of wildlife visits as compared to traditional grazing areas. The number of wildlife grazing was significantly ($p<0.05$) higher in HGA than in TGA. The proportion of wildlife walking was significantly ($p<0.05$) higher in TGA as compared to HGA.

Frequency of wildlife visits was lower during wet season than dry season, and so was the frequency of wildlife grazing during wet season as compared to dry season in both HGA and TGA .The frequency of wildlife walking in the HGA and TGA was also lower during wet than dry season.

Table 5. 1: Frequency of livestock visits to holistic and traditional grazing areas

Grazing treatment	Number of livestock grazing		Number of livestock walking		Total number of livestock	
	Dry season	Wet season	Dry	Wet season	Dry season	Wet season
Holistic Grazing Areas	$2554\pm113(74)^{a}$	$1566\pm113\ (86.2)^{a}$	$878\pm81(26)^{a}$	$251\pm81\ (14)^{a}$	3432	1817
Traditional Grazing Areas	$7411\pm113\ (57)^{b}$	$5333\pm113\ (62)^{b}$	$5684\pm81\ (43)^{b}$	$3353\pm81\ (38)^{b}$	13095	8686
LSD	279		222		1640	

Values with same superscript in the columns are not different at $p<0.05$

Table 5. 2: Frequency of wildlife visiting the holistic and traditional grazing areas

Grazing treatment/site	Number of wildlife grazing		Number of wildlife walking		Total number of wildlife	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Holistic Grazing Areas	225±10(74)[a]	38±10(79)[a]	82±6(26)[a]	10±6(21)[a]	307	48
Traditional Grazing Areas	52±10(32)[b]	6 ±10(35)[b]	104±6(68)[b]	34±6(85)[b]	162	40
LSD	24		18		28	

Values with same superscript in the columns are not different at $p<0.05$

The wildlife species that frequently visited the two areas under study included Elephants, Zebras and Impalas. The number of these species was significantly ($p<0.05$) higher in HGA than in TGA (Figure 5.3). The number of Zebras was highest both in HGA and TGA (Figure 5.3). Impalas visited the areas mostly in the evening in the absence of livestock herd. Elephants and Zebras visits were both during the day and night, were significantly lower during wet season than in dry season both in HGA and TGA.

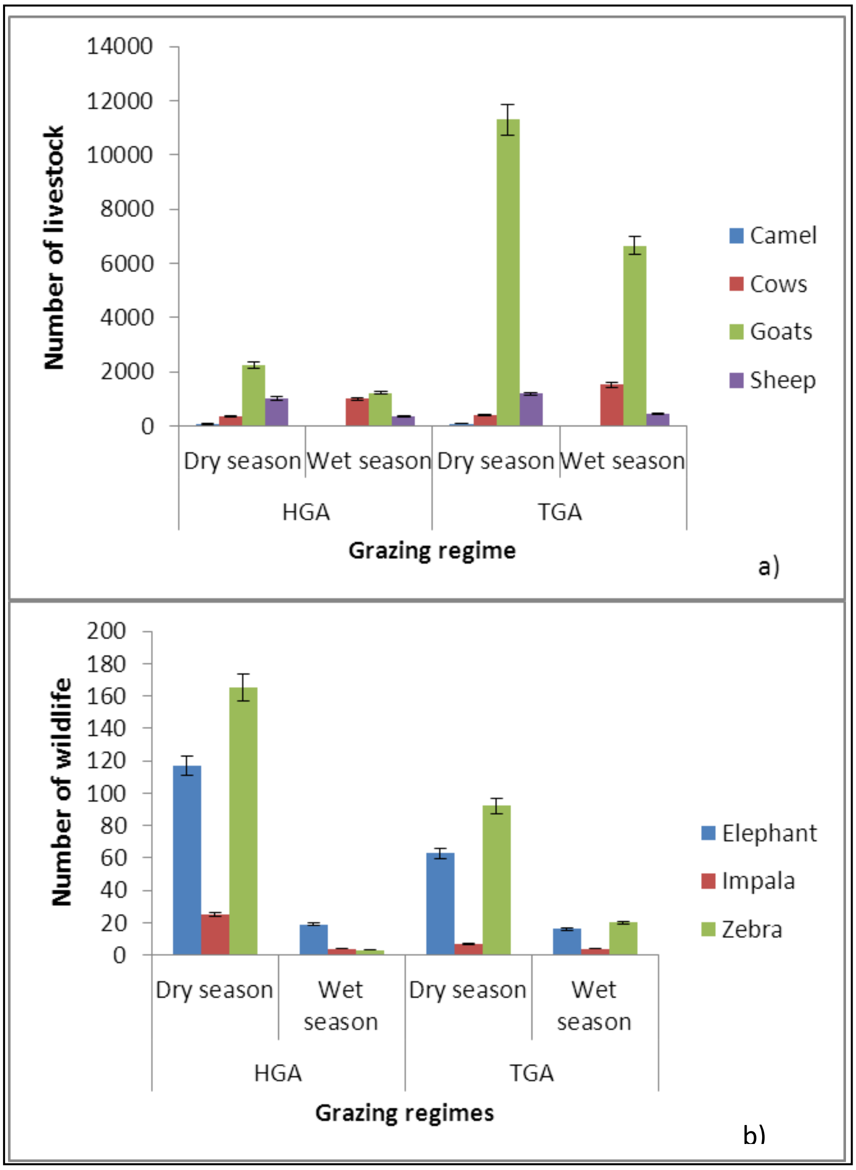


Figure 5.3: Livestock (a) and wildlife (b) visiting the holistic and traditional grazing areas

5.4 DISCUSSION

5.4.1 Livestock milk yield and weight gain

Goats and sheep in Holistic Grazing Area (HGA) had higher average daily weight gains than those in Traditional Grazing Area (TGA). In addition, goats in HGA had higher average milk yield as compared to those in TGA. Such a difference may have been as a result of expected better forage quality and quantity in HGA due to adequate rest periods between grazing seasons and even distribution of excreta which improves water and nutrient cycling and favors establishment of desirable plant species (Hart *et al.,* 1993; Brown, 2014). The distribution of excreta increases soil organic matter and nutrient content resulting in more fertile soils (Peterson and Gerrish 1995; Redden, 2014) that provides good condition for plant growth leading to increased range productivity.

Low average daily livestock weight gain and milk yield in TGA could be due to continuous grazing that leads to heavy use of preferred plants and patches while avoiding others (Willms *et al.,* 1988; O'Connor, 1992; Ash and Stafford-Smith, 1996; Bailey *et al*., 1996; Gerrish, 2004; Witten *et al*., 2005; Teague *et al.,* 2011). Due to high grazing pressure, the density of highly preferred and palatable plants is reduced (Brand and Goetz, 1986; Warren *et al.*, 1986; Amiri *et al.,* 2008) hence livestock are forced to graze on less palatable species which are less nutritious. Overuse of such nutritious plants leads to cessation of growth of certain herbaceous species (Chaichi *et al.,* 2005) such as grass hence less forage available for the animals. The results suggest that continuous grazing has a potential to negatively affecting livestock productivity through overuse of forage resources, which reduces their availability, quality especially during the critical growth stages. This in turn alters foraging patterns, nutrition and weight gain of livestock (Hepworth *et al.,* 1991; Ungar and Noy-Meir, 1988; Odadi *et al.,* 2008). Overgrazing is known to reduce vegetation cover, soil moisture infiltration and nutrients in grazing system (Perevolotsky, 1994; Amiri *et al.*, 2008) and therefore it affect the quality of forage obtained by animals when grazing. The quality of forage highly determines the returns from livestock production and when it is low, livestock production is also expected to be low.

It is evident from the results that animals grow faster and produce more milk in areas with high short-duration grazing intensity with long rest periods as compared to those with continuous grazing throughout the year. This is in agreement with Gompert (2010) observation in

Nebraska USA that holistic grazing increases forage production and enhances grassland health, and therefore better animal production per unit area. While the average daily weight gain of sheep was low in HGA, it was high in TGA during the wet season. This could be due to increased moisture content in both HGA and TGA during wet season which enhances growth of plants, thereby enabling animals to obtain more forage as compared to dry season. However in HGA, the low weight gain may have been contributed by animal hoof action that resulted in soil compaction during the wet season thereby hindering water infiltration (Mwendera and Saleem, 1997; Brown, 2014; and Mapfumo *et al.*, 2000) resulting in poor forage growth. Low infiltration rates results in low plant growth hence undermining forage productivity. As observed by Faizul *et al*. (1995); Amiri *et al*. (2008), compaction of the soil layer also causes decrease in soil organic material, which hinders growth of vegetation.

Milk yield in goats was lower during wet season than in dry season both in HGA and TGA. This may be attributed to the fact that goats are negatively affected by low temperatures during rainy in that they avoid grazing on wet vegetation and shelter from rain hence they may not graze adequately in wet season as compared to dry season.

5.4.2 Time spent and distance travelled by goats and sheep in holistic and traditional grazing areas

Goats and sheep spent more time in HGA as compared to TGA. This may be because holistic grazing areas had more preferred species and more forage due to adequate rest periods, which afforded time and growing conditions for regeneration of defoliated plants (Frank *et al.,* 1998; Teague *et al.,* 2011). In addition, the high amount animal urine and excrement increases nutrient cycling (Holland *et al.,* 1992; Teague *et al.,* 2011) which enhances plant growth in the HGA. Therefore, livestock and wildlife prefer these areas and would spend more time in them as compared to heavily grazed areas. In Traditional grazing areas (TGA), continuous grazing results in overuse of highly preferred palatable plants (Gerrish, 2004; Witten *et al.,* 2005; Teague *et a*l., 2011), which are replaced by less preferred unpalatable and less nutritious species (Chaichi *et al.,* 2005; Hosseinzadeh, 2006). Animals would therefore not spend much time in TGA and most of the times bypass them in search of areas with more preferred pasture. Animals spent more time during wet season in both HGA and TGA and this could be due to moisture availability during wet season which resulted in increased growth of forage in the sites. However, when there is availability of moisture and increased plant growth in HGA, it leads to even higher plant growth in HGA hence the higher residence period of grazing animals in them than in TGA.

Goats and sheep in HGA travelled less distance due to availability of adequate forage in these areas as a result of adequate rest periods that allow plant to recover and establish well before they are grazed again. On the other hand, goat and sheep in TGA had to travel longer distance to obtain enough forage for the day due to scarce forage in these areas. Goats are both grazers and browsers and this explains the shorter distance covered as compared to sheep which are exclusively grazers and therefore have to walk longer distance to select preferred grasses. During the wet season, distance travelled by both goats and sheep was shorter due to availability of more forage occasioned by increased moisture content in the soil both in HGA and TGA.

The grazing movement of livestock in HGA is cyclic as compared to even patterns in the TGA. This is partly due to the fact that when forage is abundant as was the case in the HGA, livestock would spend longer time in an area as compared to when forage is scarce as was in the case of TGA. During the dry season, more linear grazing movements were as observed because animals go from bomas to water points and back as they graze. In the wet season, grazing movement patterns in HGA are more cyclic and uneven than in TGA due to the fact that livestock graze nearby due to plenty forage and water points are around the boma .However in TGA livestock still cover some distance to graze even in wet season because the area around the boma is overgrazed hence the linear tracks.

5.4.3 Frequency of livestock and wildlife visits to holistic and traditional grazing areas

More livestock and wildlife visited HGA than TGA in dry and wet seasons. This could be because forage in HGA was more appealing and preferred by both livestock and wildlife due to the presence of palatable species. The number of livestock and wildlife grazing was higher in HGA as compared to TGA. This could be attributed to these areas having good quality pasture that was brought by rest periods (Frank *et al.,* 1998) manuring by animals as they graze in HGA (Holland *et al.,* 1992). More animals walked through TGA as they searched for preferred patches with preferred forage species. The number of animals walking was lower during the wet season in TGA, and this could be due to improved forage conditions caused by moisture availability during wet season. In addition, the frequency of wildlife visits declined in wet season both in HGA and TGA, and this is attributed to the fact that wildlife only uses these areas during the dry season when pastures in the protected areas are depleted. Less wildlife are therefore expected to visit during the wet season when they have plenty in the parks and reserves. This could also be due to the fact that livestock herds use these areas more during the wet season, which means that the wildlife, especially the zebras would avoid these areas due to possible conflicts with people. This concurs with Allard Blom *et al*., (2004), who reported low number of elephants in areas frequented by human and livestock.

Wildlife visits were more in the evening when livestock herds are gone back to the bomas both in HGA and TGA. This could be due to fact that the areas are open and therefore are favored by animals to avoid predation. In addition, Elephants and Zebras also prefer grazing at night when there is no interference from livestock herds and people. This concurs with De Leeuw *et al.,* (2001) who reported that wildlife avoided areas where livestock herds frequented hence they preferred to graze during the night. This is also in agreement with Reid *et al.,* (2008) findings in Mara region southern Kenya that due to competition for forage, wildlife tend to avoid areas near pastoral settlements.

5.5 CONCLUSION

The results from this study show that holistic grazing can lead to increase in animal weight gain and milk yield. They also indicate that livestock and wildlife frequent and spend more time in the holistic grazing areas than in the traditional grazing areas. These findings demonstrate that holistic grazing management has the potential to improve livestock production through increased milk production and faster growth rate of goats and sheep. This is expected to improve food security and income for pastoral households. However, there is need for long-term studies replicated in different environments to further validate these results.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

The results of this study show that holistic grazing management enhances herbaceous cover and species diversity and this is an indicator of better range productivity. It also improves milk yield and weight gains in range animals and this is expected to translate better returns in rangeland livestock production.

6.2 Recommendations

- The results show that HGM can enhance pasture productivity and animal performance and hence the need to consider animal impact as part of the solution in rehabilitation of degraded rangelands

- These findings indicate that HGM has the potential of enhancing integration of wildlife conservation and livestock production as complementary sources of livelihoods. Other factors held constant, the approach seems to suits the community-based wildlife conservancies that combine both livestock and ecotourism ventures. However, more research is needed to assess both the positive and negative socio-economic impacts of the approach to reveal the trade-offs and challenges involved under pastoral production system in order to inform its up-scaling.

REFERENCES

Abel, N. O. J., & Blaikie, P. M. (1989). Land degradation, stocking rates and conservation policies in the communal rangelands of Botswana and Zimbabwe. *Land Degradation & Development, 1(2), 101-123.*

Adler, P. B., Seabloom, E. W., Borer, E. T., Hillebrand, H., Hautier, Y., Hector, A., ... & Risch, A. C. (2011). Productivity is a poor predictor of plant species

Akbar Zadeh, M., Sharifi Yazdi, M., Rahmani, G. H., Pur Mirzaei, A., & Shahidi, K. (2006). Effect of exclosure on condition and trend of native rangelands in the different ecological zones of Kerman. AGRIS, <http://ring.ciard.net/node/10597> *{Reseach Institute of Forest and Rangeland.*

Akbarzadeh,M., M.R.Moghadam, A.Jalili, M.Jafari & H. Arzani. (2007). Vegetatation dynamic study of kuhrang enclosure Ir. *Journal of. Range desert Res.,13:324-336*

Allen-Diaz, B. (1996). Rangelands in a Changing Climate: Impacts, Adaptations and Mitigation. Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, pp.131-158

Alphayo, L.I. (2015). Effects of holistic grazing on soil physico-chemical properties and herbaceous vegetation production in Naibunga conservancy Laikipia County, Kenya *(Doctoral dissertation university of Nairobi*)

Amaha, K. (2006) *Characterization of rangeland resources and dynamics of the pastoral production system in the Somali region of Eastern Ethiopia.* Ph.D. Thesis. University of the Free State, Bloemfontein, South Africa.

Amiri F, Ariapour A & Fadai S. (2008). Effects of livestock grazing on vegetation composition and soil moisture properties in grazed and non-grazed range site. *Journal of Biological Science, 8(8): 1289-1297.*

Amiri, F., M. Basiri & Erevani M. (2005). Comparison of measurement methods on the amount of utilization of *Eurotia ceratoides*. *Journal of Science. Technology. In Agriculture and Natural. Resource., 9: 242-242.*

Anderson, D. M., & Kothmann, M. M. (1980). Relationship of distance traveled with diet and weather for Hereford heifers. *Journal of Range Management*, 217-220.

Anderson, D. M., Fredrickson, E. L., & Estell, R. E. (2012). Managing livestock using animal behavior: *mixed-species stocking. 6(08), 1339-1349*

Anderson, J. E., & Holte, K. E. (1981). Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. *Journal of Range Management*, 25-29.

Andrew, M. H. (1988). Grazing impact in relation to livestock watering points.*Trends in Ecology & Evolution*, *3*(12), 336-339.

Angassa, A., & Oba, G. (2007). Relating long-term rainfall variability to cattle population dynamics in communal rangelands and a government ranch in southern Ethiopia. *Agricultural systems, 94(3), 715-725.*

Ash, A.J., & Stafford-Smith, D.M. (1996). Evaluating stocking rate impacts in rangelands: animals don't practice what we preach. *The Rangeland Journal 18, 216–243.*

Asner, G. P., Keller, M., & Silva, J. N. (2004). Spatial and temporal dynamics of forest canopy gaps following selective logging in the eastern Amazon. *Global Change Biology*, *10*(5), 765-783.

Bagchi, S., Bhatnagar, Y. V., & Ritchie, M. E. (2012). Comparing the effects of livestock and native herbivores on plant production and vegetation composition in the Trans-Himalayas. *Pastoralism*, *2*(1), 1-16.

Bailey, D.W., Gross, J.E., Laca, E.A., Rittenhouse, L.R., Coughenour, M.B., Swift, D.M. & Sims, P.L. (1996). Mechanisms that result in large herbivore grazing patterns. *Journal of Range Management 49, 386–400.*

Barnes, M. K., Norton, B. E., Maeno, M., & Malechek, J. C. (2008). Paddock size and stocking density affect spatiaABUl heterogeneity of grazing. *Rangeland Ecology & Management, 61(4), 380-388.*

Baron, V. S., Mapfumo, E., Dick, A. C., Naeth, M. A., Okine, E. K., & Chanasyk, D. S. (2002). Grazing intensity impacts on pasture carbon and nitrogen flow. *Journal of Range Management*, 6,535-541.

Barrow, E. G. C. (1991). Evaluating the effectiveness of participatory agroforestry extension programmes in a pastoral system, based on existing traditional values. *Agroforestry Systems, 14(1), 1-21.*

Barrow, E., & Mlenge, W. (2003). Trees as key to pastoralist risk management in semi-arid landscapes in Shinyanga, Tanzania and Turkana, Kenya. In *International Conference on Rural Livelihoods, Forests and Biodiversity* (pp. 19-23).

Barrow, E., J. Davies, S. Berhe, V. Matiru, N. Mohamed, W. Olenasha & M. Rugadya.(2007). Pastoralists as shrewd managers of risk and resilience in the Horn of Africa. IUCN Eastern Africa Regional Office Policy Brief No. 1, Nairobi. [online] URL:

Bekele, N., & Kebede, G. (2014). Rangeland Degradation and Restoration in Semi-arid Areas of Southern Ethiopia:-The Case of Borana Rangeland. *International Journal of Environmental. Sci*, *3*(2), 94-103.

Blench, R., & Sommer, F. (1999). Understanding rangeland biodiversity (p. 51). *London: Overseas Development Institute.*

Blom, A., Van Zalinge, R., Mbea, E., Heitkönig, I., & Prins, H. H. (2004). Human impact on wildlife populations within a protected Central African forest. *African Journal of Ecology, 42(1), 23-31.*

Bond, W. J., & Midgley, J. J. (2001). Ecology of sprouting in woody plants: the persistence niche. *Trends in ecology & evolution, 16(1), 45-51.*

Bowns, E.J. and Bagley .F.C. (1986).Vegetation responses to long-term sheep grazing on mountain ranges. *Journal of. Range Management., 39: 431-434.*

Boydc R. Blenchd, Bournl, Drakea, Stevenson N Dp. (1999). Reconciling interests among wildlife and people in eastern Africa: a sustainable livelihoods approach. *Natural Resource Perspectives 45, ODI, London, United Kingdom.*

Brand, M. D., & Goetz .H. (1986). Vegetation enclosures in southwestern North Dakota. *Journal of Range Management* 39:434-437.

Briske, D. D., & Heitschmidt, R. K. (1991). An ecological perspective. Grazing management: an ecological perspective, 11-26.

Brooks, N., Grist, N., & Brown, K. (2009). Development futures in the context of climate change: Challenging the present and learning from the past.*Development Policy Review*, *27*(6), 741-765.

Chaichi, M. R., Saravi, M. M., & Malekian, A. R. A. S. H (2005). Effects of livestock trampling on soil physical properties and vegetation cover (case study: Lar Rangeland, Iran). *International Journal of Agriculture & Biology*, *7*, 904-908.

Collins, S. L., Knapp, A. K., Briggs, J. M., Blair, J. M., & Steinauer, E. M. (1998). Modulation of diversity by grazing and mowing in native tallgrass prairie. *Science, 280(5364), 745-747*

De Jode, H. (2009). Modern and mobile, The future of livestock production in Africa's drylands. IIED and SOS Sahel UK ISBN 978-1-84369-752-7 Eastern Ethiopia. A Ph.D ecosystems in Mbeere District, Kenya. LUCID *Working Paper Series* No. 36

De Leeuw, J., Ottichilo, W. K., Toxopeus, A. G., & Prins, H. H. (2002). Application of remote sensing and geographic information systems in wildlife mapping and modelling. *Environmental modelling with GIS and remote sensing,*,4, 125-131.

Deleeuw,J.,Waweru,M.N,Okello.O.O.,Maloba,M.,Nguru.P.,Said,M.Y….&Reid,R.S.(2001). Distribution and diversity of wildlife in northern Kenya in relation to livestock and permanent water points. *Biological conservation, 100(3),297-3006*

Derner, J. D., Briske, D. D., & Boutton, T. W. (1997). Does grazing mediate soil carbon and nitrogen accumulation beneath C4, perennial grasses along an environmental gradient?. *Plant and Soil, 191(2), 147-156.*

Dore, D. (2001). Transforming traditional institutions for sustainable natural resource management: history, Narratives and Evidence from Zimbabwe's Communal Areas. *African Studies Quarterly, 5(3), 1-18.*

Dormaar, J. F., Smoliak, S., & Willms, W. D. (1989). Vegetation and soil responses to short-duration grazing on fescue grasslands. *Journal of Range Management*, 42(3):252-256.

Dormaar, J. F., Smoliak, S., & Willms, W. D. (1989). Vegetation and soil responses to short-duration grazing on fescue grasslands. *Journal of range Management*, 252-256.

Dyksterhuis, E. J. (1949). Deferred and rotation grazing. *The Cattleman35,21*, 60.

Elmore, A. J., & Asner, G. P. (2006). Effects of grazing intensity on soil carbon stocks following deforestation of a Hawaiian dry tropical forest. *Global change biology*, 12(9), 1761-1772.

Entz, M. H., Baron, V. S., Carr, P. M., Meyer, D. W., Smith, S., & McCaughey, W. P. (2002). Potential of forages to diversify cropping systems in the Northern Great Plains. *Agronomy Journal*, 94(2), 240-250.

Eriksen, S. E. H., & Watson, H. K. (2009). The dynamic context of southern African savannas: investigating emerging threats and opportunities to sustainability. *Environmental science & policy*, 12(1), 5-22.

Faizul, B., Karlw D.M. & Murray L., (1995). Livestock grazing impacts on infiltration rates in a temperate rangeland of Pakistan. *Journal of Rangeland Management*., 46: 367–72

FAO. (2009). Review of evidence on drylands pastoral systems and climate change: Implications and opportunities for mitigation and adaptation. Edited by C. Neely, S. Bunning and A. Wilkes; Land and Water Discussion Paper 8, ISSN 1729-0554S.

Follett, R. F., & Reed, D. A. (2010). Soil carbon sequestration in grazing lands: societal benefits and policy implications. *Rangeland Ecology & Management*,63 (1), 4-15.

Frank, D. A., McNaughton, S. J., & Tracy, B. F. (1998). The ecology of the earth's grazing ecosystems. *BioScience, 48(7)513-521.*

Franzluebbers, A. J., Stuedemann, J. A., Schomberg, H. H., & Wilkinson, S. R. (2000). Soil organic C and N pools under long-term pasture management in the Southern Piedmont USA. *Soil Biology and Biochemistry, 32*(4), 469-478.

Franzluebbers, A.J., & Stuedemann, J.A.(2010). Surface soil changes during twelve years of pasture management in the Southern Piedmont USA. *Soil Science Society of America Journal, 74* (6), 2131-2141

Fuhlendorf, S. D., & Engle, D. M. (2001). Restoring Heterogeneity on Rangelands: Ecosystem Management Based on Evolutionary Grazing Patterns We propose a paradigm that enhances heterogeneity instead of homogeneity to promote biological diversity and wildlife habitat on rangelands grazed by livestock. *BioScience, 51(8), 625-632*.

Fuls ER (1992). Semi-arid and arid rangelands: A resource under siege due to patch-selective grazing. Journal of Arid Environments 22: 191–193.

Galvin, K. A. (2009). Transitions: Pastoralists Living with Change. Pages 185-198 *Annual Review of Anthropology*

Gao, Y.H., Schuman, M., Chen, H., Wu, N., Luo, P. (2009). Impacts of grazing intensity on soil carbon and nitrogen in an alpine meadow on the eastern Tibetan Plateau *Journal of Food Agriculture Environment* 7, 749-754

Garay, A. H., Sollenberger, L. E., McDonald, D. C., Ruegsegger, G. J., Kalmbacher, R. S., & Mislevy, P. (2004). Nitrogen fertilization and stocking rate affect stargrass pasture and cattle performance. *Crop science*, *44*(4), 1348-1354.

Georgiadis, N. J., Olwero, J. N., & Romañach, S. S. (2007). Savanna herbivore dynamics in a livestock-dominated landscape: I. Dependence on land use, rainfall, density, and time. Biological Conservation, 137(3), 461-472.

Gerrish, J. (2004). Management-Intensive Grazing: The Grassroots of Grass Farming. *Green Park Press, Ridgeland, MO, USA.*

Gerrish, J. R., Peterson, P. R., & Brown, J. R. (1995). Grazing management affects soil phosphorus and potassium levels. *Proceedings of the American Forage and Grassland Council*, 175-179.

Gompert, T. (2010). The power of stock density. In: Proceedings of the 2010 Nebraska *Grazing Conference. Kearney, Nebraska* .

Hart, R. H., Bissio, J., Samuel, M. J., & Waggoner Jr, J. W. (1993). Grazing systems, pasture size, and cattle grazing behavior, distribution and gains. *Journal of Range Management*, 81-87.

Heath, B. (2000). Ranching: an economic yardstick. In Wildlife Conservation by Sustainable Use, 12, 21-33). *Springer Netherlands*

Hepworth, K.W., Test, P.S., Hart, R.H., Waggoner Jr., J.W.,& Smith, M.A. (1991). Grazing systems, stocking rates, and cattle behavior in southeastern Wyoming. *Journal of. Range Management.* 44, 258–261.

Hiernaux, P.,& Turner, M. D. (1996). The effect of clipping on growth and nutrient uptake of Sahelian annual rangelands. *Journal of Applied Ecology,*33(2), 387-399.

Hobbie, S. E. (1992). Effects of plant species on nutrient cycling. *Trends in ecology & evolution, 7(10), 336-339*

Hodgson, J. (1990). Grazing management. *Science into practice. Longman Group UK Ltd*..

Holland, E.A., Parton, W.J., Detling, J.K., & Coppock, D.L. (1992.) Physiological responses of plant populations to herbivory and other consequences of ecosystem nutrient flow. *American Naturalist* 140, 685–706.

Hosseinzadeh, G. (2006). Investigation and comparison of vegetation cover changes and some characteristic of soil in grazed and un-grazed rangeland in Eskelimrood District (*Doctoral dissertation, M. Sc. Thesis, Mazandaran University, pp: 117 (In Persian).*

Huang, D., Wang, K., & Wu, W. L. (2007). Dynamics of soil physical and chemical properties and vegetation succession characteristics during grassland desertification under sheep grazing in an agro-pastoral transition zone in Northern China. *Journal of Arid Environments*, *70*(1), 120-136.

Johnson, J. M., Aiken, G. E., Phillips, T. D., Barrett, M., Klotz, J. L., & Schrick, F. N. (2012). Steer and pasture responses for a novel endophyte tall fescue developed for the upper transition zone. *Journal of animal science,90*(7), 2402-2409.

Kakinuma, K., Ozaki, T., Takatsuki, S., & Chuluun, J. (2008). How pastoralists in Mongolia perceive vegetation changes caused by grazing.*Nomadic Peoples*, *12*(2), 67-73.

Kamau, P. (2004). Forage diversity and impact of grazing management on rangeland ecosystems in Mbeere District, Kenya. LUCID *Working Paper Series* No. 36

Kassahun, A., Snyman, H. A., & Smit, G. N. (2008). Impact of rangeland degradation on the pastoral production systems, livelihoods and perceptions of the Somali pastoralists in Eastern Ethiopia. *Journal of Arid Environments* ,*72*(7), 1265-1281.

Keren, E. N., & Olson, B. E. (2006). Thermal balance of cattle grazing winter range: Model application. *Journal of animal science*, *84*(5), 1238-1247.

Kgosikoma OE. (2011). Understanding the savanna dynamics in relation to rangeland management systems and environmental conditions in semi-arid Botswana. *PhD thesis. University of Edinburgh.*

Kgosikoma, O. E., & Mogotsi, K. (2013). Understanding the causes of bush encroachment in Africa: The key to effective management of savanna grasslands. *Tropical Grasslands-Forrajes Tropicales*, *1*(2), 215-219.

Kgosikoma, O.E, Harvie B.A.& Mojeremane ,W. (2012). Bush encroachment in relation to rangeland management systems and environmental conditions in Kalahari ecosystem of Botswana. *African Journal of Agricultural Research, 7(15), 2312-2319*..

Kioko, J., Kiringe, J. W. & Seno, S. O. (2012). Impacts of livestock grazing on savanna grassland in Kenya, *Journal of Arid Land*, *4* (1), 29-35.

Kirschenmann, F., Gompert, T., & Williams, A. (2009). Grass in the Timeline of Agriculture. *Grassland: Quietness and Strength for a New American Agriculture*, 3-13.

Klein, J. A., Harte, J., & Zhao, X. Q. (2007). Experimental warming, not grazing, decreases rangeland quality on the Tibetan Plateau. *Ecological Applications*, *17(2), 541-557*.

Krätli, S. & N. Schareika 2010.‘Living off Uncertainty: the Intelligent Animal Production of Dryland Pastoralists’. *European Journal of Development Research*, *22*(5), 605-22.

Lemaire, G., Chapman, D., Hodgson, J., & Illius, A. W. (1996). The ecology and management of grazing systems. *The ecology and management of grazing systems*.

Li, H., & Reynolds, J. F. (1997). Modeling effects of spatial pattern, drought, and grazing on rates of rangeland degradation: A combined Markov and cellular automaton approach. Scale in remote sensing and GIS, 211-230.

Lund, H. G. (2007). Accounting for the World's Rangelands. *Rangelands, 29 (1), 3-10*

Maleko D .D, Mbassa G. N, Maanga .W. F & Sisya E. S. (2012) Impacts of Wildlife-Livestock Interactions in and around Arusha National Park, Tanzania. *Current Research Journal of Biological Sciences 4(4): 471-476*

Mapfumo, E., Chanasyk, D. S., Baron, V. S., & Naeth, M. A. (2000). Grazing Impacts on Selected Soil Parameters under Short-term Forage Sequences. *Journal of Range Management*, 466-470.

Maraseni, T. N., Mathers N. J., Harms. B., Cockfield G., Apan A., & Maroulis J..(2008). Comparing and predicting soil carbon quantities under different land-use systems on the Red Ferrosol soils of southeast Queensland. *Journal of Soil and Water Conservation* 63:250-256

Masike S, & Urich, P. (2008). Vulnerability of traditional beef sector to drought and the challenges of climate change: The case of Kgatleng District, Botswana. *Journal of Geography and Regional Planning Vo*l. 1(1), pp. 012-018

McIvor, J. G. (2007). Pasture management in semi-arid tropical woodlands: dynamics of perennial grasses. *The Rangeland Journal*, *29*(1), 87-100

Mertens, D. R. (1994). Regulation of forage intake. In: G. C. Fahey, Jr., M. Collins, D. R. Mertens, and L. E. Moser (ed.) Forage Quality, Evaluation, and Utilization. American Society of Agronomy, Crop Science Society of America, *Soil Science Society of America, Madison, WI.*

Mortellaro-Brown, M. (2014). Harvest Efficiency, Forage Trampling, and Litter Decomposition of Mob Grazing *(Doctoral dissertation, Natural Resource Management Department, South Dakota State University*).

Mortimore, M. Anderson, S., Cotula, L., Davies, J., Faccer, K., Hesse, C., Morton, J., Nyangena, W., Skinner, J, & Wolfangel, C. (2009). Dryland Opportunities: A new paradigm for people, ecosystems and development, IUCN, *Gland, Switzerland; IIED, London, UK and UNDP/DDC, Nairobi, Kenya. ISBN: 978-2-8317-1183-6*

Muhumuza, M. & Byarugaba, D. (2009). Impact of land use on the ecology of uncultivated plant species in the Rwenzori mountain range, mid western Uganda. *African Journal of Ecology,* 47(4), 614-621.

Mwendera, E. J., Saleem, M. M., & Woldu, Z. (1997). Vegetation response to cattle grazing in the Ethiopian highlands. *Agriculture, ecosystems & environment*, *64*(1), 43-51.F

Newman, Y. C., & Sollenberger, L. E. (2005). Grazing management and nitrogen fertilization effects on vaseygrass persistence in limpograss pastures.*Crop science*, *45*(5), 2038-2043.

Norton, B.E. (1998). The application of grazing management to increase sustainable livestock production. *Animal Production in Australia 2*2, 15–26

Oba, G., & Kotile, D. G. (2001). Assessments of landscape level degradation in southern Ethiopia: pastoralists versus ecologists. *Land Degradation & Development, 12(5), 461-475.*

Oba, G., Stenseth, N. C., & Lusigi, W. J. (2000). New perspectives on sustainable grazing management in arid zones of sub-Saharan *Africa.BioScience, 50(1), 35-51*.

O'connor, T. G., & Pickett, G. A. (1992). The influence of grazing on seed production and seed banks of some African savanna grasslands. *Journal of Applied Ecology*, 3(1),247-260.

Odadi, W. O., Karachi, M. K., Abdulrazak, S. A., & Young, T. P. (2011). African wild ungulates compete with or facilitate cattle depending on season. *Science,* 333(6050), 1753-1755

Odadi, W.O. (2010) Competitive and facilitative interactions between cattle and wild ungulates in a semi-arid savanna rangeland in Laikipia, Kenya. *PhD Dissertation. Egerton University, Njoro, Kenya*

Olofsson, J., & Oksanen, L. (2002). Role of litter decomposition for the increased primary production in areas heavily grazed by reindeer: a litterbag experiment. *Oikos*, *96*(3), 507-515.

Olson, J.M. (2006), Implications of trends in land use change in livestock systems evolution in East Africa: Lessons from the LUCID Project. Targeting and Innovations Discussion Paper No. 4, *ILRI (International Livestock Research Institute), Nairobi, Kenya, 41 pp*

Ottichilo, W. K., Grunblatt, J., Said, M. Y., & Wargute, P. W. (2000). Wildlife and livestock population trends in the Kenya rangeland. *In Wildlife Conservation by Sustainable Use, 12, 203-218). Springer Netherlands.*

Penning, P. D., Parsons, A. J., Orr, R. J., Harvey, A., & Champion, R. A. (1995). Intake and behaviour responses by sheep, in different physiological states, when grazing monocultures of grass or white clover. *Applied Animal Behaviour Science, 45(1), 63-78*.

Perevolotsky, A. (1994). Tannins in Mediterranean woodland species: lack of response to browsing and thinning. *Oikos*, 333-340.

Pérez-Prieto, L. A., & Delagarde, R. (2012). Meta-analysis of the effect of pregrazing pasture mass on pasture intake, milk production, and grazing behavior of dairy cows strip-grazing temperate grasslands. *Journal of dairy science, 95(9), 5317-5330.*

Peterson, D. (2014). Soil Health and Production Benefits of Mob Grazing. Retrieved from:http://www.forestrywebinars.net/webinars/soil-health-and-productionbenefits-of-mob-grazing.

Pickup, G. (1998). Desertification and climate change-the Australian perspective. *Climate Research*, *11(1), 51-63.*

Pickup, G., & Chewings, V. H. (1994). A grazing gradient approach to land degradation assessment in arid areas from remotely-sensed data. *Remote Sensing*, *15*(3), 597-617prince

Pillsbury, F. C., Miller, J. R., Debinski, D. M., & Engle, D. M. (2011). Another tool in the toolbox? Using fire and grazing to promote bird diversity in highly fragmented landscapes. *Ecosphere, 2(3), part 28.*

Poppi, D. P., Hughes, T. P., & L'huillier, P. J. (1987). Intake of pasture by grazing ruminants. *Livestock feeding on pasture. Hamilton: New Zealand Society of Animal Production*, *7*, 55-64.

Poppi, D. P., MacRae J. C., Brewer A. C., & Coop R. L.. 1986. Nitrogen transactions in the digestive tract of lambs exposed to the intestinal parasite Trichostrongylus colubriformis. Br. J. Nutr. 55:593

Prins, H. H. (1992). The pastoral road to extinction: competition between wildlife and traditional pastoralism in East Africa. *Environmental Conservation*, *19*(02), 117-123.

Prins, H. H., & Grootenhuis, J. G. (2000). Introduction: the value of priceless wildlife. In *Wildlife conservation by sustainable use* (pp. 1-12). Springer Netherlands.

Prins, H.H.T. (2000). Competition between wildlife and livestock in africa. In: Prins, H.H.T., Grootenhuis, J.G., Dolan, T.T. (Eds.), Wildlife conservation by sustainable use. *Kluwer Academic Publishers, Boston, 12,. 51–80.*

Qelichnia, H., (1996). Comparing the vegetation cover of the reference, key and critical areas in Golestan National Park and Pasture. Res. Reconstruct., 20: 72-75. Qaredaghi, H. and A. Jalili, 1999. A comparison between the plant cover composition of lands under grazing and exclosure of Roodshur steppe ranges. J. For. Pasture, 43: 28-44.

Rasmussen, M. S., James, R., Adiyasuren, T., Khishigsuren, P., Naranchimeg, B.,Gankhuyag, R., & Baasanjargal, B. (1999). Supporting Mongolian pastoralists by using GIS to identify grazing limitations and opportunities from livestock census and remote sensing data. *GeoJournal,47(4), 563-571*.

Redden, M. D. (2014). Grazing Methods Effects on Forage Production, Utilization, and Animal Performance on Nebraska Sandhills Meadow. *Masters' thesis: UNL*

Reeder, J. D., & Schuman, G. E. (2002). Influence of livestock grazing on C sequestration in semi-arid mixed-grass and short-grass rangelands. *Environmental Pollution, 116(3), 457-463.*

Reid, R. S., Galvin, K. A., & Kruska, R. S. (2008). Global significance of extensive grazing lands and pastoral societies: an introduction. In *Fragmentation in semi-arid and arid landscapes* (pp. 1-24) Springer Netherlandsrichness. *science*, *333(6050), 1750-1753.*

Rischkowsky B., Hohnwald S., Kreye C., Schultze-Kraft R., Camarão A. P. & King J. M. 2003. Degraded Pastures in the Bazilian Eastern Amazon:Smallholder Management Leads to High Phytodiversity. Rangelands as Dynamic Systems – Biodiversity

Conservation in Rangelands: why and how. *African Journal .of Range & Fora Science.*, 20; 80-88.

Rohde, R. F., Moleele N. M., Mphale M. ,Allsopp N., Chanda R., Hoffmann M. T., Magole L., & Young E.. (2006). Dynamics of grazing policy and practice: environmental and social impacts in three communal areas of southern Africa. *Environmental Science and Policy 9:302-316*

Sankaran, M., Hanan, N. P., Scholes, R. J., Ratnam, J., Augustine, D. J., Cade, B. S., ... & Zambatis, N. (2005). Determinants of woody cover in African savannas. *Nature 438(7069), 846-849*

Savadogo, P., L. Savadogo and D. Tiveau, 2007. Effects of grazing intensity and prescribed fire on soil physical and hydrological properties and pasture yield in the savanna woodlands of Burkina Faso. Agric. Ecosyst. Environ., 118: 80-92.

Savory, A. & Butterfield J. (1999). Holistic management: a new framework for decision making. *Island press.*

Savory, A. (1978). A holistic approach to ranch management using short duration grazing. In Proceedings of the First International Rangeland Congress. Denver, Colorado (pp. 555-557)

Savory, A. (2013). Response to request for information on the “science” and “methodology” underpinning Holistic Management and holistic planned grazing. *Savory Institute. URL http://www. savoryinstitute. Com*.

Schuman, G. E., Reeder, J. D., Manley, J. T., Hart, R. H., & Manley, W. A. (1999). Impact of grazing management on the carbon and nitrogen balance of a mixed-grass rangeland. *Ecological applications*, *9*(1), 65-71.

Severson, K.E.,& Urness, P.J., (1994) Livestock grazing: a tool to improve wildlife habitat. In: Vavra, M., Laycock, W.A., Pieper, R.D. (Eds.), Ecological Implications of Livestock Herbivory in the West. *Society for Range Management, Denver, CO., pp. 232–249.*

Sidahmed, A.E., & J. Yazman (1994). Livestock production and the Environment in lesser developed countries. p. 13-31. In: J.Yazman and A.G. Light (ed.) Proceedings of the International Tele computer Conference on Perspectives on Livestock Research and Development in Lesser Developed Countries, IDRC, INFORUM, Winrock International, November 1992 - April 1993

Smet, M., & Ward, D. (2006). Soil quality gradients around water-points under different management systems in a semi-arid savanna, South Africa. *Journal of Arid Environments, 64(2), 251-269.*

Snyman, H. A., & Du Preez, C. C. (2005). Rangeland degradation in a semi-arid South Africa—II: influence on soil quality. *Journal of arid environments,60*(3), 483-507.

Sternberg, M., Gutman, M., Perevolotsky, A., Ungar, E. D., & Kigel, J. (2000). Vegetation response to grazing management in a Mediterranean herbaceous community: a functional group approach. *Journal of Applied Ecology*, *37*(2), 224-237.

Stobbs, T. H. (1975). Factors limiting the nutritional value of grazed tropical pastures for beef and milk production. *Tropical Grasslands, 9(2), 141-150.*

Stoddart, L. A., Smith, A. D. & Box, T. W. (1975). Range management.McGraw-Hill Book Company, New YorK. 532pp**.**

Strauch, A. M., Kapust, A. R., & Jost, C. C. (2009). Impact of livestock management on water quality and streambank structure in a semi-arid, African ecosystem. *Journal of Arid Environments*, *73*(9), 795-803.

Tainton, N.M., Aucamp, A.J., &Danckwerts, J.E. (1999). Principles of managing veld. In: Tainton, N.M. (Ed.), Veld Management in South Africa. *University of Natal Press, Pietermaritzburg, South Africa, pp. 169–193.*

Tamartash, R., Jalilvand, H., & Tatian, M. R. (2007). Effects of grazing on chemical soil properties and vegetation cover (case study: Kojour rangelands, Noushahr, Islamic Republic of Iran). *Pakistan journal of biological sciences: PJBS*, *10*(24), 4391-4398.

Teague, W. R., Dowhower, S. L., Ansley, R. J., Pinchak, W. E., & Waggoner, J. A. (2010). Integrated grazing and prescribed fire restoration strategies in a mesquite savanna: I. Vegetation responses. *Rangeland Ecology & Management, 63(3), 275-285.*

Teague, W. R., Dowhower, S. L., Baker, S. A., Haile, N., DeLaune, P. B., & Conover, D. M. (2011). Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie.*Agriculture, Ecosystems & Environment*, *141*(3), 310-322.

Teague, W.R., Dowhower, S.L., Waggoner, J.A. (2004). Drought and grazing patch dynamics under different grazing management. *Journal of Arid Environments 58, 97–117.*

Tefera S, Snyman HA, Smit GN. (2007). Rangeland dynamics in southern Ethiopia: (1) Botanical composition of grasses and soil characteristics in relation to land-use and distance from water in semi-arid Borana rangelands. *Journal of environmental management*, *85*(2), 429-442.

Thurow, T. L. (1991). Hydrology and erosion. *Grazing Management: An Ecological Perspective. Timber Press, Portland, Oregon*, 141-160.

Thurow, T. L., Blackburn, W. H., & Taylor Jr, C. A. (1988). Infiltration and interrill erosion responses to selected livestock grazing strategies, Edwards Plateau, Texas. *Journal of Range Management*,41(4), 296-302.

Thurow, T.L., W.H. Blackburn & C.A. Taylor. (1986). Hydrological characteristics of vegetation types as effected by livestock grazing system, Edwards Plateau Texas. *Journal of Range Management., 39: 505-509*

Ungar, E.D., & Noy-Meir, I. (1988). Herbage intake in relation to availability and sward structure: grazing processes and optimal foraging. *Journal of applied ecology, 25, 1045–1062.*

Vinton, M. A., & Hartnett, D. C. (1992). Effects of bison grazing on Andropogon gerardii and Panicum virgatum in burned and unburned tallgrass paririe. *Oecologia*, *90*(3), 374-382.

Vinton, M. A., Hartnett, D. C., Finck, E. J., & Briggs, J. M. (1993). Interactive effects of fire, bison (Bison bison) grazing and plant community composition in tallgrass prairie. *American Midland Naturalist*, 10-18.

Warren, S. D., Thurow, T. L., Blackburn, W. H., & Garza, N. E. (1986). The influence of livestock trampling under intensive rotation grazing on soil hydrologic characteristics. *Journal of Range management*,39(6),491-495

Willms, W.D., Dormaar, J.F., & Schaalje, G.B. (1988). Stability of grazed patches on rough fescues grasslands. *Journal of Range Management 41, 503–508.*

Willms, W.D., J.F. Dormaar & S. Smoliak. (1990). Vegetation response to time-controlled grazing on mixed and fescue prairie. *Journal of Range Management., 43: 513-517*

WISP (World Initiative for Sustainable Pastoralism). (2008). Sustainable Pastoralism - moving forward with appropriate policies. WISP Policy Note No. 9

Witten, G.Q., Richardson, F.D.,& Shenker, N. (2005). A spatial-temporal analysis on pattern formation around water points in a semi-arid rangeland system. *Journal of Biological Systems 13, 1–23.*

Wolf, K. (2011). *Effects of high-density, short-duration planned livestock grazing on soil carbon sequestration potentials in a coastal California mixed grassland* (Doctoral dissertation, California Polytechnic State University, San Luis Obispo

Wright, A. L., Hons, F. M., & Rouquette, F. M. (2004). Long-term management impacts on soil carbon and nitrogen dynamics of grazed bermudagrass pastures. *Soil Biology and Biochemistry*, *36*(11), 1809-1816.

Zerihun, W. & Saleem, M.A.M. (2000). Grazing induced biodiversity in the high land ecozone of East Africa, *Agriculture, Ecosystems and Environ.*

Zimmerman, E. A. (1980). Desert ranching in central Nevada. *Rangelands*, 184-186.