A Dissertation on Growth Performance of Boer and Savanna Goat Doelings at Lobu Small Stock Ranch Under Natural Rangeland Conditions During the Late Wet and Early Dry Seasons In Kgalagadi Region (Botswana).

Submitted In Partial Fulfilment of The Requirements for The Degree
of Masters in Animal Science (Animal Management Systems)
At The Botswana University of Agriculture and Natural Resources

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July 2023

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Declaration

I declare that this thesis is my original work and that all sources of material that are used have been duly acknowledged. This thesis is submitted in partial fulfillment of the requirements for the MSc Degree of the Botswana University of Agriculture and Natural resources.

I solemnly declare that this thesis not be submitted to any other institution anywhere for academic awards.

Sign ___________________________________ Date: _______________

Acknowledgment

I ascribe all glory, honor, and gratitude to the Almighty God whose divine grace, mercy, and guidance have enabled me to complete my Master's Degree successfully.

I am sincerely indebted to my selfless team of supervisors Professor C.M. Tsopito, Professor A. Abdetta, and Dr L. Akanyang for their rich excellent advice and professional guidance that enabled me to produce this research article grandly. Their invaluable enthusiasm throughout my study period is immeasurable. May I also extend my deepest gratitude to Mr T. Khumoetsile for his outstanding assistance in the Animal Science and Nutrition laboratory. I am also thankful for the full support of Mr Kamogelo Makgobote during field data collection. This research would have not been possible without the support of LobSmall stock ranch management Mr J. Balogi and Mr P. Mannathoko as well as the dedicated Filed Assistants Mr Edward Kassie and Mr David Ikageng Osenoneng.

My thanks are due to the Department of Agricultural Research for allowing me to perform some of my chemical analysis tests in their laboratories. Last but not least, let me thank the Department of Animal Production for allowing me to carry out this research at the Lobu Small stock ranch.

Dedication

I dedicate this work to my Boys Kgotso Ngwakomonnye and Brian Ngwakomonnye for being my motivation during my studies, may God bless them.

General Abstract

Goats have the most integral socio-economic role in many African countries, hence, the ministry of Agricultural Development and Food Security, the Government of Botswana has taken a step in supporting Lobu ranch since its inception in 1978 to turn it into a small stock hub. However, there is lack of knowledge on the vegetation, nutritional status and growth performance of different types of goats in Lobu Ranch. Therefore, the objectives of the study was to determine abundance and diversity of woody plants (trees and shrubs) within the ranch, the nutritional composition of common woody plants that are consumed by the goats and also to measure growth performance of the goats. This study was performed at Lobu small stock ranch in Kgalagadi region, Botswana during the late wet and early dry seasons. The first study used a systematic sampling approach to survey woody plants along the grazing gradient (from water point). In the second study, proximate analysis of the dried and milled composite samples (herbaceous and woody species) was performed for DM, OM, Ash, CP, NDF, ADF, ADL, Fat and Gross Energy as well as IVDMD and nutritional analysis for both Macro and Micro nutrients, after abserving which plants species were commonly eaten by goats. In the third study, goats body weights were measured using a weighing scale and all body parts measurements using a measuring tape in the morning on an empty stomach for 4-5months starting from late wet to end of early dry seasons. The most dominant woody plants species in the ranch were *Asparugus asparagus*, *Rhigozum trichotomum* and *Senegelia mellifera* across the distances (near, mid and far from the kraals). Woody plants with the hihest density are those <20m ($P<0.05$). However, the above three species showed high distribution in the catergory of >2m ($P < 0.05$), with increasing distance from the kraals. There was significant difference in percentage level of chemical content within the forage species ($P<0.05$) with DM, OM, and ADF increasing as the dry season increases while CP was decreasing as the dry season increases. On the other hand, Ash, NDF, ADL and fat were high during the late wet season and decreased at the beginning of the early dry season but eventually increased at the end of the dry season. In macro nutrients only the K and N showed significant difference ($P<0.05$), K content was low during the late wet season recording 0.99% but later increased at the end of the dry season to 1.06% while N was high during the late wet season recording 1.42% and slightly decreased at the end of the dry season to 1.32% . In terms of micro nutrients, only Fe was noticed to be significantly different ($P<0.05$) increasing from 104.53-235.64ppm. Generally, the obtained results were too high ranging from 235.64ppm -104.53ppm as compared to the acceptable quantities required for growth of goats (30-50ppm) and this compromised the optimal weight gain of the animals during the seasons of study. The body weight gain of the breeds was considered similar throughout the seasons ($P > 0.05$). Though there was homogeneity in body weight gain among the breeds, the Savanna goats gained more daily weight (0.035kg/day), than the Boer goat (0.030kg/day). It should be noted that there was positive growth of the goats which was mainly influenced by the positive development of the hip height, shoulder height and body length. It should be appreciated that during the dry season the nutritional value of the range is minimal hence growth of the animals being compromised.

Abbreviations and Acronyms

ADL	**Acid Detergent Lignin**
ADF	**Acid Detergent Fibre**
AIDS	**Acquired Immune Deficiency Syndrome**
AOAC	**Association of Official Analytical Chemists**
BW	**Body Weight**
BLDC	**Botswana Livestock Development Cooperation**
C	**Calcium**
CANOCO	**Canonical Community Ordination**
CFDA	**Community First Development Area**
CRBD	**Complete Randomized Block Design**
CRD	**Complete Randomized Design**
CM	**Centimeter**
Cu	**Copper**
CP	**Crude Protein**
DM	**Dry Matter**
E	**Evenness/Equitability**
FAO	**Food and Agricultural Organization**
GLM	**General Linear Model**
GPS	**Global Positioning System**
GDP	**Gross Development Product**
GE	**Gross Energy**
Ha	**Hectare**
HIV	**Human Immune Virus**
Hrs	**Hours**
IVI	**Importance Value Index**
Ind	**Individual**
IVDMD	**Invitro Dry Matter Digestibility**
Kg	**Kilogram**
LGI	**Livestock Grazing Intensity**
Mg	**Magnesium**
Mn	**Manganese**
M	**Meter**
M^2	**Meter Squared**
NDF	**Neutral Detergent Fibre**
N	**Nitrogen**
OM	**Organic Matter**
ppm	**Parts Per Million**

P	**Phosphorus**
P value	**Probability value**
S	**Species richness**
SAS	**Statistical Analysis System**
SEM	**Standard Error of the Mean**
SPSS	**Statistical Package for Social Sciences**
Spp	**Species**
STD	**Standard**
TDN	**Total Digestible Energy**
TGLP	**Tribal Grazing Land Policy**
Zn	**Zinc**
%	**Percentage**
ºC	**Degrees celcius**
H'	**Shannon Diversity Index**
P_i	**Relative abundance**
K	**Potassium**
Fe	**Iron**
NaCl	**Sodium Chloride**
Na	**Sodium**
<	**Less than**
>	**More than**

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CHAPTER 1

GROWTH PERFORMANCE OF BOER AND SAVANNA GOAT DOELINGS AT LOBU SMALL STOCK RANCH UNDER NATURAL RANGELAND CONDITIONS DURING THE LATE WET AND EARLY DRY SEASON, KGALAGADI REGION (BOTSWANA).

1.0: INTRODUCTION

1.1 General Introduction

Goats are the first livestock to be domesticated, around 9,500 B.C. of recent, and they are one of the most dominating livestock species in the world (Marble, 2012). In many developing countries, including Botswana, goats play a significant role in low-income earning households livelihoods (Mataveia, *et. al*., 2021). In addition to low starting investments costs required, goats have more resilience and adaptability to harsh environmental conditions. The gradual increase in goats has also been observed due to their ability to have multiple birth (Kaumbata, *et. al*., 2020). According to Yurtman, *e.t. al*., 2012, goats differ from other ruminants in their grazing insticts. Selectivity, browsing and theirability to travel long distances make them unique herbivores (Assan, 2014). These positive characteristics have a significant role in goat production sustainability, especially under an extensive system where animals fend for survival.

In a review done by İsmail, *et. al*., 2021, it was found that small stock farming plays an essential role as a major source of subsistence income in most households in developing countries including Botswana.. Due to its high adaptation to climatic unpredictability and erratic rainfall, the small stock is popularly used as an insurance against variation in the agricultural sector (Ratovonamana, *et. al.*, 2013). Nonetheless, goat farming is common among subsistence farmers who are mainly dependent on indigenous knowledge, which is not based on the latest scientific research findings but is making success. According to Statistics Botswana Annual Agricultural Survey Report which was carried out in 2017, the traditional livestock statistics show a slight increase from 43 853 in 2015 to 58 332 in 2017 (33.02%) on traditional goat holdings. Hence, translates to 4.93% increase in total goats herd with a minor improvement of 17.1 in 2015 to 7.3 in 2017.

Some research efforts have been done to clarify whether there is any degradation on Botswana's rangelands (Mulale, *et. al.*, 2014) and the findings indicated that rangeland degradation is significant in Botswana. Another study by Makhubu, *et. al.,* 2019 was carried out on rangeland assessment around Molepolole village in Botswana to unearth its potential to support free range beef cattle in spite of its long term use as a grazing area. However, both studies do not go further to assess range composition and distribution in relation to its nutritional value and how this affect livestock performance.

Goats have the most integral socio-economic role in many African countries, hence, the ministry of Agricultural Development and Food Security, the Government of Botswana has taken a step in supporting Lobu ranch since its inception in 1978 to turn it into a small stock hub. However, there is lack of knowledge on the vegetation, nutritional status and growth performance of different types of goats in Lobu Ranch. It is also imperative to systematically observe the role of various forage species in meeting the nutritional requirements of different animals within the ranch, critical in managing the range ecosystem. Furthermore, it is essential to consider the impact of seasonality on the quantity and quality of forage produced within the study area. Therefore, it should be done regarding the major climatic seasons experienced locally, which are extended dry periods and short wet periods.

Predation on plants is the primary activity on rangelands and is the basis for cultures, profit-making and conservation (Johnston, *et. al*., 2018 and Vaupel, *et. al*., 2012). Maintaining browsing pressure within limits is a significant concern to Governments, Non-Government Organizations dealing with rangeland management and livestock managers (Kikoti and Mligo, 2015). Vegetation browsing has been observed and proved to encourage the production of green phytomass which provides foraging during dry seasons.

Herbivory affects plant species richness and diversity, increasing the chance of more outstanding production and better survival compared to plants that are not browsed at all (Bekele, *et. al.,* 2010). Comparative knowledge on diet selection and forage intake on different plant species are essential in understanding the browsing strategies of goats, hence, appreciating their suitability in manipulating natural vegetation species to meet either production or conservation parameters (Lebopa, 2010). Livestock production including small stock, has been practiced many decades ago and is an important biotic factor that influences vegetation ecosystem (Thapa, *et. al*., 2016).

Various studies were done on small stock production in Botswana which include among others those done by Baleseng, *et. al*., 2016, Bahta, 2013 and Sebolai, *et. al*., 2012 but none of those studies have done specifically within the Kgalagadi region to assess the composition and nutritional quality on small stock's potential. Precise knowledge relating to the feeding value of range forages is critical and it is the primary factor that influences livestock performance with the range (Gurung, 2020). The nutritional content of any forage depends on its quantity of energy-producing nutrients and its content of nutrients essential to the body (Moyo, *et. al*., 2019).The nutritional content of range forage is primarily influenced by the stage of plant maturity, edaphic influences, plant species, climate, animal species and the range condition (Baumont, *et. al.*, 2000). Therefore, the forage nutritive value, together with the forage intake, collectively determines the forage's quality in any ranch.

Although goats are mainly used for human consumption, they also have a significant role in controlling brush encroachment (Luginbuhl, *et. al*., 2021). Brush species are volatile to fire and by introducing goats in areas that are rich with these plant species may help reduce fire risks within those areas (Robles, *et. al.*, 2009). Goats are the best herbivore species for managing woody plants as they consume more browse than their counterparts (Campbell and Taylor, 2006). When grazing, goats tend to spend most of their time where there is abundant forage (Chebli, *et. al*., 2020). The availability of grass and browse species largely influence their movement during browsing and grazing because it is mainly due to the unique grazing behavior found to control their diet selection (Aregheore, *et. al*., 2006). Goats have an advantage of well-developed lips and tongue, which give them a better chance to harvest the shortest forage species and thorny forbs and shrubs (Nair, *et. al.,* 2021).

1.2 Background information on goat production in Botswana

Goats have the most integral socio-economic role in many African countries, and as such it is imperative to understand its role, the diversity of production systems, and the current production of goat products and limitations that will contribute to setting up strategies to promote the development of the sector (Agossou, *et. al*., 2017). In Sub Sahara regions, including Botswana, goats are normally kept under free-range management system.

The Kgalagadi district remains among the largest contributors of small stock in the country along with the Central, Southern and Kweneng districts. Small stock production is one area of agriculture popularly preferred by new entrants, women, youth and the unemployed mainly because of low production start-up costs. Liquidity of small stock is low as compared to other livestock farming entities hence desired by most households. The Kgalagadi district contributes around 5.5% to the national goat herd, Statistics Botswana (2016), due to its suitability for small stock production which is enhanced by few diseases and rich palatable browse species which all favours optimal performance of small stock in the region and hence the location of Lobu Small stock Farm.

Though farming in the Kgalagadi region is faced with adverse climatic conditions where most dry land areas are influenced by the climate rather than the browsing pressure, farmers must be strategic and well equipped with current knowledge to overcome the impact of drought on their livestock (Kgosikoma and Batisani, 2014). Even though goats can do well in a free-range management system, it should not be ignored that the free-range may not provide all the essential nutrients required by goats to perform to the desired and most profitable level. Hence the need to come up with strategies for managing goat herds in rangelands.

1.3 Origin and Domestication of Goats

Domesticated goat also known as *Capra aegagrus hircus* is believed to be the oldest domesticated animal after the dog. Alokan, (2008), reported that goat was domesticated in the mountainous area of Western Asia in the 7-9th Century. The modern domestic goat probably has the blood of three sub-species of *Capra agaegarus* namely the bezoar (c. agaegarusy), the ibex (C.ibex) and markhor (c.falconeriy). Generally, the bezoar is believed to be the major contributor to the ancestory of our modern day goats. However, the two breeds under this study are Boer and Savanna goats.

1.3.1 Boer goats

The boer goat was developed in the 1900's in South Africa. The development of the boer goat is unique as it did not follow the normal procedure of cross breeding, but rather selection of indigenous goats breeds in South Africa were used to come up with the pure breed (Malan, 2000). The boer goat is characterized by brown heads and white bodies while some may have completely white or brown colors (Wu, *et. al.*, 2006). They possess long, pendulous ears, fine head and round backward-curving horns (Budiarto, *et. al.*, 2021) with large framed body structure (Mokoena, *et. al.*, 2021).

Docility, high fertility and fast growth rate are some of the traits that makes it outstanding as compared to other meat breeds (Awgichew, *et. al*., 2008). The breed performs very well even under adverse climatic conditions as well as bushy terrains which may be unsuitable for other livestock (Menezes, *et. al.*, 2016).

1.3.2 Savanna goats

Savanna goats originated from South Africa and were developed in 1956 from the white boer goats (Campbell, 2003). Their white coat and black pigmentation as well as their ability to withstand harsh environmental conditions make them the most preferred breed in the sub-Sahara regions (Visser, 2017). They are known to produce tasty meat at an early age and the doelings have strong maternal instincts (Little, 2010). Multiple births were a norm and this helped in expanding the flock very quickly (Kotzé, 2018).

Birth weight averaged between 2.5 kg and 4 kg, and weaning weights were between 25 kg and 35 kg at 4 months (Casey, *et. al*., 2010). The stud maintains a kidding rate of 180% under ideal conditions (Wachida, 2018).

1.4 The role of goat farming in the livelihoods of the Sub Saharan community

Goat farming is a significant agriculture sector that provides several socio-economic benefits with the potential to improve the livelihoods of communities within the Sub Sahara region. In Uganda, about 39% of households are known to own goats and this is a clear demonstration of the importance of goats in people's livelihoods. Among these farmers, various benefits from goats' production were indicated at different levels with 98.2% stating cash income from goats' sale, 69.3% stated socio-economic value of goats, 59% stated meat production and 1.75% milk production from goats (Gamit, *et. al.*, 2020). In addition to this, some farmers kept goats for by-

products such as manure and skin representing small percentages of 27.2% and 15.8%, respectively (Byaruhanga, *et. al.*, 2015). It has been observed that goat farming plays an important role in food and nutritional security, especially in rural poor communities where crop production is uncertain mainly due to environmental conditions.

Among these communities, goats could be very useful in generating income for subsistence living (Kocho, *et. al*., 2011). More importantly, it has been found that livestock is the primary source of high-quality nutrition for low-income households, especially for pregnant women and improve the cognition skills and mental growth of children (Asresie, *et. al.*, 2015). Goat farming is a valuable genetic resource suitable for low-input agricultural production sectors, making them ideal for the resource-poor rural communities (Kaumbata, *et. al*., 2020). Other benefits of small stock farming include employment creation for the rural population, personal wealth for the farmers and economic diversification in most Sub Saharan countries.

Domestic animals such as goats are used for scientific research on farm animals, social, and economic significance. In addition, rats and mice have long been used as animal models to discover dietary requirements for nutrients and metabolic diseases resulting from their deficiencies. Furthermore, elucidation of metabolic pathways has been facilitated by the occurrence of inherited diseases in humans and animals. Therefore, extensive knowledge exists in the literature regarding the physiological and biochemical bases of nutrition in farm and laboratory animals (Wu, 2017). The Kgalagadi region is no difference to other Sub Sahara communities and due to its lack of other sectors that could sustain the livelihoods of the local community, small stock production remains the main source of income in most if not all the local people. Diversification of the economy in the region is centered around the livestock sector especially small stock which generates income to the local community and continues to show potential for export market.

1.5 Major constraints to the agricultural sector and goats' production in Botswana.

There are some common attributes to the agriculture sector's poor economic performance towards the World Gross Development Product in Sub Sahara countries. Research has shown that the following are significant major concerns among these attributes (Otte, *et. al*., 2005):

i. An economic environment characterized by a lack of investment in physical and human capital as per the World Bank report which was done in the year 2 000.
ii. High exposure to worsening terms of trade for primary product.
iii. Adverse agro-ecological and climatic conditions.
iv. Political instability and inter-and intra-state conflicts.
v. Poor health and the HIV and AIDS pandemic.

vi. Low population density which leads to low buying power.
vii. High implicit taxation of rural areas and overvalued exchange rates.
viii. Undermining the export of agricultural products while promoting industrialization.

Though Africa is considered to have the potential to perform explicitly well in agriculture, the continent is increasingly dependent on the developed countries for food imports. Food production in Africa is way too low to keep up with population growth. Reports show that Africa currently spends more than US$30 billion on food imports every year without an increase in per capita continental food supply (Keyser, 2014).

The agricultural sector in Botswana contributes a small proportion of the Gross Development Product (GDP). According to the Food and Agricultural Organization report, which was released in 2005, the agricultural sector contributes 2.5% towards the total GDP with the livestock sector, contributing to 88.7%. There are significant factors that contribute to this low proportion which among others include the following:

i. Inadequate provision of credit services. Livestock farmers find it difficult to access credit to start and expand their production. Credit providers put in place difficult conditions such as loan security, which discourages most livestock farmers from accessing credit.
ii. Scarcity of feed for livestock. The primary source of feed for our livestock is natural grazing and sometimes crop residues. The quality and availability of these resources are seasonally variable. Bush encroachment and overgrazing harm grazing resources, especially in the extensive production system.
iii. Lack of infrastructure. The required infrastructure necessary to transport livestock and livestock products from remote areas where most farming is concentrated in urban areas for marketing is lacking.
iv. Shortage of livestock technical services. Technical service for livestock production is essential to farmers, especially those with no livestock skill. The high incidence of livestock diseases poses a significant challenge in the profitable rearing of livestock.
v. Lack of market information. Livestock producers do not have access to market information which is an important driving force for increased production. There is no formal market for small stock producers in Botswana and this disadvantages them a lot.
vi. Diseases and parasites. Lack of awareness on most diseases and parasites and vaccination programs poses high percentage of livestock losses to the farming community.
vii. Cultural beliefs. Some people do not keep goats at all, mainly due to their cultural beliefs.

viii. Livestock theft. Goats are small in size and body weight and this puts them in dangers of easily carried away by thieves.
ix. Predators. Goats are mostly attacked by predators such as hyenas and lions, especially where extensive farming is practiced and wild animals have access to livestock.

To improve goat production benefits, it is essential to understand both the opportunities and challenges faced by livestock producers. In a case study done in Zimbabwe, the research indicated that there is need to promote livestock production strategies. Proper demonstration on the implementation of proven technologies and practices supported by improved extension service provision with dedicated monitoring systems could improve the livestock sector (Mutibvu, *et. al.*, 2012).

1.6 Statement of the problem

Lobu is a small rural settlement found in Botswana's Kgalagadi region with limited empowerment activities for the local community in the area. Lobu is characterized by low annual rainfalls which ranges below 250mm per annum and very high temperatures throughout the year with very dry humidity, hence hamper most of the agricultural activities that could benefit the rural community. The ranch location is also far from the market, making it difficult for the local farmers to sell at market prices. Though the climatic conditions are a significant concern, the area can be a small stock hub due to the rich vegetation cover found there. Agro-tourism is also an area that could be practiced along with livestock farming to create employment.

Through the ministry of Agricultural Development and Food Security, the Government of Botswana has taken a step in supporting Lobu ranch since its inception in 1978. However, there is lack of knowledge on the vegetation status regarding the rangeland composition as well as the nutritional status and how it is influenced by the climatic changes. Thus, this lack of rangeland knowledge is also one of the challenges farmers face in Botswana, which harms our livestock's performance. Obtaining information on how vegetation contributes to livestock's general performance could turn the industry into a profitable business.

The other factor that needs to be taken into consideration is to do thorough research on relative goat diet botanical composition on continuous grazing as compared to rotational grazing system on seasonal basis as it seems to be lacking. Providing this information to the farming community would help a lot in decision making regarding the type of grazing system to use, which could optimize goat production and utilize forage resources adequately. Generally, it is crucial to ensure that the farming community is made aware of the importance of vegetation and its impact on livestock productivity.

The on-going construction of the small stock abattoir within the ranch could be a dream-come-true for the local producers. The Trans Kalahari high way has been a considerable success for the transportation of livestock to the market but could not meet the small stock producers' needs. This study aims to assess the potential of goat production in Lobu area concerning the forage quality and determine the performance of Savanna and Boer goats under natural vegetation of Lobu ranch.

1.7 Research question

How does rangeland condition influence growth performance of the Boer and Savanna goats doelings at Lobu ranch during the late wet and early dry season?

1.8 Scope of the Study

The study focuses on the growth performance of the Boer and Savanna goat doelings under rangeland conditions at Lobu Ranch during the late wet and early dry season in the year 2021.
The focus was to gather knowledge on forage plant species, composition, their distribution and nutritional value during the early wet and late dry season in 2021. Ultimately, the performance of the animals were measured in relation to the rangeland condition of the area. During this period, the climatic change from wet to dry may have a major influence on the rangeland condition and quality.

1.9 Objectives

1.9.1: General Objective

To determine growth performance of the Boer and Savanna goat doelings under rangeland conditions at Lobu Ranch during the late wet and early dry seasons.

1.9.2: Specific objectives

1. To determine abundance, distribution and diversity of woody trees and shrubs in the ranch during late wet and early dry season.
2. To determine the nutritional composition of common forage species in the ranch during late wet and early dry season.
3. To measure growth performance (Body weight, Heart girth, Hip height, Shoulder height and Body length) of the Boer and Savanna goat Doelings under rangeland conditions during late wet and early dry season.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Introduction

Plant palatability is usually associated with plants' youngest tissues, highest protein and the most readily available plant carbohydrates on highly fertile soils. Plants palatability and forage preference of the goats herd changes with seasons. (Chebli, *et. al*., 2020). In any pasture, different plant characteristics and physical factors directly and indirectly, affect forage quality. Therefore, forage quality is primarily associated with plant nutrient concentration, consumption rate, digestibility of the forage consumed, and selection of metabolized products within the animal (Avery, *et. al.*, 2019). Forages provide essential nutrients to the animal kingdom and would ultimately determine the animal performance. It is, therefore, advisable to introduce timely forage quality analysis schedule to the farming community.

Grazing by domestic animals is commonly associated with variations in species composition in rangelands (Louhaichi, *et. al.*, 2009). Research has shown that indeed livestock grazing has a strong impact on the structure, richness and composition of rangeland. The results in an exercise done in the Southern Tunisia's rangelands of indicated that vegetation cover was decreased from 62% to 40% after grazing but recuperated to 59% after being allowed to rest for about seven months (Gamoun, *et. al.*, 2016). It is evident that the influence of livestock grazing and overall utilization of rangelands have a negative impact on vegetation cover. Thus it affects land cover, runoff and erosion, soil moisture infiltration, consequently causing a loss of nutrients from the grazing area (Amiri, *et. al.*, 2008). In degraded rangelands, which is a common factor in desert areas, grass species are least consumed by goats, rarely exceeding 5% of the goats' diets during any month. However, after the rainy season and forage condition improves, goats considerably increase their consumption of grasses by 45-68% (Mellado, 2016). Goats kept under free-range can produce high-quality meat. The feed has a high content of unsaturated (desirable) fatty acids ranging from 61 to 80 per cent and low content of saturated (undesirable) fatty acids. It has been discovered that goat meat produced on this feed quality is juicier and has a better shelf life (Dereje, *et. al.*, 2015).

2.2 Factors affecting the composition and biomass of rangeland vegetation

Rangeland vegetation is mainly influenced by climatic factors such as temperature, humidity, precipitation, light intensity and altitude (Long, *et. al.*, 2019). These climatic parameters affect respiration, assimilation, photosynthesis and metabolism and ultimately modifying the mineral and organic matter contents of plants regardless of the soil type. Contrary to this, the soil factors such as the physical, chemical and biological properties may greatly influence the plants' ecology and evolution (Getabalew and Alemneh, 2019). So it becomes essential that the livestock farmers know the climate changes and how the ecosystem responds to that. Climate change, more especially global warming has a negative influence on livestock production performance as it affects natural resources. Mostly in tropical environmental conditions, the main factor influencing the productivity of livestock is climatic seasonality .which impacts greatly on pasture quality and ultimately affecting livestock productivity (Anoh, *et. al*., 2021).

Vegetation biomass is the principal aspect of ecosystem productivity as it is used in quantifying the role of vegetation in the carbon cycle and the potential for energy production. Normally the natural vegetation is strongly related to the typical features of the climate and geomorphology, thus vegetation biomass increases due to positive effects of the global change. Conversely, the diverse and variable landscapes lower the production of biomass. (Galidaki, *et. al.*, 2017). It has been observed that high elevation vegetation may increase production with increasing temperatures. On the other hand, increased atmospheric carbondioxide concentrations modifies physiological growth processes in rangeland vegetation by enhancing water use efficiency. Warm, wet winter favors early season plant species and tap-rooted species that are able to access early-season soil water. (Reeves, *et. al.*, 2018). Plant morphology and stage of harvesting also have a significant influence on the overall plant biomass. The fiber components increases with the stage of plant growth, while crude protein and ash contents decreases as the plant matures. (Molla, *et. al.*, 2018).

2.3 Nutritional composition of vegetation preferred by goats

Nutritional analysis of rangelands is a primary indicator of rangeland status regarding degradation and livestock nutrient demand. Thus, it is used to maintain healthy and sustainable rangelands that can provide the livestock with sufficient quantity and quality of forage. The nutritional composition of any rangeland vegetation should be compared with the corresponding animal requirements for the animal's physiological status (Guevara, *et. al*., 2009). Rangeland nutrition is the principal determinant of both wild and domesticated animals' performance including the vegetation-herbivore interaction. Enhanced vegetation biomass and extended patch areas are mostly associated with large and more persistent herbivore populations (Lee, 2018).

Herbaceous vegetation such as forbs are important components in the rangeland ecosystem (Kallah, *et. al.*, 2000) and in the dry regions they are found to be palatable and able to sustain growth regardless of the harsh weather conditions. Forbs are very useful because animals acquire essential nutrients from them during dry periods when shrubs and trees have dried up having more tannins which hampers their utilization as browse feeds. It has been observed that during the wet season plants would normally have greater dry matter digestibility and crude protein contents as compared to the dry seasons. (Hernandez- Calva, *et. al.*, 2011). Thus, forage quality and availability is minimal during the dry season which results in low nutrient intake by the animals.

This, therefore, calls for intensifying supplementation of livestock feeding to ensure that animals perform to their optimal through-out the year.

Some studies (Li, *et. al.*, 2021 and Jamieson, *et. al.*, 2015) have shown that high temperatures are associated with increased tannins in rangeland vegetation as compared to low temperatures. Contrary to this, other research indicate that combined effects of low temperature and high carbon dioxide concentration may result in accumulation of tannins in some plant species. Conversely, low temperature and moisture stress may have limited impact on tannin accumulation in some plants (Lascano, *et. al.*, 2021). This concludes that environmental factors play a major role in forage quality.

2.4 Factors affecting the quality of forages

Forage quality may be defined as the capacity of forage to provide livestock nutrient requirements. The main components of forage quality are palatability, chemical composition and nutrients digestibility. When defining forage quality, the distinction between forage quality and forage nutritive value should be taken into consideration. Forage nutritive is associated with the concentration of available energy concentration of crude protein while forage quality is a comprehensive term that includes both nutritive value as well as forage intake. (Newman, *et. al*., 2016). In the study carried out in the semi-arid rangelands of Sudan by Abusuwar and Ahmed, (2010), it was observed that the late dry season was significantly higher in dry matter compared to early dry season. With regard to nutritive values in terms of crude protein and crude fiber, the early dry season had a higher crude protein percent than late dry summer. This is because early dry summer immediately follows the end of the rainy season, therefore the vegetation was still nutritious compared to late season.

Generally there are six major factors that influence forage quality and these are:
Forage maturity or stage of harvest: Plants frequently change in forage quality as they mature.
Plant species: Different plant species differ in forage quality with legumes possessing high protein content than grasses.
Harvest and storage: inappropriate harvest techniques reduce forage quality, primarily through the loss of leaves. Moisture content of forage also affects their quality.
Environment or climate: Moisture, temperature and the amount of sunlight influence forage quality.
Soil fertility: The fertility of the soil should be balanced at the time of planting and through-out the growth of plant to avoid mineral imbalances at the time of forage use.

Variety or Cultivar: Varieties with improved quality are mostly preferred as they would provide the most valuable nutrients to the animals.
Other factors such as plant pest, weeds and diseases may influence the quality and persistence of forage hence must also be taken into consideration.

2.5 Forage preference of goats

2.5.1 Shrubs

The most preferred plants by goats are shrubs which include among others the Acacia species. Shrubs remain green most of the time and start drying up as the cold season approaches. The evergreen leaves and buds from deciduous shrubs have high crude protein, phosphorus, carotene (Vitamin A) and digestibility levels while they possess lower fiber levels than grasses and forbs (Álvarez-Martínez, *et. al*., 2016). Shrubs usually preferred by goats are *Acacia tortilis* (mosu), *Acacia mellifera* (mongana), *Acacia erubescens* (moloto), *Acacia nigrescens* (mokoba) and *Acacia karroo* (mooka). Because of their small mouthparts, goats use these plants most efficiently.

2.5.2 Forbs

Forbs like shrubs are characterized by high levels of crude protein, phosphorus and lower fiber levels when actively growing compared to grasses and shrubs. Because of their lower fiber levels, forbs are highly digestible, thus allowing more consumption by goats. However, it should be recognized that many forbs are poisonous and the range should be assessed more often to guard against this. Forbs mostly preferred by goats are brambles, common and giant ragweed, honeysuckles, ironweed, lambs quarter, multiflora rose and privet tree (Kallah, *et. al*., 2000).

2.5.3 Woody trees

Goats have the advantage of being able to stand on their hind legs for a longer period while browsing. They would like to feed on tree pods, bark, thin stems and branches as well as the leaves. When trees start to lose their leaves and pods during the dry season, goats utilize these plants parts to feed Goats usually browse trees such as *Peltophorum africanum* (mosetlha), *Dichrostachys cinerea* (moselesele), *Ziziphus mucronata* (mokgalo), *Ximenia Americana* (moretologa wa podi), *Ximenia caffra* (moretologa wa kgomo), *Vangueria infausta* (mmilo), and *Elephantorrhiza burkei* (mositsane) (Marius, *et. al*., 2017).

2.5.4 Grasses

Whilst they are browsers, goats may feed on grasses to meet their nutritional needs. Usually, goats eat grass they come across within the range, and they are not so picky when it comes to grasses. They may feed on grasses such as Bahia grass, Alfalfa grass, Brome grass, Clover grass, Ryegrass, Timothy grass and Millet. Even though goats are not so selective when it comes to browsing, it was found that the composition in their diet would usually have a large proportion of trees and shrubs; 78% followed by 12-18% of forbs and lastly grass at 6-10% (Foroughbakhch, *et. al*., 2013).

2.6 Grazing distribution of goats within the range.

Livestock grazing distribution management ensures that range of plants and grasses are utilized to benefit all animals found within that zone from the natural environment resources equally concerning their morphology, genotype, and animal age. Understanding the relationship between livestock and its habitat is the most important factor in grazing management because it defines the available range resources and living conditions for the type of animal (Derner, *et. al*., 2012). The key to sustainable, enhanced livestock production is timely monitoring and managing grazing livestock's spatial. Working on grazing uniformity of goats may not be an easy task especially on extensive rangelands because of rough topography, heterogeneous landscapes, large pasture sizes, annual variations in standing crop and limited water availability. It is therefore very important to come up with management strategies that are most effective and efficient in such cases. (Swanson, *et. al*., 2015).

Ignoring grazing distribution would probably lead to grazing pressure on sites that are mostly used. When managing livestock grazing, farmers must aim for the most sustainable use of pasture as much as possible (Lyons and Machen, 2015). Goats often prefer to graze riparian locations and other sensitive grazing lands, ignoring other forage sites under-utilized. Considering the grazing pattern of livestock helps to protect other animals such as fisheries, wildlife habitat, and other vegetative and watershed resources (Bailey, 2004). The introduction of a global positioning system (GPS) has played a significant role in research about livestock grazing distribution, especially on the free-range system and where many livestock is concerned To be precise on factors influencing livestock distribution in a free-range, one has to assess when and where they are grazing and that is when the use of a GPS is essential (Augustine and Derner, 2013).

2.7 Factors affecting the productivity of goats

The most significant factors that affect livestock production including goat production are climate, health and nutrition. These are found to be the most extremely complex factors that may not be easy to quantify, more especially in extensive goat production system. Non-the less, there are other factors which are human influenced such as livestock selection, religion, cultural beliefs, marketing strategies, access to infrastructure and overall management startegies. In order to excel in the industry, it is important for one to come up with mitigation strategies at all levels. (Lamy, *et. al.*, 2012). The most important approach to comparing the efficiency of goat production, across different production systems, is to compare outputs per standardized energy input.

2.8 Nutritional requirements of goats

A nutrient is defined as a compound or substance needed to support the maintenance, growth, development, lactation, reproduction, and health of animals. With sufficient intake of nutrients, they survive, grow, develop, and reproduce as important parts of the ecosystem. Nutrition is also defined as the science that interprets the interaction of nutrients and other substances in food that influence the maintenance, growth, development, reproduction, and health of animals. Thus, animal nutrition includes essentially every biological science that can be applied to the study of nutrient utilization and nutritional problems in livestock, poultry, fish, and other species (Wu, 2017). It should be noted that feeding recommendations for farm animals in tropical and warm regions are still largely based on standards established in temperate regions. The adaptation to diet and climatic condition affects nutrients partition, animal growth, body composition and, consequently, energy and protein requirements (Salah, *et. al.*, 2014).

Goats are able to survive and often thrive on areas that do not provide minimal nutrition to support their counterparts; sheep and cattle, and the browse they consume is usually of poo sources of nutrients. They are able to survive because of their efficient digestion and/or lower requirements (Huston,1978).

The tables below shows daily nutritional requirements of goats:

Table 2. 1: Daily Macro nutrients requirements of goats in percentages

Macro Nutrients	% Requirements (Source: NRC, 1985)	Requirements (g/100gDM)
SODIUM	0.09-0.18	0.04-3.78
CALCIUM	0.20-0.82	0.40-2.71
PHOSPHORUS	0.16-0.38	0.12-0.83
MAGNESIUM	0.12-0.18	0.09-2.5
POTASSIUM	0.50-0.80	0.17-2.49

Table adopted from: ALOKAN, J. A. (2008). Small livestock is still beautiful.

Table 2. 2*:* Daily Micro nutrients requirements of goats in Parts Per Million (PPM)

MICRO NUTRIENTS	RECOMMENDED REQUIREMENTS(PPM)
IRON	30-50
COPPER	7.11
MANGANESE	20-40
ZINC	20-33

Table adopted from: **National Research Council. (1985).** ***Nutrient requirements of sheep*** **(Vol. 5). National Academies Press**.

2.9 Growth performance of the breeds during the late wet and early dry season

It has been noticed that kids born in the dry season were superior to their counterparts in the wet season in terms of initial weight. This remarkable weight was consistently maintained up to the weaning age of four months. This superiority is mainly attributed to the fact the wet season is characterized by many growth-limiting factors; the restriction imposed due to farming activities, high incidence of pests and diseases and the interplay and influence of climatic factors. Additionally, it was noticed that climatic factors influence greatly the productivity of goats especially under traditional system of management through their effects, supremely on forage, water availability, thermal stress and photoperiod which are reflected in seasonal trends in growth. (Zahraddeen, 2008).

Contrary to this study, Alade, *et. al.*, 2008 had a different observation on the pattern of seasonal effects on performance of kids. In this study it was observed that season did not have significant effect ($p>0.05$) on body weights at birth. However, animals born in the wet season performed better than those born in the dry season at 3 and 6 months of age probably due to availability of pasture of the right quality and quantity. Conversely, at 9 months, animals born in the dry cold season were better than those born either during wet or dry season. However, the superiority of animals born in the dry cold season over those born in the dry hot and wet seasons at nine months, may not be distinct with tethering carried out during the wet season that led to poor growth.

2.9.1 Boer goats

Boer does are renowned for kidding as often as two times in three years, frequently bearing twins and sometimes triplets. (Erasmus, 2000). Boer goats were developed for meat production in the early 1900's in South Africa. Their name is derived from the Dutch word "boer" meaning farmer. Boer goats are well adapted for hot, dry semi-deserts. Boer goats are herbivores and are browsers by nature, preferring brush, shrubs and broadleaf weeds rather than grass. (Mellado, *et. al.*, 2017). The development of the Boer goat in the early 1900's can be traced to the Dutch farmers of South Africa. Boer is a Dutch word meaning farmer. With meat production setting the selection criteria, the Dutch farmers developed the Boer goat as a unique breed of livestock. (Pieters, *et. al*., 2009).

2.9.2 Savanna goats

The Savanna goats have thick, pliable skins with short white hair. The Savanna has excellent reproduction, muscular development, good bones and strong legs and hooves. It has been observed that the half Savanna kid got up faster after birth and nursed quicker than their other goats. On the rugged, harsh bush country where temperatures and rainfall can vary to a marked extent, natural selection played a big role in the development of these fertile, easy to care for, heat and drought resistant animals (Marini, *et. al*., 2012). Savannas are resistant to tick-borne diseases and tolerant of goat worms and other parasites, drought, and heat. Very little healthcare intervention is required in their native veld. Despite the harsh environmental conditions experienced in the Sub Sahara regions, the Savanna goat has maintained a 150% kidding rate (Vincent, 2018).

CHAPTER 3

ABUNDANCE, DISTRIBUTION AND DIVERSITY OF WOODY TREES AND SHRUBS IN LOBU RANCH

Abstract

Trees and shrubs are the main source of fodder for small and large ruminants in most parts of Botswana because they improve animal productivity by overcoming seasonal nutritional deficits. Although the Lobu Ranch was established to produce high-quality breeds of goats, there is lack of documentation on the woody plants that are browsed by these goats. Therefore, the objective of this study was to determine abundance, distribution and diversity of woody trees and shrubs in the ranch during the late wet and early dry seasons. A sampling survey was used to determine forage availability during the late wet season when all vegetation could be easily identified. There were three types of forage species that were dominating in the field and these were *Asparugus asparagus, Rhigozum trichotomum* and *Senegelia mellifera*. The woody plants that are < 2m showed a higher density (individuals/ha) than those that are >2m ($P<0.05$. Therefore, indicating that the shrubs dominated the woody plants (410 individuals/ha) as compared to the woody plants that are > 2m (55 individuals/ha). Most of these shrubs are xerophytes and are able to thrive under hot climatic conditions as they possess drought-resistant qualities. It has also been noticed that forage diversity and species richness decreases as one moves further from the kraals and this could be an attribute of animals grazing intensity which is found to be more nearer the kraals.

3.1 Introduction

The ecosystem is mostly identified by a wide range of habitat diversity including woodlands, riverine forests, grasslands, wooded grasslands and shrublands harboring diverse flora and fauna. The nested habitats provide attractive scenery of a typical African savanna ecosystem (Mligo, 2015). Tree encroachment is defined as the thickening of assertive undesired woody species resulting in disparity of grass to tree ratio which results in a decrease in biodiversity and carrying capacity. This phenomenon is associated with the mismanagement of rangelands through overgrazing, suppression or exclusion of fire and the activities of browsers (Tokozwayo, *et. al.*, 2021). Plant distribution in rangelands is affected by factors such as climate, soil type and biotic interactions (Ravhuhali, *et. al.,* 2020). Reproduction, recruitment and survival of woodlands are known to be the driving force of population dynamics of any vegetation while herbivory and fires are known to be the primary factors of vegetation dynamics in African savannas. The forests and woodlands of Botswana cover about sixty percent (60%) of the land area and the diversity of both the herbaceous and woody vegetation provides goods and services that sustain most of the needs of the nation (Mmusi, *et. al*., 2021).

Woody vegetation cover in semi-arid rangelands has decreased over time due to pressure from the alarming human population growth and accompanying increases in demand for various tree products and services (Mengich, *et. al*., 2019). In countries like Kenya, rapid population growth, deforestation, overgrazing, agricultural activities, fuelwood collection and construction material has resulted in the decline of riparian ecosystems (Mmusi, *et. al*., 2021).

Woody plants have pertinent agronomic characteristics to contribute browse products of high nutritional value for ruminants reared in semi-arid communal rangelands (Ravhuhali, *et. al*., 2020). Trees and shrubs are the main source of fodder for small and large ruminants in most parts of our country. They improve animal productivity by overcoming seasonal nutritional deficits. Further, trees can tolerate varied climatic and environmental conditions, propagate readily and can serve as a valuable source of protein and minerals (Damron, 2013).

Studies on population structure and density of major canopy tree species can help to understand the status of regeneration of species as well as management history and ecology of the forest. Plant population structure shows whether or not the population has a stable distribution that allows continuous regeneration to take place (Gebeyehu, *et. al.*, 2019). Lobu Ranch is among the government ranches that are used for livestock production in Botswana and it was established to produce high-quality breeds of small stock. However, there is a lack of documentation on the woody plants that are utilized by the animals on the ranch hence the need to do this study.

3.2 Specific objectives

i. To determine mean density, species composition and frequency of woody trees and shrubs in the ranch.

ii. To determine diversity, evenness and Species richness of woody trees and shrubs in the ranch.

3.3 Materials and Methods

3.3.1 Materials

i. Brown sample collection papers
ii. Range poles
iii. Plant identification books
iv. Field data sheets
v. GPS receivers/trackers (s/no. 088046399130, model IMEI3541880)
vi. Clip board
vii. Measuring tape
viii. Secateurs

3.3.2: Preliminary Field visit

A site visit to Lobu ranch was done a month before the beginning of the exercise. The main purpose of the site visit was to identify the most appropriate paddock with the desired goats to be used for the entire winter/dry period while collecting data. The following activities were carried out:

- Identify the appropriate paddock with major vegetation distribution and composition.
- Obtain the coordinates of the paddock from the satellite using a Global Positioning System (GPS) then saved them for mapping.
- Draw transects on the satellite image for the sampling points to be used during the field work.

3.3.3: Description of the Study area

The study was undertaken at Lobu Small Stock Ranch which is located in the Kgalagadi district (Figure 1). The ranch has Kalahari sand soils which are mostly fine sand-sized and are predominantly deep, structure less and lacking in Nitrogen, Phosphorus and organic matter. The natural vegetation of the Kalahari region is well adapted to low water and nutrient availability but is sensitive to changes in soil properties. Dougill and Thomas, (2004) linked the extensive bush encroachment occurring in the Kalahari area associated with heavy grazing to increased leaching of water and nutrients over the years. The vegetation in the Kalahari areas comprises a woody layer (mainly single-stemmed, seasonally deciduous trees and shrubs), with a ground layer of grasses and forbs. A strong summer seasonality in the rainfall encourages woody shrub production

(Palmer and Ainslie, 2006). The rain falls mainly between the months of November and March with a long-term annual average of less than 250 mm and high variability. Maximum temperatures reach 45°C in summer while minimum winter temperatures can be as low as-4°C. The vegetation is classified as shrub/bush savanna, which is dominated by woody species such as *Acacia erioloba, Acacia mellifera, Terminalia sericea* and *Acacia luederitzii*, while grasses include *Eragrostis lehmanniana, Stipagrostis uniplumis* and *Schmidtia kalahariensis* (Mosalagae and Mogotsi, 2013).

3.3.4: Research design

This study was a sampling survey (forage availability) with the aim of determining the distribution and abundance of woody trees and shrubs at Lobu ranch during the dry season. The sampling survey was based on gradient of livestock grazing intensity (LGI) (Lange 1969), hence transects were radiating from the kraals and water points covering the whole paddock to estimate vegetation production and nutritional quality. LGI is expected to decrease with the distance from the kraals and water points (Andrew and Lange 1986). Three transects were chosen because it was economical to do so and at the same time covering most of the paddock (Akanyang, 2019). Nevertheless, more than three transects could produce more detailed data, but it would not be feasible because of the time limitation and the costs involved. However, the sampling survey was only conducted during the late wet season when identification of vegetation species is easier. Each transect was limited by the distance of paddock boundary from the kraal/water point. Vegetation production and nutritional quality was established at each sample point along the LGI gradient, hence, three transects reflecting a decrease in LGI were established. Transect delineation were done using recent google earth images for easy systematic location of the sample points.

The coordinates of each sample point were collected from the google earth image and stored in the GPS receiver for the location of the sample point in the field. However, during the fieldwork, sample points locations were adjusted accordingly to represent the average stand of vegetation, such that the sample points include as much heterogeneity of floristic composition and habitat structure as possible (Bonham, 2013). For example, when the sample point is located in a stand of *Senegalia mellifera*, but not covering the nearby open grassland, the sample point was re-located in such a way that it covers both stands of *Senegalia mellifera* and open grassland following the requirements for Braun-Blanquet surveys (Lamarque, *et. al.*, 2009). Sample were at intervals of 250m to capture details of vegetation resources used by the goats. Therefore, approximately at least 7 sample points per transects (depending on the transect length) were established, making a total of at least 23 sample points in a paddock.

Figure 3. 1:: Sampling survey area showing the transects and sampling point locations

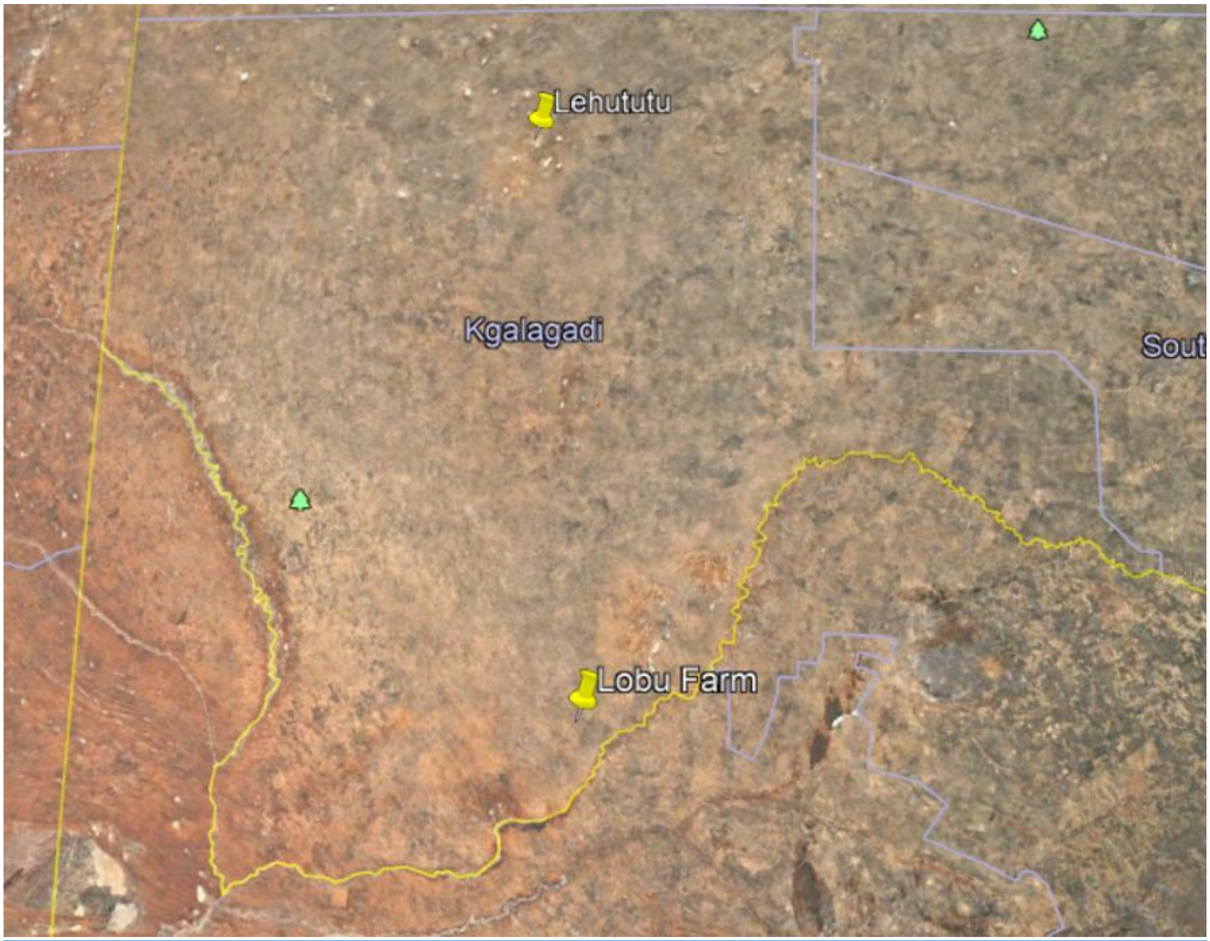


Figure 3. 2: Location of the study area

All settlements are represented by a star symbol. TGLP – Tribal Grazing Land Policy ranches, CFDA - Communal First Development Area ranches, BLDC – Botswana Livestock Development Cooperation.

At each sample point, woody plants and shrubs attributes such density, composition, diversity, evenness and frequency were identified and recorded to the species level (Table 3.1) to explore their distributions within the paddock. Woody species variables were assessed within the plot of 20m x 20m quadrats (400m^2), an area found to be suitable for woody plants (Skarpe, 1986) in the Kalahari ecosystem. The distance between the 20m x 20m plots was 250m to encompass variability in biodiversity at each sample point.

Table 3. 1: Woody species variables to be measured at each sample point

Plant variables	Output
Species composition	Number of woody, poisonous, invasive and threatened species established.
Density and frequency	To explore the woody plant vegetation abundance and special distribution, hence, reflecting forage availability.
Species diversity and evenness	Woody plant species diversity between different sample points.

3.3.5: Sampling frame and data collection procedures

Below are the sampling procedures according to the main objectives to show how the data for each objective wall collected. First, the sampling procedures on vegetation production and vegetation heterogeneity are discussed, followed by procedures on nutritive quality of forage plants within the ranch and lastly how data on growth and reproductive performance of the boer goats is going to be collected.

3.3.5.1: Vegetation production and vegetation heterogeneity

The vegetation attributes were assessed concentrating on woody plants and shrubs at each sample point. Woody plants and shrubs' attributes were measured within the two 20m x 20m plots (Skarpe, *et. al*.,2003).

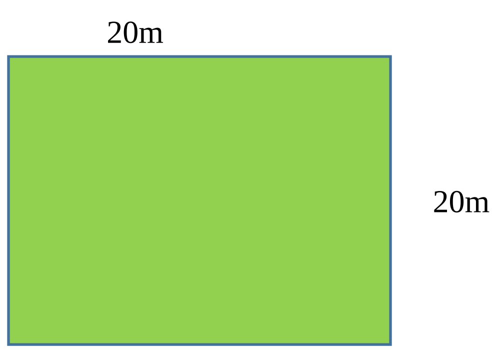


Figure 3. 3: Sampling plots for woody plants and shrubs

3.3.5.2: Woody plants and shrubs attributes

Trees and shrubs were quantified to species level because they provide browse to livestock, hence, trees and shrubs are an indicator of forage availability and vegetation heterogeneity. According to a study by (Moleele and Perkins, 1998), browsing by livestock is superior throughout the season as compared to grasses and forbs which are only nutritious at the beginning of the growing season. The density of woody plants was estimated using counting methods (McCoy, 2005) at every sample point. Other plant density methods such as abundance, class and distance methods (McCoy, 2005) were deemed not appropriate because they are not cost-effective. Therefore, all the trees/shrubs, rooted within and on the boundary of the plots (i.e., 20m x 20m and) were counted to species level to estimate plant density, frequency and species composition, diversity and evenness (Moleele and Mainah, 2003).

3.6: Data analysis

3.6.1: vegetation analysis

The data collected from all the 400 m^2 quadrats was analyzed as follows.

Species richness was determined from the total number of plant species (woody and herbaceous species) recorded in all the quadrats. In addition, to establish the plant species richness, plants observed outside the quadrats and plots were included.

Diversity of the plant species was determined by using the Shannon-Weiner Diversity Index, i.e.:

$$\boxed{\boldsymbol{H' = -\sum_{i=1}^{S} Pi \ln Pi}}$$

where, H' = Shannon Diversity Index, S = species richness, P_i = proportion of S made up of the i^{th} species (relative abundance).

Evenness or Equitability (E), a measure of similarity of the abundances of the different plant species in the ranch, was analyzed by using Shannon's Evenness or Equitability Index (E) (Krebs, 1989; Magurran, 2004). Evenness/Equitability assumes a value between 0 and 1 with 1 being complete evenness. The following formula was used to calculate evenness:

$$\boxed{\boldsymbol{E = H' / \ln S}}$$

where, E = evenness, H' = Shannon Diversity Index and S = species richness.

Abundance of plant species was determined by summing the total number of individuals of the plant species (woody and herbaceous plants) recorded in all the quadrats and plots.

Densities of the different plant species, i.e., their number of individuals per ha, in the ranch was determined from the total number of individuals recorded in all the quadrats and plots.
Frequencies of the plant species was determined from the number of times a species recorded in all the quadrats and plots.

Similarities in species composition of the woody species in the ranch was determined by employing Jaccard's Similarity Coefficient (Chong, *et. al*., 2007; Metzger, *et. al.*, 2005).

Ecological importance of each plant species was then determined by using Importance Value Index (IVI). The IVI value of each woody species was calculated by summing up its relative density, relative frequency and relative dominance (Metzger, *et. al.*, 2005).

Density, abundance and species composition of poisonous plants were deduced from the density data of poisonous plants.

3.7 Statistical Analysis

SPSS was used to analyze the calculated results. Canonical Community Ordination (CANOCO) software was used to carry out other multivariate analysis. CANOCO was used to relate community composition (Plant species attributes) to environmental variables. All tests were conducted at 95% confidence level, therefore results with $P < 0.05$ are considered statistically significant. Mean density was determined using SPSS program. The Post Hoc test is used for mean separation where results with $P>0.05$ are considered to have no significant difference.

3.8 Results Analysis

3.8.1 Mean density of Woody plants and shrubs recorded at proposed site during field work.
The Post Hoc test was used to analyze the results and all woody trees and shrubs species' mean densities are not significantly different ($P>0.05$) (Table 3.2) regardless of their height and the distance from the starting point being the kraals.

Table 3. 2: Mean density of woody trees and shrubs sampled at three transects at three intervals

Species	Mean Density (individual/400m^2						P value	
	Near	**STD Error**	**Mid**	**STD Error**	**Far**	**STD Error**	**Near-mid**	**Near-far**
Senegalia mellifera 1	1.89	1.099	0.22	0.222	0		0.336	0.381
Senegalia mellifera 2	0.67	0.471	1.11	0.807	1.00	0.632	1.000	1.000
Vachelia erioloba 1	0.89	0.655	0.33	0.236	0		1.000	0.725
Vachelia erioloba 2	1.11	0.722	0.78	0.364	0.60	0.600	1.000	1.000
Vachelia karoo 1	0.11	0.111	0		0		0.830	1.000
Vachelia karoo 2	0		0.22	0.222	0		0.830	1.000
Vachelia haemotoxylon 2	0.44	0.444	0		0		0.830	1.000
Vachelia hebeclada 1	0		0.11	0.111	0		0.830	1.000
Gevia flava 1	2.22	0.846	1.89	0.588	1.00	1.000	1.000	0.991
Rhigozum trichotomum 1	0		1.22	1.222	4.60	4.600	1.000	0.375
Boscia albitrunca 1	0.11	0.111	0.56	0.176	0.40	0.245	0.167	0.834
Andy shrub 1	0.22	0.147	0.44	0.242	0.40	0.400	1.000	1.000
Unknown shrub 1	0		5.22	4.974	0		0.763	1.000
Terminalia sericea 2	0		0.11	0.111	0		0.830	1.000
Rhus tenuinervis 1	1.78	0.969	0.33	0.167	2.00	1.265	0.567	1.000
Asparagus asparagus 1	2.67	1.555	2.89	2.648	1.60	0.812	1.000	1.000
Ehretis spp 1	0		0.11	0.111	0		0.830	1.000
Rhigozum brivasponosum 1	0.78	0.778	0		0.20	0.200	0.843	1.000

Post Hoc test used for mean separation; P values >0.05 means that there is no significance. Species denoted with 1 are those <2m tall while those denoted with 2 are >2m tall.

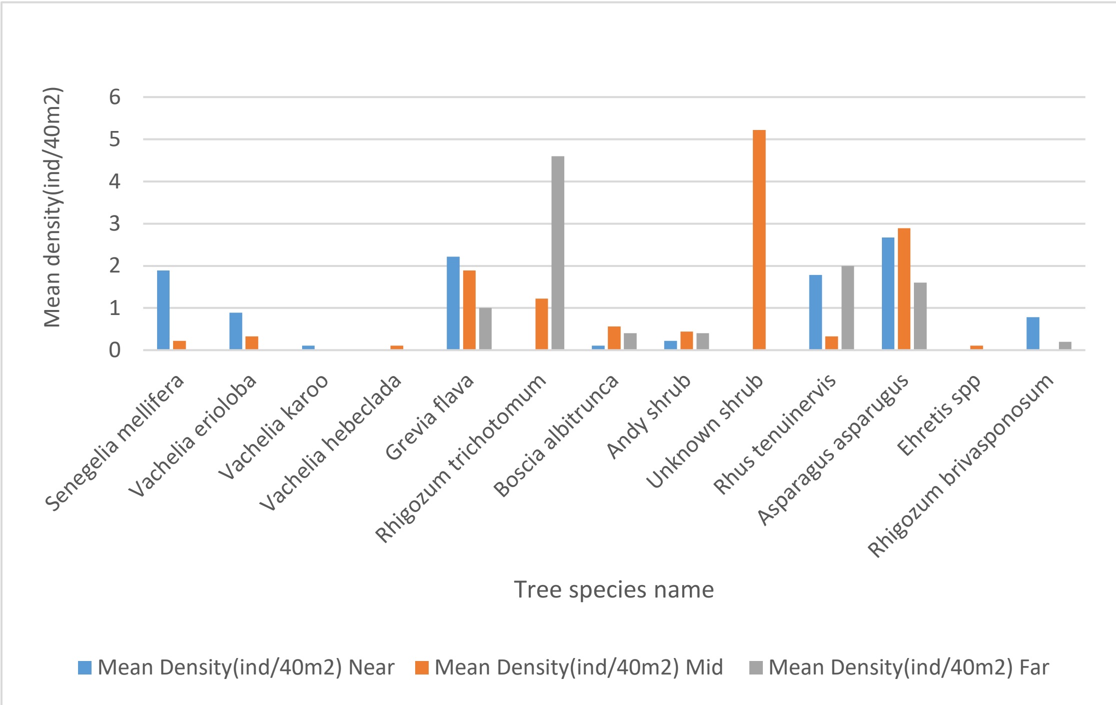


Figure 3. 4: Mean density of woody trees and shrubs with height less than two meters.

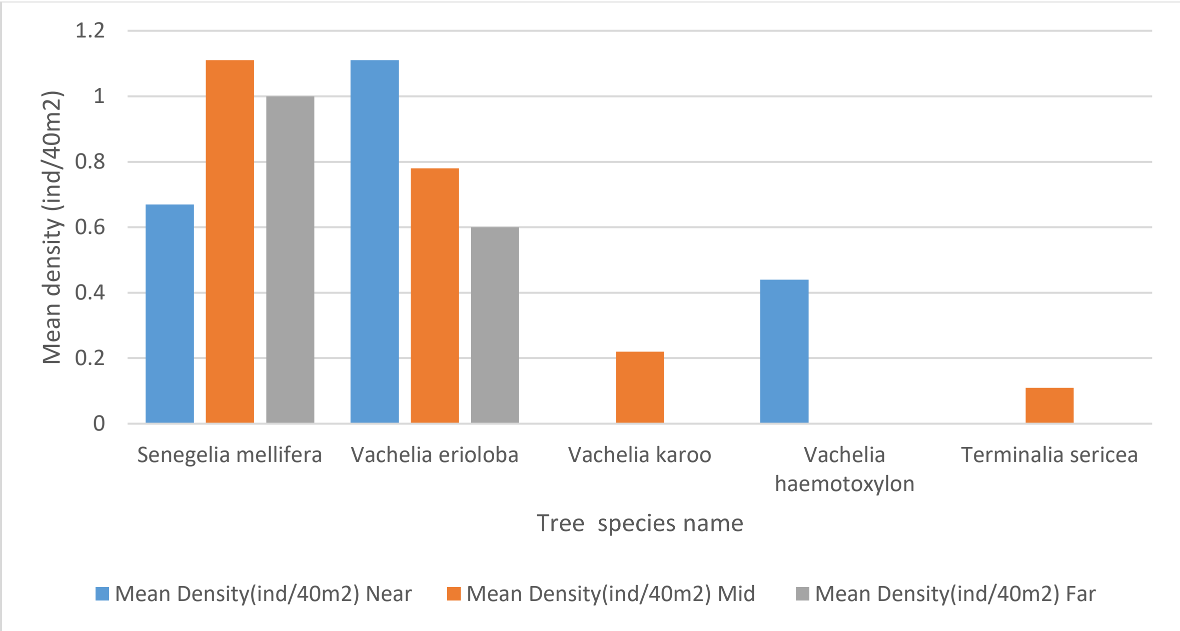


Figure 3. 5: Mean density of woody tress with height more than two meters

Though the figures 3.4 and 3.5 show a difference in mean density, statistical analysis interprets that there is no significant difference (P>0.05), that is; the density of the trees and shrubs is the same across the three distances.

3.8.2 Distribution and abundance of woody trees and shrubs with height of less than two meters.

3.8.2.1 Distribution and abundance of woody trees and shrubs found near the kraals

The ten tree species recorded in the field near the kraals covered a total density of 266.7 individuals/ha, one of them being the *Asparugus asparagus* is the most abundant with density of 66.7 individuals/ha (Table 3.3) while the least abundant is *Vachellia karoo* (Mokhaa) with density of 2.8ind/ha. Three are rare species (< 20 individuals/ha) Andy shrub, *Grevia flava* (Moretlwa) and *Rhigozum brivasponosum* while the rest are abundant (>20ind/ha). Hence, these are the least dominant woody species, and they need attention when developing the project.

The two mostly distributed species recorded in the site are *Asparugus asparagus* and *Senegelia mellifera* (Mongana) with the same frequency of 44.4% while the least distributed is *Vachellia karoo* (Mokhaa), Andy shrub and *Rhigozum trichotomum* (Mokurubana) Table 3.3 .

Table 3. 3: Density, Species composition and Frequency of woody trees and shrubs (<2m height) found near the kraals

Species name	Setswana name	Density ind/ha	Species composition	Frequency%
Vachellia erioloba	Mokala	22.2	8.3	33.3
Senegalia mellifera	Mongana	47.2	17.7	44.4
Vachellia karoo	Mokhaa	2.8	1.0	11.1
Grevia flava	Moretlwa	13.9	5.2	22.2
Rhigozum trichotomum	Mokurubana	41.7	15.6	44.4
Boscia albitrunca	Motlopi	2.8	1.0	11.1
	Andy shrub	5.6	2.1	22.2
Rhus tenuinervis	Rhus	44.4	16.7	33.3
Asparugus asparugus	Asparagus	66.7	25.0	44.4
Rhigozum brivasponosum	Rhibri	19.4	7.3	11.1
	TOTAL	266.7		

3.8.2.2: Distribution and abundance of woody trees and shrubs found mid way from the kraals

Among the ten species found in the field, the *Unknwon shrub* has the highest density of 136.1 individuals/ha (Table 3.4) followed by the *Asparugus asparugus* with density of 72.2 individuals/ha while the least abundant are the *Vachellia haematoxylon (*Mokholo) and *Ehretis spp* (Morobe*)* both with recorded density of 2.8 individuals/ha. The total density covered by all trees found in the field is 347.2 individuals/ha with most of the species rare (<20individuals/ha), *Vachellia erioloba* (Mokala), *Senegalia mellifera* (Mongana), *Grevia flava* (Moretlwa), Andy shrub and *Rhus tenuinervis*.

On the other hand, the most distributed trees recorded is found among the Unknow species and the least among the *Vachellia haematoxylon (*Mokholo) and *Ehretis spp (*Morobe) with frequency of 435.6% and 8.9% respectively (Table 3.4).

Table 3. 4 Density, Species composition and Frequency of woody trees and shrubs (<2m height) mid way from the kraals

Species name	Setswana name	Density ind/ha	Species composition	Frequency%
Vachellia erioloba	Mokala	8.3	2.4	26.7
Senegalia mellifera	Mongana	5.6	1.6	17.8
Vachellia haematoxylon	Mokholo	2.8	0.8	8.9
Grevia flava	Moretlwa	16.7	4.8	53.3
Rhigozum trichotomum	Mokurubana	61.1	17.6	195.6
	Andy shrub	19.4	5.6	62.2
Unknown shrub	Unknown shrub	136.1	39.2	435.6
Rhus tenuinervis	Rhus	8.3	2.4	26.7
Asparugus asparugus	Asparagus	72.2	20.8	231.1
Ehretis spp	Morobe	2.8	0.8	8.9
	TOTAL	347.2		

3.8.2.3: Distribution and abundance of trees and shrubs far from the kraals

There are eight tree species found in the field covering total density of 410 individuals/ha. Among these species, *Rhigozum trichotomum (*Mokurubana) is the most abundant with density of 160 individuals/ha (Table 3.5) and the least abundant is *Boscia albitrunca (*Motlopi*)* which recorded density of 10 individuals/ha.

The most distributed species is *Asparugus asparagus* while the least distributed is the Unknown species and *Rhigozum brivasponosum* which recorded frequency of 60% and 20% respectively (Table 3.5). Most of the species are highly distributed (>40%) and these are *Rhigozum trichotomum* (Mokurubana), *Boscia albitrunca* (Motlopi), Andy shrub and *Rhus tenuinervis.*

Table 3. 5: Density, Species composition and Frequency of woody trees and shrubs (<2m height) far from the kraals

Species name	Field name	Density ind/ha	Species composition	Frequency%
Senegalia mellifera	Mongana	45.0	11.0	0.0
Rhigozum trichotomum	Mokurubana	160.0	39.0	40.0
Boscia albitrunca	Motlopi	10.0	2.4	40.0
	Andy shrub	15.0	3.7	40.0
Unknown shrub	Unknown shrub	20.0	4.9	20.0
Rhus tenuinervis	Rhus	20.0	4.9	40.0
Asparugus asparugus	Asparagus	105.0	25.6	60.0
Rhigozum brivasponosum	Rhibri	35.0	8.5	20.0
	TOTAL	410		

3.8.3. Distribution and abundance of woody plants with height of more than two meters

3.8.3.1: Distribution and abundance of woody plants found near the kraals

Woody plant species recorded in the field are *Vachellia erioloba* (Mokala), *Senegalia mellifera* (Mongana) and *Vachellia haematoxylon* (Mokholo). The total density covered by these species is 55.6 individuals/ha with *Vachellia erioloba* (Mokala) being the most abundant and *Vachellia haematoxylon* (Mokholo) being the least abundant with density of 27.8 individual/ha and 11.1 individual/ha respectively (table 3.6). All three species recorded in these quadrats; hence they need attention when developing the project.

Similarly, the distribution of these woody species is highest among the *Vachellia erioloba* (Mokala) while the least is *haematoxylon* (Mokholo) with frequency of 555.6% and 222.2% respectively (Table 3.6).

Table 3. 6: Density, Species composition and Frequency of woody trees (>2m height near the kraals

Species name	Field name	Density ind/ha	Species composition	Frequency%
Vachellia erioloba	Mokala	27.8	50.0	555.6
Senegalia mellifera	Mongana	16.7	30.0	333.3
Vachellia haematoxylon	Mokholo	11.1	20.0	222.2
	TOTAL	55.6		

3.8.3.2: Distribution and abundance of woody plants found mid way from the kraals

The three woody species found in the field are *Vachellia erioloba* (Mokala), *Senegalia mellifera* (Mongana) and *Vachellia karoo* (Mokhaa). The total density covered by these species is 50 individuals/ha with *Vachellia erioloba* (Mokala) being the most abundant at 22.2 individual/ha and *Vachellia karoo* (Mokhaa) being the least abundant at 11.1 individuals/ha (Table 3.7). Nonetheless, all these woody species are rare (<25 individuals/ha) and need to be preserved.

Similarly, the most highly distributed woody species is the *Vachellia erioloba* (Mokala) while the least distributed is the *Vachellia karoo* (Mokhaa) with frequency of 44.4% and 11.1% respectively (Table 3.7).

Table 3. 7: Density, Species composition and Frequency of woody trees (>2m height) mid way from the kraals

Species name	Field name	Density ind/ha	Species composition	Frequency%
Vachellia erioloba	Mokala	22.2	44.4	44.4
Senegalia mellifera	Mongana	16.7	33.3	22.2
Vachellia karoo	Mokhaa	11.1	22.2	11.1
	TOTAL	50		

3.8.3.3 Disribution and abundance of woody plntas far from the kraals.

Only three woody species are found in the field and are *Vachellia erioloba* (Mokala), *Senegalia mellifera* (Mongana) and *Terminalia sericea* (Mogonono). The total density covered by these species is 45 individuals/ha with *Vachellia erioloba* (Mokala) being the most abundant at 15 individual/ha and *Terminalia sericea* (Mogonono) being the least abundant at 11.1 individuals/ha (Table 3.8). Nonetheless, all these woody species are rare (<25 individuals/ha) and need attention in order to protect.

The most highly distributed woody species is *Senegalia mellifera* (Mongana) while the least distributed are *Terminalia sericea* (Mogonono) and *Vachellia erioloba (*Mokala) with frequency of 40% and 20% respectively (Table 3.8).

Table 3. 8 Density, Species composition and Frequency of woody trees (>2m height) far from the kraals

Species name	Field name	Density ind/ha	Species composition	Frequency%
Vachellia erioloba	Mokala	15	33.3	20
Senegalia mellifera	Mongana	25	55.6	40
Terminalia sericea	Mogonono	5	11.1	20
	TOTAL	45		

3.8.4. Diversity, evenness and species richness of woody plants and shrubs recorded in the proposed site during the field work.

Woody plants and shrubs' diversity and evenness are recorded in table 4.1. Both records were taken with regard to the plants' distance from the kraals (Near, Mid way and Far). The trees were categorized as Trees and shrubs <2m and Woody plants>2m.

The records indicate that diversity is slightly high in trees and shrubs near the kraals, 1.97 and decreases to 1.67 as the distance from the kraals increases (Far). Contrarily, diversity of woody plants was recorded higher mid-way from the kraals and the least far away from the kraals at 1.06 and 0.94, respectively (Table 3.9).

Evenness of the plants from categories is consistent through out the field regardless of the distance from the kraals ranging from 0.73-0.86 among trees and shrubs <2m and 0.85-0.97 among woody plants >2m (Table 3.9). The range of the tree evenness is very low indicating that there is need to protect the tree vegetation found in the field.

Table 3. 9: Diversity, evenness and Species richness of woody trees recorded during field work

	Trees and shrubs <2m			Woody plants >2m		
	Diversity	**Evenness**	**Spp richness**	**Diversity**	**Evenness**	**Spprichness**
Near kraal	1.97	0.86	10	1.03	0.94	3
Mid way from kraal	1.76	0.73	11	1.06	0.97	3
Far from kraals	1.67	0.86	7	0.94	0.85	3

3.9 Discussion

The results obtained from this study has revealed that quite a number of species are shrubs with height of less than two meters with density as high as 410 individuals per hacter(Table 3.2) and high frequency of more 400 percent (Table 3.4). Most of these shrubs are xerophytes and are able to thrive under hot climatic conditions as they possess drought-resistant qualities. The presence of chlorophyl in their outer tissue found in their skin and stems assist them to photosynthesise food, while their small leaves, waxy skin and spines minimise moiture loss and the deep root system allows them to access deep under ground water hence survive the unfavourable weather conditions.

Tree species density is noticed to be high in short trees (<2m) as compared to tall trees (<2m) and this could be due to high species richness which is noticed in short trees. This observation is in agreement with findings by Menaut, *et. al.,* (1995), who indicated that high species richness is an attribute of habitat heterogeneity which increases tree diversity of woodlands and savannas in Africa. Species richness and diversity differ significantly from place to place due to variations in habitats, biogeography, competition and disturbances (Kacholi, 2019). The most frequent trees found in the area are among others Asparugus *asparagus*, *Rhigozum trichotomum, Rhus tenuinervis* and *Senegelia mellifera*. It has been observed that species richness decreases as one moves further from the kraals and this could be an attribute of animals grazing intensity which is found to be more nearer the kraals. There are other factors that determine tree species richness in semi-arid savanna ecosystems and these include moisture, soil characteristics, landscape position and species-specific growth requirements (Hall, *et. al*., 2020). Soil fauna also influences the spatial distribution of trees. (Ettema, *et. al*., 2002).

Similarly, species diversity is also high in short trees ranging from 1.67-1.97 which is within Shannon-Wiener diversity index but lower in tall trees ranging from 0.94-1.06 (Table 3.9). However, the species evenness of the trees is observed to be homogeneous across all species regardless of the height. Woody trees abundance has been found to decrease from 55.6 individual/hacter (Table 3.6) to 45 individual/hacter (Table 3.8) as the distance from the kraals increases with *Vachellia erioloba* dominating at a decreasing rate from near the kraals to far away from the kraals. On the other hand, species composition is generally low ranging from moderate (50%) as shown in table 3.6 to as low as 11.1% (Table 3.8) towards the far end of the paddock and this is supported by Moleele and Perkins (1998), who noted that overgrazing influences tree biodiversity. The decline in species composition as the distance increases from the kraals may be due to the fact that goats browse more near up to mid-way from the kraals as they can’t walk long distances of more 5 kilometres.

Interestingly, species composition among tall woody trees showed no trend as observed in *Vachellia erioloba* decreasing from 50% near the kraals (Table 3.6) to 33.3% far from the kraals

(Table 3.8) while the opposite was observed in *Senegelia mellifera* which is increasing from 30% near the kraals (Table 3.6) to 55.6% far from the kraals (Table 3.8). This indication might be due to species preference by the animals, in this case the goats were browsing more of *Vachellia erioloba* and enjoying its pods as compared to *Senegelia mellifera* because of its high palatability. However, it is very important to appreciate that species diversity among the tall woody species is minimal hence the need to conserve them. The loss of forest area endangers not only livelihood of people who depend on the forests for socio-cultural, ecological and economic services, but also it affects the forest composition, structure and regeneration of trees as well as existing biodiversity (Kacholi, 2019).

3.10 Conclusion

Mean density was high in woody trees and shrubs less than two meters in height across the ranch as compared to those more than two meters in height. However, species composition was more in woody trees and shrubs more than two meters in height as compared to those less than two meters in height in the ranch. The distribution of trees with height more than two meters was decreasing as the distance from the kraals increases while with trees less than two meters high, the distribution was more near the kraals but decreases mid way from the kraals and ultimately increased as the distance from the kraals increased. Woody trees and shrubs less than two meters in height showed higher species richness and diversity as compared to those less than two meters but a slight difference was noticed with their evenness which was a bit more in tall trees as compared to short ones.

3.11 Recommendation

Timely research and study on distribution and abundance of woody trees and shrubs at Lobu ranch should be conducted. This should include the update on the current conservation status of the available species as well as the endangered and red list species data bases.

Last but not least, the study recommends the reduction of human activities that put pressure towards the reserve by prohibiting or planning for controlled harvest and grazing.

Chapter 4

NUTRITIONAL COMPOSITION OF COMMON FORAGE SPECIES IN THE RANCH.

Abstract

Pasture, forbs, and browse are usually the primary and most economical source of nutrients for sheep and goats. Trees and shrubs, which often represent poor quality roughage sources for cattle, because of their highly lignified stems and bitter taste, may be adequate to high in quality for goats. Adequate knowledge on nutritional quality of forage utilized by the goats at the Lobu Ranch is lacking. Therefore, the objective of this study is to determine nutritional content of composite samples obtained from forage species which are consumed by the goats during the late wet season to the early dry season. The study is an experimental design where the samples were analyzed in the laboratory using appropriate methods for various nutritive measures. AOAC, 1996 was used to determine DM, OM and CP contents; ANKO, 1998a was used to determined Ash, Gross energy, NDF, ADF, ADL and IVDMD and Atomic Absorption Flame Emission Spectrophotometer used to determine the macro and micro nutrients level. Significant differences ($P<0.05$) in chemical composition were observed during the late wet and early dry season with a consistent increase of DM content at the beginning of the dry season recording 94.5% May and 99.16% in August. OM was low during the late wet season recording 88.55% and increased as the dry season approaches recording 89.15-92.45. The ash content was higher ranging from 7.735-11.846% as compared to the results obtained in a study done by Klašnja, *et. al*., 2013). Crude Protein content was ranging from 8.246-8.925% which is lower than the recommended nutritional requirement of 16% (Alokan, 2008). There was an increase in ADF, NDF and ADL content with the dry season recording 32.45%,45.59% and 4.42% in May and 33.38%, 49.38% and 4.44% in August respectively. On the other hand, a drastical decrease in fat content was noticed, in May it was 9.53% and 7.67% in August while gross energy was low during the late wet season and increases to 18.53% as the dry season approaches and ultimately dropped again towards the end of dry season to 16.87%. There was variance in percentage level of IVDMD which ranges from 29.22-45.833. In macro nutrients only the K and N showed significant difference ($P<0.05$), K content was low during the late wet season recording 0.99% but later increased at the end of the dry season to 1.06% while N was high during the late wet season recording 1.42% and slightly decreased at the end of the dry season to 1.32% . In terms of micro nutrients, only Fe was noticed to be significantly different ($P<0.05$) increasing from 104.53-235.64ppm. Generally, the obtained results were too high ranging from 235.64ppm -104.53ppm as compared to the acceptable quantities required for growth of goats (30-50ppm) and this compromised the optimal weight gain of the animals during the seasons of study (Alokan, 2008).

4.1 Introduction

Goats are well known as efficient browsers and prefer picking brushy plants along with some other woody and weedy plants while feeding on ranges. The nutrient requirements of goats are determined by age, sex, breed, production system (dairy or meat), body size, climate and physiological stage. Feeding strategies should be able to meet energy, protein, mineral, and vitamin needs depending on the condition of the goats. The daily feed intake of goat ranges from 3-4% of body weight as expressed in pounds (dry matter/head/day). The daily feed intake is influenced by body weight, percentage of dry matter in the feeds eaten (12-35% in forages, 86-92% in hays and concentrates), palatability and physiological stage of the goats (Rashid, 2008). As farmers, it is very important to know the essential nutrients required by goats and their roles in growth, production and reproduction (Yan, *et. al*., 2018). The biological qualities of a feed have much greater meaning in predicting the productive response of animals. However, they are more difficult to precisely determine because there is an interaction between the chemical composition of the feed and the digestive and metabolic capabilities of the animal being fed (Stanton, *et. al*., 2010).
Plant analysis is the quantitative determination of the elements in plant tissue. Plant analysis is quite different from other crop diagnostic tests in that it gives a comprehensive picture of the nutrient levels within the plant at the time the sample was taken. It's use is based on the concept that the nutrient level present is a result of all factors affecting the growth of the plant. Plant analysis has proven convenient in confirming nutrient deficiencies, toxicities or imbalances, identifying "hidden hunger," evaluating fertilizer programs, determining the availability of elements not tested for by other methods, and studying interactions among nutrients. (Schulte and Kelling, 2004). Small ruminants require energy, protein, vitamins, minerals, fibre and water. Energy (calories) is usually the most limiting nutrient, whereas protein is the most expensive. Deficiencies, excesses, and imbalances of vitamins and minerals can restrict animal performance and lead to various health problems. Water is the cheapest feed ingredient, yet often the most neglected (www.uaex.uada.edu). Fibre (bulk) is required to maintain a healthy rumen environment and prevent digestive upsets. The two types of fiber which are normally found in animal feed are Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF). ADF is highly related to digestibility in the animal. NDF is related to voluntary intake of the feed and the availability of net energy from digestible energy. Both measures relate more directly to previse animal performance (Stanton, *et. al.,* 2010).

The goat is not able to digest the cell walls of plants as well as the cow because feed stays in its rumen for a shorter time period. A discrepancy as to what is meant by "poor quality roughage" is necessary in order to make resolutions concerning which animal can best utilize a particular forage. Trees and shrubs, which often represent poor quality roughage sources for cattle, because of their highly lignified stems and bitter taste, may be adequate to high in quality for goats (Luginbuhl, 2006). Under extensive pasture or range conditions, animal activity will increase even more and it may be necessary to increase the maintenance level by 50% to 75% (Rayburn, *et. al*., 2013).

Pasture, forbs, and browse are usually the primary and most economical source of nutrients for sheep and goats, and in some cases, pasture is all small ruminants require to meet their nutritional needs. Pasture tends to be high in energy and protein when it is in a vegetative state. However, it can have high moisture content, and sometimes it may be difficult for high-producing animals to eat enough grass to meet their nutrient requirements. As pasture plants mature, palatability and digestibility decrease, thus it is necessary to rotate pastures to keep plants in a vegetative state. During the early part of the grazing season, browse (woody plants, vines and brush) and forbs (weeds) tend to be higher in protein and energy than ordinary pasture (Simbaya, 2002).

Lobu ranch is characterized by a variety of vegetation species which are mainly woody trees, shrubs, grasses, and some forbs. However, there is a lack of adequate knowledge on the nutritional quality of these forage species which are utilized by the animals at the Lobu Ranch.

4.1.1 Essential nutrients required by goats

Carbohydrates

Sugars, starches (found in grains) and fibre (cellulose) are the carbohydrates that transform into volatile fatty acids (energy) by rumen flora (beneficial bacteria). Normal goat diet (browse, forbs, and grasses) is high in cellulose and requires digestion by rumen flora to be converted into energy. Fresh pastures and young plants may have highly digestible fibre and provide high energy compared to older plants. Higher energy levels come from lower fibre feeds. Energy is represented as total digestible energy (%TDN). .It is advisable to maintain at least 12% crude fibre in the diet of goats. Energy requirements for different physiological stages of maintenance, pregnancy, lactation and growth vary. The maintenance requirement for energy remains the same for most goats except dairy kids; they require 21% energy higher than the average. It is important to feed high-energy rations at the time of breeding, late gestation and lactation (Silanikove, 2000).

Proteins

Proteins are digested and broken down into amino acids and are eventually absorbed in the small intestine. Those amino acids are building blocks for body proteins (muscles). The rumen plays a major role in breaking down consumed protein into bacterial protein through bacterial fermentation. Feeds like forages, hays, pellets (alfalfa), barley, peas (screenings, whole, split), corn, oats, distilled grains and meals (soybean, canola, cottonseed meals) are common sources of protein for goat rationing. The protein requirements are higher during growth (kids), milk synthesis (lactation), and mohair growth. Producers may need to supplement protein sometimes during the year, especially in late fall or winter (Silanikove, 2000).

Minerals

Requirements for minerals have not been established definitively for goats at either maintenance or production levels. Research has been conducted with goats in mineral metabolism studies, especially with calcium and phosphorus. In general, these data support assumptions that several mineral requirements for goats are similar to those for sheep (Pugh, 2020). Minerals can be classified as macro and micro minerals. Calcium, phosphorus, magnesium, sodium, potassium, sulfur and chlorides are a few of the microminerals needed in a goat's diet. Microminerals usually supplemented in goat rations are iron, copper, cobalt, manganese, zinc, iodine, selenium, molybdenum, and others. Feed tags report microminerals as parts per million (ppm) and microminerals on a percentage basis. Feeding of calcium and phosphorus (2:1 ratio) is recommended for better structural and bone strength, while other minerals are necessary for other systems like nervous and reproductive. Minerals should be added into the feed keeping in mind the quality of forages as some forages can be high in some of the minerals and low in others. It is important to feed enough copper (10-80 ppm) to goats as they have a tendency to be copper deficient. High levels of molybdenum in a goat's diet can easily offset the copper levels in the body. Goats are not sensitive to copper, whereas in sheep even 20 ppm of copper can be very toxic. Selenium (0.1-3 ppm) is another mineral required for goats. The addition of specific minerals such as phosphorus for dry winter forages and selenium in deficient areas to salt (NaCl), preferably in granular form and offered free choice has been found to assist in prevention of most mineral deficiencies and improves performance (Pugh, 2020).

Calcium requirements are generally met under grazing conditions with either Angora or meat-type goats, but levels should be checked in high-producing dairy goats because (Grass: less than 0.5%; legumes: more than 1.2%), so calcium is low only if high grain diets are fed, which would be unusual for goats. **Phosphorus** deficiency results in slowed growth, unthrifty appearance, and occasionally a depraved appetite. The calcium: phosphorus ratio should be maintained between 1:1 and 2:1, preferably 1.2–1.5:1 in goats because of their predisposition for urinary calculi. Phosphorus deficiency in grazing goats is more likely than a calcium deficiency. In cases of struvite calculi, the ratio should be maintained at 2:1.

Magnesium deficiency is associated with hypomagnesemic tetany (grass tetany), but ordinarily this condition is less common in grazing goats than it is in cattle. Goats do have marginal ability to compensate for low magnesium by decreasing the amount of magnesium they excrete. Both urinary excretion and milk production are reduced in a magnesium deficiency. **Salt** (NaCl) is usually recognized as a necessary dietary component but is often forgotten. Goats may consume more salt than is required when it is offered ad lib; this does not present a nutritional problem but may depress feed and water intakes in some arid areas where salt content of the drinking water is quite high. Salt formulations are used as carriers for trace minerals, because goats have a clear drive for sodium intake.

Potassium has an important role in metabolism. However, forages generally are quite rich in potassium, so a deficiency in grazing goats is extremely rare. Marginal potassium intake is seen only in heavily lactating does fed diets composed predominately of cereal grains. **Iron** deficiency is seldom seen in mature grazing goats. Such deficiency might be seen in young kids because of their minimal stores at birth, plus the low iron content of the dam's milk. Iron deficiency can be prevented by access to pasture or a good quality trace mineral salt containing iron.

Iodine Conditional iodine deficiency may develop with normal to marginal iodine intake in goats consuming goitrogenous plants (plants that contribute to nitrogen fixation). Marked deficiency of iodine results in an enlarged thyroid; poor growth; small, weak kids at birth; and poor reproductive ability. **Zinc** deficiency results in parakeratosis, stiffness of joints, smaller testicles, and lowered libido. A minimal level of 10 ppm of zinc in the diet, or a trace mineral salt mixture

of 0.5%–2% zinc, prevents deficiencies. It has been found that eexcessive dietary calcium (alfalfa) may increase the likelihood of zinc deficiency in goats.

Fats

Fats can also be a source of energy for goats. Goats do consume some amount of fats while browsing. Excess energy produced by carbohydrates is stored in the form of fat especially around internal organs. The stored fat in the body is used during high energy needs, especially the lactation period. Supplying fats may not be a cost-effective idea for goat production (Rashid,2008).

Water

Goats should be provided unlimited access to fresh, clean, freely accessible water. Goats are among the most efficient of domestic animals in their use of water; however, only ~10% of body water loss may prove fatal. They appear to be less subject to high temperature stress than other species of domestic livestock but should be kept in environments that provide shade. In addition to a lesser need for body water evaporation to maintain comfort in hot climates, goats can conserve body losses of water by decreasing losses in urine and faeces. Factors affecting water intake in goats include lactation, environmental temperature, water content of forage consumed, amount of exercise, stage of production (growth, maintenance, lactation, etc), and salt and mineral content of the diet. Goats grazing lush pastures may consume much lower quantities of water than those feeding on dry hay. Still, it is imperative to allow free access to water for all goats regardless of age, breed, purpose, stage of life cycle, or environment (Silanikove, 2000).

4.1.2 Specific objectives

i. To determine nutritional quality of composite forage species samples browsed by goats within the ranch.
ii. To determine Invitro Dry matter Digestibility of forage samples browsed by the goats within the ranch.

4.2 Materials and Methods

4.2.1 Materials

i. Dried ground composite forage samples
ii. Nutrient analysis chemicals
iii.Sartorius Analytical balance (s/no. 21704518,model TE3151)
iv. Ceramic crucibles
v. Spatula
vi. Forced draft oven (s/no. 0900003502, model 221 EQ000880)
vii. Pencil and Pen
viii. Permanent markers
ix. Sample grinder (s/no. 1610251234A, model FZ102)
x. Desiccator (s/no. 1911-41A, model FA2025-0000)
xi. Muffle furnace (s/no 5300A05, model FB1415M-TS)
xii. Check samples
xiii. Lens tissue
xiv. Buchi Distillation unit (s/no. 410171010001, model ZZ000806)
xv. Gerhardt Digestion block (s/no.7440-22-4, model VW35000000)
xvi. Measuring cylinders
xvii. Heat sealant (s/no. 102558, model HS 00238F)
xviii. ANKOM^{220}Fibre analyser (s/no.8 000, model MTS-6000A)
xix. Fiber bags
xx. Extraction instrument (s/no. XT 10220132, model XT 1022)
xxii. Vaccum flask
xxiii. Rumen fluid
xxiv. ANKOM DAISY^{II} Incubator (s/no. D3163, model EQ000958)
xxvi. Filtration device
xxvii. Fibre analyser (s/no. A20000220042, model A2000I)
xxviii. Glass beakers (BIG-IP 1600, model 172.19.216.82)
xxix. Atomic Absorption Flame Emission Spectrophotometer (s/no. MY16050001, model EQ002254)

xxx. Volumetric flasks
xxxi. Brown paper bags

4.2.2 Preliminary Field visit

Site visit to Lobu ranch was done prior to commencement of data collection. During the visit, the goats were assessed and history of the goats obtained from the farm manager. This was to ensure that all relevant information concerning the goats is collected for proper selection of the stock to be used during the exercise. The most critical information recorded include among others the following:

-Identification of the breeds to be used which are the Savanna and Boer goats.
-Selection of the appropriate number of goats to be used.
-Information on date of birth of birth, weaning date and weaning weight.
-Tag/Identification numbers of the goats to be used for the exercise.

4.2.3 Research Design

This study is an experimental design with the aim of determining the nutritional quality of forage species in the paddock used by Boer and Savanna goat doelings at Lobu ranch during the late wet and early dry season. An observational study was carried out whereby the doelings were followed from 0800hrs when they leave the kraals until 1700hrs when they return to the kraals. The binoculars were used to observe what the goats were browsing/feeding on and the aim of doing so was to collect those frorage species samples for nutritional analysis and how they impacted on the performance of the doelings during the entire period of the exercise. The collected samples were put inside the brown paper bags and later sun dried at room temperature to ensure that they are stored in the correct moisture content before grinding.

4.2.4 Sampling frame and data collection procedures

During observation of the goats while browsing, only plants that were browsed by the goats were collected and put inside the brown paper bags.

The nutritive quality of forage plants collected from the field were determined by the proximate analysis method in the laboratory. The dried samples were weighed and data recorded (W1) before drying them inside the oven at 60℃ for 72hrs. The weight after drying(W2) was recorded before grinding them and the composite powder stored in a tight sealed glass bottle for chemical and nutritional analysis (proximate analysis) in the laboratory.

- The nutritive qualities determined were: Dry matter, Organ matter, Ash, Crude protein, Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL), Fat and Gross energy. The macro nutrients determined were Phosphorus, Potassium, Nitrogen, Sodium, Magnesium and Calcium while the micro nutrients were Copper, Iron, , Manganese and Zinc.

The nutritive quality of sampled forages were determined using approved methods and calculated following standard formulas:

i. Association of Official Analytical Chemists (AOAC, 1996) method was used to determine Dry Matter, Organic Matter and Crude Protein contents.
ii. The ANKOM (1998a) methods was used to determined Ash, Gross energy, Neutral Detergent Fibre, Acid Detergent Fibre, Acid Detergent Lignin and Invitro Dry Matter Digestibility (IVDMD).
iii. The blast photometer was used to determine the macro and micro nutrients level in plants samples.

4.2.5 Data Analysis

4.2.5.1 Nutritional analysis

Data consisting of initial and final weights, correctional factor and level of nutrients was recorded in tabular form in Microsoft Excel. Data for all the parameters to be analyzed was coded accordingly (using alphabets) to suit the SAS program. All tests were conducted at 95% confidence level, results were analyzed using Duncan's Multiple Range where $P>0.05$ indicates that there is no significant difference in the level of chemical percentage in a certain feed sample.

4.2.6 Statistical analysis

The experimental design was a Complete Randomized Design (CRD) and an observational study where the animals were followed from morning to evening to observe the type of species they browse. The difference among treatment means were detected using least significance difference.

Statistical model Used:

The overall nutritional composition data was analysed using a one-way analysis of variance using SAS (SAS, 2002-2012) according to the general linear model below to test effects of time (month).

$Y_{ij} = \mu + d_i + E_{ij}$

Where Y_{ij} = response variable (chemical composition), μ = general mean, d_i = the fixed effects of time, E_{ij} = random error associated with observation $_{ij}$ = assumed to be normally and independently distributed. The level of significance was set at $p < 0.05$.

Analysis of variance was carried out on chemical composition and IVDMD using General Linear Model procedure of Statistical Analysis System (SAS, 2001). Species, season and their interactions were the independent variables while DM, OM, ash, CP, NDF, ADF, ADL, Fat, Gross Energy and IVDMD were the dependent variables.

4.2.7 Results

4.2.7.1 Nutritional analysis of composite forage species samples browsed by goats within the ranch.

There is a significant difference in the percentage level of all the parameters that were analysed during the late wet and early dry seson within the ranch (P<0.05). This imples that there was a great heterogeneity in chemical content of the feed. Fat content decreases with time as the dry season increases (Table 4.1). Nonetheless, Acid Detergent Lignin is a bit high in May and August when plants are affected by the dry wind and eventually drops in mid-winter (June-July) when plants lose most of the waxes due to intense winter temperatures.The Dry Matter Content increases while the Crude Protein decreases as the dry season increases. A slight significant difference was noticed in Organic Matter and Ash Content throughout the months of the dry season. The Gross Energy level increases in mid-winter but seems to be low at the beginning and towards the end of the season.

Table 4. 1: Percentage level of nutritional analysis of composite feed browsed by the goats consisting of common forage species within the ranch.

Level of Trt	N	DM	OM	ASH	CP	NDF	ADF	ADL	FAT	GROSS ENERGY
May	2	94.505[c]	88.55[b]	11.846[a]	8.866[b]	45.593[b]	32.345[a]	4.422[a]	9.531[a]	16.803[b]
June	2	97.336[b]	92.45[a]	7.735[a]	8.925[a]	43.572[bc]	32.3[a]	2.183[a]	9.788[a]	18.531[a]
July	2	99.159[a]	89.15[ab]	10.939[ab]	8.561[c]	41.399[c]	32.417[a]	3.041[a]	8.236[a]	18.31[a]
August	2	97.516[b]	89.2[ab]	11.022[a]	8.246[d]	49.378[a]	33.384[a]	4.439[a]	7.672[a]	16.869[b]
SEM		**7.672**	**0.46**	**0.46**	**0.05**	**0.51**	**2.65**	**0.13**	**0.66**	**0.54**

The test used is the Duncan's Multiple Range

[abcd] Means with the same letter are not significantly different at P>0.05

DM=Dry Matter; OM=Organic Matter; CP=Crude Protein; NDF=Neutral detergent Fiber; ADF=Acid Detergent Fiber; ADL= Acid Detergent Lignin; GE= Gross Energy; SEM=Standard Error of the Mean

4.2.7.2 Level of macro nutrients in composite forage species samples browsed by the goats within the ranch.

The results on table 4.2 show that there is no significant difference in percentage nutritional level of Phosphorus, Calcium, Sodium and Magnesium; ($P>0.05$) during the time of sample collection while the Nitrogen level shows a significant difference of a decrease (Figure 4.2) as the moisture content and ether extracts decreases in the plants ($P<0.05$). There is a significant difference noticed with Potassium content ($P<0.05$) as shown in figure 4.2.

Table 4. 2: Percentage level of macro nutrients in common forage species browsed by the goats during the late wet and early dry season.

Level of TrT	No.	P	Ca	K	N	Na	Mg
May	2	0.17	1.46	0.99[b]	1.42[b]	0.04	0.05
June	2	0.16	1.6	1.03[a]	1.43[a]	0.05	0.57
July	2	0.15	1.62	0.93[c]	1.37[c]	0.05	0.58
August	2	0.11	1.28	1.06[a]	1.32[d]	0.05	0.60
SEM		**0.0142**	**0.0083**	**0.1848**	**0.0001**	**0.0001**	**0.03**

The test used is the Duncan's Multiple Range

[abcd] Means with the same letter are not significantly different; P>0.05

P=Phosphorus; Ca=Calcium; K= Potassium, N=Nitrogen, Na= Sodium, Mg= Magnesium

SEM=Standard Error of the Mean

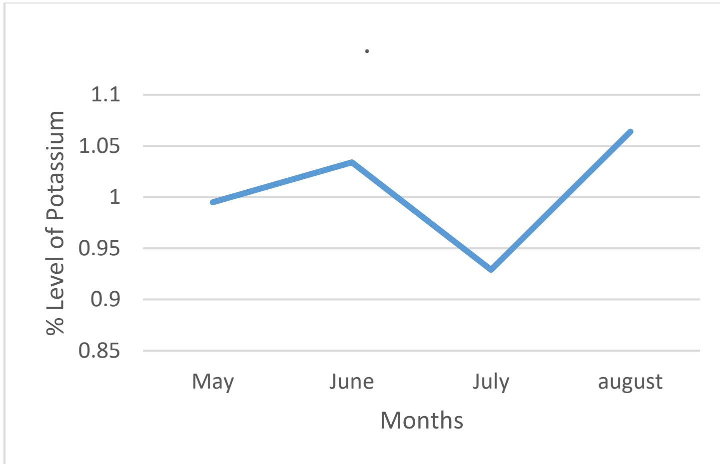


Figure 4. 1: Potassium Content Level Recorded in Percentages In Common Forage Species Browsed by the Goats During the Late Wet and early Dry Season

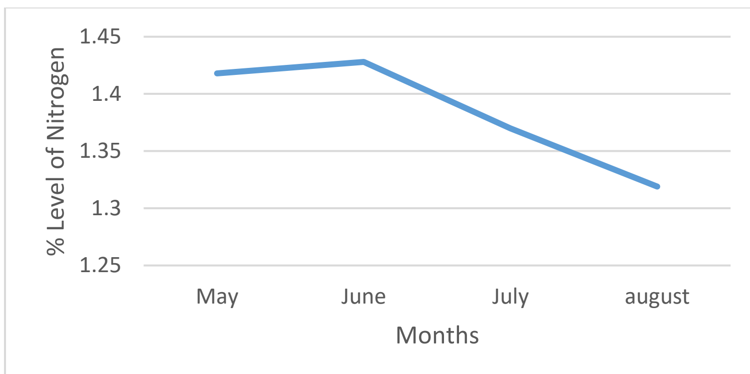


Figure 4. 2: Nitrogen Content Level Recorded in Percentages In Common Forage Species Browsed by the Goats During the Late Wet and early Dry Season.

4.3.7.3 Level of micro nutrients in composite forage species samples browsed by the goats within the ranch.

The micro nutrients show some homogeneity in nutritional level recorded in parts per million ($P>0.05$) as shown in Table 4.3. Though the recorded data shows a bit of increase in the nutritional level of Copper, Zinc, Sodium and Manganese the Duncan's test interprets otherwise that there is no significant difference through-out the seasons of sample collection. The content of iron in trees and shrubs shows a positive increase (Figure 4.3) as the dry season increases though at the beginning of the dry season there seems to be a consistent level($P<0.05$).

Table 4. 3: Nutritional level of micro nutrients of common forage species browsed by the goats during the late wet and early dry seasons measured in parts per million.

Level of Treatment	No.	Cu	Fe	Zn	Mn
May	**2**	4.69	106.52[ab]	20.48	43.34
June	**2**	4.99	104.53[b]	23.86	55.56
July	**2**	6.05	164.98[ab]	24.69	70.27
August	**2**	7.28	235.64[a]	33.31	96.67
SEM		**0.728**	**40.834**	**42.533**	**3.202**

The test used is the Duncan's Multiple Range
[ab] Means with the same letter are not significantly different; P>0.05
Cu=Copper; Fe=Iron; Zn=zinc; Mn= Manganese
SEM=Standard Error of the Mean

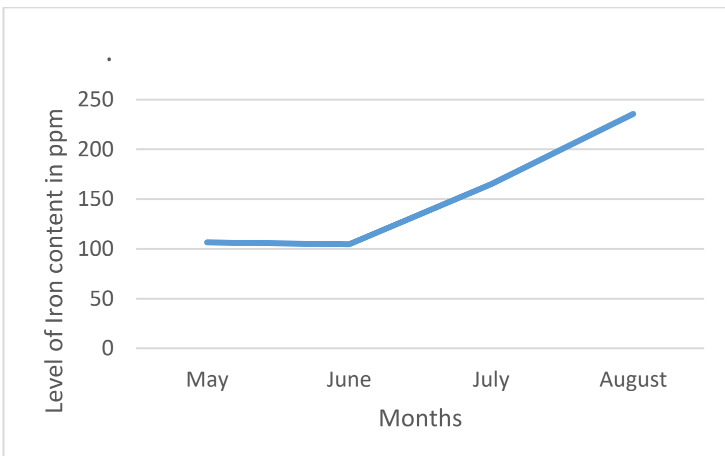


Figure 4. 3*: Iron Content Level Recorded In Parts Per Million for Common Forage Species Browsed by the Goats During the Late Wet and Early Dry Seasons*

4.3.7.4 Invitro Dry matter Digestibility of forage samples browsed by the goats within the ranch.

The Invitro Dry Matter Digestibility (IVDMD) of the plants decreases with time as the dry season increases ($P<0.05$), implying that there is a difference in digestibility due to an increase in dry matter in plants as the dry season increases. The recorded data on table 4.4 indicates that more feed constituents are absorbed by the animals' body at the beginning of the dry season and decreases as the dry season increases. This trend is also observed as the time of digestion increases, hence could be concluded that in this study IVDMD is highly influenced by the seasons and incubation time taken by feed in the animal's rumen.

Table 4. 4: Percentage mean level Of IVDMD in forage samples browsed by the goats per month during the late wet and early dry seasons.

Level of Treatment	N	3hrs	6hrs	9hrs	12hrs	24hrs	48hrs	72hrs	SEM
May	**2**	40^{b}	45.833^{a}	41.154^{b}	42.456^{b}	39.961^{b}	42.113^{b}	31.61^{c}	**0.844**
June	**2**	36.979^{ab}	41.429^{a}	35.318^{ab}	31.302^{b}	35.189^{ab}	36.706^{ab}	30.693^{b}	**2.9327**
July	**2**	36.516^{ab}	38.34^{a}	36.159^{ab}	36.653^{ab}	33.401^{bc}	36.927^{ab}	29.429^{c}	**1.2875**
August	**2**	37.572^{ab}	40.717^{a}	30.749^{bc}	37.973^{a}	36.577^{ab}	36.927^{ab}	29.222^{c}	**2.0441**

The test used is the Duncan's Multiple Range

^{abc} Means with the same letter are not significantly different; P>0.05

SEM=Standard Error of the Mean

4.3 DISCUSSION

4.3.1 Nutritional composition of forage browse species browsed by the goats within the ranch.

Browse plants remain the principal source of feed during the period of scarcity because they are capable of surviving and retaining most of their nutritional value during the dry season in most arid and semi-arid regions. This qualifies them to be the main source of feed for small stock as they are easily accessible to farmers in communal areas who are financially constrained to buy commercial feeds. The browse species are diverse and have various fodder components which include leaves (green/brown), twigs, flowers, pods and fruits of which have a much longer period of availability throughout the seasons. Significant differences in chemical composition have been observed during the late wet and early dry seasons (Table 4.1) with a consistent increase noticed in Dry Matter in which there was an increase from the month of May which recorded 94.5% to June and July which recorded and increses of 97.336 and 99.159% respectively, while the Organic Matter was noticed to have inconsistent increase through out the months of sample collection. In this study it was revealed that the ash content was higher during late the late wet season and the end of early dry season with high percentages of 11.846 and 11.022 respectively while a decrease was noticed during the early dry season with the month June at 7.735% and July with 10.939% (Table 4.1) and this is in contast with the results obtained in studies done by Klasnja, *et. al*., (2013) and Marius, *et. al*., (2021) who noticed slightly lower results. This could be as a result of the high Dry Matter accumulation in this study. Therefore, the high ash content found in these species gives an overall representation of the Organic Matter present in the feed material that is essential for improving livestock growth performance (Hassen, 2015).

Seasonal change is very important in the overall availability of forage for animal consumption, especially during the months when plant growth is less active. Plant growth tends to be slower in the winter season because of the negative effect of low ambient temperatures on growth (Hassen, *et. al.*, 2007), thus low rainfall (a limiting factor) and other climatic conditions impose additional constrains for the process of photosynthesis to take place, therefore less forage yield is produced and Crude Protein content is likely to be lower. However, in this study the crude protein results were optimal through out the late wet season and the early dry season (Table 4.1). During the months of May and June a percentage of 8.866 and 8.925 were recorded with respect to these months and a significant slight decrease in the months of July and August recording 8.561% and 8.246% respectively. These results are in agreement with Nigatu, *et. al.,* 2010 who noted that the minimum Crude Protein content of the browse species at 7–8% DM which is required for optimum rumen function and feed intake in ruminant livestock. Contrarily, this was not the case in the study performed by Lee (2018) with the aim of comparing nutritive value of forage plants where the value of Crude Protein was as high as 15%. The results for Acid Detergent Fiber obtained in this study (Table 4.1) were comparable to the ones reported by Lee, 2018 which were both ranging around 32%. In this study, ADF was recorded to be lower in May and June recording 32.345% and 32.300% and a significant increase in July and August recording 32.417% and 33.384% respectively. However, there was a difference with the results for Neutral Detergent Fiber (Table 4.1) where a higher percentage of 45.593 was noticed in May and a significant decrease observed as the dry season approaches where 43.572 and 41.399% was recorded in June and July respectively and the highest percentage of 49.378 recorded towards the end of early dry season (August). A similar trend was also noticed with the Acid Detergent Lignin which recorded a high percentage of 4.422 as the wet season comes to an end and eventually drops to 2.183% and 3.041% in June and July respectively where the early dry season begins and gradually increases towards the end of the dry season in August recorcording the highest percentage of 4.439. this is in agreement with Lee (2018) where NDF was at around 57% and ADL at 6% during the dry season. Generally, the NDF concentration in winter is higher than summer because of the high intensity of solar radiation and the less amount of rainfall caused faster maturation during the winter season, of which it resulted in higher cell wall contents than those in the summer season (Aruwayo & Adeleke, 2019). Interestingly, the obtained results for NDF concentration in this study is much higher than the ones recommended by Van Saun (2006).

4.3.2 Nutritional Analysis for minerals in forage browse species browsed by the goats within the ranch.

Nutritional analysis was also performed for both macro and micro nutrients in the feed samples and recorded in percentages and parts per million, respectively. In the results obtained in macro nutrients analysis, there was no variation($P>0.05$) noticed in Phosphorus, Sodium, Magnesium and Calcium level but not the case with Potassium and Nitrogen (Table 4.2). The Phosphorus level was decreasing gradually as the dry season advances recording 0.17, 0.16, 0.15 and 0.11% from May, June, July and August respectively while the acceptable percentage ranges from 0.25-0.5% and this could have an impact on the performance of the goats hence the need for supplementation at this time of the year. Interestingly, the calcium content in this study is acceptable which recorded 1.46, 1.60, 1.62 and 1.28 percent in May, June, July and August respectively (Table 4.2) and these results are within the acceptable range of 0.2-1.5% (Alokan, 2008). This indicates that the Calcium content is quite good in the browse species consumed by the animals during the lat wet and early dry season. The level of Potassium and Nitrogen are a bit impressive showing an increase from early wet season with K recording 0.99% to a high perecentage of 1.06 as the dry season advances and both results showing a positive correlation with the study performed by Hart (2011).

In the results obtained for micro nutrients (Table 4.3), the difference ($P<0.05$) was noticed in Iron content while the rest showed no variation ($P>0.05$) throughout the late wet season and early winter season. The iron content recorded an increase from 106.52ppm as the late wet season ceases and quite a significant increase of 164.98 and 235.64ppm during the months of July and August respectively in the early dry season which is in agreement with the ones obtained by Hart (2011) which ranges between 50-250ppm. Similarly, the rest of the micro nutrients were also in line with the researcher though had no variation. Overall, it should be noted that the nutritional level of range plants is largely influenced by the soil nutritional status which in this study could have played a major role as the soil in this area is sandy hence leaching of nutrients is highly experienced.

Mineral requirements of goats is dependent on the stage and level of production, age, and season. minerals are essential for normal physiological function and body system development. deficiencies in minerals can lead to poor performance, health issues as well as physiological function disruption. Several studies (Pereira, *et. al.,* 2019 and Teixeira, *et. al*., 2015) indicate that mineral deposition is reduced as weight gain proceeds due to increased fat deposition and reduced deposition of bone and muscle tissue. Minerals are required by animals in smaller quantities, with essential macro minerals required at 0.1% or more in the diet (Freer, 2007) and the research from the NRC, 1985 came up with standard daily macro mineral requirements perecntage ranges of 0.09-0.018, 0.20-0.82, 0.16-0.38, 0.12-0.18 and 0.50-0.80 for Na, Ca, P, Mg and K respectively. In this study the percentages of all macro minerals recorded were more than the stipulated percentage requirement. The recorded percentage ranges were 0.11-0.17, 1.28-1.62, 0.93-1.06, 1.32-1.43 and 0.05-0.60 for P, Ca, K, N and Mg respectively and these recordings are within the ranges recommended by the NRC requirements; while Na recorded below the required amount at 0.04-0.05%.

These positive amounts of minerals found in this study (Tables 4.2 and 4.3) contributed to the positive growth of various body parts of the goats as Ca is an essential constituent of the bones and teeth and is essential for regular heart action and muscular activity while P is essential for blood and all cells in the body. P is also involved in chemical reactions that release energy in the body of animals hence the two minerals should be availed in the ration in the proper proportions in order to maintain optimal body weight. Na and K are required for the osmotic and acid base balances of an organism, and they should be present at a constant ratio in the body to perform their balance functions (Zhang, *et. al.,* 2018). Mg on the other hand is required for neuromascular activity and activation of enzymes, including those involved in the transfer of phosphate. It has been noticed that an increase in the requirement of Mg for gain as the animal grows is directly associated with the expenditure of energy involved in the formation of adipose tissue deposits (Teixeira, *et. al*., 2015). As protein is required to repair old tissues and build new tissues, it has been observed that the doelings in this study were able to maintain fast growth from the first four months after birth and this could be attributed to more protein in browse species during the wet season which then declined as the dry season advanced.

The micro minerals studied in this research are Cu, Fe, Zn and Mn and all were found to be within the recommended range according to the NRC, 1985 except for Fe which were much higher . The obtained results from this study showed that Cu ranged between 4.69 and 7.28, Zn between 20.48 and 33.31 while Mn between 43.34 and 96.67 and comparing these results with NRC, 1985 recommendations of 7-11, 20-33 and 20-40 for Cu, Zn and Mn respectively it shows that the studied results are within the recommended requirements with Mn showing even more nutritive value and this again has contributed to the positive growth of the animals during the time of study. Mn is an essential dietary element required for skeletal development and reproductive efficiency and this is shown by the positive development of the body parts that were measured in this study. Cu as an essential trace element plays an important role in the biochemical reactions of the animals' body while Zn is a nutritionally essential trace element required for growth and health of an animal as well as for gene expression and in regulating the animal's appetite (Zhang, *et. al.,* 2018). On the other hand, Fe content was very high ranging from 104.53ppm -235.64ppm while the acceptable range is between 30-50ppm. This high content of Fe could have a direct impact on body weight gain of the animals which is below optimal.

4.3.3 In Vitro Dry Matter Degestibility Content in Forage Species

A lot of research has shown and elaborated detailed account on the nutritive value and degradability of browse leaves and was noticed that rumen degradability is capable of reaching up to more than 600 g/kg when there is a higher concentration of Crude Protein than fibers in the feed diet (Nigatu, *et. al.,* 2010). In this study, the aim was to determine the percentage level of Invitro Dry Matter Digestibility of browse feed samples on monthly basis during the late wet and early dry seasons at prescribed time intervals during (Table 4.4). The obtained results indicate that there is variance in percentage level of IVDMD as the dry season advances. These results indicate a high percentage during the late wet season with May recording 31.61-45.833 and a significant decrease as the dry season approaches with June ranging from 30.693-41.429%, July 29.429-38.34% while August as low as 29.222-40.717% (Table 4.4).

This shows that there is a decrease in digestibility of browse species as the winter season advances which implies that nutrients availability may not be sufficient to meet the energy needs of the animals hence affecting their performance growth. It should be realised that during winter there is normally a high concentration of tannins and phenolics which could have a direct impact on the obtained results. The obtained results differ with Fentahun, *et. al.,* (2020) who noted that a high to medium Dry Matter Digestibility is essential in winter as it is of great value for browse feeds to livestock. In this study it is observed that digestibility of browse species increased with an increase in the incubation time (Table 4.4) meaning that it requires more time to be broken down by microbes which maybe as a result of its high fibre contents and this in line with the findings discovered by Ravhuhali, *et. al.,* (2021). Therefore, this indicates that various extent and the rate at which browse species respond to rumen degradability is due to their different chemical composition profile and the variability with seasons which implies that absorption rate is higher during the wet season as opposed to dry season. In this study it is noticed that during late wet season digestibility of browse was high and eventually drops as winter season approaches (June-July) and eventually a slight increase in August as the dry season comes to an end (Table 4.4).

4.4 CONCLUSIONS

There was an increase in the content of dry matter, organic matter and Acid Detergent Fiber as well as Potassium, Magnesium, Copper, Iron, Zinc and Manganese as the dry season increases. However, the opposite was noticed in Crude Protein, Fat, Phosphorus, Calcium and Nitrogen where the nutritional content decreased as the dry season increased. Sodium was consistent through out the seasons while Acid Detertent Lignin content was high during the late wet season and dropped as the early dry season begins and ultimately increased towards the end of the dry season. On the other hand, Gross Energy level was low during the late wet season but increased at the beginning of the dry season and later on decreased at the end of the dry season.
Invitro Dry Matter Digestibility was decreasing with time as the dry season increases.

4.5 Recommendation

Timely range assessment and nutritional evaluation is required followed by adequate inventory of nutritional database of woody trees and their nutritional status. This is necessary in developing improved methods that are desirable to evaluate the current status and the potential of range lands' utilization systems as well as to guide management and domesticating some species. Further studies need to be taken to investigate the level of bioactive compounds found in these woody species for amelioration and maximizing browsing of these species.

CHAPTER 5

EVALUATION OF GROWTH PERFORMANCE OF BOER AND SAVANNA GOATS DOELINGS UNDER RANGELAND CONDITIONS OF LOBU RANCH.

Abstract

Performance evaluation of some goat breeds progeny under specific production environments is necessary to determine better performing breeds. It is important to know the body mass of small stock as it is very useful for good animal management, including understanding medication doses, adjusting feed supply, monitoring growth and choosing replacement doelings. However, documentation of the perfomance of different goats breeds during different seasons at Lobu ranch is lacking. The study was aimed at evaluating the growth performance of fifteen Boer and fifteen Savanna doelings at Lobu ranch during the late wet season to the early dry season. The study is a Complete Randomized Design (CRD) where two breeds being Boer and Savanna were selected randomly from the flock aged 8-9 months old. Morphological measurements were taken from four variables which include body length, heart girth, hip height and shoulder height and monthly body weight. Data was taken in the morning when animals are on empty stomach during the late wet and early dry season on monthly basis for four months, starting from May upto August 2021 on the first week of each month. The data were analyzed using the general linear model (GLM) by SAS program. Duncan's Multiple Range was used to differentiate the results. The results indicate that there was no variance ($P>0.05$) in monthly body weights of the two breeds during the dry season. Though there was homogeneity in body weight gain, the Savanna goat gains daily body weight of approximately 0.035kg/day as compared to the boer goats which gained less daily body weight of approximately 0.030kg/day. The results also indicated that body measurement traits were significantly different among breeds ($P<0.05$) during the late wet and early dry season except the development of heart girth of savanna goat.

5.1 Introduction

Performance evaluation of some goat breeds progeny under specific production environments is necessary to determine better performing breeds. (Ssewannyana, *et. al*., 2004). Small ruminants, specifically, goats have been observed to play important role in animal protein production since they have the ability to convert forages, agricultural and industrial by products to useful body products. However, in Africa, they are faced with poor nutrition, particularly, during the dry season. This is because during these periods, animals suffer phases of starvation as an effect of scarcity and decrease in the nutritional quality of forages. In times like these, most accessible ruminant feedstuffs turn out to be fibrous, with little nutrient and dry matter digestibility, thus, leading to poor livestock production. Processing some of these products might be a way of meeting up the nutrient gap during the dry season (Ogbiko, *et. al*., 2020).

Goats are mostly competent at selecting the most nutritious plants or parts of plants. Because of their foraging characteristics, meat goats fit well on poor or fair grazing areas as long as adequate plant material is available to consume. This aspect allows goats to respond very well to an improved quality forage-feeding program. Goats are capable of converting vegetative matter into meat and milk, requiring little need for other feed sources such as corn or processed feeds. (Lee, *e.t al*., 2019 and Ørskov, 2011**).**

Growth rate can be effectively divided into two periods: pre-weaning average daily gain and post-weaning average daily gain. A high pre-weaning average daily gain not only reflects the genetic potential of the growing animal, but also the mothering ability of the doe. In some production systems, kids are sold at weaning and therefore pre-weaning average daily gain is an important production trait to consider. In other production systems kids are sold as yearlings or as older animals and post-weaning average daily gain becomes an important production factor (Luginbuhl, 2015). It is important to know the body mass of small stock as it is very useful for good animal management, including understanding medication doses, adjusting feed supply, monitoring growth and choosing replacement doelings. The most instinctive way to rate body mass is weighing animals with the most suitable scale. The various lengths, heights and girths of live animals are measured to evaluate the relationship between these variables and the live weight (Canaza-Cayo, *et. al*., 2021). The body weight information is useful in determining the value of animals and efficiency of rearing. Body measurements are essential data sources in terms of reflecting breed standards and are also important for providing information about morphological structure and development ability of the animals. Body measurements differ according to the factors like breed, gender, productivity, age and climatic condition (Sun, *et. al*., 2020).

Lobu ranch was established in the Southern part of Botswana in the Kgalagadi region to be a supreme small stock hub. As such, it has been found that documentation of the performance of different goat breeds during different seasons at the ranch is lacking.

5.1.1: Specific Objectives

i.: The determine the body weight gain of Boer and Savanna goat doelings in Lobu ranch

ii: Evaluate the level of growth of body parts (heart girth, hip height, shoulder height and body length) of Boer and Savanna goat doelings in Lobu Ranch

5.2 Materials and Methods

5.2.1 Materials

i. 15 Boer doelings
ii. 15 Savanna doelings
iii. Measuring tape
iv. Field data sheets
iv. Clip board
v. Framed Weighing scale (s/no. 0943AZ0083, model HL-3-001)
vi. Binoculars (s/no. 9822150000, model IMEI 1158AB)
vii. GPS receivers/tracker (s/no. 08804639913, model IMEI 3541880)

5.2.2 Preliminary Field visit

Field visit to Lobu ranch was done prior to data collection and is explained in detail in chapter 4, section 4.3.1.

5.2.3 Research Design

This study was an experimental design as explained in chapter 4, section 4.3.2 and the two breeds of goats were selected randomly (Complete Randomized Design) from their age group within the flock.

5.2.4 Sampling Frame and data collection procedures

5.2.4.1 Sample size

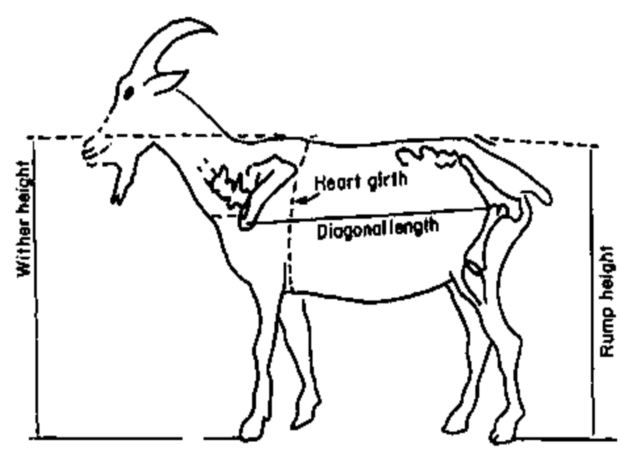
A total of thirty Boer and Savanna goat doelings were selected for experimental use and were consisting of fifteen animals per breed. The age group of the selected animals were ranging from eight to nine months weighing between fifteen kilograms and eighteen kilograms. All doelings were the commercial breeds.

5.2.4.2 Body parameters to be measured

Data was collected on hip height, shoulder height, body length and heart girth. The four body parts were measured using a tape on monthly basis the entire winter season. Measurements of the hip height were taken from the rump down to the rear hoof, while that of the shoulder height was from the whither down to the hind hoof (Ogbiko, *et. al.,* 2020). The heart girth was measured from the whither down to the chest floor (Natsir, 2010) while body length was measured from the base of the ear to the base of the tail where it joins the body. All measurements were recorded in Microsoft Excel 2019 in tabular forms and the unit of measurement is in centimeters.

5.2.4.3 Body weight measurement

The doelings' body weights were taken on the first week of the month from May 2021 to September 2021 using a digital weighing scale. The doelings were weighed in the mornings on an empty stomach by allowing each animal in the weighing frame and the readings taken from the digital scale while the animal is standing still. All readings were recorded in kilograms in tables drawn in a hardcover book before computerizing in Microsoft Excel 2019.



Picture 4. 1: Body parameters of a goat to be measured during the study.

Picture adopted from Natsir, 2010.

5.2.5 Data Analysis

All the measurements taken were recorded in Micro Soft Excel 2019 and analysis of variation (ANOVA) performed considering the type of breed of the goats and observing the significant differences among the mean values. Data was then be analyzed using regression analysis using the SAS program. All tests were conducted at 95% confidence level, results were analyzed using Duncan's Multiple Range where P>0.05 indicates that there is no significant in animals' body weight gain or loss. The results were then tabulated and linear graphs drawn for each parameter.

5.2.6 Statistical Analysis

The experimental design was a Complete Randomized Design (CRD) and an observational study where the animals were followed from morning to evening to observe the type of species they browse. The difference among treatment means were detected using least significance difference.

Statistical model used:

$$Y_{ijk} = \mu + d_i + T_j + (T \times d)_{ij} + E_{ijk}$$

Where Y_{ijk} = response variable (body weight, heart girth, body length, hip height and shoulder height), μ = general mean, d_i = the fixed effects of breed, T_j =effect of month, $(T \text{ x } d)_{ij}$ = effects of interaction between breed and month, E_{ij} = random error associated with observation $_{ijk}$ = assumed to be normally and independently distributed. The level of significance was set at $p < 0.05$.

Analysis of variance was carried out on live body weight and body parameters using General Linear Model procedure of Statistical Analysis System (SAS, 2001). Animal species were the independent variables while body weight and body parameters were the dependent variables.

5.3 Result analysis

5.3.1 Body weight gain of Boer and Savanna goat doelings in Lobu ranch

There is no significant difference in body weight gain of the two breeds throughout the months of the dry season (P>0.05), this implies that the growth performance of the goats is homogeneous in all the months of the dry season (Table 5.1).

Table 5. 1: Mean body weight of Boer and Savanna goat doelings in kilograms.

Level of Treatment	Birth weight	Weaning weight	May	June	July	August	**SEM**
SAVANNA	2.067	15.34	19.993	21.053	20.993	21.193	**0.887**
BOER GOATS	2.033	13.713	20.14	21.027	21.633	21.027	**0.897**

The test used is the Duncan's Multiple Range
Means with the same letter are not significantly different; P>0.05
SEM=Standard Error of the Mean

5.3.2: Level of growth of body parts (heart girth, hip height, shoulder height and body length) of Boer and Savanna goat doelings in Lobu Ranch

5.3.2.1: Level of growth of heart girth for Boer and Savanna goat doelings in Lobu Ranch

There is a difference in the development of heart girth of the boer goat with regard to the months of the dry season (P<0.05). However, there is a slight decrease in the development of the heart girth of boer goat towards the end of the dry season (Table 5.2 & Figure 5.1).

Table 5. 2: Mean length of heart girth of Boer and Savanna goat doelings in centimeters

Level of TREATMENT	N	MAY Mean	JUN Mean	JUL Mean	AUG Mean	SEM
Savanna doelings	**15**	65.600^{a}	66.333^{a}	65.533^{a}	66.000^{a}	**0.906**
Boer doelings	**15**	65.800^{a}	66.467^{a}	64.333^{ab}	62.333^{b}	**1.026**

The test used is the Duncan's Multiple Range
^{ab} Means with the same letter are not significantly different; P>0.05
SEM=Standard Error of the Mean

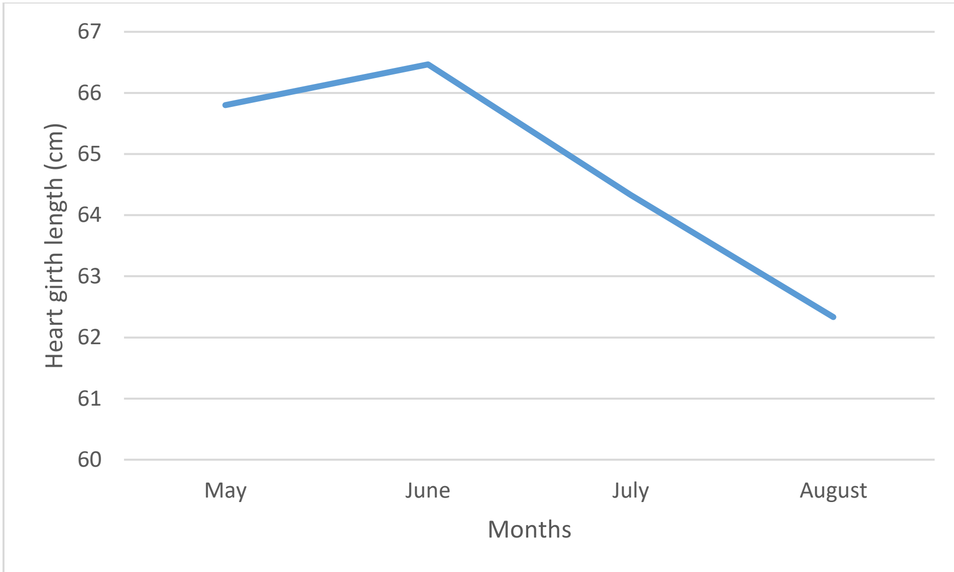


Figure 5. 1: Mean Length Of Heart Girth Of Boer Goat Doelings In Centimeters

5.3.2.2: Level of growth of hip height for Boer and Savanna goat doelings in Lobu Ranch.

There is a significant difference in the development of the hip height of the two breeds with regard to the different months of the season ($P<0.05$) as shown in Table 5.3. The Savanna goat shows a consistent positive development of the hip height while the boer goat starts showing some positive growth on the second month and a reduced growth towards the end of the dry season (Figure 5.2).

Table 5. 3: Mean length of hip height of Boer and Savanna goat doelings in centimeters.

Level of treatment	May	June	July	August	SEM
Savanna	52.067[b]	53.667[b]	55.867[a]	57.267[a]	**0.7691**
Boer goat	52.667[b]	52.667[b]	56.467[a]	58.133[a]	**0.9182**

The test used is the Duncan's Multiple Range
[ab] Means with the same letter are not significantly different; $P>0.05$
SEM=Standard Error of the Mean

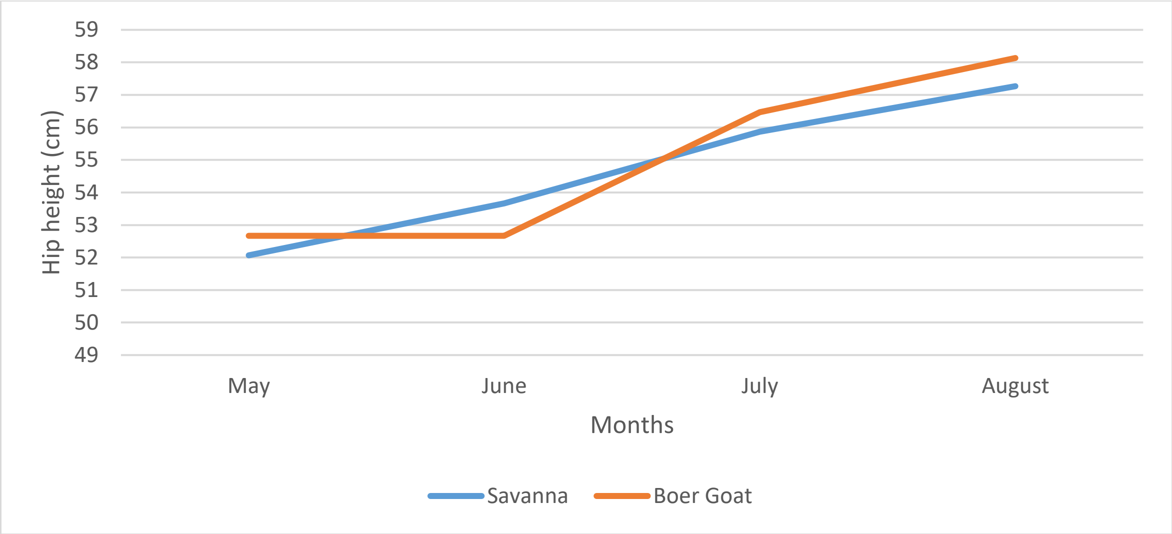


Figure 5. 2: Mean length of hip height of Boer and Savanna goat doelings in centimeters.

5.3.2.3: Level of growth of shoulder height for Boer and Savanna goat doelings in Lobu Ranch.

There is a significant difference in the development of the shoulder height of the two breeds with regard to all the months of the dry season ($P<0.05$) (Table 5.4). The two breeds are showing a much higher development towards the end of the dry season (Figure 5.3).

Table 5. 4: Mean shoulder height of Boer and Savanna goat doelings in centimeters

Level of TREATMENT	N	MAY	JUN	JUL	AUG	SEM
Savanna doelings	**15**	51.400^{b}	51.867^{b}	52.867^{ab}	55.000^{a}	**0.8026**
Boer doelings	**15**	48.600^{c}	50.000^{c}	52.733^{b}	55.133^{a}	**0.7450**

The test used is the Duncan's Multiple Range
^{abc} Means with the same letter are not significantly different; $P>0.05$
SEM=Standard Error of the Mean

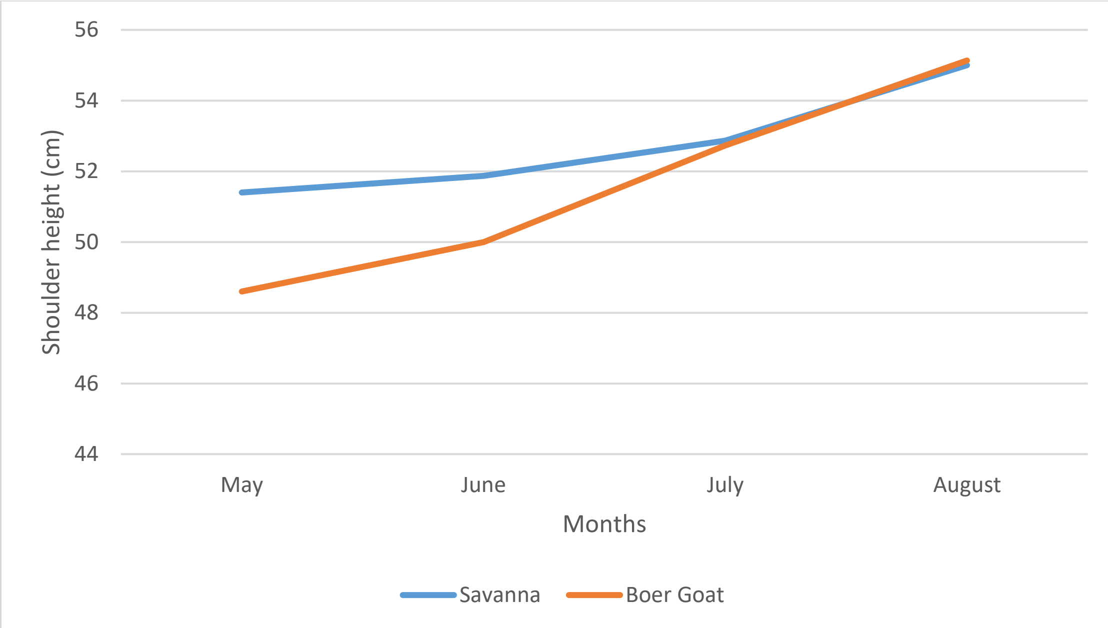


Figure 5. 3: Mean length of shoulder height of Boer and Savanna goat doelings in centimeters.

5.3.2.4: Level of growth of body length for Boer and Savanna goat doelings in Lobu Ranch.

There is a significant difference in the development of the body length of the two breeds during the dry season ($P<0.05$) (Table 5.5). The savanna goat is showing a much faster growth in body length as compared to the boer goat (Figure 5.4).

Table 5. 5: Mean body length of Boer and Savanna goat doelings in centimeters.

Level of TREATMENT	N	MAY	JUN	JUL	AUG	SEM
Savanna doelings	**15**	55.67^{c}	57.13^{bc}	59.27^{ab}	61.27^{a}	**0.8816**
Boer doelings	**15**	53.20^{d}	55.27^{c}	57.67^{b}	60.20^{a}	**0.5532**

The test used is the Duncan's Multiple Range

^{abcd} Means with the same letter are not significantly different; $P>0.05$

SEM=Standard Error of the Mean

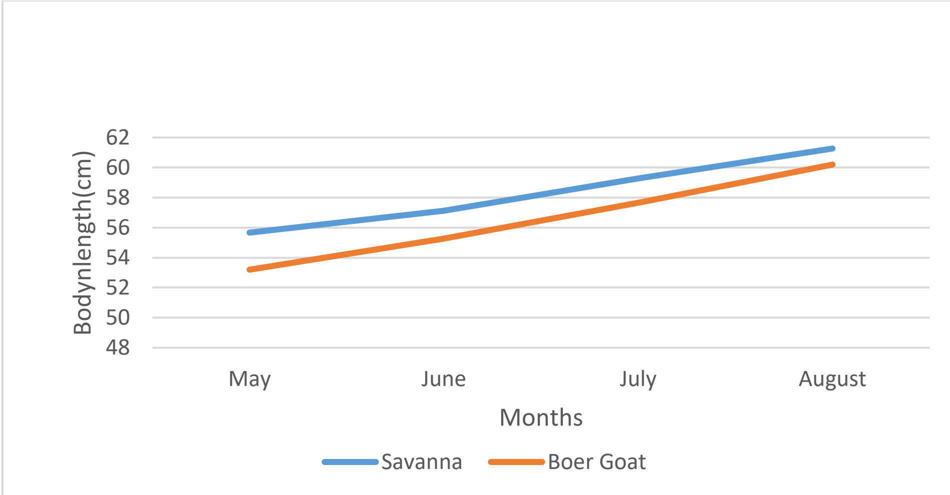


Figure 5. 4: Mean body length of Boer and Savanna goat doelings in centimeters.

5.4: Discussion

5.4.1 Body weight gain of Boer and Savanna goat doelings

Monthly body weights of the two breeds were evaluated from data which was recorded from May-August 2021 while their birth weights and weaning weights were obtained from the records. The two breeds consist of fifteen goats from each breed and the results obtained indicate that there is no variance ($P>0.05$) in monthly body weights of the two breeds during the late wet and early dry season. Though there is homogeneity in body weight gain, the Savanna goat gains daily body weight of approximately 0.035kg/day as compared to the boer goats which gains less daily body weight of approximately 0.030kg/day. In this study it is noticed that the birth and weaning weights of the savanna is much higher than those of the boer goat. Contrary to this study, it has been noticed that the boer goat has significantly much higher body weight than other breeds such as the Kalahari red (Visser and Marle- Köster, 2018). The body weight in livestock is an essential trait as it is directly associated with economic value. The highest body weight will generate the most attractive price of a goat (Fajemilehin, *et. al*., 2008).

5.4.2: Level of growth of body parts (heart girth, hip height, shoulder height and body length) of Boer and Savanna goat doelings

The results of the analysis indicate that body measurement traits were different among the breeds during the late wet and early winter season except the development of heart girth of savanna goat. The savanna has shown positive consistence in growth development of the four body parameters with the body length maintaining the highest development throughout the seasons followed by the shoulder height. This observation could interpret that the two body parameters have a strong correlation with body weight gain. Contrarily, this differs with Afolayan, *et. al.*, (2006), who concluded that the heart girth is the most related trait to live body weight as it is associated with the abdominal cavity and digestive tract of the animal which accounts for 10-25 percent of the live body weight. Interestingly, other studies by Abd-Allah, *et. al.*, (2019) came up with general conclusion that there are high correlation coefficients between live body weight and body measurements, either of these variables or combination could provide a good estimate for predicting live weight in goats. Although the level of estimation accuracy of the body weight is not more accurate than directly measuring body weight, the estimation of weight through body size is able to provide a picture of the performance and characterize the breed. Overall, it should be noted that the accuracy of functions used to predict growth performance from live animal measurements is of immense financial contribution to the livestock production enterprises (Adeyinka and Lakpini, 2006). Body measurement characteristics could also be useful for grouping animals (Kusminanto, *et. al.*, 2020) as in small, medium or large framed animals.

In this study, it is observed that the animals' growth pattern from birth to weaning stage was greater and after weaning, the growth curve for the body parameters measured started to develop at a much slower rate and this indicates that the net requirements of minearls was greater at the start of life and eventually decreases as the animals grow. As the animals grow, there is an increase in the proportion of fat followed by a reduction in the proportion of proteins and minerals in the body, particularly as they reach body weight of more than 20kg of which is the case in this study where this was noticed in the early winter season and beyond. This pattern of nutrient deposition in the body is directly linked to the stage of development of the bone, muscle and adepose tissue. Among these body parts, the bone tissue has the earliest development followed by the muscle and then the fat tissue (Teixeira, *et. al.*, 2015). It should be noted that with the advance of growth, there is an increase in fat tissue deposition. Meat goats including boer and savanna goats possess smaller proportions of bone tissue in their carcass.

5.5: Conclusions

The body weight gain of the two breeds was similar during the late wet and early dry season. However, there was a difference in the development of the heart girth of the boer goat which was noticed by a slight decrease towards the end of the dry season while the savanna showed no difference in the development of the heart girth. The two breed showed a positive growth of the hip height, shoulder height and body length during the late wet and early dry seasons.

5.6: Recommendation

Livestock producers should be educated on the importance of maintaining the best body conformation of their animals as it could help them in predicting their performance status. It is also important to develop a standard and simple chart that indicates the body parameters and their corresponding live body weights which can be adopted by all livestock stakeholders.

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